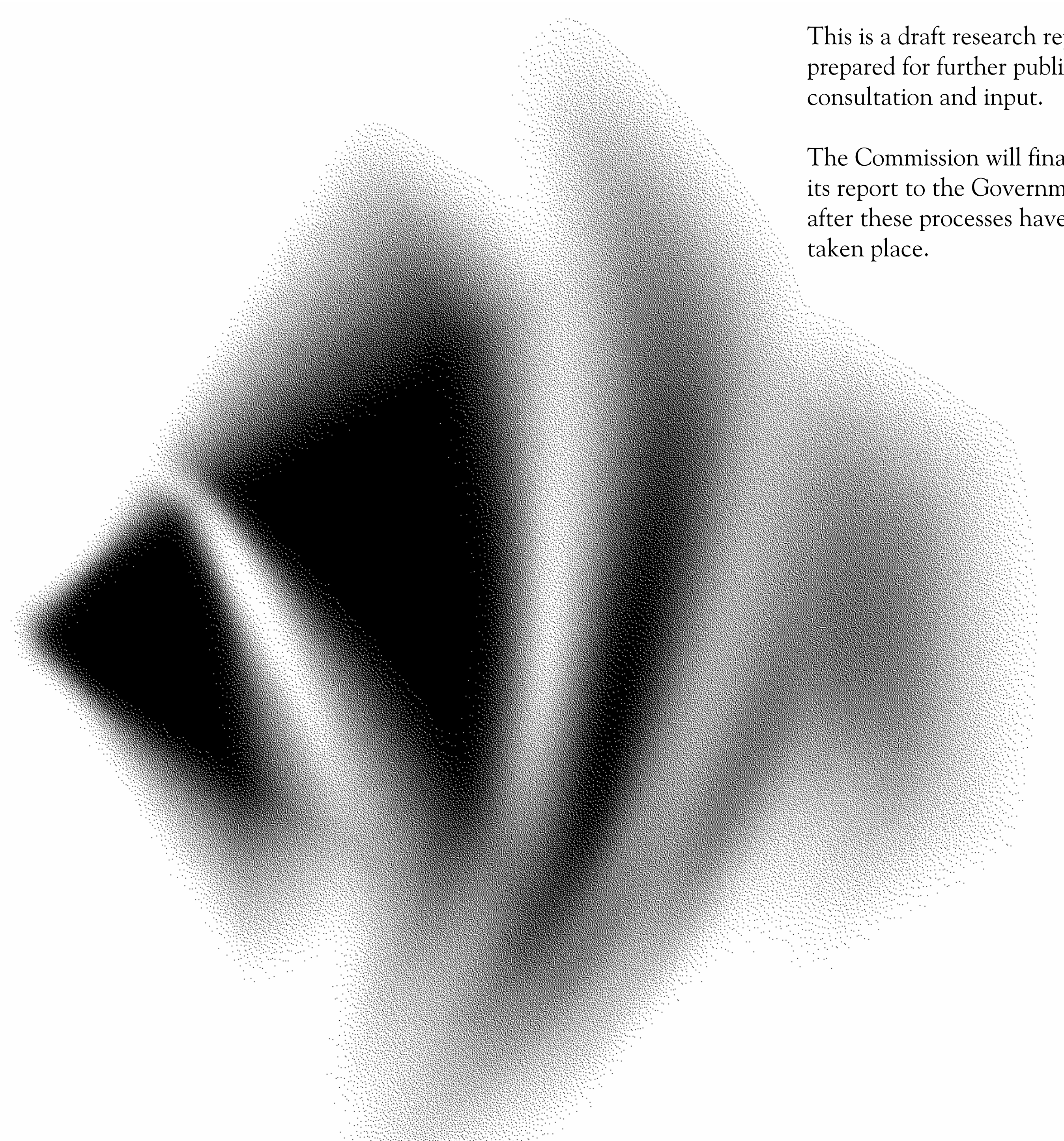
Australian Government
Productivity Commission

Public Support for Science and Innovation

Productivity Commission Draft Research Report



This is a draft research report prepared for further public consultation and input.

The Commission will finalise its report to the Government after these processes have taken place.

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The Productivity Commission

The Productivity Commission, an independent agency, is the Australian Government's principal review and advisory body on microeconomic policy and regulation. It conducts public inquiries and research into a broad range of economic and social issues affecting the welfare of Australians.

The Commission's independence is underpinned by an Act of Parliament. Its processes and outputs are open to public scrutiny and are driven by consideration for the wellbeing of the community as a whole.

Information on the Productivity Commission, its publications and its current work program can be found on the World Wide Web at www.pc.gov.au or by contacting Media and Publications on (03) 9653 2244.

Opportunity for further comment

You are invited to examine this draft research study and to provide written submissions to the Commission. Submissions should reach the Commission by Thursday, 21 December 2006.

In addition, the Commission intends to hold a limited number of consultations to obtain feedback on this draft.

The Commission intends to present its final report to the Government in early March 2007.

Terms of reference

PRODUCTIVITY COMMISSION ACT 1998

The Productivity Commission is requested to undertake a research study on public support for science and innovation in Australia.

Background

The Australian Government has identified science and innovation as one of its strategic priorities, recognising its contribution to Australia's economic and social prosperity. The Government has provided significant support for science and innovation, which it has augmented since 2001 through Backing Australia's Ability (BAA) , and funding now exceeds $5 billion per annum. In light of this investment, the Government considers that a study of public support for science and innovation is warranted. This study will complement the ongoing and planned reviews of BAA programmes.

Scope of the study

The Commission is requested to:

1. Report on:
   - the economic impact of public support for science and innovation in Australia and, in particular, its impact on Australia's recent productivity performance;
   - whether there are adequate arrangements to benchmark outcomes from publicly supported science and innovation and to report on those outcomes as measured by the benchmarks.

   The analysis should cover all key elements of the innovation system, including research and development, taking into account interaction with private support for science and innovation, and paying regard to Australia's industrial structure.

2. Identify impediments to the effective functioning of Australia's innovation system including knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration between research organisations and industry, and the creation and use of intellectual property, and identify any scope for improvements.

3. Evaluate the decision-making principles and programme design elements that:
   a. influence the effectiveness and efficiency of Australia's innovation system; and
   b. guide the allocation of funding between and within the different components of Australia's innovation system;

   and identify any scope for improvements and, to the extent possible, comment on any implications from changing the level and balance of current support.

4. Report on the broader social and environmental impacts of public support for science and innovation in Australia.

Although the Commission is not requested to review individual programmes, it can, where necessary, undertake case studies of particular types of public support for science and innovation. It should also draw on relevant international experience.

The Commission is to produce a draft report and a final report within 12 months of the receipt of this reference. The report is to be published.

CHRIS PEARCE

[Reference received 10 March 2006]

Foreword

Governments direct significant public resources to science and innovation. The central question of this study has been what are the benefits that arise from this spending. These impacts are not just the gains that end up in gross domestic product or other more tractable measures of the economy, but the non-economic social and environmental benefits as well.

The study has also examined: how funding levels are determined; how programs are designed delivered and administered; how funding is allocated among programs; how funds within programs are allocated to the various participants; and how those participants themselves allocate the funding they receive to their various activities. A further issue for this study has been the effectiveness of program monitoring.

The Commission sought to draw broad lessons and conclusions from the existing programs rather than attempt a more narrow detailed analysis of their individual strengths and weaknesses or assess the appropriate levels of public support for them.

In preparing this draft report, the Commission has drawn on information from a large number of submissions, consultations with governments, public research agencies, universities, businesses and other relevant organisations and research bodies as well as from a range of previous Australian and international studies.

The Commission wishes to thank each of the groups and individuals that have contributed to the study. The Commission will be providing opportunity for further comment and consultation following the release of the Draft Report.

The study is being overseen by Commissioners Mike Woods and Steven Kates, with a staff research team headed by Ralph Lattimore.

Gary Banks
Chairman

November 2006

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Abbreviations

ACIS	Automotive Competitiveness and Investment Scheme
ADO	Australian Defence Organisation
ANSTO	Australian Nuclear Science and Technology Organisation
ARC	Australian Research Council
AUQA	Australian Universities Quality Agency
AVCC	Australian Vice-Chancellors’ Committee
BAA	Backing Australia’s Ability
BCR	Benefit–cost ratio
BERD	Business expenditure on R&D
BIHECC	Business, Industry, and Higher Education Collaboration Council
CHASS	Council for the Humanities, Arts and Social Sciences
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEST	Department of Education, Science and Training
DSTO	Defence Science and Technology Organisation
EPI	Environmental performance index
ESI	Environmental sustainability index
GERD	Gross expenditure on R&D
GOVERD	Government intramural expenditure on R&D
HECS	Higher Education Contribution Scheme
HERD	Higher education expenditure on R&D
HREC	Human Research Ethics Committee
IAC	Industries Assistance Commission
IC	Industry Commission

IP	Intellectual property
MFP	Multifactor productivity
NCRIS	National Collaborative Research Infrastructure Strategy
NHMRC	National Health and Medical Research Council
NRPs	National Research Priorities
OECD	Organisation for Economic Co-operation and Development
PC	Productivity Commission
PFRA	Publicly funded research agency
PSRA	Public sector research agency
R&D	Research and development
RAE	Research Assessment Exercise (of the UK)
RQF	Research Quality Framework
RRDC	Rural Research and Development Corporation
RRTMR	Research and Research Training Management Report
S&I	science and innovation
SMEs	Small and medium enterprises
TPA	*Trade Practices Act 1974*

OVERVIEW

Key points

- Australia is well served by its public funding support — some $6 billion in 2002-03 — for science and innovation.
  - It is not possible, given a host of measurement and methodological issues, to provide accurate estimates of the contributions of such R&D to the economy, but indications are that they are significant.
  - There are also important social and environmental dividends for Australians.
- There are no grounds for a radical overhaul in total public funding or in the allocation of that funding. However, incremental improvement is needed in some areas.
- The adequacy of existing evaluation arrangements is mixed, with some notable shortcomings in business programs.
- The net payoff from the R&D Tax Concession could be improved by orienting the program towards its 175 per cent incremental component. This offers the prospect of increasing the amount of new R&D encouraged per dollar of revenue allocated to the program. The design of the incremental component could also be improved to make it more attractive and efficient.
- Strong public support of Rural R&D Corporations with a public good orientation is justified, but the level of government subsidies for *some* more narrow industry-focused arrangements may crowd out private activity and produce only weak external benefits outside the supported rural industry. However, no changes should be made while persistent drought conditions remain.
- Although, collaboration can generate significant benefits, the CRC program is only suited to longer-term arrangements. The Commission has outlined some complementary options for business collaboration with public sector research agencies and universities that could provide more nimble, less management-intensive, arrangements than the present CRC program.
- There is a wide range of perceived obstacles to commercialisation by universities, but only some of these warrant policy action.
  - There may be a case for providing universities with some additional funding to demonstrate promising technologies so they can be more easily transferred to businesses. However, there are several options for supporting such transfer that do not involve a new dedicated funding stream.
- The structure of funding for higher education research has increasingly eroded the share of block grants. Further erosion would risk undermining their important role in enabling meaningful strategic choices at the institutional level.
- While the proposed Research Quality Framework has some benefits, it also has considerable costs. The Commission suggests that a final decision about its implementation should be delayed pending the exploration of some other options.

Overview

Innovation is critical to Australia's growth and its preparedness for emerging economic, social and environmental challenges. Governments play a major role in shaping the innovation system through the design and governance of institutions, in partly funding the education and training of scientists and engineers, and in encouraging high-value research that would not otherwise be undertaken by businesses. Australian governments play a direct role in the innovation system by financing R&D in public sector research agencies, universities and businesses, with overall funding of around $6 billion in 2002-03.

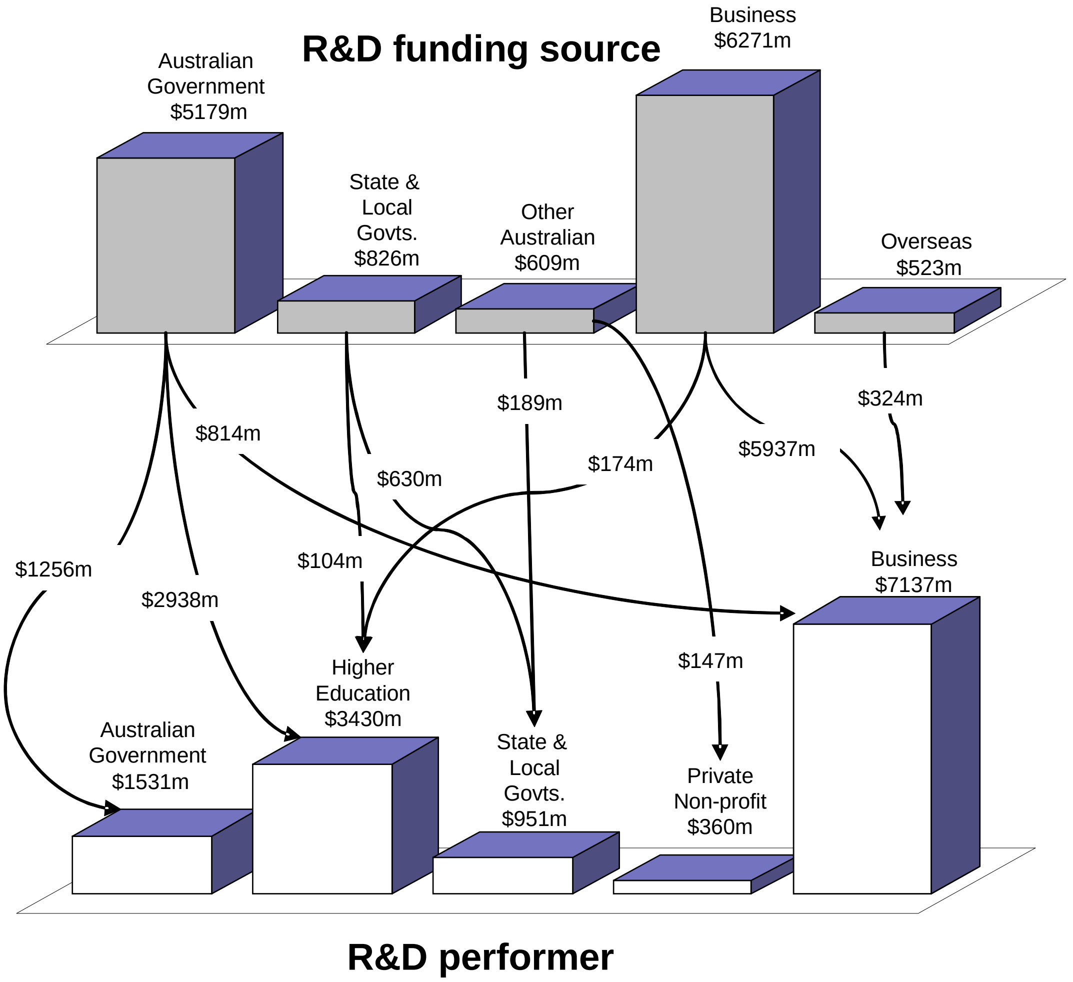
This draft report examines the impacts of such funding support for science and innovation, and considers the prospects for improving outcomes by eliminating impediments to innovation or changing the way government support is channelled to its various competing uses. The overall conclusion, at this stage, is that Australia's innovation system does not warrant radical overhaul in either its total funding or in the allocation of that funding. The existing system, by and large, provides good returns for Australians and has, over time, adapted to meet new challenges.

Nevertheless, there are grounds for incremental improvements in several areas. The effectiveness of business programs could be enhanced. The growing emphasis on the public support of the commercialisation stages of innovation in both business and non-business sectors should be re-considered. There is a requirement for better methods of evaluating the impacts of programs, but a need for caution in adopting new, potentially costly, appraisal methods for the assessment and funding of university research.

Rationales for evaluating public funding support

Public funding support for research and development, an important input into innovation, is substantial (figure 1). Accordingly, its provision should be based on clear and credible rationales, which should then underpin the evaluation criteria used to assess the net benefits of each program.

Figure 1 **Where does the money come from and where does it go?**
Major flows, Australian R&D funding and spending 2002-03



The study has found that the strongest reasons for public support of R&D are the returns that cannot be captured by the innovator (*spillovers)* — whether in the public, private or not-for-profit sectors.

The mere presence of spillovers does not, in itself, justify public support. Many investments that produce spillovers have sufficient private returns for firms to invest without that support. The challenge for public policy is to elicit private investments that would not otherwise have been made ('additionality'), but for which the collective private and spillover returns are still positive. Moreover, some spillovers accrue to foreigners, which are not relevant to the appraisal of net benefits for Australia.

R&D is also often an *input* into activities that are public goods, such as defence and how best to deal with environmental problems. Such R&D should be financed even if it does not, itself, generate spillovers — though this will often also be the case.

This provides strong arguments for financing research into areas like the environment. However, it does not necessarily follow that such publicly-funded research must be undertaken within the public sector.

There are various other rationales for public support. Those found during the study to have some validity include:

- intangible factors — the values that science elicits and entail (national prestige, identity, curiosity, wonder);
- the asymmetric tax treatment of risky investments — profits are taxed now whereas the tax value of losses fall through discounting as they are carried forward; and
- possible limitations of capital markets — however, the Commission is cautious in advocating policy changes in this area, since apparent imperfections may merely reflect high, but unavoidable, transactions costs of dealing with some firms.

Other rationales often given for support — the indivisibility of very large research projects; business myopia; and the goal of transforming Australia's industry structure — have little merit.

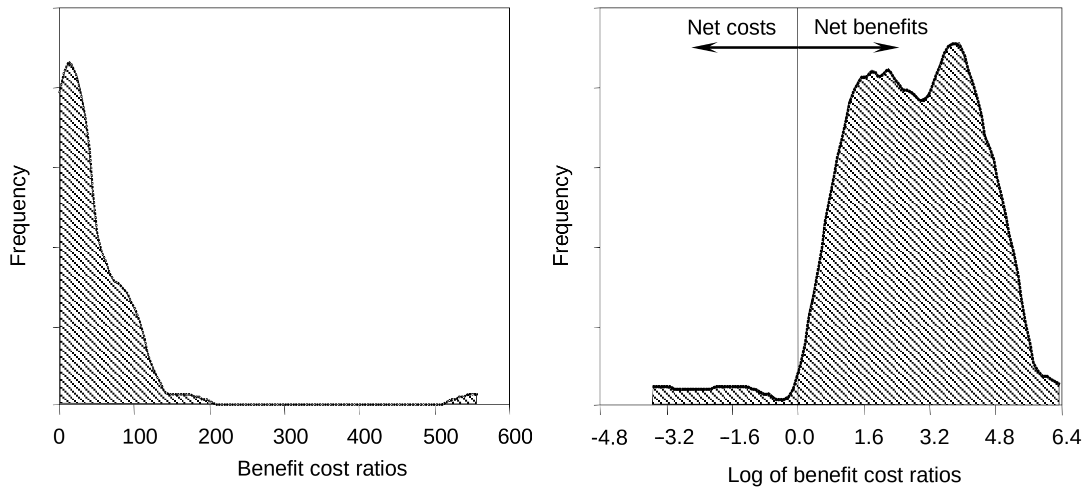
Before providing public support, other factors also needs to be assessed. These include the ability of firms to appear to be undertaking additional research where none has occurred, the inefficiency costs of the taxation required to finance the programs, the utilisation of resources on administration and compliance, and the risks of poor choices when selecting projects to be funded.

Impacts of public funding support

The conclusion that R&D contributes to the growth of national productivity is supported by case studies, aggregate time series analysis, panel data analysis across Australian States and a variety of cross-country studies.

Case studies reveal high rates of return to R&D (figure 2). In the Commission's analysis of existing studies, average benefits exceeded costs by a median 8.5 to 1. But case studies have sometimes been selected because they have been successful, thus biasing the results. The report provides a critique of current methods, but nevertheless finds useful evidence on the ways in which R&D can generate gains. Analyses of portfolios of projects, where selection biases are less germane, still suggest high returns — with benefits exceeding costs by around two to one.

Figure 2 **Australian case studies suggest good average returns**



The aggregate time series approaches — often the basis for estimates of the productivity effects of R&D — cannot realistically measure rates of return accurately (box 1). Nevertheless, these approaches point to positive rates of return to R&D.

This is also buttressed by the Commission's preliminary analysis of the sources of economic growth over time between Australian States and Territories, which suggested high rates of return to R&D. Similar studies undertaken across countries and time also tend to find significant returns. A different approach, based on allocating productivity growth to its likely sources, found that rates of return to R&D relevant to the Australia market sector could readily lie in the band from 35 to 100 per cent.

In sum, there is empirical evidence of benefits from R&D. However, the public policy issue is the magnitude of benefits from *publicly supported* science and innovation, not from R&D in total. The bulk of such public funding — around five in every six dollars — is provided to universities or public sector agencies with the remaining flowing to business. The Commission judges that there are positive net impacts from publicly supported R&D undertaken in universities and public sector research agencies, with those impacts being sufficient to justify current levels of support.

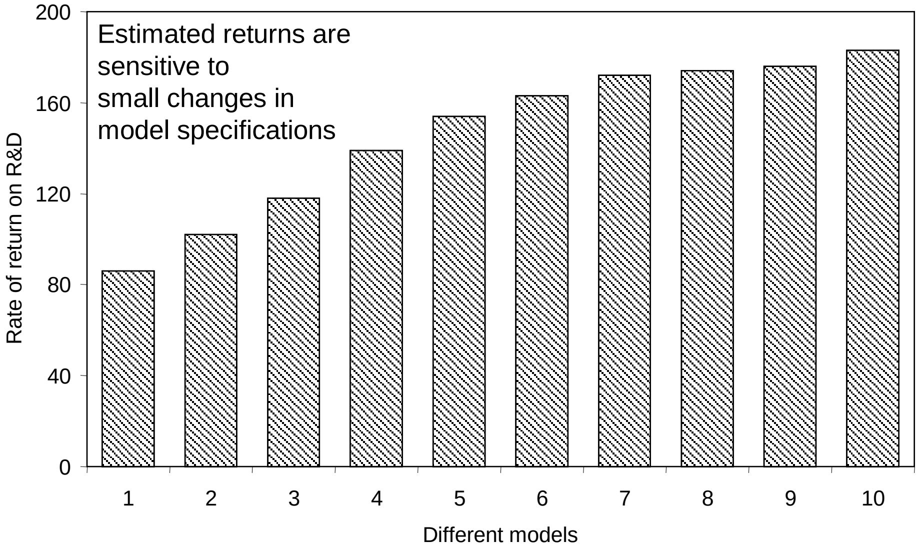
Box 1 The problems with numbers

Aggregate time series studies — often the basis for estimates of the productivity effects of R&D — cannot realistically measure rates of return accurately. This reflects the complex causal pathways through which R&D affects productivity growth, an excessively short span of data, errors in data, the potentially long lags from the conduct of R&D to ultimate benefits, and difficulties in controlling for the other factors that also influence productivity. Accordingly, the econometric modelling of the kind used by Commission staff in a recently released econometric study (Shanks and Zheng 2006) can find it difficult to measure the effects of domestic R&D with any precision.

However, a detailed consideration of statistically adequate models of productivity presented by that study finds that more often than not there *are* returns to domestic R&D in their models — with an average return of around 50 per cent.

The preliminary analysis of this report is also able to find some statistically and theoretically adequate models that are associated with positive returns to domestic R&D. These new results, which vary significantly by model specification (see below) are usually very high — between around 85 and 180 per cent — but have wide confidence intervals. On the basis of other evidence on the sources of economic growth, these point estimates are likely to be implausibly large, with more credible numbers lying in the range from 35 to 100 per cent.

Overall, the results from such modelling cannot realistically aspire to produce accurate estimates of the rates of return from R&D. However, the empirical evidence adds weight to the hypothesis that R&D produces significant returns to the market sector through productivity increases that are not captured as rents by the firms undertaking R&D.



In the absence of public support, R&D in these institutions would contract significantly ('additionality' is high). In some cases, such as R&D for many environmental purposes, the net gains are mostly not measured in GDP (at least in the short-run), but are nonetheless worthwhile. R&D has:

- increased preparedness and reduced risks in some areas;
- been widely adopted in a range of settings (public health, risk abatement in the environment and social and educational policy);
- developed advanced problem-solving skills among Australian graduates; and
- provided spillovers to business, for example in the mining industry.

Other indirect indicators of impacts, such as academic quality, suggest that Australian scientists are performing well by comparison with those in other advanced economies.

There are also likely to have been positive net effects on the economy from existing public support for R&D in the business sector. However, the benefits are constrained due to several factors:

- a large share of the R&D eligible for concessional treatment would have taken place in any event;
- a considerable amount of public support is directed at incremental, catch-up R&D, where the spillover benefits may be relatively small;
- individual businesses have incentives to minimise spillovers; and
- support has been concentrated in a few relatively declining sectors — such as the auto industry.

Innovation system impediments

Participants in this study identified a range of possible impediments to the operation of the innovation system. Many of these related to perceived deficiencies in the level of funding, structure, multiplicity and administration of the public support programs. These issues are discussed later. The remaining R&D impediments focused on apparently poor commercialisation, human capital, some unexpected consequences of regulation and factors that may weaken the capacity for knowledge diffusion in basic research.

Commercialisation

There is a wide range of perceived impediments to commercialisation, which includes the size of the domestic market; the distance from foreign markets; financing; incentives and cultural barriers within universities; a lack of effective linkages between research organisations and firms; intellectual property management; and skill shortages.

Some of these impediments do not, however, constitute a compelling basis for government action. For example, Australia's location and size are unalterable features of the business environment. And apparent cultural barriers in universities may reflect the preferences of researchers who are driven by curiosity, research excellence and public sharing of ideas. Addressing any cultural 'barrier' requires prudence because it poses risks for the core research functions of universities and the motivation for science career choices.

Other impediments are mainly the subject of existing, often recent, government policy measures and actions by the research organisations themselves. These should be given the time to determine if they work effectively.

However, there is possible scope for measures to deal with some residual impediments.

- Public sector research agencies and universities should ensure consistency in the management of intellectual property within their organisations to reduce transactions costs for businesses dealing with them.
- Only the largest research universities are likely to be able to develop dedicated commercialisation arms of sufficient scale and expertise to operate effectively. More flexible arrangements — including the use of private sector intermediaries — may allow universities to draw on the commercial expertise they need in a more efficient and cost-effective way.
- Universities can sometimes find it difficult to transfer commercialisable ideas to business because the concepts have not been adequately demonstrated. Funding to universities for this purpose may be warranted. One option is for new dedicated 'third stream' funding of universities. Another option that does not require a hypothecated grant is to supplement block funding and allow universities to determine themselves how much, when and what types of research should be taken along these initial commercial paths.
  - These (and other) options have both pluses and minuses. At this stage, the Commission considers it best to await the outcomes of the present examination of these matters by the Business, Industry, and Higher Education Collaboration

Council and to analyse any resulting proposals against the program design guidelines set out in this report.

The increasing policy imperative for commercialisation is built on an overly pessimistic view of Australia's capabilities. In fact, despite the existence of some impediments, there is evidence of much successful commercialisation in Australia in areas close to Australia's traditional comparative advantages in the mining and agricultural sectors, the wine industry being a current example. Australia has also successfully commercialised R&D within certain manufacturing niches, such as medical technology.

Placing undue emphasis on commercialisation may have unintended effects. The overall place of commercialisation in government innovation policy needs to be balanced.

- Universities' core role remains the provision of teaching and the generation of high quality, openly disseminated, basic research. Even where universities undertake research that has practical applications, it is the transfer, diffusion and utilisation of such knowledge and technology that matters in terms of community wellbeing. Commercialisation is just one way of achieving this. The selection of the transfer pathway should be based on maximisation of the overall community benefits, which will only sometimes favour commercialisation.
- While public spending to support business commercialisation is smaller than the support given at the earlier stages of the innovation process, business programs are increasingly oriented at commercialisation objectives. However, there are fewer clear-cut spillovers at the later stage, which weakens the rationale for public support for commercialisation in businesses. There are also large potential private returns to commercialisation — failure to commercialise gives rivals the time to poach the pre-existing R&D knowledge. So public support risks supporting investments that would occur anyway.
- Calls for governments to assume the risks for highly risky commercial ventures also have a poor basis, since such an approach would merely transfer commercial risks from firms to taxpayers.

Barriers to future growth of human capital

There is a recognised shortage of engineers and secondary school teachers in science and mathematics. The shortage of engineers has been reflected in the rapid growth in salaries for both graduate and experienced engineers, encouraging entry into the profession. In the case of science and mathematics teachers, such price signals have not been able to respond to shortages due to the inflexible pay levels and structures. Rather, shortages have sometimes been accommodated by using teachers without adequate skills in these subjects. This may adversely affect student engagement and decrease future university enrolments in the sciences.

Research infrastructure

There is some evidence of deficiencies in public support for research infrastructure, and some States are directing funding to provide supporting infrastructure as a supplement to (and a way of leveraging) Australian Government program funding. There is also a diverse range of pricing and sharing arrangements for infrastructure between public institutions that may sometimes result in inadequate utilisation. The Commission broadly supports the recommended pricing approach of the National Research Infrastructure Taskforce. Fixed and standing operating costs should be met through public funding. Prices of major infrastructure should then be set at marginal costs for research users — with congestion charging for infrastructure that is over-utilised. A stocktake of existing research infrastructure would also help to deal with poor utilisation.

Impediments to diffusion in the basic research community

There are several possible barriers to knowledge dissemination in basic research.

Legal uncertainty about the use of patents for research has the potential to impede knowledge dissemination. One option proposed by the Australian Law Reform Commission and the Advisory Council on Intellectual Property is to introduce a provision in the Patents Act for exempting researchers from infringement when they make experimental use of patented intellectual property. This model has been applied in the United Kingdom, several European countries and Japan, and is proposed in New Zealand. The intention is to reduce legal uncertainty about the use of patents for research, without affecting commercial incentives to invest in innovation. However, the extent to which such legal uncertainty actually acts as a barrier to innovation is unclear, as are the costs and risks of any unintended consequences of implementing the proposed model.

The growth of the Internet has made it possible to lower the marginal costs of disseminating much basic scientific knowledge to zero. Current models of scientific publication, while changing, have nevertheless been perceived as limiting the possibilities of diffusion of publicly supported research. Major funding bodies in the United Kingdom and the United States have already instituted reforms.

There is scope for the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC) to play a more active role than they currently do in promoting access to the results of research they fund. They could require as a condition of funding that research papers, data and other information produced as a result of their funding are made publicly available such as in an ‘open access’ repository.

Privacy and ethics regulation

Complexities associated with privacy regulation across jurisdictions and multi-site ethical review processes can adverse affect the conduct of some types of research, particularly in the medical field. This report recognises the valid aims of both regulatory approaches. However, streamlining the ethical review of multi-site research and introducing national consistency in privacy regulation of health information can achieve the objectives of the regulations, while imposing fewer costs on researchers.

Performance evaluation

Performance evaluation and benchmarking can assist in achieving the most effective and efficient allocation of funding, both across programs and to projects within programs.

The adequacy of existing performance evaluation and benchmarking is mixed. Programs with significant budgetary implications should be subject to routine, transparent and independent evaluation, and use scientifically rigorous methods to determine program effects. These features are not always present. There are some notable shortcomings in relation to the evaluation of business programs.

There are also deficiencies in the assessment of the quality and impacts of higher education block funding for the purposes of funding allocation. The proposed Research Quality Framework (RQF) is intended to remedy this, but as noted later, has its own limitations.

Institutions such as the CSIRO, the ARC and the NHMRC are constantly developing their research management and evaluation approaches, appropriate to their specific research contexts. For example, in line with its mission-oriented research agenda, over the last few years CSIRO has adopted a process that involves:

- setting priorities to identify new-to-the-world research opportunities with strong potential impacts;

- management of ongoing research with staged financing that depends on constant re-assessments of future impacts; and
- an independent peer reviewed ex post scientific assessment of impacts and quality.

This approach should be considered by other mission-focused research institutions, and its wider potential applicability gauged as experience is gathered in the use of sophisticated research management methods.

Ex ante peer review plays a very significant role in the assessment of research in most programs, especially those of the ARC and the NHMRC. Ex post impact assessments often measure impacts indirectly by gauging whether potential diffusion of ideas has occurred through publication and whether such publications are of high quality (based on their citation rates). It is less easy to develop broader measures of social and economic impacts akin to that used in ARC Discovery Grants or CSIRO's science assessment process because of the more basic nature of the research and the high transaction costs of assessing many thousands of small projects.

National Research Priorities

The Australian Government has articulated the broad direction of its priorities for publicly-funded science through its National Research Priorities (NRPs), though these are neither binding nor quantitatively expressed.

The Commission supports the retention of the priorities in the present level of detail as, in the main, these provide sufficiently meaningful signals of areas for research. Any marked loosening or tightening of the priorities would be problematic. Any broader level of prioritisation would no longer usefully guide research at all, whereas greater precision faces major informational and transaction cost challenges. Central government control would lack the flexibility and information to prescribe detailed research agendas.

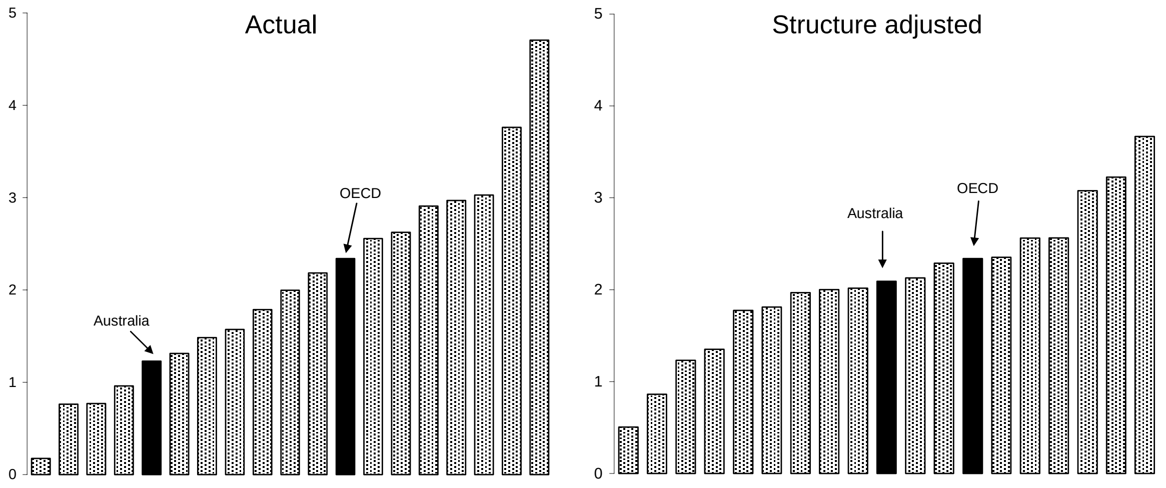
Funding issues

Although the study's terms of reference seek guidance about where and how public funding should be allocated, several participants also addressed concerns about the actual quantum — unsurprisingly the majority submitting that the level of funding should be increased.

There are several indicators and processes that help guide whether funding levels are appropriate. International comparison is a useful broad indicator of adequacy, but must be interpreted carefully. Some participants in this study claimed the apparently low Australian aggregate R&D to GDP ratios are an indicator of significant under-investment, requiring redress through increased government funding. However, international differences in aggregate R&D ratios mainly reflect differences in industry structure, not the size of government funding for R&D (figure 3).

Figure 3 **The R&D 'gap' narrows considerably once industry structure is taken into account**

BERD/value-added ratio (per cent), 2002[a]



a The structure-adjusted estimates use the (OECD average) industry structure.

Other macro indicators — multifactor productivity growth and business innovation propensities — suggest that Australian businesses are performing well with their current R&D investments.

Neither industry nor government research agencies suggested that under-funding was a major problem, while the area where the most concern was raised about resourcing levels — higher education — is not towards the low end of the distribution of R&D spending to GDP among OECD countries.

And while apparent measured rates of return to R&D are high, the results are too imprecise to provide a clear case for significant further funding. In any case, large increases would run into supply constraints over the shorter run. New spending measures also have transaction costs associated with compliance and unexpected incentive effects, as well as the costs of raising finance through distortionary taxes (or those associated with displacement of other public spending). A decision to spend more has to balance the marginal benefits against the marginal costs.

In regard to the spending mix, the evaluation of the effectiveness and efficiency of the current programs is important. Are there any obvious poor performers? Are the marginally funded projects in one program achieving significantly better outcomes than in another program? Do the governance structures and processes consistently specify objectives and desired outputs? Do they factor performance measurement into initial design, follow through, and also feedback? Is there independence and transparency of assessment? The Commission has suggested several improvements in these areas.

Several participants considered that the balance of public support had shifted inappropriately towards applied R&D and commercialisation at the expense of basic and strategic R&D. While there is no absolute standard against which to judge the appropriateness of this shifting balance, it is clear that, when assessed against the rationales for public support for R&D, there are dangers if the trend goes too far.

A further aspect of decision making about levels and mix of funding is the Budget process, set in a framework of incrementalism, diversity and devolution. It usually results in an incremental reallocation of the quantum of funding to science and innovation relative to other priorities, and a reallocation of the science and innovation quantum between competing programs. This process works adequately, but the Commission considers that better performance evaluation of programs would enhance the outcomes of the annual Budget deliberations.

Australia's State and Territory Governments are increasingly active in the provision of public support for R&D. At the intergovernmental level, federalism creates interesting experiments in new program design, but also risks program proliferation, poor coordination and overlaps.

Business programs

Australia's current suite of business support programs could be improved to target more effectively the twin objectives of encouraging research activity with high social benefits (spillovers), which would not take place without public support (additionality).

Reforms of general business R&D funding arrangements

The R&D tax concession — including its incremental component — is the most important single mechanism for public funding support of business R&D. It has the advantage over grant programs in that it leaves businesses with the flexibility to undertake the kinds of R&D suited to their business strategies and needs. Its total budget costs were over $600 million in 2005, which was around 60 per cent of total direct business R&D support by the Australian Government.

One of its major limitations is that the criteria for the basic 125 per cent tax concession do not screen out R&D that would have happened anyway. This increases the costs to revenue from stimulating any additional R&D and reduces the likelihood of net benefits from the program.

The net payoff from the concession could be substantially improved by rebalancing the R&D tax concession away from the generally available 125 per cent subsidy towards the 175 per cent incremental component of the program. This could be achieved, for example, by maintaining the basic concession for smaller firms, whose R&D is more responsive to the subsidy, but otherwise using the 175 per cent incremental component as the principal vehicle for stimulating business R&D. Alternatively, the scheme ultimately could be shifted completely to the 175 per cent component, if threshold issues about firm size were considered to provide adverse incentives for the growth of smaller R&D-intensive enterprises.

The effectiveness and attractiveness of the 175 per cent incremental scheme itself could be enhanced by:

- adopting a fixed base of an R&D-to-sales ratio as the basis for payment, rather than the current rolling base;
- giving start-up firms access to the premium component from which they are currently excluded because they do not have a three year history of R&D performance to determine the base;
- considering relaxing the beneficial ownership requirements by allowing foreign subsidiaries holding their IP abroad access to the incremental concession only; and
- potentially even increasing the concession rate for the premium component or introducing a tiered system with progressively higher subsidy rates depending on the extent of the increase in a firm's R&D activity.

As noted previously, the increasing focus of some business programs — most notably the Commercial Ready program — on later-stage commercialisation rather than research runs the risk of supporting R&D that might have occurred anyway and of shifting support away from the R&D stage where spillovers are most likely. The various manufacturing industry-specific programs, while generously funded, should be evaluated, in part, against a broader objective of facilitating structural adjustment — the automotive industry program being a case in point.

Subsidy rates for some types of RRDCs should be re-calibrated — in the long run

The governance design of the Rural R&D Corporation model is inherently sound. In the absence of compulsory levies to fund rural research, individual producers may attempt to free-ride on the R&D of others, with resultant significant under-provision. Levies that are decided by, and apply to, all beneficiaries of the R&D overcome this. There are also strong grounds for significant public co-funding of RRDCs that provide spillover benefits beyond industry members and where that research would not proceed in the absence of support (for example, research into improving salinity-damaged areas). Government contributions should aim to ensure sufficient research of this type occurs.

However, the Commission considers that there is a weak rationale for the present substantial co-funding of some industry-centred RRDCs. The government contribution rates per dollar of R&D in such industry-centred RRDCs are from three to ten times that received in manufacturing and other sectors. Yet there is little compelling evidence that there are correspondingly higher additionality or spillover rates that could justify these differences.

However, in considering changes to these arrangements, the Commission is aware of the severe financial situation that many rural producers face over the short to medium term as a result of persistent drought conditions. In this context, a reduced government contribution in the short term would probably not be made up through increased levies, putting at risk R&D that is important for the future sustainability of the sector. This suggests that the present arrangements should remain in place until the effects of the current severe climatic conditions have receded.

There may be grounds for a complementary program to CRCs

The Cooperative Research Centre (CRC) program received mixed responses from participants, some arguing there are high returns while others pointing out low ultimate impacts, high start-up costs and ongoing compliance burdens. Current cost-sharing arrangements seem to direct high levels of subsidies to the business collaborators, as they are primary beneficiaries of the Centres.

Several options may improve collaborative arrangements of this kind.

The original objectives of the program — the translation of research outputs into economic, social and environmental benefits — should be reinstated. This is likely to produce better outcomes than focusing public support on the commercialisation of industrial research alone.

The low incentives for CRCs to wind up early if research targets are not met considerably lowers the potential returns from R&D through such ventures. Allowing parties to retain all, or a significant portion of, the unspent funds left over after the early termination of CRCs may address current poor incentives.

The CRC is geared toward large-scale, longer-term research programs, which are more suited to big research users, with relatively cumbersome avenues for CRC partners to enter and exit the venture and a heavy compliance burden. There is scope for complementary options for business collaboration with public sector research agencies and universities that could provide more nimble, less management-intensive arrangements than the present CRC program. There are several options in the design of such arrangements, but whatever design is selected would need to ensure that the joint goals of flexibility, additionality and spillovers were likely to be achieved. Some eligibility criteria that may achieve these goals are mooted by the Commission. Any new arrangement should be piloted.

There may be grounds for also supporting flexible collaborative R&D arrangements just between businesses, but these would need to involve a sufficient number of partners that they would be unlikely to occur in the absence of support. The development of other forms of intermediation between business and research organisations is discussed in the report.

Higher education

Funding of higher education research accounts for over 40 per cent of total Australian Government financial support for science and innovation. Universities receive block funding direct from the Australian Government (about $1100 million in 2004). They are also the primary recipient (about $700 million in 2004) of the competitive-funding programs administered by the ARC and the NHMRC.

The conceptual arguments for dual streams of funding of higher education research are sound, encouraging researchers to compete on quality and impact (competitive grants), while providing institutions with a base research-funding level intended to allow them to make their own strategic choices (block grants) with reduced transaction cost burdens of external grant applications. (Similar arrangements apply to CSIRO and appear to work well.) But funding for higher education research has increasingly eroded the share of block grants. The Commission assesses that further shifts away from block grants would risk undermining their important role.

Block grants are currently given out on a formula-basis that does not include direct peer review or direct assessment of economic, social and environmental benefits.

The proposed RQF would rely on peer review and, as well, assess impact. But such differing funding allocation methodologies have both benefits and costs.

While the current block-funding methodology does have shortcomings:

- there is no clear evidence pointing to deficiencies in the scientific quality of research currently funded through this mechanism; and
- block grants are implicitly exposed to peer review since they are used to support competitive grants, where these processes are already established.

The RQF may well allow the development of better measures of quality and impact. There is, however, evidence that the RQF will bring significant costs as well as benefits — such as through the additional burden it would place on resources for peer review. At this stage, it is not possible to assess the balance.

The Commission suggests that it is too early to make a final decision about implementation of the RQF, and suggests that its adoption should be delayed, pending the following investigation and analysis:

- continue with limited trials, based on RQF peer-review principles, but focused on providing indicators of the quality and impact of research dependent on block funding;
- examine whether current procedures within institutions are sufficiently rigorous to promote the quality and impact of block funded research;
- examine what benefits, if any, fine tuning of existing block-funding formulae could bring; and
- examine the merits of externally applied, risk-minimisation approaches to enhancing the quality and impact of block-funded research applied in conjunction with formula-based approaches to funding.

Draft findings

DRAFT FINDING 3.1

There are strong rationales for the provision of public funding support for science and innovation.

DRAFT FINDING 4.1

Taking account of multiple sources of evidence, the Commission considers that there are significant positive economic, social and environmental impacts from publicly supported science and innovation.

DRAFT FINDING 5.1

Several impediments to innovation should be addressed:

- *major publicly funded research infrastructure should be priced to maximise utilisation, while avoiding congestion;*
- *there should be national consistency in the application of privacy regulation and in ethical review of multi-centre research;*
- *published papers and data from ARC and NHMRC-funded projects should be freely and publicly available; and*
- *there should be greater flexibility in pay structures for teachers to help address science and maths teacher shortages.*

DRAFT FINDING 6.1

Decision making within universities in relation to the transfer, diffusion and utilisation of research outputs should not focus unduly on an objective of commercialisation to the detriment of maximising the social return from the public's investment.

DRAFT FINDING 7.1

Performance evaluation and reporting arrangements have developed significantly in recent years, particularly through the adoption of an outputs/outcomes focus. There are, however, examples of major deficiencies. Arrangements should be reviewed against the following criteria.

- *Outputs and intended outcomes should be defined in relation to the rationales for public support and to the community benefits expected from that support.*
- *Evaluation should be developed in a benefit–cost framework, balancing greater precision against administrative and compliance costs.*
- *Where undertaken, selective case studies of impacts should be placed in a supplementary rather than central evaluation role.*
- *Assessment should be undertaken with adequate frequency — this might vary between different types of measure.*
- *Assessment should be as independent and transparent as reasonably possible.*
- *Feedback mechanisms that promote continuous improvement in terms of funding allocation to programs and to projects should be developed and implemented.*

DRAFT FINDING 8.1

There is no evidence that the overall quantum or mix of public support for science and innovation in Australia is currently inappropriate for Australia's needs and aspirations. However, there are concerns if the trend towards publicly funding applied science and innovation, at the expense of basic and strategic science and innovation, goes too far.

DRAFT FINDING 9.1

The R&D tax concession could be improved by:

- *shifting the orientation of the concession towards its 175 per cent incremental component;*
- *relaxing the beneficial ownership requirement and the expenditure and turnover thresholds for the tax offset for the incremental scheme alone;*
- *changing the base on which the incremental subsidy is paid to a firm's ratio of R&D to sales at a given, fixed date; and*
- *allowing access to the incremental scheme to start-up firms.*

DRAFT FINDING 9.2

In principle, competitive grant programs such as Commercial Ready provide greater scope to target socially valuable R&D projects that would otherwise not proceed. However, this can be compromised by the current focus on commercialisation objectives.

DRAFT FINDING 9.3

There are strong grounds for significant public co-funding of RRDCs that provide spillover benefits beyond industry members where that research would not proceed *in the absence of support. But there is a weak rationale for the present substantial co-funding of some industry-centred RRDCs. Any changes to current support arrangements should be delayed until current economic conditions in the rural sector have improved.*

DRAFT FINDING 9.4

The CRC program could be improved in several ways:

- *the original objectives of the program — the translation of research outputs into economic, social and environmental benefits — should be reinstated. This is likely to produce better outcomes than focusing public support on the commercialisation of industrial research alone; and*
- *the share of public funding should be aligned to the level of social benefits provided by each CRC, thereby reducing some of the large rates of subsidy to business collaborators.*

DRAFT FINDING 9.5

A complement to the CRC program with broader collaboration goals could be developed which supports smaller, shorter and more flexible collaborative arrangements between groups of firms either independently or in conjunction with universities and public sector research agencies.

DRAFT FINDING 10.1

The Commission considers that the current real level of public appropriation funding for CSIRO should not be reduced. Aspects of its approach to priority setting and performance management may have wider applicability to other parts of Australia's innovation system.

DRAFT FINDING 10.2

The effectiveness of DSTO research is heavily dependent on the effectiveness of the procurement practices and the research directions set by the Australian Defence Organisation.

DRAFT FINDING 11.1

Consideration should be given to delaying the adoption of the RQF further, while undertaking the following investigations and analyses:

- *continue with limited trials based on RQF peer-review principles, but focus them on providing indicators of the quality and impact of research dependent on block funding;*

- *systematically examine whether current procedures within institutions are sufficiently rigorous to promote quality and impact of block-funded research;*
- *examine what fine tuning of existing formulae, if any, might be advantageous in promoting incentives for continuing enhancement of quality and impact of research funded through block funding; and*
- *examine the merits of externally applied, risk-minimisation approaches to enhancing the quality and impact of block-funded research (applied in conjunction with formula-based funding).*

1 Introduction

Key points

- This study has three major aims:
  - to assess the impacts of public support for science and innovation;
  - to identify any major impediments that affect the operation of the innovation system and the scope for mitigating such impediments; and
  - to evaluate frameworks for assessing where and how public funding should be allocated, including any scope for improvements.
- The Commission has adopted conventional definitions of R&D and science. The definition of innovation is a broad one and entails deliberative processes by firms, governments and others to add value to the economy or society by improving products, services, processes or organisational forms. Catch-up to global frontiers is included as innovation and is one of the most important drivers of economic growth.
- While there are strong private incentives for imitation and catch-up, these do not always apply to the generation of R&D. This is why, despite occupying a small part of the innovation terrain, policies relating to science and R&D justifiably occupy a large part of public innovation policy in general.

1.1 Why is this study timely?

Innovation is seen as crucial to future wealth and prosperity, and the capacity to tackle social and environmental challenges locally, nationally and globally. It is widely identified as increasing the adaptability of an economy to future global uncertainties. Australian governments play a major role in the innovation system, setting regulations, establishing institutions, shaping capabilities and through direct support. They provide significant support to science and innovation, mainly through financing R&D. Public support from all Australian governments accounted for around $5.4 billion of the $12.8 billion of R&D undertaken nationally in 2002-03.[1]

[1] DEST (2005a, pp. 51-52). This excludes funding of science education, which is usually not counted as part of the science and innovation budget. See box 1.3 for some of the definitional issues surrounding R&D.

Given the scale of government involvement in the provision of R&D, there are many questions about the future role of public support for science and innovation, the most important being how well past arrangements have worked and the manner in which the innovation system has functioned. What are the benefits of public support? Are the linkages between the supported parts of the system and innovation functioning well? How can governments' administrative and legislative arrangements for the supported parts of the system make their biggest contribution? Should there be a different orientation? Should the level of public support be raised, lowered or remain where it is?

This study — commissioned by the Australian Government in March 2006 — seeks to answer these questions. As specified by the terms of reference (reproduced at the front of the report), this study considers three major issues:

- *Economic, social and the environmental impacts.* To what extent does government support for science and innovation achieve something useful for Australians? The Commission interprets impacts widely (such as tangible new services, processes and products, reduced costs, 'feel good' factors, environmental benefits, reduced disease burdens and future risk reduction). However, as specified by the terms of reference, in considering economic impacts, particular emphasis is placed on the effects on Australia's recent productivity performance. The study also assesses whether there are adequate arrangements to measure outcomes from publicly supported science and innovation for performance management purposes.
- *Impediments.* The study aims to identify impediments to the effective functioning of Australia's innovation system, including whether there are impediments to knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration between research organisations and industry, or in the creation and use of intellectual property. It also aims to identify any scope for improvements.
- *Design of the system*. The study evaluates the decision-making principles and program-design elements that firstly, affect the performance of the innovation system as a whole and that secondly, guide funding allocation between its parts. Possible improvements to the system and the implications of changing the level of support or its mix are considered.

A companion to this study, released by the Commission in April 2006, assessed the impacts of business R&D on Australia's productivity performance over the last three decades (Shanks and Zheng 2006). That study is used as an input into chapter 4 of this report. This stream of work continues a sustained examination of innovation by the Productivity Commission (box 1.1).

Box 1.1 Past Commission research on science and innovation

The Commission (or its institutional antecedent) has undertaken many studies/inquiries that directly examine the innovation system or its impacts. In the last decade these include the inquiry into research and development (Industry Commission (IC) 1995); the consideration of R&D programs in the ICT (IC 1998) and telecommunications industries (IC 1998); the role of training and innovation in workplace performance (Laplagne and Bensted 1999); the evaluation of the Pharmaceutical Industry Investment Program (PC 2003a); and the companion study to this report by Shanks and Zheng (2006).

If a broader view of innovation is taken, the Commission has also undertaken studies that have considered the impacts of the *adoption* of innovation and technological change. Among these are studies into the role of information technology changes in productivity growth (PC 2004, Gretton et al. 2002 and 2003, Parham 2002a and 2002b and Parham et al. 2001), medical technology (PC 2005) and the links between technology change and skilled employment (Laplagne et al. 2001). The Commission has also considered parts of the innovation system that are critical to its effective functioning, such as the patent system (Gruen et al. 1996), the wider intellectual property rights system (Revesz 1999); and university resourcing (PC 2002c).

1.2 What we are *not* doing

It is important to indicate the limits to this study's ambitions. The first limit is given by the terms of reference. The Commission was not requested to systematically review individual programs, whether that be funding of specific institutions, such as the CSIRO, or in the broad-based financing arrangements, such as the R&D Tax Concession. However, the general functioning of the system and its parts almost certainly suggest potential improvements to individual programs.

The second limit revolves around the choices for detailed analysis. Some limits to the scope of the study are provided by the definitions we employ (section 1.3). Even then, science and innovation is a vast area. In the Commission's 1995 inquiry into research and development (R&D), Dr John Stocker, the then chief executive officer of CSIRO, commented that in just a few months CSIRO had participated in 66 different reviews (IC 1995, p. 46). More reviews of the system and many statistical and analytical reports have been conducted since (box 1.2). Many of these reviews and reports provide useful information about the performance and nature of the innovation system. On the basis of this developed field, the Commission has made strategic choices about areas of emphasis, and in particular, has decided to undertake less study of areas where quality expert analysis has already taken place. For example, this report does not duplicate the detailed descriptive picture of the system that is annually completed by DEST (in its *At a Glance* and *Snapshot* series), though it draws on this information for different types of analysis.

Box 1.2 **Recent government reviews and reports on science and innovation**

Department of Education, Science and Training (DEST) 2005b, *Australian Science and Technology at a Glance* and 2005a, *Australian Science and Innovation System — A Statistical Snapshot*. These draw on ABS, budget information and OECD data to provide an insight into the trends, structure and performance of Australian science and innovation.

Fell, C. (Chair, External Reference Group) (DEST 2004c), *Evaluation of Knowledge and Innovation Reforms*. The evaluation was asked to provide an assessment of the arrangements by which the Australian Government distributed block research funding to Australia's universities via the Research Training Scheme (RTS), the Institutional Grants Scheme (IGS) and the Research Infrastructure Block Grants Scheme (RIBG).

Sargent, M. (Chair, National Research Infrastructure Taskforce) (DEST 2004e) *The Final report of the National Research Infrastructure Taskforce*, DEST considered the important elements of an Australian research infrastructure strategy.

McGauchie, D. (Chair), *Review of Closer Collaboration Between Universities and Major Publicly Funded Agencies*, (DEST 2004f), DEST.

Grant, J. (Chair) 2004, *Sustaining the Virtuous Cycle For a Healthy, Competitive Australia: Investment Review of Health And Medical Research, Final report*, (The Grant Report), December, Commonwealth of Australia, Canberra. This assessed impacts of additional investment made in health and medical research following the Wills Review (1998) and the organisational fitness of the National Health and Medical Research Council (NHMRC).

Science and Innovation Mapping Taskforce (DEST, DITR, DCITA) (DEST 2003c), *Mapping Australian Science and Innovation*, McMillen, Canberra. This stock take of Australia's science and innovation system, identified strengths, weaknesses and opportunities.

Batterham, R. (Chief Scientist) 2002*, Review of the External Earnings Targets Policy Applying to CSIRO, ANSTO and AIMS*.

Having examined past research, the Commission has chosen to focus on the three key analytical issues of interest, building on and sythensising previous Australian studies, but with the following differences.

- The aim is to consider a wider assessment of impacts, in contrast to past Australian studies, which have tended to concentrate on specific methods or on specific parts of the system.

- A greater variety of analytical methods will be applied than have normally been used in single Australian studies. For example, this study will include more sophisticated approaches to international comparisons, longitudinal approaches assessing whether commercialisation strategies have contributed to the growth of firms, the use of panel data methods for considering the impacts of R&D on Australian productivity and bibliometric approaches that assess academic impacts between States and Territories.
- The final aim is to consider the governance and design aspects of the system more deeply than has usually been analysed previously in Australian assessments, one exception being the previous broad Industry Commission inquiry.

1.3 What is science and innovation?

The study of science and innovation is laden with old terminology put to new uses. This sometimes invites futile debates about which semantic boundaries are 'right'. For example, there are disputes about the difference between the 'information economy' and the 'knowledge economy'. But while it is often useful to distinguish knowledge from information, it appears that, in *this* context, nothing is particularly lost in using one over the other. A pragmatic approach is adopted in this study. Definitions that best convey an understanding of the underlying concepts and relations have been chosen.

The definitions of science and R&D are considered first below. Although science and R&D are important, they are ultimately best understood in their role as inputs into the innovation process. Then the central concept of this report, innovation is examined, and the innovation system in which it takes place.

Science

Science is the methodical, replicable, accumulation of knowledge and perspective about the nature of 'things' (the natural world, social systems, the economy), based on conjectures that can be subjected to empirical tests. Another approach is to define science as what scientists do, which is useful when counting the resources devoted to science in universities or public agencies. These are not precise definitions. Mathematics is not an empirical subject, yet would usually be included as a science because of its requirements for internal coherence and the usual capacity for demonstration of the validity of its conjectures through proofs. In any case, it is one of the fundamental tools of science.

The study covers the physical, biological and mathematical sciences, including engineering. The social sciences are also included in the scope of this study. The social sciences may have their own direct beneficial impacts, as in applications in public health, or they may add value by increasing the productive use of the 'hard' sciences within the innovation system (University of New England, sub. 17, p. 7). However, where research in the social sciences has no palpable social, environmental or economic impacts, they are excluded from the scope of this study. (This does not mean that research into the social sciences and humanities without a link to innovation is unimportant, but rather that it lies outside the principal concerns of this study.)

Further, in this study, science education and teaching are included only to the extent that they affect skills development and may promote, or present obstacles to, the effective functioning of the innovation system. Similarly, scientific and technological services are generally excluded, except where deficiencies in these affect the innovation system.

Gans (sub. 10, pp. 5–6) proposes an alternative definition of science as a:

> … particular way of allocating resources, that is, an institution. … science is a way of deciding which projects should be undertaken. First, it is scientist driven in that scientists propose the projects and scientists review them. Second, it has a priority-based reward system whereby there is a commitment to give a reward to those scientists who are first to establish a new fact or way of understanding the world ... those rewards are paid upon success through citation and academic promotion and notoriety.

Gans' definition valuably describes some of the common features of basic science as an institution for allocating resources within universities and it is a useful framework for discussing some of the processes used by government in the design of the system. However, it is incomplete as a description of science as an institution outside universities and basic research. And, for the definitional purposes of this chapter, it does not indicate the features which distinguish the discipline of science from other research activities.

While science is sometimes supported for its own sake (chapter 3), the predominant interest in science in this report centres on its role *within the innovation system* (see below) — the mechanisms that determine choices about how much to do, in which institutions, for what innovative purposes, its impacts on innovation and impediments to its useful diffusion and adoption.

Research and development

The conventional definition of R&D is:

> … creative work undertaken on a systematic basis to increase the stock of knowledge including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. Any activity classified as research and experimental development is characterised by **originality**, should have **investigation** as a primary objective and should have the potential to produce results that are sufficiently **general** for humanity's stock of knowledge (theoretical and/or practical) to be recognisably increased. (DEST 2005c, p. 9)

R&D is a major part of the innovation system[2] — accounting for a major share of the activity of government research institutions and approximately one third of Australian business expenditure on innovation. It can take various forms, at the broadest level being categorised as 'basic', 'applied' or 'experimental' (box 1.3). Even though much basic research is not directed at developing new or improved products or services (in the short term), it often plays the most crucial role in supporting successful innovation over the medium to longer term — thus, all forms of R&D associated with science and innovation are relevant to this study.

R&D should not just be judged on its immediate promise of improvements in products, services or processes, but also on its ability to provide the capacity for better decision making in the future. For example, the Defence Science and Technology Organisation's (DSTO's) capabilities are intended to assist in making more informed future procurement decisions.

Innovation

In this study, innovation is defined as deliberative processes by firms, governments and others that add value to the economy or society by generating or recognising potentially beneficial knowledge and using such knowledge to improve products, services, processes or organisational forms.[3] From the perspective of this study,

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2 Whether R&D is included as innovation per se depends on how broad a definition of innovation is used. Most business R&D has the purpose of improving business performance and so, in an ex ante sense, should be included as part of innovation. Pure basic research has no specific application in mind, and is often not regarded as an innovation in itself, though it may support subsequent innovation. But either way, R&D has an important function within the innovation system, and debates about where precise boundaries may lie are probably not very useful.

3 This process should not be misunderstood as a linear one of having an idea for innovation and then implementing it sequentially (though this is still important in firms), but rather the process of always being alert for opportunities, and then using them when they are identified.

these improvements may be specific to the entity, to the industry, country or world, and could be incremental or novel.

Box 1.3 **Definitions of R&D**

(1) The common understanding

In common parlance and within a commercial context, R&D is undertaken with the aspiration that it will, at some point, be used to develop new (typically commercial) applications, even when no specific application is apparent during the research phase. In other words, the *goal* of development is an important aspect of the categorisation of an activity as R&D. This distinguishes R&D from research, and indeed many university scholars would use the term research for their activities, but not R&D. This does not mean that research cannot be useful; in fact it often is. But research need not be undertaken in a context that has useful applications in mind, whereas this is a necessary feature of R&D as commonly understood by its actors.

(2) The statistical and policy conventions

In policy documents and statistics on R&D a wider definition is adopted, in which research without development is termed part of R&D. Accordingly, in ABS, DEST and OECD statistics (and analysis of) R&D, ancient history is defined as R&D because it involves research. The difference between this convention and the more commonly understood meaning should be noted.

In this report, most statistics relate to the second definition because it is the basis on which data are gathered and which inform policy discussions. However, wherever possible, the Commission attempts to break down the data and analysis into types that have connections with the commonly understood use of the term. This is possible because three types of R&D are recognised that allow these distinctions to be drawn.

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. (Sometimes basic research is divided into **pure basic research** and **strategic basic research**, with the latter directed at acquiring knowledge towards specified broad areas in the expectation of useful discoveries.) As shown in chapter 2, most basic research is undertaken within universities, though they also undertake other forms of R&D.

Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.

Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units.

Source: Commission analysis and material adapted from OECD 2002, *Frascati Manual*, Proposed standard practice for surveys on research and experimental development, p. 30.

Innovation can be distinguished from knowledge generation per se, since to comprise innovation, any knowledge must be productively incorporated into an entity's activities and outcomes, often using core resources and decision making processes (Rogers 1998).

Innovation is not just technological in nature. Entities can be highly innovative but undertake little or no R&D. A recent study of Australian business innovation (broadly defined) found that R&D was a very poor predictor of innovation (Jensen and Webster 2004). Less than 3 per cent of the variation in innovative behaviour between firms was explained by variation in their R&D expenditure.

The Commission's approach shares many common features with that used by the Australian Bureau of Statistics in its definition and measurement of innovation, though the most distinctive difference is the Commission's inclusion of non-businesses and gradual catch-up to global technological frontiers (box 1.4). The Commission's definition is also generally commensurate with the broad approach of Schumpeter (1934) and modern adherents, such as Baumol (2002, p. 10)[4], Fagerberg (2003), Lundvall (2000, p. 8) and, in an Australian context, the BCA (2006, p. 2).[5] The broad approach has slowly gained ascendancy as the more appropriate conceptualisation of innovation because it more satisfactorily explains economic growth and the dynamism of the service sector than historical approaches centred on major technological innovations in manufacturing.

Innovation is multi-dimensional

Innovation has many dimensions. It can be categorised by actor, location, knowledge source and by type. In this study it is important to distinguish three different types of innovation (figure 1.1).

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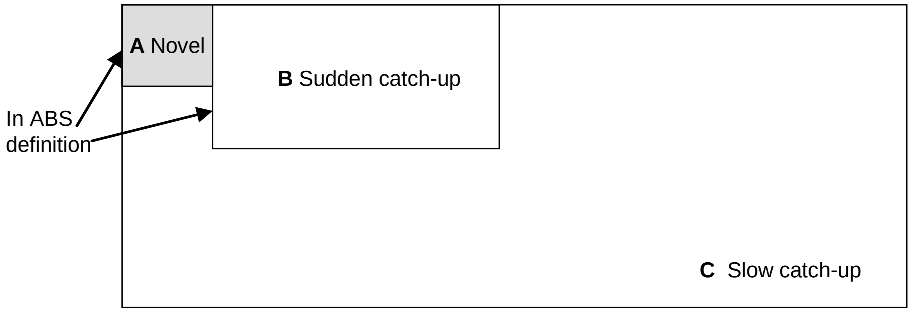
4 Baumol defines innovation as the 'recognition of opportunities for profitable change and the pursuit of those opportunities all the way through to their adoption in practice; in particular, as the activity of recognising economically viable inventions and doing whatever is necessary to bring them to market or to ensure their effective end use by some other means.' Baumol's definition valuably indicates that innovation is a *process* that includes recognition of opportunities and which is purposeful, not just the culmination of an effective end-use. However, his definition excludes imitation, which he categorises as another (though often complementary) strategy (pp. 208ff). This is the most distinctive difference from the definition adopted by the Commission.

5 The BCA describes it as 'the application of knowledge to create additional value and wealth' through improved goods, services, processes, management and organisations.

Figure 1.1 **Novel innovation is a small corner in a big room**



First, there are novel innovations, which are innovations that occur across products, processes and organisational forms at the global technical frontier (partition A). These comprise a small share of actual innovation in Australia (figure 1.2), even using the narrower ABS definition (box 1.4). This form of innovation is dynamically critical to economic growth and to social and environmental advances, since catch-up is premised on the existence of the original breakthroughs and revolutionary applications. In an Australian context, while it comprises the non-dominant form of innovation, novel innovation has played a particularly important role in industries close to Australia's natural endowments, such as agriculture and mining.

Second, there is sudden catch-up, which represent significant improvements in products, processes and organisational forms, but which do not occur at the global technical frontier (partition B).

Finally, in the Commission's schema, there is slow catch-up, which represents changes that occur gradually on the path to the global technical frontier (partition C). Undoubtedly, a large part of the economic growth of every country reflects the steady application and adaptation by firms of knowledge and innovations that are quite dated from an international perspective, but are new to their own productive practices. To look only at novel or even rapidly diffused new knowledge (partitions A and B respectively in figure 1.1) is to miss out on an extremely important source of economic growth (partition C).

Box 1.4 How does the ABS define (and measure) innovation?

The ABS defines (business) innovation as the process of introducing new or significantly improved goods or services and/or implementing new or significantly improved processes. New goods or services or new processes may involve the development of new technology, an adaptation of existing technology to a new use (for example, electronic commerce), or may be non-technological in nature (for example, organisational and managerial change, some changes in marketing). Innovation has been classified into three categories. A new good or service means any good or service or combination of these which is new to a business. Its characteristics or intended uses differ significantly from those previously produced. A new operational process is a significant change for a business in its methods of producing or delivering goods or services. A new organisational/managerial process is a significant change to the strategies, structures or routines of the business which aim to improve performance.

While the Commission's approach is similar it differ in three respects.

- Governments, communities and their agencies are included, as well as businesses.
- Gradual catch-up to technological frontiers is included. In contrast, the ABS approach would exclude many incremental changes to products, services or organisations, that when cumulated, represent major changes over a longer period of time (for example, the gradual diffusion of some information technologies throughout firms and governments).
- It also incorporates preparedness — an enhanced capacity for dealing with future uncertainties. For example, a water utility may have undertaken research that, while not resulting in any changed practices now, may nevertheless be seen as having a significant option value because it reduces future risks.

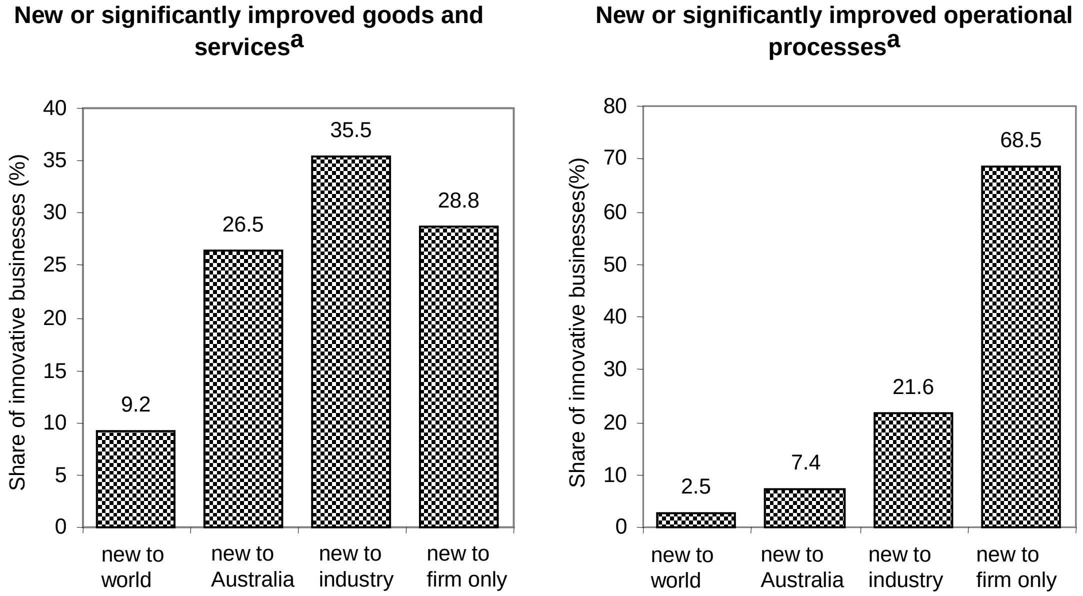
That said, the choices made by the ABS are pragmatic for the purpose of *measuring* business innovation through survey methods. If all the factors encompassed by the Commission's definition were counted as innovation, every organisation would be recorded as innovating. This would render meaningless simple counts of the frequency of innovating versus non-innovating firms and invalidate international comparisons of business innovation.

Source: ABS (2006a).

Some commentators argue that major inventions with a high degree of novelty are the most beneficial form of innovation, but this confuses the issue when catch-up (both rapid and slow) is the way in which new innovations are diffused in practice. Catch-up is dependent on innovations at the frontier. The importance of catch-up innovation (B and C) is especially significant in small open economies that undertake, from a global perspective, only a very small share of innovation at the frontier.

Figure 1.2 **Many innovations are not very novel**

Australia, innovations introduced 2001-2003



a The shares relate only to those innovating businesses that introduced new or significantly improved products in the first panel and those innovating businesses that introduced new or significantly improved operational processes in the second.

Data source: ABS (2006a).

Implications of a wide definition

The Commission's wide definition focuses policy on broader impediments frustrating the performance of the innovation system. It is usual to accentuate impediments such as access to finance by firms to commercialise highly novel technologies, the design of licensing arrangements, the problems of non-appropriable spillovers for innovators and adequate protection of intellectual property. These mostly relate to the small part of innovation represented by partition A in figure 1.1.

If the broader view of innovation is adopted, additional relevant factors that may impede innovation become apparent. They can comprise: general skill levels; competitive pressures that affect the motivations for firms and their staff to improve continuously; deficits in intermediaries that provide technical advice; and the impacts of taxes and regulations that may frustrate adoption (for example, workplace demarcation rules or inappropriate standards). The BCA (2006, pp. 40-50) has highlighted these policy-related impediments in its recent report on innovation, rather than those factors usually identified in studies that focus on novel, technological innovation.

The broader view also explains some of the links that might exist between economywide productivity growth and public support for science and innovation. Catch-up in firms and in other parts of society may, for example, rely on the human capital and capabilities of the more narrowly conceived science and innovation system. So increases in A may not just increase B and C by shifting outwards the frontier for which catch-up is a target, but increase the capacity for catch-up as well.

While it is important that government establish appropriate macro and micro conditions for innovation to flourish, most forms of innovation, at least within businesses, do not need *direct* public support. This is because there are strong incentives for rivalrous firms to routinely innovate. Baumol (2002) has persuasively outlined the autonomous mechanism for innovation within businesses:

> Under capitalism, innovative activity — which in other types of economy is fortuitous and optional — becomes mandatory, a life-and-death matter for the firm. And the spread of new technology, which in other economies has proceeded at a stately pace, often requiring decades or even centuries, under capitalism is speeded up remarkably, because, quite simply, time is money. (p. 1)

However, this general principle is not necessarily true for innovations based on certain kinds of research and development (R&D) nor on its closely complementary activities (an issue explored closely in chapter 3).

In this study, the Commission has been asked to examine the parts of the system that receive public funding support. These primarily comprise the most narrow aspect of innovation — partition A, of figure 1.1 — and indeed, mainly just one fragment of this, innovation resulting from public support for technological research and development.

This is why, despite occupying a small part of the innovation terrain, policies relating to science and R&D occupy a large part of public innovation policy in general.

But while this study focuses on (A), it is important to remember that the wider impacts of innovation, and the policy issues surrounding these, are complementary factors in economic growth. The implications of the links and contrasts between both ends of the innovation continuum are drawn out at various points in this study. They are particularly relevant in interpreting how public support for science and innovation might have economic and social impacts and in identifying impediments to the operation of the innovation system.

From whose perspective is innovation gauged?

While the measurement of innovation has been most developed in a business context, this study includes non-business innovation because it is an important target of public support for the science and innovation system.

- Considerable publicly-funded social and economic research is undertaken by universities, which is then used by government agencies to improve the delivery or design of their services. Governments have explicitly recognised their role as innovators in various innovation and economic policy statements (for example, Queensland Government, 2006) and that influences their demands on the knowledge generating capabilities within the publicly-funded system.
- The DSTO provides research services directly to the Australian Defence Organisation (ADO) for use in its decision making.
- Research on the environment by universities and the CSIRO has been important in tackling various environmental issues. Regulations can sometimes also be seen as innovative responses to new knowledge generated in this way.
- Health research, while also raising significant opportunities for innovation within firms, has also been directly diffused through public agencies.
- Research within universities and the CSIRO has been used for community innovation.

Box 1.5 shows some examples.

The value of innovations undertaken by governments and communities are generally harder to measure than business innovations. But their exclusion from the definition of innovation would miss many of the important applications of knowledge generated in the publicly supported system and one of the major rationales for public funding support of science and innovation.

Box 1.5 **Examples of non-business forms of innovation**

The Higher Education Contribution Scheme, used as a major source of financing of Australian university teaching, was devised by Bruce Chapman of the Australian National University (and member of the Wran Committee).

CSIRO has undertaken research into biodiversity, weed control, water management and soil degradation that has been widely diffused in farms and in the general environment. A specific example is the development of a successful biological control of Salvinia, which is an aquatic weed that chokes lakes and slow moving rivers. CSIRO found and released the Salvinia weevil, which eats the stem of the weed and its terminal buds. This brought the weed under control.

Australian DRGs and casemix funding provides an illustration of innovation that brought together overseas research, public authorities, clinicians and university researchers. Diagnosis related groups (DRGs) are used to classify inpatient stays into clinically meaningful categories of similar levels of complexity that consume similar amounts of resources. DRGs were initially developed by Professor Robert Fetter of Yale University to assist with quality assurance programs, but were subsequently adopted in the US for hospital funding systems — the so-called 'casemix' funding model. Australia then adopted this model, but altered the DRGs to reflect Australian clinical practices. The Australian Commonwealth Department of Health and Ageing created its own DRG version, in consultation with the Clinical Casemix Committee of Australia, clinical coding and classification groups, the National Centre for Classification in Health (based at the University of Sydney and the Queensland University of technology), State and Territory Health Authorities and other organisations (http://www.rch.org.au/casemix_rch/)

Sulphur dioxide emissions trading reflects both scientific knowledge about environmental damage developed in universities and other research agencies and economic knowledge about efficient abatement methods.

The first prospective evidence on the risks to sudden death of the prone positioning of infants was obtained by the Tasmanian Menzies Institute in 1991 using the Tasmanian infant cohort. The research led to a rapid public health policy response that cut sudden infant death syndrome (the most common postneonatal cause of death in Australia at the time) by around 80 per cent over the next 10 years (Van der Weyden 2003).

Research within universities and non-profit research agencies has played a major role in the evaluation and generation of policies in school education. For example, the Australian Council for Educational Research (ACER), a non-profit organisation, has (among other things) undertaken or coordinated detailed and influential research on school education based on a unique longitudinal data set — the Australian Longitudinal Study of Youth.

Plowman et al. (2003) from the University of Queensland undertook research that showed that differences in the attitudes to change and creativity between otherwise similar rural towns were fundamental in determining whether they declined or prospered. The Queensland Government is diffusing this research for community change through its *Engaging Ideas* initiative (http://www.getinvolved.qld.gov.au/share_your_knowledge/training/ideas.html).

From whose perspective is improvement gauged?

The categorisation of innovation involves a normative assessment that the change is, or is even just likely to be, an improvement with that assessment conventionally based on whether the innovation serves the interest of the innovator or their immediate customers, rather than the world at large. However, sometimes innovations impose costs that are not borne by their users or progenitors.

- Many innovations with large benefits for business productivity (and therefore consumers) have also imposed significant environmental costs. Fertilisers and pesticides, for instance, have had large impacts on agricultural productivity, but have also imposed collateral environmental costs through damage to water supplies and ecosystems. In these cases, the benefits have outweighed the costs, but the costs should not be neglected in analyses of the impacts of innovation. Many subsequent innovations provide benefits by abating the costs of historical innovations (as in greenhouse abatement technologies or pest-resistant crops that do not require pesticide use).
- A firm's organisational or operational innovation that decreased competition in an industry may benefit shareholders, but decrease overall public benefits. For example, it has been argued that various innovative patent strategies — such as patent blocking and patent thickets — have been used to reduce competition from rivals (Shapiro 2001). New standards, tying and bundling arrangements may sometimes also have these effects.[6]

This study adopts the conventional stance by defining innovations by their ex ante goals, but it avoids the sometimes associated non sequitor that particular innovations are consequently always good from a public benefit perspective. This is most relevant to case studies.

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[6] Identifying whether such arrangements really are anti-competitive is very difficult. A recent Australian instance is a (minor) innovation cited by the Business Council of Australia (BCA). Coles Myer retailers formed an alliance with Shell petrol stations to offer discounts for petrol if customers exceed prescribed spending amounts at Coles Myers stores (BCA 2006, p. 18). It represented an innovative extension to this market of bundling arrangements that have been applied in many other business contexts (Gans and King 2004) and created value to the two firms by increasing combined consumer demand and loyalty. However, its benefits for the competitive environment and consumers were contested by Gans and King (2004), who argued that many customers would be unable to benefit. However, the competition watchdog, the ACCC (2004) disagreed, considering that the arrangements were beneficial to consumers.

The science and innovation system

The notion of an innovation system is a very simple idea, though its simplicity is often concealed by unhelpful over-abstraction. The idea is that many things and actors contribute to innovation and that they affect each other (figure 1.3):

> Popular folklore notwithstanding, the innovation journey is a collective achievement that requires key roles from numerous entrepreneurs in both the public and private sectors (Van de Ven et al. 1999, p. 149).

So it is not usually the case that someone in a laboratory has an idea, which is developed, prototyped, and then commercialised in an orderly linear sequence. This is the appropriately rejected 'linear' model.[7]

The usefulness of looking at innovation as a system is that, firstly, it suggests that improved outcomes might occur through any of the factors that influence innovation and that, secondly, it reinforces the point that innovation is much broader than just technological invention. The principal components of the system are:

- the relevant institutions that pursue innovation (for example, businesses, universities, government-funded science-based organisations and communities) or that organise it (for example, DEST, the ARC and the NHMRC);
- the embedded economic and social incentives that encourage or discourage innovation, such as systems of intellectual and other property rights, standards making, subsidies, social capital and cultural norms on the positive side, and various forms of taxation and inappropriate regulation that can slow the innovation process;
- the capacity for diffusion of knowledge and innovation, which can occur through:
  - individuals who take knowledge and skills from one enterprise or entity to another;
  - the existence of a diverse group of information intermediaries who can help firms and government agencies discover new product technologies or processes, or can assist them to adopt these when they have been discovered;
  - adopt appropriate technologies and management systems;
  - the development of technologies that facilitate diffusion (for example, libraries, databases and the availability of good telecommunications and internet services); and

[7] Some participants in this study, however, said this does reasonably describe biotechnology innovation.

- linkages between the parts of the system (including, particularly for small open economies, those that exist with actors located overseas);

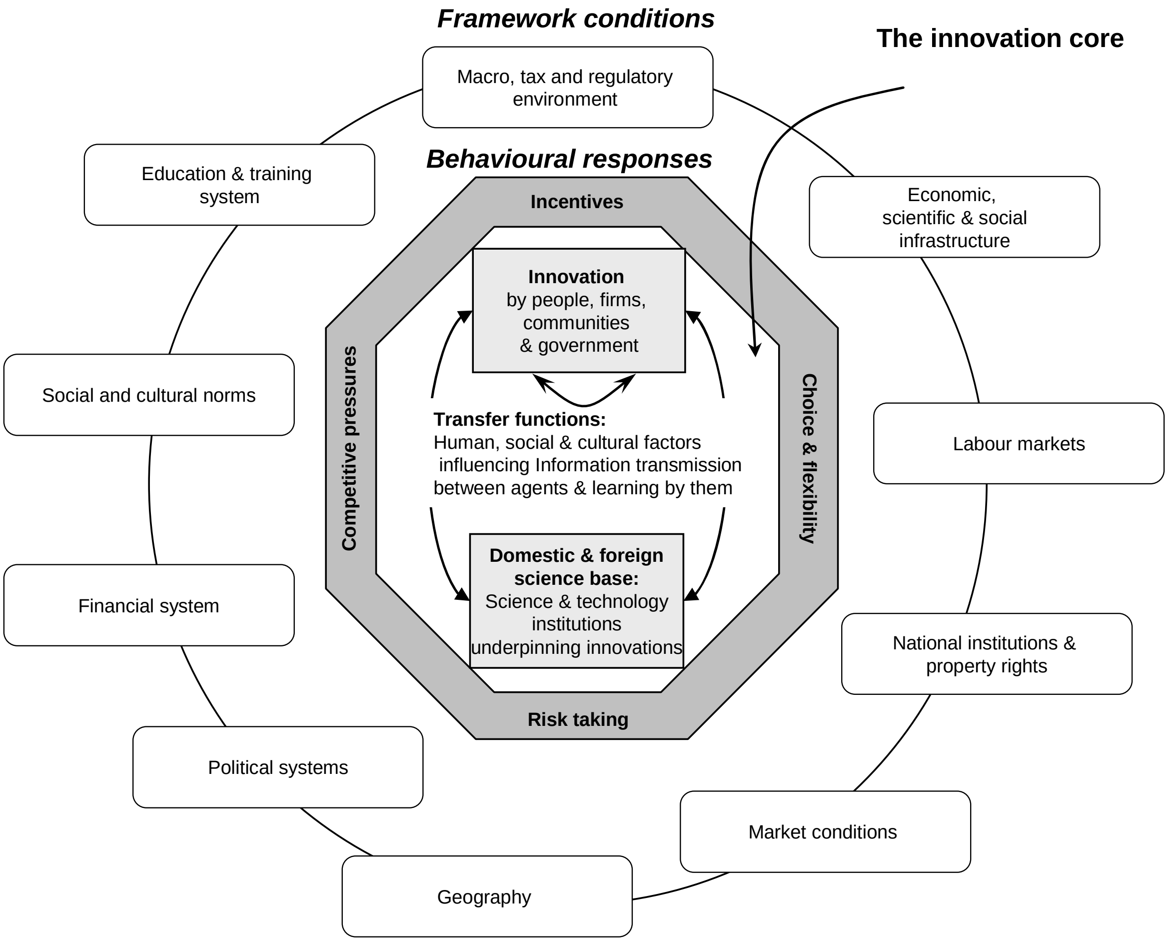
- a skilled and capable workforce (not just scientists), entrepreneurship and high-quality training and education;
- the stability and sophistication of the financial system; and
- the multiple feedbacks in the system that can enhance or frustrate the prospects for learning, diffusion, and innovation. These feedbacks imply, for example, that customers can be the trigger for innovation, and play active parts in R&D and commercialisation, rather than just act as passive beneficiaries at the end. It means that not only does scientific knowledge generate technological developments, but that technological development can also generate new scientific knowledge. It also implies that research can occur throughout the process of commercialisation as new problems emerge and that this, in turn, can generate, surprising new commercial opportunities.

Faults in innovation systems — weak incentives, social and economic instability, bad infrastructure and inadequate human capital — reduce the capacity to develop and apply knowledge innovatively, and to close any gap with global best practice. With this interpretation, the Australian innovation system has a prime influence on the nature, extent and impact of innovation undertaken in Australia, including the emulation and adoption of innovations and knowledge developed overseas.

Governments worldwide continuously try to improve framework conditions to get closer to world's best practice in business and government services, but they label this micro or macro economic reform, not innovation policy. It does not matter what it is called if it is done. The only issue for this report is whether some of the imperatives necessary to make the innovation system function well are missing from the current agendas for micro reform. We only highlight them where they are.

In practice, what is termed 'innovation policy' around the world still focuses on the innovation core in figure 1.3 below — R&D and its related concerns of an adequate science base (including science and engineering personnel), financing, diffusion, adoption, commercialisation and any direct impediments affecting the smooth functioning of these factors. As noted earlier, that is also the major orientation of the terms of reference given to the Commission.

Figure 1.3 **The innovation system**



a There are many different representations of the innovation system (such as the 2nd Oslo manual and OECD 1999). While drawing from these, the representation shown here gives primacy to the framework conditions that set the range of opportunities for innovation, the behavioural responses (and feedbacks) these conditions elicit and the actors that respond to (and craft) them. Some depictions only see firms as innovators, but in the context of this study, all agents are regarded as potential innovators.

Source: Productivity Commission.

1.4 Participation in the study

The Commission has consulted with a wide range of people, institutions and governments about the functioning of the science and innovation system (appendix A). Submissions were sought from interested parties and 105 were received prior to the publication of the draft report.

1.5 Structure of the report

Chapters 2 provide a brief snapshot of the inputs into the system, while chapter 3 explores the appropriate (and inappropriate) rationales for public support. These condition the nature of impacts, the possible source of impediments and the design of public support arrangements.

Chapter 4 presents information on the impacts of Australia's science and innovation system, addressing the appropriate methodologies and findings. This report distinguishes standard economic impacts (on such factors as living standards, employment and productivity) from social and environmental impacts (such as poverty reduction and cleaner air).

Impediments to the efficient operation of the science and innovation system are considered in chapter 5. Chapter 6 then examines issues related to commercialisation and utilisation of research.

The remaining chapters examine the administrative and legislative arrangements that affect the functioning of the publicly supported components of the innovation system. The study looks at how funding levels are determined, how programs are designed, delivered and administered, how funding is allocated among programs, the allocation of funding to program participants, and how those participants themselves allocate that funding to their various activities.

Supporting material is provided in appendices.

2 A snapshot of Australia's science and innovation system

Key points

- Direct government support for science and innovation has been concentrated on research funding for universities, CSIRO and other public agencies, rather than business R&D and other knowledge assets.
- Where business support is provided by the Australian Government, it is overwhelmingly aimed at stimulating R&D, rather than commercialisation or diffusion of ideas.
- Around half of the direct funding support of the Australian Government for innovation is directed at basic research of some type, significantly more than any other actor in the system, including State, Territory and Local governments.
- Industrial production and technology are the principal targets of Australian Government support, followed by human health, which has been assuming a greater importance. The relative importance of support for agricultural research has been falling.
- It is common to assert that the various research-performing institutions fulfil relatively rigid roles in the Australian system. This is true for some sectors. Business principally undertakes applied and experimental R&D; public sector research agencies tend to undertake strategic basic and applied research. But higher education institutions undertake a broad mix of research types and not primarily basic research, as often thought.
- International comparisons suggest Australia has about the average business innovation propensity, but a low relative BERD to GDP ratio. There are many reasons why such unadjusted comparisons should not be used as a basis for policy arguments for changes in public support.
  – For example, variations in business R&D intensities across countries only weakly explain variations in business sector innovation propensities.
- Australia has been converging to have a pattern of R&D more like that of the typical OECD country, with a greater weight towards business R&D.

2.1 Introduction

A major goal of this study is to assess the outputs and impacts of public support for Australia's science and innovation system. A useful starting point is to identify the amount of public spending in the system and the types of activities that have been supported. This is the goal of this chapter. Given some studies have already compiled comprehensive statistics on these features (as noted in chapter 1), the Commission has chosen to summarise the main features of the system and, sometimes, to provide new views of existing data. (The conventional statistical definitions defined in box 1.3 in chapter 1 are usually adopted as this is the basis on which the data are available.)

2.2 An overview of investment in knowledge capital

Given the broad (and elusive) nature of innovation, a comprehensive measure of investments across the economy is not available. However, some indicators are available, which collectively suggest that Australian society invests substantially in science and innovation.

- Gross domestic spending on R&D in 2002-03 for governments, businesses, the higher education sector and others was around $12.8 billion (in current prices) or about 1.64 per cent of GDP (DEST 2005a, p. 51).
- Non-R&D innovation spending by business (which ignores the likely significant investments in non-R&D innovation by governments) was around $13.1 billion or another 1.67 per cent of GDP.
- Australia's investment in 'knowledge' — a synthetic measure covering expenditure on R&D, investment in ICT and expenditure on tertiary education — equalled some 4.1 per cent of GDP in 2002 (OECDb 2005).

Direct government funding support for science and innovation has been concentrated on research in universities, CSIRO and other public agencies, rather than on business R&D and other knowledge assets. Where business support is provided by the Australian Government, it is overwhelmingly aimed at stimulating R&D, rather than commercialisation or diffusion of ideas (table 2.1). The orientation to R&D, rather than other forms of innovation, reflects the view that this is where the risk of private underinvestment is highest.

Table 2.1 **The focus of the Australian Government's public support for business innovation is on R&D, rather than business diffusion or commercialisation**

2004-05 to 2006-07[a]

Type of measure	*2004-05*	*2005-06*	*2006-07*
Support value	$m	$m	$m
Support for industry performed R&D[b]	887.6	1 001.7	1 140.7
Business commercialisation and diffusion programs[c]	91.9	91.7	148.0
Other industry-centred R&D programs not typically undertaken in industry	1 130.0	1 196.8	1 199.3
Non-industry centred R&D	3 328.9	3 661.2	3 486.0
Total	**5 438.4**	**5 951.4**	**5 974.0**
Shares of total support	%	%	%
Support for industry performed R&D[b]	16.3	16.8	19.1
Business commercialisation and diffusion programs[c]	1.7	1.5	2.5
Other industry-centred R&D programs not typically undertaken in industry	20.8	20.1	20.1
Non-industry centred R&D	61.2	61.5	58.4
Total	**100.0**	**100.0**	**100.0**

[a] The table is based on allocating each Australian Government innovation program to the four categories. Some programs span more than one category. In these cases, judgment has been used to allocate them to a specific group. [b] The Commercial Ready program is included as support for industry-performed R&D as it principally acts as a support mechanism for R&D for commercially promising products in small and medium enterprises, However, it also provides some finance for commercialisation of already developed ideas. [c] Included are measures used to diffuse technologies, best practice or information to business, as well as financing measures for commercialisation.

Source: Commission calculations (appendix B) based on DEST (2006f).

Government exercises two roles in the support of science and innovation: it undertakes R&D (GOVERD) and it is a major funder.

2.3 Government undertakes R&D

The Australian Government[1] is a major R&D performer through Australian government agencies (such as the CSIRO, ANSTO and the DSTO), with aggregate R&D spending on major federal research agencies of about $1.5 billion in 2002-03 (DEST 2005a).[2] State and Territory government research agencies like the

[1] The Commission has followed the recent convention of using the term the 'Australian Government' to denote the Commonwealth or Federal Government. The term 'Australian governments' will be used to denote the Australian and State and Territory governments.

[2] More recent data are available, but for major Federal research agencies only. In 2005-06, the estimated actual spending on these by the Australian Government was $1343 million, up in current prices from $1218.1 million in 2002-03 for the same group of agencies (DEST 2006f). This also constitutes a modest increase in real terms.

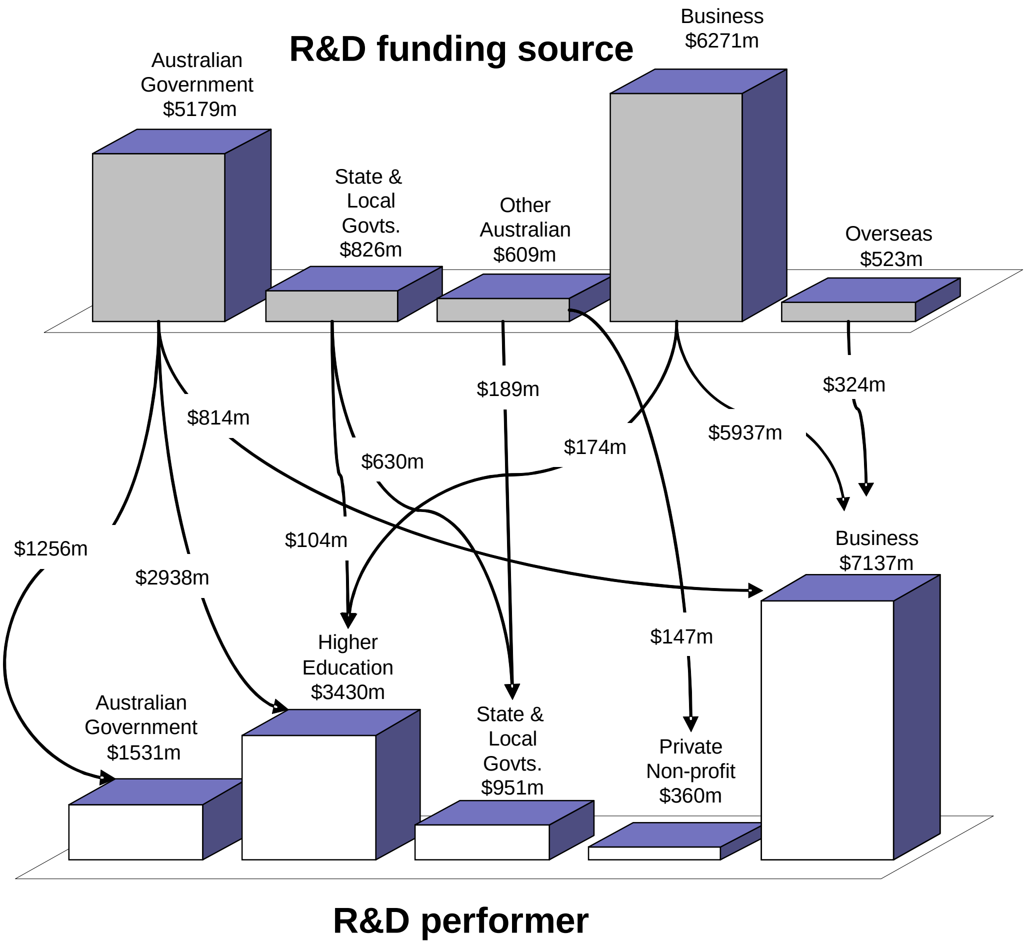
Queensland Department of Primary Industry and Fisheries, also undertake significant R&D, with collective spending of around $950 million in 2002-03 (DEST 2005a, p. 51). The overall importance of State and Territory governments as a funding source has been increasing.

2.4 Governments are major funders of R&D

Second, government — overwhelmingly, the Australian Government — funds the bulk of its own and most higher education R&D (HERD) from consolidated revenue (figure 2.1).

Figure 2.1 Where does the money come from and where does it go?

Major flows, Australian R&D funding and spending 2002-03



[a] Only the major flows are shown and the sectoral descriptions are those used by DEST. The data are as shown by DEST (2005a), but with one major exception. The original data used by DEST were in line with the OECD Frascati manual, which is applied by the ABS. However, this excludes some important funding measures, in particular, funding provided through the R&D Tax Concession to the business sector. Accordingly data on government spending on the tax concession in 2002-03 (of $566 million) has been added to Commonwealth funding and to business sector expenditure.

Data source: DEST (2005a, p. 53) and DEST (2006f).

The data presented in figure 2.1 indicates the major spending areas and funding sources across all Australian jurisdictions. It is important to note that the graph has been adjusted from its original source (DEST) to include the Australian Government's spending on the Tax Concession ($566 million of spending in 2002-03). The adjustment was required to address the implications of the framework used to measure government funding of business R&D (box 2.1).

Box 2.1 **What is counted as R&D funding?**

Great care must be taken in interpreting figures on governments' funding of R&D. As in all statistical measures, conventions determine what is counted. In the case of R&D, the conventions set down in the Frascati manual provide a consistent framework for comparisons between OECD countries, but only of *direct* flows of R&D funding. In some instances, the Frascati principles mean that some important public sources of funds are excluded from the scope of the statistics. In particular, the implicit subsidy to business R&D from the R&D Tax Concession is not counted as a source of funds for the business sector from the Australian Government sector as it is not a direct payment for R&D.[3]

As a consequence of the scope of the definition used for R&D funding, the ABS, which applies the Frascati manual, indicates $247 million dollars of Australian Government-financed R&D in 2002-03.

In contrast, budget estimates reveal that outlays by the Australian Government for business R&D and innovation were $969 million in 2002-03 (table 2.2), around four times higher than the flow from the Australian Government to business suggested by unadjusted ABS data. These aspects of the Frascati principles also need to be considered in comparisons between OECD countries of the extent of governments' funding of business R&D. The OECD records an amount of government financing of business R&D in Australia that is well below the real total amount.

Budget data for the Australian Government (table 2.2) gives a generally more comprehensive indicator of funding patterns for this level of government than figure 2.1. The higher education sector is the single most important direct recipient of science and innovation funding from the Australian Government, commanding around four in every ten dollars. The remaining six in every ten dollars are roughly evenly distributed between government agencies, business and multisectors (NHMRC, CRCs and other research activities that are allocated to more than one sector).

3 Where some entities span sectors — such as Cooperative Research Centres — decisions about where to classify the joint entity can also affect the measured flows between sectors (ABS 2006b).

Table 2.2 **Summary of major Australian Government support for science and innovation through the budget and other appropriations**

1997-98 to 2006-07, current prices

Actual cost Incurred in year (accrual basis)			*Estim. actual*	*Budget estim.*
	1997-98	2002-03	2005-06	2006-07
	$m	$m	$m	$m
Intramural expenditure on science and innovation				
Major Australian Government research agencies				
DSTO	212.1	283.4	349.1	340.7
CSIRO	466.8	532.1	593.9	607.2
Other R&D Agencies	256.4	402.7	399.9	403.8
Subtotal	935.3	1218.2	1342.9	1351.7
% of total	25.3	25.0	22.6	22.6
Extramural expenditure on science and innovation				
Business enterprise sector				
Industry R&D support	420.0	566.0	622.0	657.0
Other R&D support	20.0	158.6	63.4	81.6
Other Innovation support	120.4	244.4	427.3	513.9
Subtotal [a]	560.4	969.0	1 112.7	1 252.5
% of total	15.2	19.9	18.7	21.0
Higher education sector				
Australian Research Council	0.0	298.3	546.2	570.3
Performance based funding	0.0	1 086.5	1 234.7	1 214.3
R&D spending under former framework[b]	1 675.4	0.0	0.0	0.0
Other R&D support	2.5	588.0	449.7	449.7
Subtotal	1 677.9	1 972.8	2 230.6	2 234.3
% of total	45.4	40.5	37.5	37.4
Multi-sector				
NHMRC and other Health	179.9	291.3	698.9	467.0
Cooperative Research Centres	144.3	148.6	208.2	189.4
Rural	140.5	204.3	220.7	221.4
Energy and the environment	25.2	29.1	64.1	140.6
Other science support	28.7	39.2	73.1	117.2
Subtotal	518.6	712.5	1 265.0	1 135.6
% of total	14.0	14.6	21.3	19.0
Total support	3 692.2	4 872.5	5 951.2	5 974.1
In constant prices (2002-03 prices $m)[c]	4 170.6	4 872.5	5 451.2	5 325.7

[a] Spending in the business enterprise sector shown above is different from the sum of ‘Business commercialisation and diffusion programs’ and ‘Support for industry-performed R&D’ in table 2.1. This is because some minor items in the broad sectors were re-categorised in table 2.1. [b] 1997-98 was prior to the introduction of performance-based block grant processes and the establishment of the ARC as an independent statutory body, which is why these are recorded as zero in that year. Data for the former framework are listed. [c] The deflator for 2006-07 used to derive the measure of real science and innovation spending is based on the economywide inflation rate of 2.75 per cent estimated in the 2006-07 Australian Government Budget.

Sources: Based on classifications and data from DEST (2005a, 2006f).

2.5 A plurality of modes of delivery

The Australian Government delivers its support to science and innovation activities through a variety of arrangements (box 2.2).

Box 2.2 Current funding arrangements for public support

In broad terms, the current arrangements used to provide public support for science and innovation in Australia involve competitive funding, block funding and tax concessions and subsidies (DEST 2003c, p. 395).

Competitive funding arrangements involve:

- *peer reviewed competitive grants* — allocation is on the basis of quality in response to researcher initiated proposals (ARC and NHMRC research grants);
- *competitive tenders against predefined objectives* — precise project objectives and outcomes are specified by the funding agency (such as RRDC funded research); and
- *other competitive grants and loans* — all other competitive grants and loans for which project objectives are not specified in advance. For example, this includes CRC grants, Commercial Ready (combining R&D Start and other industry R&D support programs) and industry-specific grants like Pharmaceutical Partnerships Program (P^3) and the vehicle producers; component of ACIS.

The main types of block funding used are:

- *mission driven block grants* — funding provided to public agencies with defined missions in which the recipient agency is responsible for internal allocations of this funding (eg funding for CSIRO, ANSTO, DSTO etc); and
- *formula based block grants* — grants for which the funding between competing recipients is determined entirely or to a large part by a formula (eg university operating grant funding expended on R&D).

Tax concessions and subsidies without a competitive element include:

- the R&D Tax Concession and Tax Offsets for any firm undertaking eligible R&D activities; and
- subsidies and grants. For example, this includes industry specific support such as that provided to the automotive sector though ACIS and to the TCF industry through the Strategic Investment Program.

The percentage distribution by mode of delivery for 2003-04 is estimated as follows: formula-related block grants — 32 per cent; mission driven block grants — 27 per cent; peer reviewed competitive grants — 15 per cent; other competitive grants and loans — 10 per cent; tax concessions and other subsidies — 9 per cent; and competitive tenders against pre-defined objectives — 7 per cent.[4]

2.6 Where are resources allocated?

Public support for science and innovation in general, and for particular programs, can have a range of economic, social and environmental objectives. Although there are detailed data that break down total R&D *expenditure* by socio-economic objective in the Australian system, readily available data on the distribution of public *funding* among competing priorities are only readily available for the Australian Government (table 2.3). Some of the objectives shown can have economic, social and environmental overlaps. The data reveal that industrial production and technology are the principal targets of Australian Government support, followed by human health. The biggest shifts in priorities for funding have been to human health and the environment, away from agricultural production and from untargeted research financed from general university funds.

Table 2.3 **Australian Government support for science and innovation by socio-economic objective**

Share of total support, 1996-97 and 2005-06

Objective	*1996-97*	*2005-06*	*Change*
	%	%	Points
Exploration and exploitation of the earth	5.5	5.4	0.0
Infrastructure and general planning of land use	1.1	1.6	0.5
Control and care of the environment	1.0	3.9	2.8
Protection and improvement of human health	6.5	14.3	7.8
Production, distribution and rational use of energy	2.2	2.6	0.4
Agricultural production and technology	7.5	4.3	-3.2
Industrial production and technology	22.5	23.9	1.4
Social structures and relationships	0.6	1.9	1.2
Exploration and exploitation of space	0.0	0.6	0.6
Defence	6.0	6.2	0.2
Objective not-specified			
Research financed from general university funds	45.9	29.5	-16.4
Non-oriented research	1.1	5.7	4.6
Other civil research	0.0	0.1	0.1
Total	100.0	100.0	0.0

Source: DEST (2005a), table 2.1.9 and DEST (2006f), table 5.

4 Calculated from DEST 2003c, *Mapping Australian Science and Innovation — Main Report*, figure 5.41).

It is not known with accuracy how much public support is channelled into basic research versus other types of R&D. Nevertheless, Commission estimates (table 2.4) suggest that around half of the R&D support of the Australian Government is directed at basic research of some type, significantly more than any other actor in the system, including State, Territory and Local governments.[5] Relatively little funding from governments (around 13 per cent) are directed to experimental development, which remains the research priority of projects funded by business. Around two-thirds of business research funding is provided for experimental research.

Counting all R&D conducted in the economy, regardless of its financing source, pure basic research accounted for some 10 per cent of GERD, strategic basic research 16 per cent, applied research 36 per cent and experimental development 39 per cent in 2002-03 (table 2.4). These figures highlight how public support is strongly tilted towards the basic and away from the experimental end of the R&D spectrum, as distinct from the overall quantum of R&D undertaken nationally.

Roles of the R&D-performers

It is common to assert that the various R&D-performing institutions fulfil relatively rigid roles in the Australian system: business undertakes applied and experimental R&D; public sector research agencies undertake strategic basic and applied research; and higher education institutions undertake basic research. (Non-profit private entities are different again, specialising almost entirely in just two fields, biological sciences and health and medical sciences, with a substantial orientation to basic research.)

[5] The estimates in table 2.4 are likely, if anything, to underestimate the importance of basic research to the Australian Government. The estimates are based on the assumption that basic research in any given performing entity — such as businesses — are funded in proportion to the overall source of funds to that entity. So, as the Australian Government funds 4 per cent of business R&D, it is assumed that it funds 4 per cent of the (small amount of) basic research that business performs. In fact, it is likely that government programs tend to favour the riskier end of the R&D continuum in business, so that the true estimate should be higher than 4 per cent.

Table 2.4 **Who funds what type of research in the Australian innovation system?**

Estimated shares (%), 2002-03[a]

Type of research	Aust. Gov.	State & LGov.	Bus.	Other	OS	Total
	Funding source					
Priorities of spending by funding source						
Pure basic research	20.4	9.0	1.9	12.1	8.6	10.1
Strategic basic	24.7	17.1	7.0	25.1	14.1	15.5
Applied research	41.2	61.2	26.9	46.7	31.7	35.7
Experimental	13.7	12.7	64.2	16.1	45.7	38.6
Total	100.0	100.0	100.0	100.0	100.0	100.0
Allocation of research type by funding source						
Pure basic research	75.9	6.0	8.7	5.9	3.6	100.0
Strategic basic	59.9	7.4	20.9	7.9	3.9	100.0
Applied research	43.3	11.5	34.9	6.4	3.8	100.0
Experimental	13.4	2.2	77.3	2.1	5.1	100.0
Total	37.6	6.7	46.4	4.9	4.3	100.0

a It is not possible to determine exactly whether any given funding entity funds pure basic research or other forms of R&D, since data by funding source are not collected on this basis and entities may not earmark funds for a particular type of R&D. Nevertheless, an indication of the underlying priorities of spending and allocation of research types across funding sources can be estimated by considering the extent to which funders provide funds to R&D performers that are intensive in a particular type of research. For example, it is known that business mostly performs non-basic research and that most of the funds provided for research in business are provided by business itself. Consequently, it must be the case that most business funding is directed at non-basic R&D. The data for the table above are estimated by first calculating the shares of funding to any given performer of R&D (k = business, higher education, public sector etc) that are sourced from various alternative funders (j = the Australian Government, State and local governments, business, overseas, other), so that:

$\text{Share}_{jk} = \text{Source}_{jk} / \text{Spend}_k$ where j is the jth source of funds and k is the kth performer of R&D.

Then the amount of research of any given type (m=pure basic, strategic basic etc) for each funder (j) is estimated by applying these shares to the spending on this research activity by the various performers.

$\text{Research}_{jm} = \sum_{k=1}^{5} \text{share}_{jk} \times \text{perform}_{mk}$ where perform_{mk} is the amount of research of type m undertaken by performer k. These are the basis of the shares shown above.

Source: PC estimates based on ABS 2004, *Research and Experimental Development, All sector summary, 2002-03*, Cat. No. 8112.0.

This characterisation is reasonable from an aggregate perspective (table 2.5), but it ignores the large variations across fields within the higher university sector. Unlike the three other R&D performers, universities do not show a consistent pattern of selecting a particular niche within the basic-applied-experimental spectrum across scientific fields (figure 2.2).[6] Several fields — shown as group A, including

[6] Businesses are excluded from the figure because the data are not shown by field. Nevertheless, across all individual industries a consistent pattern of specialisation in applied and particularly

mathematics and the physical sciences — are highly oriented to basic research. On the other hand, many fields — bunched together in the group C in figure 2.2, principally in the social sciences — show a high orientation to applied and experimental R&D. Another group — group B — lie in an intermediate position. It is notable that disciplines with a strong connection to public policy and services (economics, education), general business (commerce), or to Australia's natural endowments (earth sciences, biology, agriculture) tend to have a stronger orientation to applied and experimental research.

Table 2.5 **R&D by type by performing sector**
2002-03

Sector	*All basic*	*Applied*	*Experimental*	*Total*
	$m	$m	$m	$m
Government	754.7	1338.3	389.2	2482.2
Non-profit	212.8	109.5	37.2	359.5
Higher education	1778.2	1390.7	260.7	3429.6
Business	398.4	1540.5	4039.8	5978.6
Share of sector R&D	%	%	%	%
Government	30.4	53.9	15.7	100.0
Non-profit	59.2	30.5	10.4	100.0
Higher education	51.8	40.6	7.6	100.0
Business	6.7	25.8	67.6	100.0

a 'All basic' includes pure basic and strategic basic research.

Source: ABS Cat. No. 8104.0 (business), Cat. No. 8109.0 (government & non-profit) and Cat. No. 8111.0 (higher education).

The other distinctive feature of higher education research is its variety. The four top spending fields in higher education research account for about 55 per cent of total spending.[7] The comparable figures for government performed and non-profit private R&D is around 70 per cent[8] and over 90 per cent[9] respectively. (Business research is not categorised in the same way.)

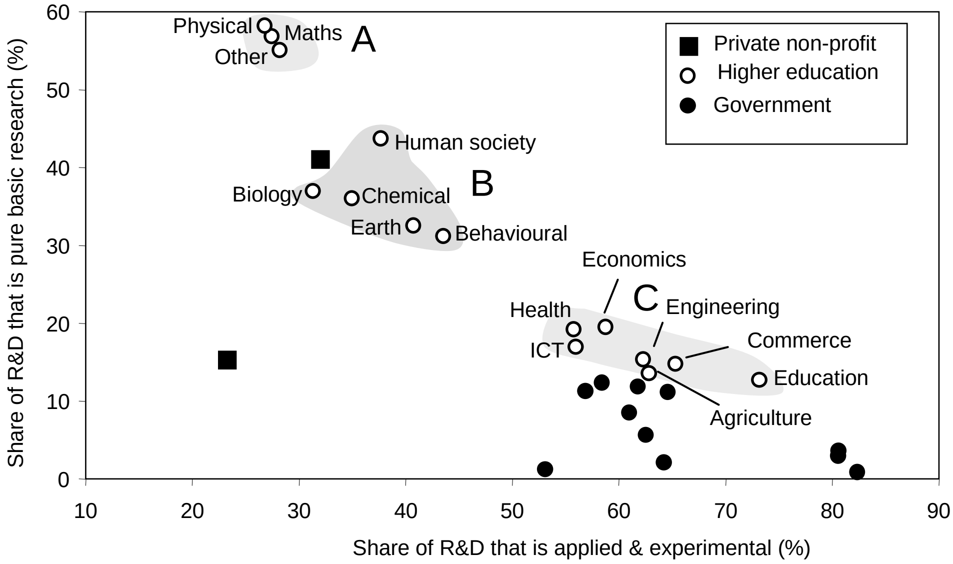
experimental R&D is evident. As noted in table 2.5 overall, pure and strategic basic research accounts for only 6.7 per cent of total business R&D spending.

[7] The top four fields (from rank 1 to 4) are medical and health sciences; biological sciences; engineering and technology; and agricultural, veterinary and environmental sciences.

[8] The top four fields (from rank 1 to 4) are agricultural, veterinary and environmental sciences; engineering and technology; biological sciences; and earth sciences.

[9] The top four fields (from rank 1 to 4) are medical and health sciences; biological sciences; information, computing and communication science; and chemical sciences.

Figure 2.2 **Research in universities spans all types and forms**
2002-03



a Each data point represents a field of research (such as biological sciences) undertaken within a particular sector, with an indication of the share of that field oriented towards pure basic or applied and experimental R&D. The reason all data points do not lie on a 45 degree line is that strategic basic is excluded. It s value can be inferred as a residual after subtracting the values for applied, experimental and pure basic from 100. The shaded areas depict the three separate groups of higher education research orientation.

Data source: As in table 2.5.

2.7 The business perspective

Most R&D in Australia is undertaken and self-financed by business. This spending is directed towards innovation in goods, services, processes and organisational forms (figure 2.3).

As observed in chapter 1, the ABS uses a definition of innovation for statistical purposes, which is narrower than the conceptual definition used throughout this study. Using the ABS approach, an innovator is a firm that introduces any new or significantly improved products, services, processes, organisational or management methods. On this narrower basis, most Australian firms (65.2 per cent) say they did *not* innovate in the three years ending in December 2003. Not surprisingly, given their greater scale, the likelihood of any innovative activity was significantly higher in larger enterprises than small and medium enterprises (SMEs). On the other hand, SMEs account for around 40 per cent of business R&D (a part of innovation) in Australia, which is much more than most other OECD countries.[10] Such SMEs are

[10] The comparisons are adjusted for differences in the statistical definition of innovation in the Eurostat and ABS surveys and for differences in their scope.

often the target of public support in Australia to increase aspects of their innovative activities.

More than two thirds (69.1 per cent) of innovating businesses said they undertook no R&D spending in 2002-03, compared with 94.1 per cent of non-innovating businesses. Spending on combined R&D and innovation by Australian businesses in 2002-03 was $20.3 billion,[11] of which about one third assumed the form of research and experimental development. These data reveal two aspects that are important for this study.

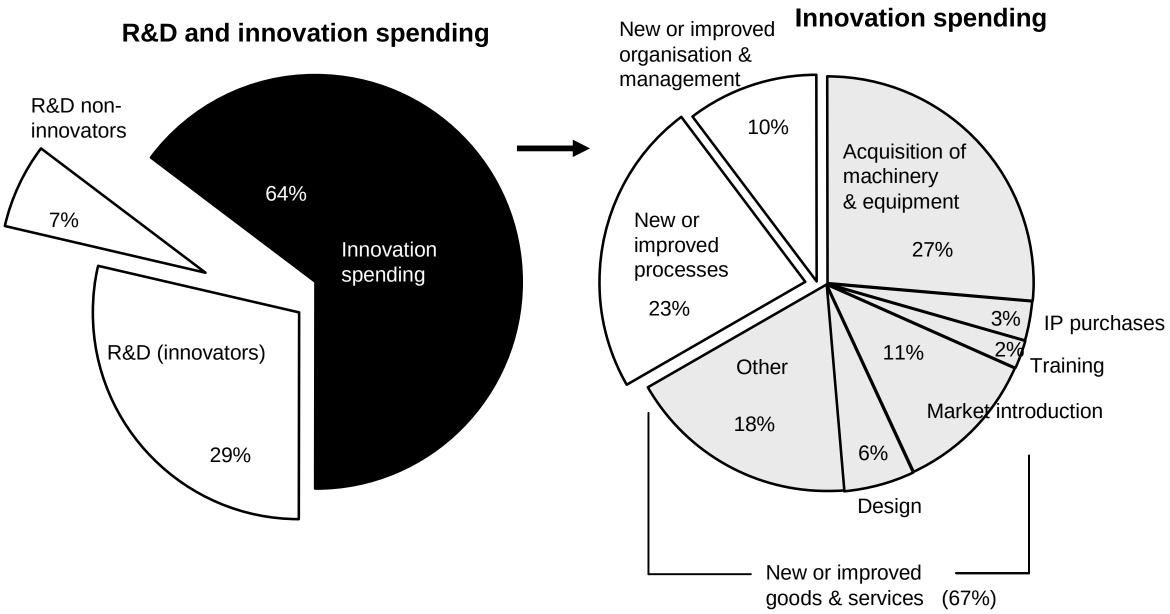
- They confirm that firms' own R&D, the main focus of public funding support in the business sector, is not always a necessary feature of innovation, and where it is, only accounts for a part of total business spending on innovative activities (even when innovation is defined narrowly).
- It is often claimed that the rule-of-thumb ratio of expenditure on research, development and commercialisation is 1 to 10 to 100 (Floyd 2005; Allen Consulting 2003, p. 64). If accurate, this suggests that innovation spending, which includes commercialisation, would be around 10 times that of R&D. This implies that firms should be barely receptive to subsidies directed at R&D alone, any more than people buying cars would respond to a 10 per cent subsidy on the tyres. Yet the ABS data suggest that, on average, innovation spending may be more like two times that of R&D (figure 2.3).[12] This offers at least some potential for successful public support for business R&D.[13]

[11] This excludes any entities out of the scope of the innovation survey (those in General Government; Government Administration and Defence; Agriculture, Forestry and Fishing; Education; Health and Community Services; and Personal and Other Services).

[12] Since some of this spending is associated with innovations that required no R&D, this implies that the commercialisation costs directly associated with R&D projects may be even less than $2 for each dollar of R&D.

[13] The BIE (1993, p. 116) also found that the non-R&D costs of completed innovations were much lower than the popularly applied estimate. Using midpoints of their cost share ranges, it is estimated that R&D to commercialisation costs were roughly 1:1. The BIE study includes incremental innovations.

Figure 2.3 **The relative significance of R&D and innovation spending**
2002-03, Australia



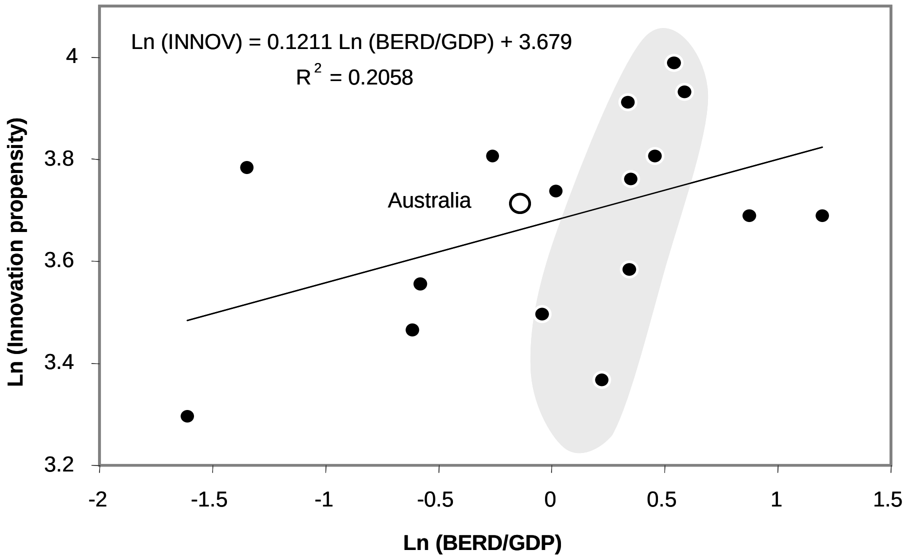
[a] The ABS notes that there are relatively high standard errors of estimates of innovation spending, so that these estimates should be regarded as indicators. It should be emphasised (as discussed earlier) that for the purposes of the survey, the ABS excludes innovation that took the form of small incremental improvements. Consequently, the measure will understate, probably significantly, the extent of spending actually related to innovation.

Data source: ABS 2006, *Innovation in Australian Business 2003*, Reissue, Cat. No. 8158.0.

The weak relationship between innovation at the firm level and R&D spending in Australia is replicated at the international level. Variations in countries' business R&D to GDP ratios 'explains' about 20 per cent of the cross-country variation in innovation propensities by their industries (figure 2.4). There are a whole range of countries — shown in the grey area — that exhibit very little difference in their business R&D intensities, yet show substantially different innovation performances.

Figure 2.4 **High business R&D intensities only weakly predict high innovation propensities**

Australia and European Union countries in the 2000s



[a] The Australian Innovation Survey results were adjusted by the ABS to make them consistent with the EU survey of business innovation. The Australian innovation data are for 2001-2003, while the EU data are for 1998-2001. The R&D data are typically for the year 2002, but data for the year 2001 were used for Greece and Sweden, while data for 2000 were used for Luxembourg. It should be emphasised that the diagram shows the relationship between innovation at a broad level and R&D. It may be that there are stronger relationships between R&D and more fundamental innovations, but the consistent cross-country data for that are not available to test this conjecture.

Data sources: As in figure 2.3 above and OECD, OECD *Main Science and Technology Indicators*, 2005-2, Electronic database, Paris.

The finding that other factors are *also* important for business innovation does not render R&D irrelevant. It simply means that innovation policy has to look at more than one explanatory factor and that these additional factors are of great importance.

Moreover, as one participant in this study noted, R&D effects can have 'stealthy' pathways — their business impacts are often hard to trace. A firm may improve without its managers categorising that as innovation, and without being aware that the improvements can be tracked ultimately to some R&D. For example, a firm may buy some new equipment in which the R&D is embodied or hire a new staff member, whose skills and knowledge have benefited from association with R&D.

In any case, public policy for R&D generally is not aimed at business innovation alone. It can also probe social and environmental problems or lead to government or community innovation. It may also have values that are not related to their immediate ends (as discussed later).

2.8 The international perspective

Measuring the impacts of R&D is hard, as shown in chapter 4. Because of this, policymakers and others often use international comparisons of R&D inputs as a proxy for impacts and to assess the adequacy of R&D investments.

The focus on R&D in such international comparisons is also driven by the availability of data. There are agreed definitions of R&D among national statistical agencies and many countries have collected data on a reasonably comparable basis for some period, in part because of the historical legacy of a focus on technological invention, rather than innovation more broadly. There is far less data on innovation, a more central determinant of growth prospects (though some is shown in figure 2.4).

Figure 2.5 shows the distributions of R&D intensities across different countries, with Australia's position shown within each distribution. Such international R&D comparisons (figure 2.5) reveal that:

- Australian BERD to GDP is lower than those of advanced economies generally, as is the business researcher to employment ratio. Business R&D still is the most important component of GERD, so low BERD to GDP translates to low relative GERD to GDP ratios; and
- Spending on government and higher education R&D to GDP (GOVERD and HERD) is around the median of advanced countries, and in higher education, surprisingly, towards the higher end of researchers to employment rates.

Data, such as that presented in figure 2.5, often assume an iconic status as 'proof' of endemic underinvestment in business R&D in Australia, especially among those wishing to attract more funding. However, comparisons of input ratios are usually a conceptually unsound basis for assessing optimal investment in R&D. Nothing says that 'high' input ratios are necessarily better than 'low' ones, since it is possible to both under or over-invest in R&D. For most other inputs — such as labour or capital — the usual interest is not in maximising inputs per output, but rather maximising its inverse (output per input or productivity).

That said, such input ratios can be useful as soft indicators of potential sub-optimal investment if they identify a striking disparity with other countries that cannot be readily explained. But, first, Australia is not at the end of the distribution in R&D input ratios shown in figure 2.5 — which is probably the more sensible trigger for policy investigation.

Second, it *is* possible to identify factors that provide a partial explanation of why Australia has 'low' R&D intensities. These include an industry structure that largely omits the highest R&D intensive sectors (defence, aerospace and pharmaceuticals); the higher relative importance of SMEs as R&D performers in Australia; the apparently lower price of R&D labour inputs; and the role of foreign multinationals, which tend to import their knowledge capital, rather than creating it in Australia.

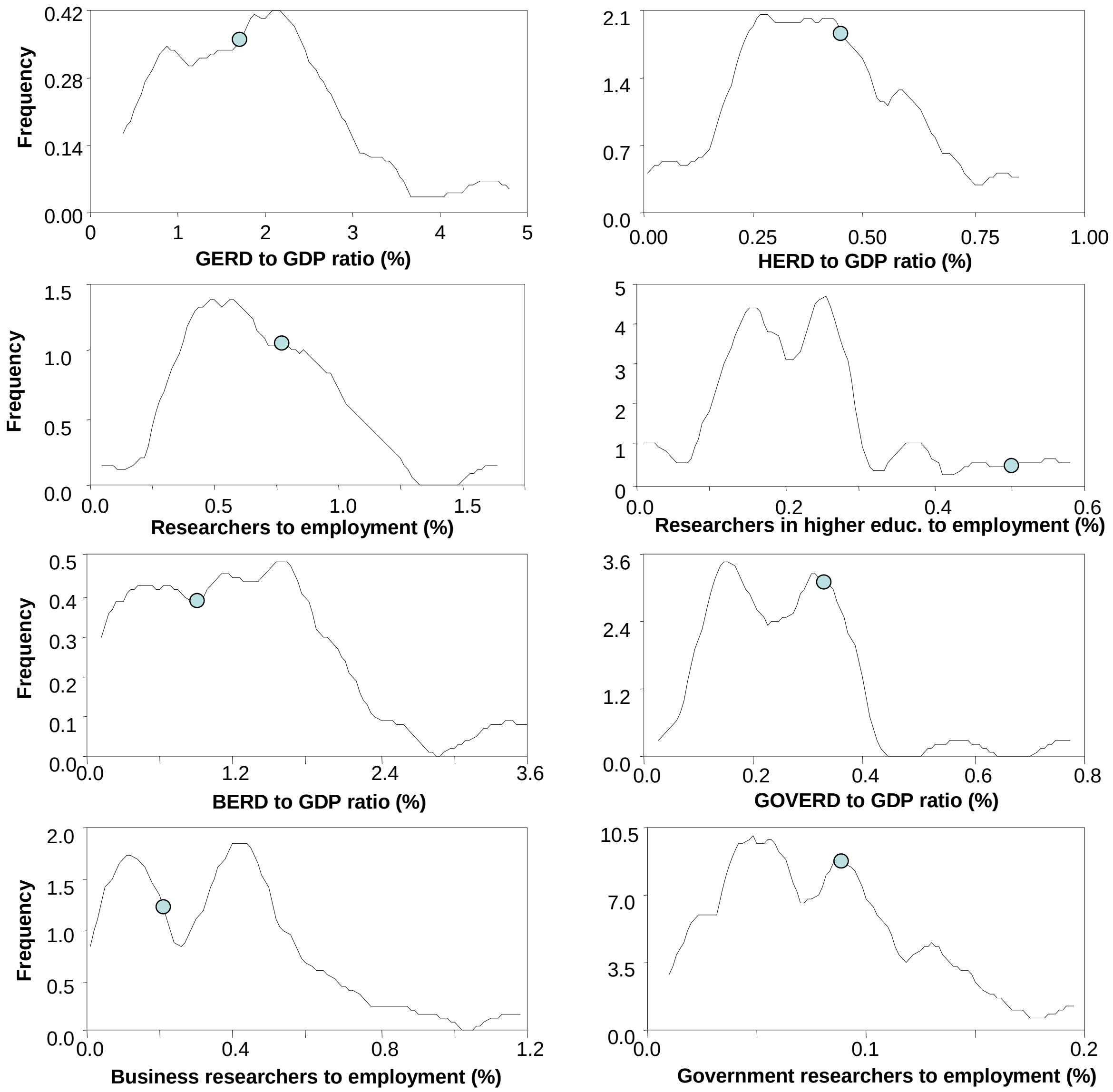
Third, other indicators suggest that notwithstanding its ranking in global R&D intensities, Australia has done well compared with many high R&D performing countries. Australia's multifactor productivity growth record — probably the best summary measure of innovation performance — has been strong. The two major international indexes of fundamental competitiveness, the IMD World Competitiveness Index and the World Economic Forum Growth Competitiveness Index, place Australia as one of the top global performers (6^{th} globally using the IMD data and 10^{th} globally using the WEF data — figure 2.6). And as shown in figure 2.4, Australian business sector innovation propensities are about average by international standards and generally not well predicted by R&D intensities.

That said, big discrepancies between Australia's R&D to GDP ratios and that of other countries should be investigated routinely to find out why they occur. The nature and source of these discrepancies is explored more thoroughly in appendix C. The Commission's analysis suggests that many of the discrepancies that currently exist in BERD to GDP can be explained by benign differences between Australia and other OECD countries. In that case, unadjusted league tables of R&D to GDP ratios should not be used to assess whether Australia's R&D performance is good or bad.

When combined with measures of productivity, innovation or other indicators of wealth generation, international variations in patterns of R&D are also useful for exploring the economic impacts of R&D. This is the approach, for instance, used in Gans' estimates of the returns to R&D (sub. 10) and in chapter 4.

Figure 2.5 **Are Australian R&D inputs low by world standards?**

International distributions of R&D ratios, 2002[a]

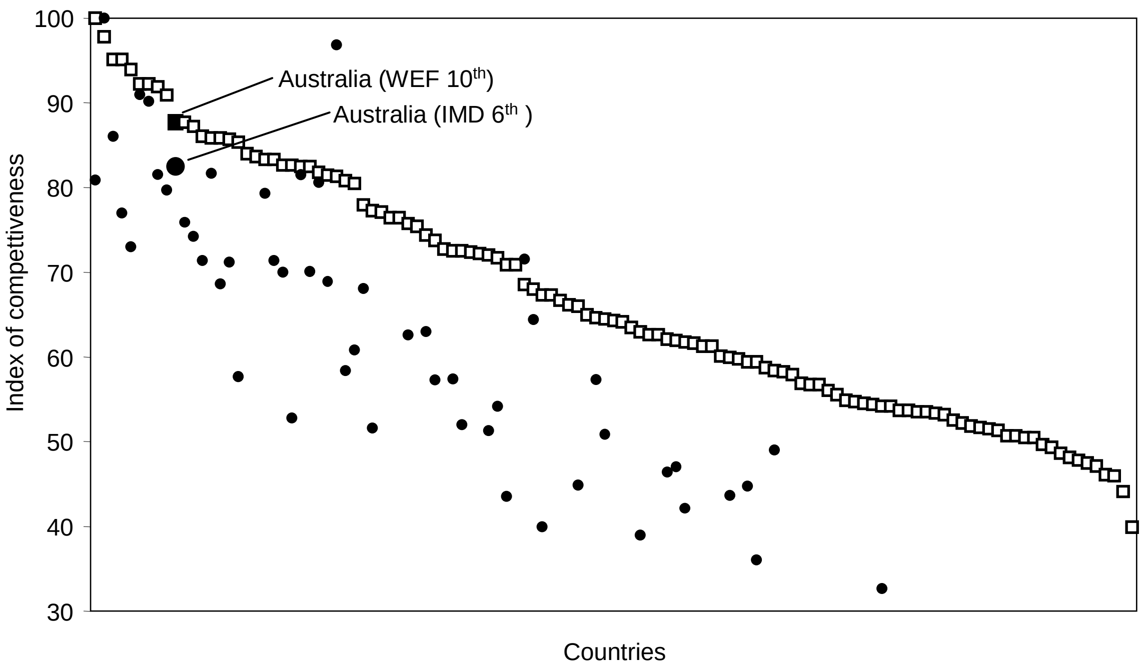


[a] The data generally relate to 2002, except where the OECD notes otherwise. Countries are from the OECD plus a range of rich non-OECD countries like Israel and Singapore. The growth rates in GERD relate to the period from 1992 to 2002. The densities are estimated using an Epanichenikov kernel using RATS v.6.1. The dots mark Australia position in the distributions.

Data source: OECD *Main Science and Technology Indicators*, 2005-2, Electronic database, Paris.

Figure 2.6 **Australia is highly ranked highly in international competitiveness indexes**

WEF and IMD indexes[a]



[a] The WEF index is based on the growth competitiveness index for 117 countries in 2005-06 and the IMD index is based on scores for 53 nations for 2006. The WEF index was normalised so that the highest ranked country was given an index value of 100. For its 2006-07 estimates, released in late September 2006, the WEF introduced a new measure, the '*global* competitiveness index' which the Commission has not yet assessed.

Data sources: IMD World Competitiveness Year Book 2006 and the WEF is from the Global Competitiveness Report 2005-06.

2.9 Public support and conduct is in flux

There have been significant changes in the role of the Australian Government public support of science and innovation over time.

Direct funding of Australian Government research agencies has barely grown in real terms over the past 25 years, compared with relatively strong growth for other components of funding (table 2.6). This has meant that Australian Government support of government agencies roughly halved as a share of GDP between 1981-82 and 2005-06 (figure 2.7). Part of the reason for this has been the growth of multisector funding (such as the CRC program), a component of which has been directed to Australian Government research agencies. Another contributing factor may be the greater supply of funding of such agencies from sources outside the Australian Government, which may have substituted for direct government payments.

All other funding streams have increased over the long run, both in real terms and as a share of GDP. However, business funding has fallen as a share of GDP from its apogee in the mid 1990s, with the alteration of elements of the R&D Tax Concession that were used as vehicles for gaining the maximum tax benefit, such as R&D Syndication, feedstock and pilot plant provisions (Lattimore 1996; Field 1996).

Total funding of science and innovation by the Australian Government has actually fallen slightly as a share of GDP between 1981-82 and 2005-06 (figure 2.8). But science and innovation funding as a share of total outlays by the Australian Government, which is a better measure of government priorities, is now significantly higher than it was in the early 1980s, and has increased strongly since 1997-98 with a series of major funding initiatives.

Table 2.6 **Australian Government research funding trends differ by destination**

Various periods, 1981-82 to 2005-06, constant prices

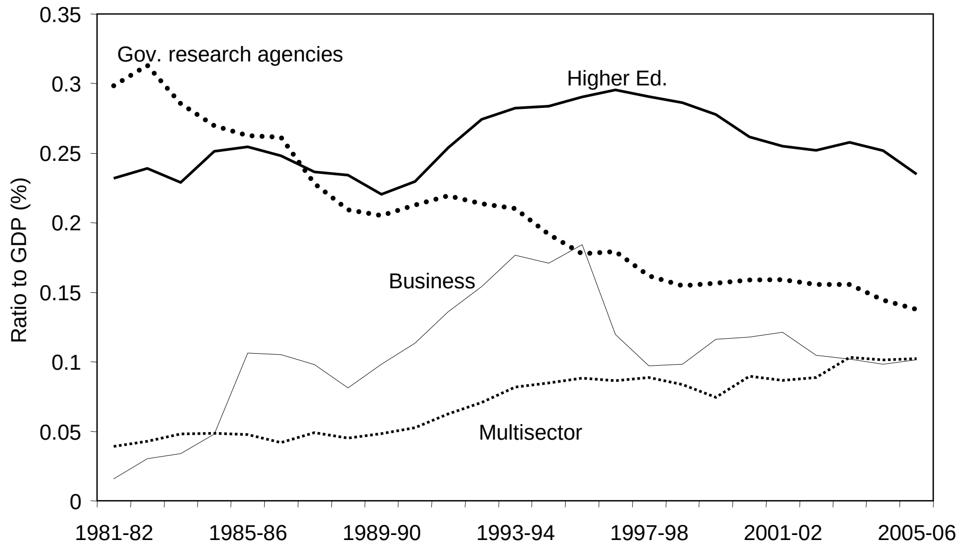
Sector	*The last 5 years*	*The last 10 years*	*The last 25 years*
	%	%	%
Government agencies	4.9	12.7	1.1
Business	4.3	-19.9	1296.3
Higher Education	8.6	17.6	121.9
Multisector	37.9	68.6	474.2
Total	11.0	13.2	115.7

a The last 5 years = 2000-01 to 2005-06; the last 10 years = 1995-96 to 2005-06 and the last 25 years 1981-82 to 2005-06. Note that funding shown in this table relates only to the Australian Government, not State and Territory governments. The data in table 2.6 (and figures 2.7 and 2.8) are constructed using budget data from DEST and does not exactly correspond to the (Frascati) framework used by the ABS and the OECD to categorise funding.

Source: Data on budget outlays were provided by DEST.

Figure 2.7 **Australian Government support for innovation and science**

By spending component, 1981-82 to 2005-06

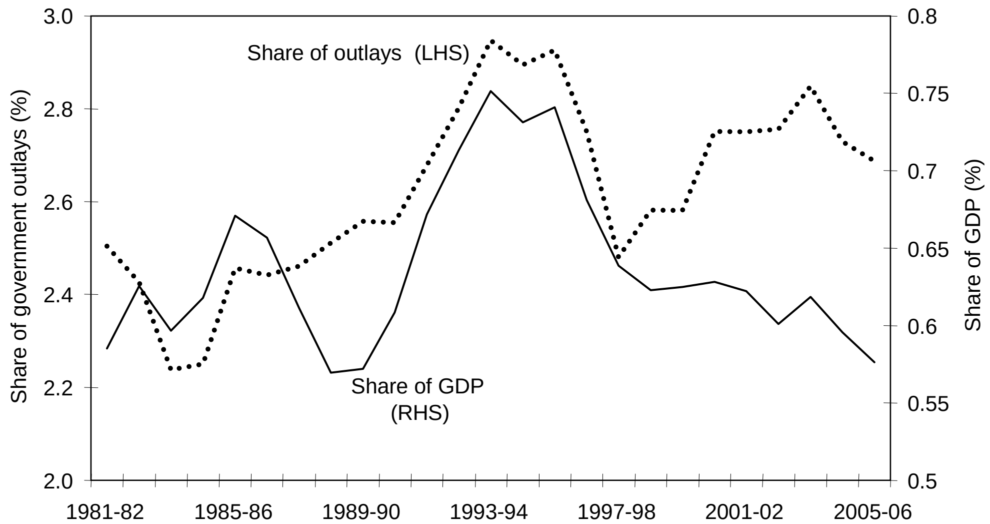


[a]The GDP datum for 2005-06 was estimated on the basis of three quarters of data and extrapolation of the June quarter. Multisector may be accessed by several sectors including Commonwealth research agencies. It includes the NHMRC and other health, CRCs, rural research and energy and the environment.

Data sources: Data on budget outlays were provided by DEST. GDP data are from the ABS, *Australian National Accounts: National Income, Expenditure and Product*, Cat. No. 5206.0, released in June 2006.

Figure 2.8 **Total Australian Government support for science and innovation**

1981-82 to 2005-06



[a] See previous chart for notes and sources.

The picture of public support suggested by figures 2.7 and 2.8 and table 2.6, should not be taken to imply that the *conduct* of R&D by government research agencies has barely grown in real terms:

- governments other than the Australian Government are also funders and performers of own government research;
- funders outside government have, over the long-run, increased their investment in R&D within government research agencies, such as the CSIRO; and
- government research agencies have benefited from the strongly growing funding of multisector R&D (such as CRCs).

The real value of resources devoted to spending in government research agencies (across all Australian jurisdictions) has risen by around 50 per cent and their use of researchers by around 20 per cent from 1981-82 to 2002-03.[14]

Even so, it is still the case that governments' spending on R&D to GDP has fallen. In 1981-82, government spending in its own agencies (GOVERD) accounted for 0.43 per cent of GDP. This fell by 0.1 percentage points over the next 25 years to 0.33 in 2002-03.[15]

And spending in these agencies now amounts for less than one in five dollars spent on Australian R&D — however funded — compared with nearly one in two dollars in the early 1980s (table 2.7). Some of this fall is illusory, reflecting the greater outsourcing and privatisation of activities formerly undertaken in government-owned agencies, such as Telstra. But mostly, the relative decline is due to the large absolute increase in business (and to a lesser extent, higher education) R&D activities. This pattern also holds for many other OECD countries, revealing the shift in balance in the allocation of research resources to business globally (figure 2.9). Within business, there has been a growing orientation to R&D within the service sector, reflecting its growing importance in the economy (table 2.7). This re-orientation has been particularly marked for Australia compared with the European Union.

[14] The real value of own-government R&D spending was $1169 million (PPP) in 1981 and $1786 million (PPP) in 2002 (Indicator 54, OECD 2005b). FTE-researchers in government increased from 6794 to 8036 over the same period. Cost structures have been evolving too, with the amount of real GOVERD (comprising wages and other costs) per full-time equivalent researcher increased by about 30 per cent over the period from 1981 to 2002 (contrasting with a fall in EU15 countries collectively of around 20 percent, OECD 2005b).

[15] The aggregate decline can be wholly attributed to Australian Government agencies (0.31 to 0.20 per cent of GDP) compared with those in the States and Territories (0.12 to 0.13 per cent of GDP) (DEST 2005a, p. 109).

Table 2.7 **Australia and many other countries have shifted the emphasis of their R&D spending in the last two decades**

1981 and 2002[a]

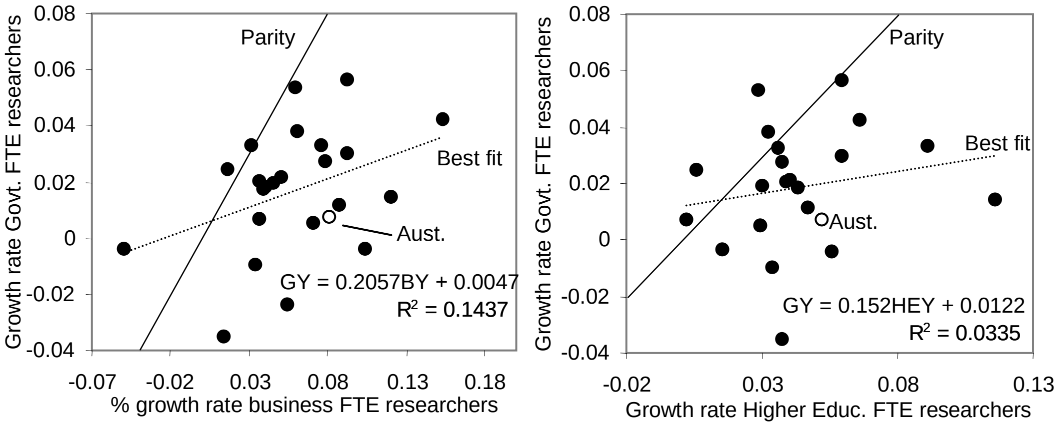
	Australia		*EU15*		*% change*	
	1981	2002	1981	2002	Aust.	EU15
GDP shares						
GERD to GDP share (%)	0.94	1.69	1.66	1.91	79.8	15.1
BERD to GDP share (%)	0.24	0.87	1.03	1.23	262.5	19.4
HERD to GDP (%)	0.27	0.45	0.29	0.42	66.7	44.8
GOVERD to GDP (%)	0.43	0.33	0.31	0.24	-23.3	-22.6
Share of GERD, by performing sector						
Business (%)	25.0	51.2	62.3	64.3	104.8	3.2
Higher education sector (%)	28.5	26.7	17.6	21.9	-6.3	24.4
Government sector (%)	45.1	19.3	18.8	12.7	-57.2	-32.4
Not-for-profit sector (%)	1.3	2.8	1.4	1.2	115.4	-14.3
Share of BERD financed by:[b]						
A - Business (%)	88.6	90.3	77.2	81.9	1.9	6.1
B - Government (%)	9.8	4.0	19.0	7.3	-59.2	-61.6
C - Other national sources (%)	0.1	0.8	0.1	0.1	700.0	0.0
D - From abroad (%)	1.8	4.9	3.6	10.7	172.2	197.2
Full-time equiv researchers						
Total number (‘000)	24.2	73.3	488.4	1044.1	203.0	113.8
Per 1000 employees	3.6	7.8	3.5	6.1	116.7	74.3
Share of FTE researchers in:						
Business (%)	14.3	28.1	50.0	51.7	96.5	3.4
Higher education (%)[c]	56.2	58.3	32.0	35.3	3.7	10.3
Government (%)	28.1	11.0	16.0	11.8	-60.9	-26.3
Other measures						
Share of BERD undertaken in the services sector (%)	10.0	42.2	5.4	14.8	322.0	174.1
HERD financed by industry (%)	1.4	5.1	2.0	6.6	264.3	230.0
GOVERD financed by industry (%)	1.8	5.2	4.1	5.8	188.9	41.5

[a] The European Union, rather than the OECD, was used as the comparison group because some data for the OECD as a whole were missing or not sufficiently comparable to Australian data. Nevertheless, where OECD data were available, the results were very similar to that of the EU15. The correlation coefficient was 0.994 for 1981 and 0.999 for 2002 and of 0.70 for the percentage change from 1981 and 2002. [b] Data for Australia listed for 1981 are for 1984 and for the EU15 are for 1983. It should be noted that BERD financed from abroad is low for the EU15 (and nearly zero for OECD countries) because financing between member countries is excluded from the total. Since most financing from abroad is from industry, a reasonable indication of total funding from industry is given by totalling the amounts shown at A and D. [c] EU data listed for 2002 are for 2001.

Source: OECD *Main Science and Technology Indicators 2005-2*, Paris (Electronic database).

Figure 2.9 **Growth in R&D has favoured business and higher education research over government-performed research**

OECD countries 1981-2002



a The data relate to the average annual (log) growth rates of full-time equivalent researchers in each economy calculated over the period from 1981 to 2002 (or where data are missing, over a near comparable period). If growth in these parts were equivalent then they would be scattered around the line of parity shown in each diagram. In this instance, the share of researchers in government agencies would remain stable over time. However, the best fitting line is far from the line of parity. Australia is below the best fit line, showing that Australia has even less growth in government researchers than would be predicted on the basis of its experience of growth in business or higher education researchers.

Data source: PC calculations based on data from the OECD *Main Science and Technology Indicators 2005-2*, Paris (Electronic database).

A similar shift in emphasis is apparent for the funding as well as the conduct of R&D. Over the long run, industry has played a larger (and Australian governments collectively a lesser) role as a funder of R&D, whether it be performed within industry itself, in higher education institutions or government research agencies.

Within the university sector, there has been a shift in the governance arrangements for funds. Relatively fewer funds are given directly to universities for them to determine where they should be allocated through their own governance arrangements. More is mediated through external, peer-review entities such as the ARC and the NHMRC.

Globally, Australia has converged to have a pattern of R&D spending and funding more like that of the European Union and OECD countries (box 2.3). The percentage of the OECD pattern 'explained' by the Australian pattern was less than 3 per cent in 1981, but more than 40 per cent in 2002.

Box 2.3 Measuring convergence of Australian and OECD patterns of R&D

Data on 16 measures of R&D spending and funding were derived for Australia and the OECD as a whole for two years, 1981 (or thereabouts) and 2002 (or thereabouts). These were all of the data items in table 2.7 except the financing shares of BERD and the service sector share of BERD. This generates four series, each with 16 elements: $R_{Aust1981}$, $R_{Aust2002}$, $R_{OECD1981}$ and $R_{OECD2002}$.

To determine the extent to which variations within the OECD series 'explained' the variation within the Australian series, regressions of $R_{Aust1981} = \alpha_1+\beta_1\ R_{OECD1981}$ and of $R_{Aust2002} = \alpha_2+\beta_2\ R_{OECD2002}$ were undertaken (giving an R^2 of 2.8 per cent and 41.4 per cent respectively).

This approach provides a measure of the extent to which patterns of funding and spending in Australia have converged on those of the OECD as a whole.

3 Rationales for public support

Key points

- Public support of science and innovation should be based on clear and credible rationales. These also help in designing appropriate support mechanisms and, where empirical evidence on impacts is absent or uncertain, enable policymakers to better judge whether particular forms of public support are likely to produce net benefits.
- The strongest reason for directly supporting science and innovation is spillovers from innovation that cannot be captured by the innovator and that cannot be realised without support.
- The spillovers may arise through high quality human capital development, the development of basic knowledge capabilities, the resolution of public good problems and diffusion of new ideas among firms and others. They arise from research undertaken in universities, businesses and public sector research agencies.
- While spillovers provide a strong rationale for public support, it is important to note that:
  - not all research in universities and public sector agencies create significant spillovers, especially if research is mediocre or research is poorly managed;
  - not all spillovers matter for policy;
  - some apparent spillovers are illusory; and
  - the areas where public support for commercially-oriented R&D is likely to produce the biggest spillovers depend on the methods used to ‘absorb’ knowledge generated by others, the costs of absorption and the nature of the R&D being absorbed.
- Spillovers not only provide a rationale for public support, but pinpoint other policies that are important in increasing the effectiveness of an innovation system. These include measures that reduce the costs of absorption (such as skill upgrading) and facilitate research cooperation.
- Other reasons for public support with some validity are:
  - intangible factors such as national identity and prestige, which relates mostly to scientific research in universities and public sector research agencies;
  - the asymmetric tax treatment of highly risky investments, which mainly relate to R&D undertaken in small or newly created businesses;
  - with strong provisos, problems in capital markets that could affect the availability of finance to risky or uncertain investments in small firms and start-ups; and
  - problems in information provision by public sector agencies.
- Some cited reasons for supporting the system, such as indivisibilities, business myopia, and the aspiration to achieve a transformation of Australia’s industry away from its present structure have weak validity. In many instances, they would entail completely different support arrangements than those currently observed.

3.1 Introduction

This report focuses on the impacts of public support for science and innovation, the impediments to the operation of the innovation system and the frameworks for assessing where and how public funding should be allocated and overseen.

A fundamental starting point for all of these tasks is the assessment of rationales for government intervention. This chapter explains why rationales are an important first step in deciding whether to support an activity (section 3.2). A wide range of rationales for public support for R&D is then explored, with the major categories of rationale shown in figure 3.1.

A useful principle for judging the importance of rationales for public support is the likely implications were no public support to be provided. In most forms of current support, this amounts to assessing how much R&D would be carried out without public support and whether any forgone R&D would have been welfare-enhancing or not.

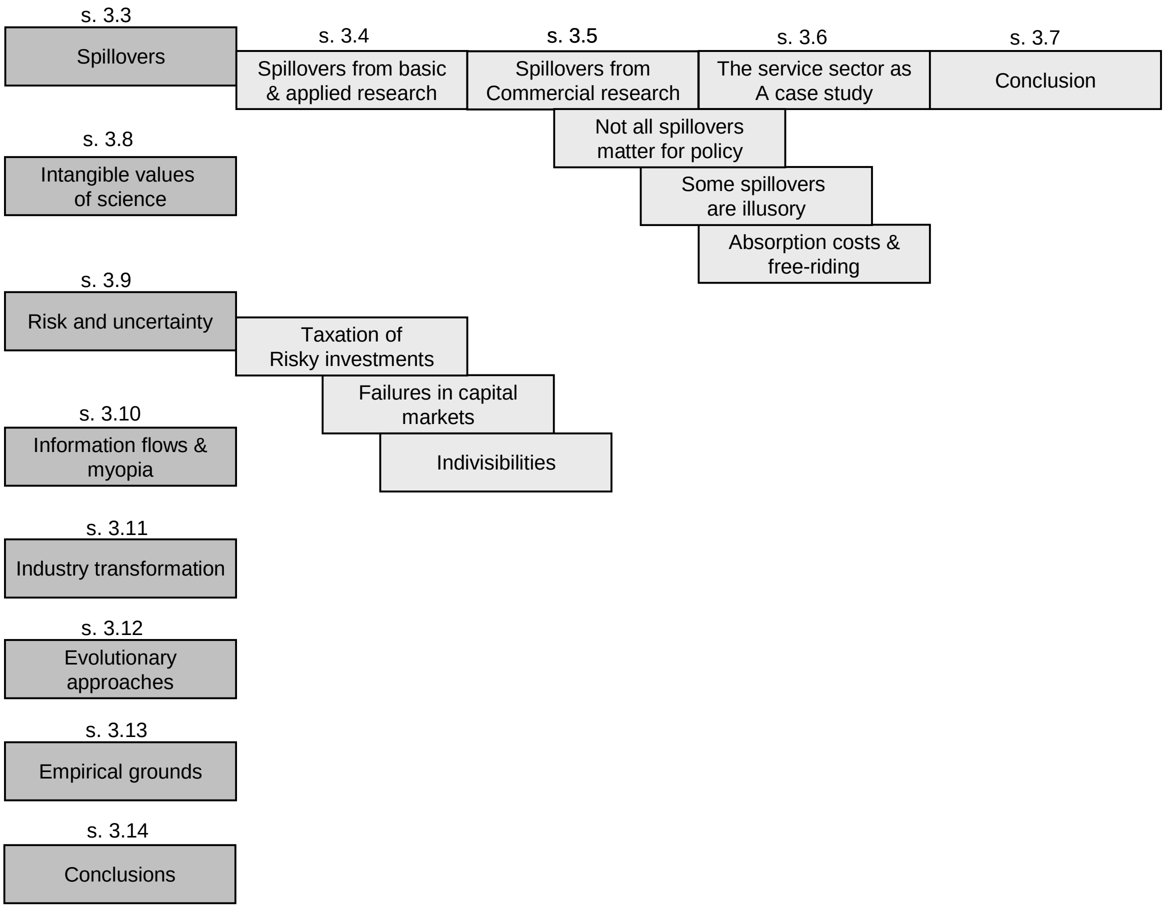
3.2 Why do rationales matter?

Public support of science and innovation should be based on clear and credible rationales. Such rationales identify areas where government actions are likely to provide net national benefits. They weaken claims for interventions based on other grounds, such as the demands of interest groups. Rationales usually describe a mechanism underpinning the need for an intervention (such as specific problems in markets that lead to less than optimal investments in R&D), not just a desired objective (such as productivity growth or reduction of poverty).

Describing rationales precisely has several major advantages.

It enables policymakers to test whether the problems that justify intervention exist and how widespread and enduring they are. For example, if private venture finance is not adequate for commercialising innovation by R&D start-up companies, is that for all types and phases of commercialisation, all sizes of start-up companies and all types of management structures?

Figure 3.1 **A 'map' of the main set of rationales**



The specific form of a rationale shapes the design and evaluation of programs. Where the rationale is under-investment in R&D due to the incapacity of firms to capture a sufficient share of the total gains from R&D, the commensurate measures might be creating research consortia that internalise the gains, as in Rural Research and Development Corporations, or where that is not practical, subsidy arrangements. In this case, an evaluation strategy would focus on whether more R&D was performed and whether the benefits were diffused. If the rationale for a measure is failure in capital markets (section 3.9), then loans or equity arrangements that provide a full return to the government may be warranted, rather than pure subsidies. Such a program is self-evaluating, since if it does not produce an adequate return, it cannot be true that capital markets have really failed at all.

Assessing the credibility of specific rationales allows policymakers and evaluators to better judge whether particular forms of public support are likely to produce net benefits, especially where empirical evidence on program impacts is uncertain. Chapter 4 reviews evidence about the aggregate impacts of public support and concludes that public support is likely to generate benefits for Australians in excess of budget spending. However, the Australian Government alone provided science and innovation support through at least 75 specific measures totalling $5.4 billion in 2004-05 (appendix B). While evaluations of specific measures provide some evidence of their impacts, it is often the case that these impacts are difficult to quantify in rigorous cost-benefit terms. Assessing the rationales for specific measures provides another basis for judgment about whether such measures are likely to have big impacts or not, which can then feed into decisions about where to allocate public support in the best way.

It should be emphasised that rationales are a necessary feature of sensible public support, but are not sufficient. Policies that are, in principle, justified by appropriate rationales may, nevertheless be difficult to implement efficiently. There may be high administration and transactions costs, unintended impacts, capture by private interests, poor design and a range of other problems.

The dual importance of rationales and design principles is why this report has a large emphasis not just on establishing that a convincing and robust rationale must exist (the basis for this chapter), but also in avoiding some of the pitfalls of past practices through improved program design (the theme of chapter 9).

3.3 Knowledge spillovers — the conventional rationale

It is often argued that R&D investments provide knowledge that beneficially and cheaply 'spills' over beyond the investor (Arrow 1962). The existence of such 'spillovers' provides the principal economic argument for government interventions.

Spillovers arise because knowledge can have some distinctive characteristics.

First, researchers often cannot appropriate the full returns from new knowledge, so that at the margin they do not invest in new knowledge. This may occur:

i. if firms and others cannot sufficiently exclude others from observing and using new knowledge generated by innovation (*non-excludability*) — spillovers may reduce incentives for developing new knowledge. Secrecy of, or complexity in, knowledge may give its generators some capacity to appropriate the returns, but usually not for long. Knowledge is therefore said to have only partial excludability;[1] or

[1] There are, of course, instances where the innovator can use secrecy or the complexity of an innovation to at least partially exclude.

ii. if the value of a single fragment of knowledge is significantly increased when it is openly shared and combined with other fragments *and* it is difficult to negotiate prices for mutual exchange of knowledge. Individual investments in knowledge contribute to a body of knowledge at the industry, country or global level that is collectively useful, even when the parts that contributed to it are not very useful to their individual generators (Hall 2004). A physical analogy may be a jigsaw puzzle. The intangibility of knowledge, the scale of knowledge sets and the complexity of contracts for market exchange between parties, suggest that firms may often be unable to arrange coalitions among each other to jointly internalise the benefits of collective knowledge.

Second, the generation of new knowledge may have high ex ante fixed costs, but the ex post incremental costs of diffusion are often relatively low (Stephen 1996). This trait of knowledge increases the likelihood that spillovers are large and also provides the scope for public support to meet the fixed costs of research, which is then diffused at marginal costs to many users. Such incremental costs are particularly low when:

iii. knowledge can be codified, transparently embodied in a product/process, or otherwise readily copied;[2] *and*

iv. there is an economical capacity to understand and employ it. More efficient ways of processing and sharing information through ICT have probably increased the capacity for cheap knowledge flows of these kinds.[3]

One way of addressing some spillovers is to assign property rights to intellectual property, through patents and copyright. However, property rights primarily deal with (i) and not (ii), (iii) or (iv). Nor can they be readily assigned to some forms of knowledge due to the costs associated with enforcement. Even where rights can be assigned, they may still reveal useful information to rivals. They reveal that certain outcomes are technologically possible — aeroplanes or synthetic fibres, for example. Moreover, they must disclose the scientific mechanisms underlying the innovation, hence the proliferations of 'me-toos' in the pharmaceutical industry. More generally, Levin et al. (1987) found that patent disclosure was the single most common way that competitors found out about rivals' technologies. Similarly,

[2] This contributes to the prospects of (ii) above.

[3] It is commonly argued that knowledge exhibits *non-rivalry* in consumption. This arises when use by one party does not reduce the potential for its simultaneous use by another. While this is true for pure public goods, like defence, it is less clear that this holds strictly for knowledge. As Boldrin and Levine (2002) have argued, knowledge is only economically useful when it is embodied in people, machines or goods, which *are* rivalrous in consumption. In this case, considering the incremental cost of usefully embodying knowledge (diffusion) is probably a more useful way of understanding how spillovers might arise.

copyright may protect given pieces of content, but they do not stop creative mimicry that selects very similar themes.

In any case, there is a tradeoff between intellectual property protection, which creates incentives to create new knowledge, and the costs of monopoly, which is why the statutory provisions of protection are limited.

So spillovers appear to be associated with R&D, even when an intellectual property regime is in place.

It is useful to consider arguments based on spillovers for three types of knowledge:

- basic research (primarily undertaken in universities);
- applied research into areas where the main user will be the public generally (mainly undertaken in public sector research agencies, not-for-profit private research agencies and universities); and
- commercially-valuable applied research activities, usually undertaken in business, but also sometimes in universities and public sector research agencies. This kind of research is the immediate driver of business-based innovation and has been the most rapidly growing part of Australian GERD.

3.4 Spillovers from basic and applied research

Basic research

Basic research, including knowledge about experimental methods and new instrumentation,[4] has some of the properties of knowledge described above. In particular, basic research has the property that its value is higher when it is aggregated into a collective stock of knowledge (condition (ii)). It is not likely that any private sector arrangements could successfully achieve such agglomeration benefits given the diverse nature and scale of basic knowledge. It can also often be readily codified (condition (iii)). Within universities there are established institutional conventions that attempt to aid the cheaper diffusion of basic science by encouraging its codification, ranking its quality (Gans, sub. 10) and increasing its assimilation through conferences, reviews, text books and other means. Given these

[4] It is sometimes claimed that experimental methods and instrumentation derived from basic research are ‘not necessarily part of the knowledge system of science’ (Martin et al. 1996), and that therefore this economically valuable aspect of basic science constitutes a *separate* basis for public support. However, in most cases, the requirement for openness and replication of scientific experimental results, also requires disclosure of information about such methods and equipment. Accordingly, we treat this knowledge as part of the knowledge system of science.

conditions, public funding and the adoption of institutional arrangements that facilitate its global sharing may be the best way of maximising its collective value.

This characterisation of basic research does not require non-excludability or ease of use (conditions i and iv) be met, as sometimes argued (for example, Romer 1992). Were public support not to be provided, the institutions that facilitate codification and open exchange would be weaker. Firms could, if they chose to, exclude others' use through secrecy given the complex nature of much basic knowledge, while the high costs of absorbing complex knowledge would allow potential appropriability. After all, it is claimed that even in the presence of the current institutions for spreading knowledge, absorption costs by users create large barriers to the use of basic knowledge:

> Individuals need to develop substantial skills and to expend considerable resources to understand codified knowledge. It is a labour intensive process, involving extensive trial and error, effort and learning. Moreover, among individuals and organisations there are wide variations in the ability to make sense of the codified knowledge available to them. The ability to understand codified knowledge requires organisations to maintain a substantial and often expensive research capability. (Martin et al. 1996)

Therefore, the most important rationale for public support of basic science rests on the fact that this creates an institutional form for the conduct of science that maximises agglomeration benefits and variety. These institutional arrangements also allow the development of globally recognised qualifications, educational processes and professional networks that develop highly specialised human capital. Hiring new graduates and tapping into such networks is recognised by innovating firms as an important source of new expertise and knowledge for generating business innovation.

Basic research need not always generate spillovers

While basic research has a form that encourages spillovers, it does not guarantee that such spillovers will always be actually realised. There are three major criteria, which are taken up again in subsequent chapters, that are relevant to realising spillovers within the basic research community:

First, high spillovers require research of reasonably good quality. Peer review provides a major quality sorting mechanism within the basic science system, but not all research funding is subject to its disciplines and even peer-review funding systems have flaws. Consequently, some mediocre research will be conducted. Sufficiently low quality research is unlikely to be published in influential journals or diffused widely, if at all, and is unlikely to generate substantial spillover returns. For every dollar of public funding allocated to projects of the lowest quality, the economic loss could be around $1.20 to $1.30 — the original dollar of funding, plus around 20 to 30 cents, associated with the economic costs from raising public finance.[5]

Second, the governance arrangements for research within the system should be of high quality. The risk otherwise is that even if the research is potentially of high quality, it may not be funded efficiently, or complementary inputs may not be adequately provided, such as IT, laboratory and field work expenses.

Third, knowledge diffusion mechanisms need to be efficient. The reason that basic research is different from the kinds of research that are often undertaken within firms is that it exists in a system in which the exchange of research ideas is actively encouraged through publication, conferences, sabbaticals and other mechanisms. However, any weaknesses in these systems, including gaps in the way that knowledge may be disseminated to businesses, can erode the spillover returns, even if their potential exists.

Much applied research is an input to public goods

Applied research that aims to address broad, publicly-useful, problems is often an *input* into applications that are public goods. The applications of such knowledge are non-excludable, even if the knowledge being used fails to meet the criteria (i) to (iv) above. Such public goods include:

- defence (for example, DSTO's functions);
- alleviation of social and public health problems (for example, crime reduction involving research into forensic science; social and psychiatric determinants of crime); and
- broad environmental problems (for example, resolution of salinity problems, weed and pest controls, and climate modelling).

In these cases, funding of the public good is necessary to ensure its optimal provision and this funding would need to recognise complementary research capabilities. In some instances, such as DSTO, it is efficient for funding to be provided through an intermediary public sector agency that has principal

[5] Moreover, the poorest choices within the basic research system are likely to be more costly than ones in the business sector. In the latter case, the most common risk is that research projects are funded that would not otherwise have occurred. For every dollar of public funding allocated to these projects, the economic loss is around 20 cents, representing the economic costs from raising public finance. The rest is a transfer to the firm, which is still undertaking valuable research activity. This does not mean that funding should be shifted to private R&D, since much R&D within the basic system is of high quality and, ultimately, may have high social returns.

responsibility for the provision of the public good in question (such as the Australian Defence Organisation). In some other public good areas, it may be difficult for the responsible department to contract potentially politically damaging research, even if it is ultimately in the public interest; or no single agency is responsible. Salinity, for example, affects tourism, environment, industry, agriculture and regional employment, which are the responsibility of multiple government departments across many Australian jurisdictions, so that it can be more efficient for funds to go directly to research agencies (as in the majority of funding to CSIRO).

But regardless of the conduit for funding, the absence of public support would mean considerable under-provision of knowledge and inefficient supply of public goods that are dependent on this knowledge. The problem of under-provision would occur even if the knowledge itself were nearly fully excludable, as it is in the case of:

- much of the research undertaken by DSTO, where enforceable secrecy provisions apply; or
- climate research, where substantial investments in human capital, software and equipment may be needed to absorb, test and interpret results.

In many instances, however, it is also likely that the *useful* component of knowledge from applied research itself is only weakly excludable, and the knowledge itself then assumes many of the characteristics of a public good. This provides further grounds for public support of such applied research. For example, the actual research that determines the best biological control for a given pest/weed can be technical and not necessarily easily transferred except to other biologists in that field. But the knowledge relevant to the particular application it generates is only weakly excludable because it often takes a simple form — what the biological control is, where to find it and how to release it. This knowledge is hard to appropriate by the researcher. So worthwhile projects would remain unfunded if they were left to private provision. Moreover, the low marginal costs of copying the knowledge and applying it suggests that it is optimal to encourage its adoption through zero pricing — as with public goods.

These facets of applied research imply public support is necessary, but does not automatically require that the research be undertaken by publicly owned agencies or even within Australia. In some cases, it may be desirable to have private and public agencies compete for applied research projects. The desirable choices for institutional location and organisation of applied research will ultimately depend on synergies with other research activities, the advantages of Australian capabilities, and relative cost efficiencies.

Summing up

In both research involving spillovers and that which is undertaken as an input to public goods, there are a priori grounds for some form of public support. However, there are still many questions about which specific research activities should be supported, their ownership, location, governance arrangements and the total quantum of funding that cannot be addressed by establishing a rationale for some support.

3.5 Spillovers from commercially-oriented research

In the third type of research, commercially-useful applied research, there is also a strong case that spillovers exist and that public support is warranted. This is because the conditions underlying spillovers set out in section 3.3 also apply to research undertaken within commercially driven projects.

Firms' research results often involve tangible outcomes in goods and services that can be emulated by competitors or by other firms. Employees are the footloose carriers of ideas. At the margin, this implies that firms will under-invest in research activities. Moreover, while the capacity for codification and useability (conditions iii and iv) above are often seen as mainly applying to basic science, in fact there are market mechanisms for both to occur in a business context. There are intermediaries that seek to codify firms' spillovers and to diffuse them efficiently, such as technical consultants. Institutional arrangements, such as trade conferences and trade journals also increase the diffusion of such ideas. Patents provide detailed disclosure of knowledge.

However, just as it is important to question whether all research in the basic system generate spillovers that warrant public support, it is equally useful to probe the nature of business R&D and to consider possible variations in spillover intensities. This can help determine where public policy might best be used to support business R&D. In the business case, the issues that adversely affect what sorts of research might be funded are more complex than those outlined above for basic research. They rest on three main contentions:

- not all spillovers matter for policy;
- some apparent spillovers are illusory; and
- the extent to which public support is justified depends on the methods used to 'absorb' knowledge generated by others, the costs of absorption and the nature of the R&D being absorbed.

These issues are examined in the next section.

Not all spillovers justify government intervention

Only marginal spillovers matter

Sometimes policymakers and others argue that spillovers per se need to be compensated to ensure efficient innovation. However, *if* the private returns are above the required rate, then the investment will proceed regardless of the magnitude of any spillovers. In such inframarginal projects, subsidies would have no effect on whether the investment is made, and no matter how big spillovers were, there would be no case for public support.

So spillovers are only a relevant rationale for public support when including their impact would change the decision about whether to proceed with an investment.

Firms can develop more sophisticated inter-firm relations to internalise spillovers

The 'firm' is an organisational form that economises on certain transactions costs associated with contracts (Coase 1937; Williamson and Winters 1993), but that nevertheless has many other explicit and implicit contracts with external parties that are often close to those that exist internally. Once seen this way, the boundaries of firms are often ill-defined and fluid, with firms having the capacity to forge complex symbiotic relationships with other firms through consortia, supplier and customer relations and loose networks. This suggests that firms may have greater opportunities for appropriating the benefits of spillovers than the usual firm-centric view of R&D incentives suggests.

This is shown in real world situations over a long time span.

- In the industrial revolution, firms in the iron industry formed a loose network that freely exchanged technical information with competitors about the construction details and performance of their new blast furnaces and typically did not patent new methods as they developed them (Allen 1983).
- Likewise, in Cornwall, dissatisfaction with technological progress under Watt's extended patent-based monopoly on the steam engine, led to the creation of a loose collaboration and open sharing (including a widely available publication of technical results) that helped spur best practice use and better engineering in Cornish mines (Nuvolari 2001).
- Similar, loose networks are currently commonplace in software (West and Gallagher 2006).

- Patent pools, in which collaborating firms enjoy access to a communal patent pool if they provide their own IP, have been used extensively, such as by US steel makers (Morison, 1966) and European GSM telephone manufacturers (Bekkers et al. 2002).
- In Australia, the Australian Mineral Industry Research Association (AMIRA) International, is an industry association that manages collaborative research for its members in the global minerals industry. By taking a partnership approach to research and development, which is managed by AMIRA, members gain better access to leading edge technology. Information is distributed via a web page, with password-protected access to the detailed technical results of research projects for sponsors. Some projects are co-funded by public research agencies.
- Some rural research funding pools in Australia are based on voluntary contributions (though these come with the sweetener of additional R&D subsidies from the Australian Government — chapter 9).
- In Australia, around one in seven large innovating firms (those employing 100 or more persons) engaged in joint R&D with other firms during 2003 (ABS 2006a). This form of collaboration was considerably lower in smaller firms (about 6 and 7 per cent in small and medium sized innovating firms).

Such arrangements represent efforts by firms to facilitate spillovers, typically without the need for public support. As noted in section 3.4, such arrangements are not feasible for broad areas of knowledge generation — such as basic science — but they are much more applicable to reasonably narrow, but mutually advantageous commercially-focused research.

The potential for such arrangements can also mean that it may be more effective for public policy directed at increasing spillovers to reduce some transaction costs between firms, rather than supporting R&D per se. The legal structures that allow mandatory R&D levies within certain rural industries in Australia are an example. There may be other ways in which public policy can reduce obstacles to, or otherwise facilitate, the formation of such cooperative arrangements.

The policy drawback is that the member firms will often need to apply a variety of policing efforts to ensure widespread cooperation (such as the reciprocity arrangements in patent pools), which can sometimes have implications for competition policy. However, fortunately, they are not usually constrained by competition watchdogs.

Some apparent spillovers may be illusory

Sometimes looking at spillovers in isolation misses other ways in which innovating firms can make adequate returns to justify their investments.

Spillovers are partly internalised through the labour market for technical personnel

Movements of people carrying knowledge are likely to be a major source of information exchange between firms and other organisations. This is explicitly recognised within the public research system through mechanisms that encourage sabbaticals and collaborative arrangements.

However, businesses generally try to constrain the spread of trade secrets through this route, encapsulated by the quip from the Intel general consul: 'Don't let your employees do to you what you did to your former boss'.[6] It is commonly considered that labour mobility is a major source of spillovers because the recipient firm does not have to compensate the source firm for ideas that it has developed, but which are then transferred through the knowledge and skills of the mobile employee.

But Møen (2001), among others, has questioned whether such information exchanges necessarily constitute spillovers. To the extent that research has a training element, then technical personnel may pay for its accumulating benefits through lower starting wages with the original firm (and are subsequently rewarded by higher wages when more experienced). Using matched employee-employer data for the Norwegian machinery and equipment industries, Møen finds a steeper experience-earnings profile in research intensive firms relative to other businesses, which is consistent with this hypothesis. Various alternative explanations for this pattern are tested and rejected.

But there are several important provisos:

- even in the firms studied by Møen, the results suggest some internalisation of spillovers by businesses through lower wages, but do not rule out the existence of some residual spillovers;
- in other cases of firm innovation, this wage mechanism may not be present; and
- universities and public sector research agencies have quite different internal labour markets from firms and have different objectives for undertaking R&D. Accordingly, Møen's findings should be seen as relevant only to spillovers from business R&D.

6 Cited in Møen (2001).

Nevertheless, Møen's results weaken the intuitive assumption that finding a potential route for spillovers means that they are significant.

Firms may encourage the diffusion of their intellectual property if they can make money from associated activities

Firms may be able to extract the benefits from an innovation in unexpected ways even if they receive no compensation for the free or cheap use of their intellectual property by others. In this case, incentives for innovation are not dampened even at the margin. The apparently 'spilled' knowledge is like a loss leader.

It is common in the IT sector for firms to seek small or sometimes zero returns for the distribution of their intellectual property in the form of software, but to seek to make their returns through advisory services where bigger revenues are available, or in better versions of software that can be sold (West and Gallagher 2006). Open source software (where the code is published and where there is a process of continued improvement from a multitude of users) can expand the market for associated services or fuel other innovation within the hosting firm sufficiently to warrant the divulgence of knowledge. In fact, in these products, free transmission of intellectual property is not resisted by innovators, but used as a strategy for maximising competitiveness and future revenue.

Absorption costs and free-riding

As in the case of basic science, firms and other agencies must often make some investments in an absorptive capability to gain the benefits of others' commercially-useful knowledge. This reduces the prospects for free-riding on the global science and innovation system. But the nature of absorption costs and the type of knowledge that is being absorbed or created affect the extent to which the presence of absorption costs are relevant for public science and innovation policy. Appendix D sets out a taxonomy of such conditions as a guide to policy. The arguments underlying these are complex, and so are not repeated here. The general conclusions are discussed below.

Where innovative firms are engaged in competitive rivalry, each will undertake R&D to absorb each others' ideas, develop new innovations and to gain a temporary edge — thus pushing the knowledge frontier further out in a virtuous cycle. Public support may potentially intensify such cycles of innovation. These circumstances are more likely in innovative oligopolistic industries, where firms are undertaking more radical business innovations.

Where absorption of external knowledge is based on R&D that exploits non-R&D strategies (such as hiring experts) or that does not produce its own global spillovers, then the grounds for support are often weaker. Absorptive strategies aimed at relatively cheap imitation of widely available technologies, while commercially useful, are likely to proceed without public support.

On the other hand, the costs of absorbing the equivalent foreign R&D could sometimes be high, but once available domestically may not be costly to copy. Leading domestic firms are then effectively forced to undertake more costly larger-scale R&D to absorb and partly re-create foreign stocks of knowledge. But if other domestic firms can cheaply absorb the knowledge created by these leaders, then the leaders have weaker than optimal incentives to undertake R&D and subsidies are potentially justified. Again, these spillovers are more likely to arise if the novelty of the innovation is greater and there are a wide group of other domestic firms than can exploit the knowledge generated within Australia by the technological leaders.

The same situation can apply if there is a need for innovation that is highly specific to Australian circumstances and the investments of leading firms can, as above, be cheaply imitated by rivals.

The importance of absorption further undermines simple international comparisons of R&D intensities. Pure free-riding is not possible, but clearly there are huge knowledge transfers across borders and a multitude of strategies to enhance these flows. It is more sensible to diagnose the capacity of the innovation system to allow efficient information flows from abroad and between the parts of the domestic system, than to consider a single metric that represents a particular narrow way of achieving this end. Public policy strategies, such as investment in human capital at all levels, trade openness, the free movement of (especially highly skilled) people across borders, the development of excellent ITC infrastructure, and appropriate standards are important methods for reducing the costs of absorption and are likely to widen the types of investments that can be successfully used to promote absorption.

3.6 The paradoxical role of the service sector

The service sector is the most rapidly growing segment of the Australian economy (PC 2003b and McLachlan et al. 2002). The innovation dynamism of this sector (Potts, sub. 18) provides a challenge to the conventional thinking about the role of public policy and spillovers. Spillovers appear to be ubiquitous in many parts of the service sector. In these industries, many of the innovations visibly affect organisational structures (outsourcing arrangements, alliances), business processes (billing methods, customer self-service, database use and construction, spam and tele-marketing) and customer products (bundling, new access points, and speed of services). By their nature, the broad ideas underlying these innovations are easily understood and reproduced in ways that are far less ambiguous than for knowledge flows in any other part of the economy.

However, these apparently ubiquitous spillovers in the service sector do not provide as strong a case for direct public subsidies for innovation as might initially be thought. This reflects that the patterns of innovation in this sector illustrate the points made about spillovers in the previous section.

As in the case of the software industry described above, spillovers in the service sector may sometimes be encouraged by individual firms since the gains from expanding the market for everyone exceed the losses from sharing.

In many instances, the broad ideas are not expensive to create — such as the idea of self-service, new billing methods or a distinctive bundle of services. For small firms, arguably, many innovations reflect the routine, incremental experimentation that is merely part of the business of being a successful service supplier. The marginal effects of subsidies intended to elicit additional innovation are likely to be small in these firms. Other public policies aimed at facilitating easy entry and exit, risk taking and entrepreneurship may be more effective at stimulating innovation.

For that part of the service sector dominated by large players or characterised by economies of scale it is likely that many of the benefits of innovation can be internalised because:

- the specific realisation of the ideas often involve more appropriable technologies, such as proprietary software or complex, rapidly changing algorithms;[7]
- of their logistical capacity — realising the gains from the innovation requires efficient coordination of different functions and parts of the business; and
- of the need for co-specialised assets (Jaffe 1996), such as the ability to finance and undertake large scale complimentary investments to put the innovations into practice. For example, in the finance industry, changes to billing arrangements or customer information systems require large associated IT expenditures. New

[7] Internet search engines provide an illustration. The idea of *having* an internet search engine is easily observed and able to be copied, as are general methods like web-crawling or popularity-based indexing, whose basic ideas are published. But the specific algorithms used to deliver efficient searches is not, either through secrecy, speed of development, or patenting. For example, in 2003, *Google* was successful in its patent application on its search engine algorithm.

service bundling arrangements often require changes in the management of these services within the firm and substantial marketing costs.

For all of these reasons, few policy analysts contend that spillovers in the service sector affect the amount of innovation to a degree that would warrant general public support for these activities. (Even were support to be warranted in principle, it is highly unlikely an appropriate policy instrument could be feasibly designed.)

Of course, while this applies generally, it may not apply to particular R&D projects or to research undertaken in universities or public research agencies that might have generic benefits for service sector agencies (for example, developments in e-health).

Moreover, there are stronger rationales for policy actions in the information economy, comprising content (written material, film and sound) and distribution networks (the Internet, broadcasting, telecommunications). This part of the service sector plays a central role in the creation and diffusion of knowledge. This is directly relevant to innovation, broadly defined, since media creation is a significant form of innovation in its own right, with large economic impacts.

- This places a spotlight on the design of copyright laws, which influence the creation and efficient diffusion of information, especially in a world in which electronic transmission of ideas has effectively reduced the marginal cost of dissemination to zero.
- It suggests the importance of infrastructure complementary to the electronic transmission of ideas, such as high bandwidth services and efficient postal services, both of which are regulated.
- It also emphasises the importance of avoiding regulations that frustrate the introduction of new services.[8]

Emerging policies for this segment of the service sector also recognise that another rationale for public support based on spillovers is not directed at their creation, but at lowering the cost of their absorption, especially for codified knowledge that is generated as part of publicly-funded research. For scientific creation there are specific concerns about the efficiency and practices of scientific publishing, which is taken up in chapter 5.

[8] Several studies have examined the adverse impacts of regulation on new services (Prieger 2001, Hausman 1997). For example, regulatory arrangements that delayed the introduction of just one service — voicemail — in the US imposed annual costs of US$1.2 billion (Hausman 1997). The PC (2000) analysed some of the effects of Australian broadcasting arrangements on the development of new services.

3.7 The bottom line on spillovers as a rationale

The existence of spillovers that, at the margin, reduce the private incentives for research, has been seen by economists as the major rationale for government support. The Commission has frequently cited this as the prime basis for public support (Industry Commission 1995 and PC 2003a). And as shown in chapter 4, there is strong empirical evidence for their existence.

The rationale, however, should not be regarded uncritically as the basis for subsidies to research activities. Apparent spillovers may be captured in surprising ways or may not adversely affect incentives to innovate by as much as formerly thought. The strongest case for public support based on spillovers occurs:

- as a complement to environmental, social and other public good activities. Even such public good justifications may not be permanent. For example, given concerns over global warming there is a strong rationale for publicly funded research into technologies that lower CO_2 emissions or that lock up existing atmospheric CO_2. However, the argument for *public* support of this research would weaken (but not vanish) were taxes on global CO_2 emissions to become a feasible policy option. Taxing would provide stronger incentives for more private funding of the research by emitters;
- for basic research in science, especially where governance and funding mechanisms concentrate on the highest quality and efficient diffusion practices;
- where businesses are engaged in novel R&D activities that either spill over cheaply to others or that trigger cycles of innovation by rivals. The spillover benefits will be greatest when there are many potential domestic beneficiaries from spillovers (generic technologies, or many potential users of the spillover technology because of industry structures).

Spillovers not only provide a rationale for public support, but pinpoint other policies that are important in increasing the effectiveness of an innovation system. These include measures that reduce the costs of absorption (such as skill upgrading); that facilitate research cooperation; and that provide new mechanisms for the legal distribution of knowledge in a digital world (eg copyright and journal publishing models).

3.8 Intangible values: a cultured and worthwhile society

Generally, the value of public support for the science and innovation system is cast in hard cost-benefit terms, reflecting its productivity effects or the specific environmental or social problems it can solve cost-effectively. These are clearly the major criteria for assessing the extent and nature of public investments in the system.

The net benefits to society from support of science and innovation also includes intangible benefits, though these are sometimes overlooked. The World Bank (2001) has explicitly adopted a broad framework that recognises these intangibles when assessing, for example, the role of higher education.

In this context it is important to pose the question of the role of public support for science and innovation in a 'good' society. The value of re-casting it in this way is that it considers aspects of the system that are still valuable, but which might otherwise be neglected (Marginson 2001). As the Nobel prize winning physicist, Richard Feynman, quipped 'Physics is like sex: sure, it may give some practical results, but that's not why we do it.'[9]

From this broader perspective, there are three major grounds on which public support of science and innovation might be justified:

- as a cultural statement of the kind of society we have created for ourselves;
- to increase national prestige; and
- to meet moral obligations.

Identity and prestige

The important role of the scientific mode of thinking about the world is one of the defining aspects of our society. This mode values the application of rationality and evidence when considering issues — whether social, political, economic or in the natural world. It can be seen as promoting social self-knowledge and reinforcing an important part of our cultural identity, such as pleasure from knowing more about Australia's unique environment or the appreciation of the role of Australian science in world breakthroughs, such as the recently successful development of a vaccine for cervical cancer. The Queensland Government (2005, p. 31), for example, argued that valuing science was both economically useful, but also important in this wider sense:

> A vital culture is one that embraces a sense of discovery, creativity and imagination at the same time as basic human values of compassion and respect. Our future depends on valuing the status of knowledge and a curiosity about new ideas.

[9] http://en.wikiquote.org/wiki/Richard_Feynman.

Science and innovation can also increase national prestige. The race by the US and the then USSR to get the first person in space after the second world war is an indication that national prestige can be a non-trivial reason for support (Dick 2005).

These arguments for support can be conceived as a special form of public good, because the value people get from these aspects of science could not be appropriated by the originators of new knowledge and because any individual's benefits do not come at the expense of others. For example, suppose that a voluntary subscription service were proposed to fund the Parkes radio-telescope, which played a major role in space exploration and research. There would be a risk of under-subscription because many people would be still able to gain pleasure and a sense of national pride from its major scientific achievements, without having to subscribe (the standard 'free-rider' problem).

There are many policy questions about how arguments based on prestige or identity can be translated into decisions about the quantum and allocation of science and innovation funding.

- If scientific curiosity is the trait to be valued, and budgets are limited, why not stick to curiosity about a less broad range of scientific fields?
- Are the views of the general public to be taken into account? If people are more interested in astronomy, health and the environment, does this suggest preferential funding for these disciplines over other fields?
- What measures should be used for gauging prestige — large publicly successful scientific projects, medical breakthroughs, Nobel or other international prizes, and excellence generally?
- To what extent should scientists be expected to engage generally with the public about the meaning and value of their work, and should the system generally encourage public science understanding?

Whatever methods are used to answer these questions, the decisions about public support for science and innovation based on national prestige and cultural identity would clearly need to be made in a different way and with a different discourse from that used for support undertaken on more utilitarian grounds. Inevitably and appropriately, decisions would ultimately require value judgments, and therefore be made through the political process.

The values of cultural identity and national pride — while hard to quantify — have strong validity as a basis for public support of science when they reflect people's preferences.

A moral obligation

Finally, public support could be seen as an obligation by a rich country to make a significant contribution to the stock of world knowledge. Whether this is a convincing rationale depends on whether such knowledge production is a more cost-effective way of meeting such global obligations than other possible solutions. But it is, at least, a strongly defensible rationale, especially in areas where research activities represent a form of foreign aid.

3.9 Risk, uncertainty and capital markets

It is commonly argued that there are major market failures in the provision of finance for risky R&D projects. This section sets out the mechanisms for these failures and outlines some of the evidence used to indicate their existence. It also raises questions about whether all of the apparent failures are real or instead represent reasonable market responses to unavoidable and costly phenomena, such as information asymmetries.

Tax treatment of risky investments

The strongest grounds for concerns about capital markets stems from the actions of government itself — through regulatory and taxation arrangements. Of these, the treatment of tax losses in many income tax systems may be an important source of distortion for risky investments, of which R&D is a particularly risky class. In most corporate tax systems, including Australia's, tax losses are treated asymmetrically. Profits are taxed now, while losses must be carried forward and thus lose value through discounting. Since many firms with large upfront tax losses fail, the present value of tax losses can be small. In effect, under the current system, governments generally share 30 per cent of the gains of risky investments if they yield positive returns, but bear considerably less than 30 per cent of the losses if they do not.

The literature on the effects of corporate tax asymmetry is highly complex and assumption-dependent, but generally suggests that for entities facing ultimate taxation of their cash flows, the asymmetry reduces incentives for risky irreversible investments (Heaton 1987, Myers and Majid 1986, and Auerbach 1986). For example, Heaton concluded:

> The unwillingness of the government to share equally in firms' gains and losses for tax purposes … leads to a bias against high risk projects that may result in underinvestment in these projects. In addition, if the institutional framework of debt markets is such that high risk projects have more difficulty obtaining debt, then this disincentive to invest in high risk projects is exacerbated. If the government wishes to offset the disincentive to

invest in very risky projects in which risk is measured by the variance of outcomes, it may need additional incentives such as the research and development tax credit.

The asymmetry appears to affect two groups of firms particularly — entry by new firms; and firms that cannot flexibly adapt their sources of finance (Faig and Shum 1997). Small, young, R&D-intensive firms may, therefore, be particularly affected.

In theory, the asymmetric treatment of losses is not a rationale for R&D policy per se, for there are many classes of investment that are potentially affected. However, there are several theoretical and pragmatic considerations that suggest that a broad approach is not warranted and that the asymmetry does provide a rationale for dealing with its effects for (certain kinds of) R&D assets alone.

Why is asymmetry a rationale for special treatment of R&D alone?

It is not possible to remedy the broad effects of the asymmetric treatment of losses in the current tax system by allowing immediate deductions for all tax losses without the risk of widespread rorting. The R&D Syndication program demonstrated the risks of this in the 1990s.

One practical remedy with fewer risks to general revenue is to quarantine immediate deductions for tax losses for risky innovative investments alone, as is currently done for the losses of small firms (box 3.1). The main issue, even within a quarantined arrangement for exchanging tax losses, is whether the rationale for privileged tax treatment is limited to some firms or investments. There are several relevant dimensions to these boundaries — the size of the firm (or its losses) and type of risky investment.

Box 3.1 **The R&D Tax Offset**

The Tax Offset component of the R&D Tax Concession allows small firms to obtain the full benefit of their tax concession claim, regardless of whether they are in profit or not. For example, a firm spending $100 000 on R&D eligible for the 125 per cent deduction will be given a tax benefit of:

Tax_rate x *(1+concession_rate)* x *R&D* = 0.3 x 1.25 x $100 000 = $37 500

Had it had to wait five years to realise the gain, then with a discount rate of 10 per cent, the value of the realised deduction would have been $23 284 or 38 per cent less. In this example, the tax offset is combined with a concessional treatment of R&D (which relies on another rationale), but in theory, were the concessionary component to be removed, there would still be *a priori* grounds to preserve the tax offset for the non-concessional component.

Size

The existing R&D Tax Offset program is available to firms with R&D that lies between $20 000 and $1 million and with group turnover below $5 million. Clearly many R&D performing firms with tax losses will exceed these thresholds and will be unable to make use of the Tax Offset provisions.[10]

On the other hand, the absence of any conditions may lead to strategic exploitation of the provisions through the manufacture of tax losses. Moreover, larger firms have generally more scope for diversifying their activities so that they can offset losses in one area against another, and arguably may be more able to restructure their business or choose financing rules that reduce the biases of tax asymmetry (Faig and Shum 1997).

The type of risky investment

There are non-R&D investments associated with early commercialisation of R&D that remain highly risky (as well as other investments quite unconnected with R&D, such as new business ventures in new industries). Accordingly, it is difficult to know how the lines should be drawn in determining where policy should attempt to counteract the impacts of tax asymmetry.

It may be argued that the level of risk associated with R&D investments is particularly high relative to other projects, and that the ability for the firms that undertake it to diversify or fund it in tax-effective ways are more limited than many other risky projects (like infrastructure developments). It is possible that this argument may be extended to early commercialisation costs too. In the latter case, it is probably not appropriate to provide tax offsets given risks of abuse, but it *may* provide a (tentative) rationale for subsidies to eligible early commercialisation projects or venture capital provision that meets appropriate risk criteria. Of course, governments already support the early stages of commercialisation and the venture capital market. Thus, even if this rationale were accepted, it may not have a significant impact on the current policy landscape.

[10] While now dated, the BIE survey of Tax Registrants undertaken in the 1990s provides some indication of the extent to which R&D-performing firms with tax losses would be eligible for Tax Offsets. At that time, just over one half of R&D-performing tax loss firms would have been eligible (on an inflation adjusted basis) for Tax Offsets, but given the small size of their R&D values, the effective value of their R&D tax losses were only around 10 per cent of total effective R&D tax losses.

‘Failures’ in capital markets

Quite apart from possible regulatory, taxation and institutional problems in capital markets, it is often claimed that there are major market failures that affect the efficiency of debt or equity provision for risky R&D projects (Stiglitz 2002, Hall 2002). As we show later, it is not clear that these really are failures, but it is worthwhile setting out the arguments and the evidence for them.

The problems are grouped into three categories.

First, it is often argued (starting with the seminal work of Arrow 1962) the high risks entailed by research activities and, in some cases, the absence of knowledge even about how the underlying probability distribution of project returns (uncertainty) means that socially worthwhile projects will be left unfinanced.

Second, a similar argument is that there can be asymmetric information about the quality of a research project that can frustrate financing — the researcher ‘knows’ it is worthwhile, but the potential backers do not know, and cannot trust the researcher. This is akin to the ‘lemons’ problems associated with the sale of second-hand cars and can mean that good projects will not be financed.

Third, recent theoretical elaborations of these, essentially information-related, problems suggest that there can be other sources of financing constraints, associated with principal-agent problems within the firm and difficulties in signalling to markets the value of intangible assets, such as R&D human capital (Hall 2002).

Sometimes the statements by risky firms that they face barriers to finance is seen as adequate substantiation that capital markets are failing. Certainly, innovative firms cite greater difficulties in obtaining finance or face higher costs of finance (table 3.1).

Another strand of evidence, supported by numerous international studies (Hall 2002), is that firms’ R&D is ‘excessively’ responsive to retained earnings. These results suggest that firms must have some unexploited R&D opportunities that provide adequate rates of return to the firm, but which could not attract external finance, or that were not profitable using costly external finance. Either way, this excess responsiveness suggests a gap between internal and external costs of finance. However, there are sizeable econometric and measurement problems affecting these estimates. Such excess sensitivity was not found by the Commission in its analysis of business data from the ABS Innovation Survey (appendix R).

Table 3.1 **Perceived problems accessing finance**

2003, Australian firms, by employment size[a]

Share of firms facing obstacle:	*Small* 5-19 persons	*Medium* 20-99 persons	*Large* 100+ persons	*Total*
	%	%	%	%
Innovating firms				
Cost or availability of finance	19.3	20	15.1	19.2
Excessive economic risk perceived by financiers	4.7	11.5	6.5	6.7
Excessive economic risk perceived by the business	23.7	25.3	28.2	24.4
Non-innovating firms				
Cost or availability of finance	9.9	9.1	6.2	9.7
Excessive economic risk perceived by financiers	4.1	3.9	1.9	4.0
Excessive economic risk perceived by the business	8.3	10.4	8.1	8.7

a It should be emphasised that the data relate to innovating firms, which is a far wider group than firms that undertake R&D. So patterns found for R&D performers may be different from those for innovators.

Source: ABS (2006a).

A further indicator of the potential for market failure would be if the diversified portfolios of venture capital firms *systematically* earned higher returns than the market, since it could be expected that entry would occur to compete away the premium.[11] This is supported by some evidence that United States' VC firms as a group earn higher rates of return at the margin, despite significant entry (Hall 2002).

There is evidence that capital constraints may be more significant for small firms and start-ups than for large firms. The fact that the venture capital industry mainly avoids larger businesses, suggests that big firms have reasonable avenues to access finance for risky projects, internally through their capacity for diversifying risk or through conventional equity markets. In Australia, the smallest innovative firms (employing 5–19 persons) more commonly tended to access debt finance compared with larger firms[12] and to less commonly access internal financing sources. Debt will typically be less 'patient' than other financing sources and exposes the borrower to default risk.

On the other hand, the *difference* in the proportion of firms nominating the cost of finance (or its availability) between innovating and non-innovating groups was

11 A rival explanation for premia could be the presence of tax or regulatory problems.

12 33 per cent of small firms, compared with 9 per cent for medium and large firms (ABS 2006a, p. 71).

about the same across firm size (table 3.1). This is not consistent with deeper problems for the smallest firms. This may reflect that the ABS data relate to innovation broadly, and not to R&D.

In summary, there is evidence that certain types of risky projects, usually undertaken by start-ups and small firms, find it more difficult to access finance than other projects. The fundamental question is whether these difficulties reflect imperfections in markets or the real costs that financial intermediaries face when dealing with small risky firms.

Do difficulties in accessing finance represent market 'failures' in capital markets?

A major limitation of some descriptions of 'market failure' problems based on information asymmetries and other transactions costs is the definition of the appropriate counterfactual. If the counterfactual is a market with no information gaps, then the existence of information asymmetries and its consequences are indeed 'failures'. But if the counterfactual is one in which transactions costs are viewed as real features of the market, like other costs, gaps in finance do not necessarily constitute a failure (Zerbe and McCurdy 2000, Demsetz 2002). These costs may be like other transaction or production costs, such as transport costs. Few would argue that there are efficiency grounds for governments to act as freight intermediaries or to subsidise freight costs because some trades do not take place in the presence of transport costs.

From this perspective, a gap between internal and external costs of finance need not signal a 'market' failure, but reflect the role of the firm as an economiser of transactions costs that are higher outside the firm. Inside the firm, principal-agent problems associated with information asymmetries are much less. Managers know more about the merits of various projects and whether their internal advocates may be exaggerating their benefits and prospects, and these managers have a wide range of carrots and sticks, not available to outsiders, for penalising poor internal disclosure.

A rationale for action would have to be based on a privileged capacity for government to:

- use its own judgments to economise on transactions costs for firms who need to access external finance because they do not have recourse to retained earnings; or
- apply coercion, subsidies or guarantees, which do not reduce transactions costs, but that result in improved welfare outcomes.

Of the two, the first is implausible. It is hard to imagine circumstances when government has a capacity superior to private agents for processing and collecting information about the prospects of R&D projects.

In the second case, there are *theoretical* instances when governments can improve finance outcomes and overall welfare through simple measures, such as interest rate subsidies, without overcoming information asymmetries.[13] However, some theoretical studies suggest taxes on credit not subsidies (de Meza and Webb 1987); others find that the apparent benefits of government policies are offset by strategic responses by intermediaries. The results are strongly dependent on model assumptions; and in all models, financial intermediaries are characterised as relatively unsophisticated.

This belies the actual characteristics of financial intermediaries and ignores the dynamic capacity for such intermediaries and their clients to develop their own solutions to information asymmetries, adverse selection and other agency problems. For example, warranties, collateralisation, development of specialised expertise in judging risky R&D ventures, and giving up managerial control to financiers have been developed as mechanisms to solve or reduce the problems posed by asymmetric information in goods and finance markets. Finance markets are continually adapting to develop new approaches for dealing with asymmetric information, whether it be R&D or other risky investments. Indeed, in models of risky finance, Lacker (1994) was unable to find circumstances where government intervention in loans markets was superior to new forms of financial intermediation. Government interventions in capital markets risk impeding the development of innovative private initiatives.

A further concern for policy interventions in highly risky activities, like R&D, is that governments face political penalties for bearing risk. Wallsten (1997) examined the US venture finance program, the Small Business Innovation Research (SBIR) program and found that the SBIR had low additionality, almost completely crowding out private finance. He conjectured that the low additionality reflected the political need for commercial success, which prompted fund managers to select the most promising projects, which would have received private funding anyway.

An alternative problem is that governments may be less able to credibly commit to early exit strategies from financing a firm’s project because it may be seen, politically, as failing to provide sustained support. This is important because the existence of highly uncertain, but potentially highly profitable, R&D projects suggests an options approach to financing projects compared with the usual static financing approaches. Under an options approach, the financier puts forward

[13] For example, Ordover and Weiss 1981, Mankiw 1986, and Minelli and Modica 2006.

finance for a project to commence, with the option of discontinuing finance if the technology looks unpromising later. But failure to exit at the right time eliminates the virtue of the options approach.

Overall, a broad reading of the literature suggests limited scope for governments to use policy instruments to improve welfare outcomes from any financing gaps. As Parker (2002, p. 28) concluded:

> While credit rationing is impossible to reject on theoretical grounds, human ingenuity at devising rich and specialised contracts can be expected to reduce the scope for its emergence; and its empirical relevance appears to be rather limited at best. In view of the … fragility of policy analysis based on credit rationing models, this is probably just as well.

These concerns about capital market imperfections suggest significant caution in giving public support on this basis. It suggests any policy measures should have sunset clauses and periodic evaluation. They should not be premised on the unrealistic potential for government to wield superior information, in which case they will have to demonstrate that other arrangements, such as subsidies, will yield positive welfare outcomes. The ultimate test of whether capital market failures are present is fortunately transparent (if they are evaluated). Government should observe long-run gains from such financing that are higher than other private investments. If these fail to materialise, the rationale is an empty one.

It is important to distinguish policies that might use capital markets as a mechanism for public support from policies that are intended to overcome deficiencies in capital markets themselves. For example, stock-option grants, a form of equity finance (chapter 9), aim to identify truly additional R&D projects with high spillovers, not to overcome capital market problems.

Indivisibilities

A project may have to be very large to be profitable, and its scale may be beyond the capacity for private financing. Examples might be pharmaceutical development, major aerospace projects, space and defence technologies and nuclear fusion development. This might be seen as more severe in a small country. However, the argument provides a poor foundation for government intervention as many businesses — or consortia of businesses — have been able to undertake very large R&D investments, without government assistance. As noted by Boldrin and Levine (2005) in a US context:

> The famous big movies “The Titanic” and the “Lord of the Rings” cost $200 million each in 1997 USD; DiMasi et al. [1991] estimate the average cost of bringing a new drug to market at $231 million 1987 USD, including clinical trials (which are a public

good). Hence, privately financed ideas have an indivisibility that is, at most, 1/10,000 of US GDP. … Finally… we are all familiar with the "Genoma Project" and the fact that, because its indivisibility was [apparently] so large, it had to be financed by the public purse. Still, we are also all aware that, in spite of the public project to be already underway and, hence, in spite of the fact that the most of the (de)coding of the human genoma was going to be in the public domain, a relatively little private entrepreneur was able to pay for that large indivisibility, recover it, and make a non negligible profit by competing against the public enterprise. (pp. 56-57)

Cooperative arrangements between firms, on many occasions across national boundaries, can resolve the costs of development for very large projects. For example, this is often used in aerospace development or, for small biotechnology companies, by taking a drug to market through licensing to a large global pharmaceutical company. Many of the large projects cited as examples of indivisibilities are really financed by governments for public good and prestige reasons (such as the Manhattan project, development of the European fighter and the Apollo program).

Empirically, the rationale is revealed to be largely irrelevant to public support decision making. Most Australian public sector research and almost all university research is directed at relatively small-scale projects. Exceptions are large expenditures associated with certain infrastructures — nuclear technologies (ANSTO), the Synchrotron and telescopes. But their justification is not some indivisibility. Rather, they represent a shared resource for basic research with spillover benefits and capability building (or, in ANSTO's case, a complementary isotopes manufacturing capacity).

3.10 Tackling myopia and information deficiencies

The issues that potentially reduce the efficiency of financial markets are part of a broader class of potential difficulties affecting information exchange between principals and agents (Stiglitz 2002). In particular, it is sometimes claimed that smaller firms lack good internal resources for assessing the usefulness of external information. They will therefore tend to place a discount on the uncertain value of information services offered by intermediaries (such as advice on technology and commercialisation). This may eliminate exchanges that are, absent such asymmetries, worthwhile to small firms' capacities for innovation.

This argument suffers the same pitfalls that beset assertions of market failure in capital markets, but with one possible exception. Public sector agencies — universities, public sector research agencies, standards bodies, and regulators — often act as providers of information services, because, by the nature of their tasks, they have privileged access to certain information (for example, a particular technology that has been developed in a university). Yet these agencies are often not subject to the competitive pressures of private services and, therefore, may not have the same incentives to develop measures that reduce the impacts of information asymmetries. This may provide a rationale for at least being open to policy proposals that might lessen the impact of information asymmetries between publicly-owned bodies and private ones. For example, these might include:

- developing contingent fee arrangements on IP, whereby IP is transferred on the basis that it is free unless subsequently used in a successfully commercialised project. This is effectively a stock-option grant, but with the grant being in the form of initially free IP; and
- encouraging the development of more effective commercialisation arms in universities or units within public sector research agencies.

Information policies may also have a role as mechanisms for providing subsidies that might be better than cash grants. For example, giving away IP in some circumstances may be preferred to a subsidy for R&D because the IP is more likely to stimulate truly additional R&D and to generate spillovers than general grant or R&D concession schemes. But such information programs are not intended to overcome information problems per se.

A more contentious class of information problems occurs *within* firms. It is sometimes argued that businesses, especially small ones, are myopic or fail to act on information that is cheaply available and of benefit to their enterprises. There is considerable evidence that R&D is often privately profitable for firms, but some firms do not undertake much R&D or access technologies that are important for innovation. There are several grounds for questioning whether this provides a basis for public support for R&D and technology/commercialisation extension services.

First, it is hard to know where myopia is present and where not, because there are other equally hard-to-observe factors that can explain why firms might not undertake R&D when it appears to be privately profitable. For example, in these cases, low R&D might be testimony to high transactions costs or the absence of complementary assets in the firms concerned.

Second, firms are continuously learning and so are constantly overcoming information problems as they emerge. Competition is a dynamic process that discourages myopia or other information deficiencies. Poorly performing firms have incentives through low profits to improve or die. And intermediaries — like banks and consultancies — have strong incentives to provide information that overcomes any deficiencies.

The most appropriate policy response to apparent business information failures of these kinds is to ensure that competitive processes and institutions are functioning adequately (such as ensuring the removal of excessively costly regulatory entry and exit barriers, the introduction of strong competition policies, appropriate bankruptcy provisions, and improvements in the quality of education systems).

To the extent that information problems remain, it is more likely that they lie at the periphery of the key strategic concerns of business managers.[14] Innovation, however, is central to firms' strategic concerns. The grounds for using myopia as a rationale for public funding support for innovation are weak.

3.11 Successful firms and transformed industries

The rhetoric and objectives for some industry R&D programs are *not* cast in terms of the realisation of outcomes related to valid rationales, like spillovers or specific capital market failures. They often emphasise business goals.

For example, the Australian Government's premier business R&D support measure, the R&D Tax Concession, aims to make 'eligible companies more internationally competitive' (AusIndustry and the Australian Tax Office 2006). There is a requirement in the *Industry Research and Development Act 1986* (section 39D) that the project be 'for the benefit of the Australian economy', but it is clear that the interpretation of this is not in a spillover sense, but that the profits or gains *directly* accruing to Australian residents from the exploitation of the innovation be sufficient.

In contrast, perhaps indicating its more recent vintage, the objectives for *Commercial Ready*, a suite of grant programs for SMEs specify a national benefit test that is clearly and appropriately related to the spillover rationale:

> …customers for *Commercial Ready* funding must carry out their activities in a way that provides some identifiable benefits beyond those that can be captured by the customer. In order for your application to be competitive, you must demonstrate that you will conduct the project, and/or exploit its outcomes, in ways that will benefit Australia… Successful projects can benefit Australia in many ways, including: improved national productivity and contribution to economic growth; diffusion of knowledge, skills and know-how to other parts of the Australian economy; increased collaboration between Australian businesses and/or research institutions, or generation of societal, environmental or community benefits. (AusIndustry 2005)

[14] For example, it is sometimes claimed that firms neglect options for improved energy efficiency.

Other innovation programs or science and innovation statements may refer to the standard rationales for public support, such as national productivity improvement, but they also cast government innovation policy in terms of industry policies that create jobs (IR&D Board 2005, p. 18); meet specific competitive threats from low wage economies like China (for example, Queensland Government 2005, p. 5); or that transform industry so that it may better compete in an increasingly knowledge-based global economy (Western Australian Technology and Industry Advisory Committee 2002).

Taken literally, these rationales provide weak grounds for public funding support of R&D.

Competitiveness is an appropriate goal for firms, since it will determine their long-run profits. But firm competitiveness, as conventionally defined, is a difficult goal for governments, if for no other reason than that flexible exchange rates act as an equilibrating mechanism to ensure that enough firms are always 'competitive'. If Australian firms are highly productive, then the exchange rate required to achieve competitiveness is higher; if they are low in productivity, the exchange rate associated with that competitiveness is lower. (It may be that the literal goal of 'competitive' firms is intended to be interpreted figuratively as policies that promote multifactor productivity. This would be a legitimate policy goal, but the rhetoric is open to misinterpretation.)

Labour market theory suggests that technological change has an ambiguous effect on job creation. The fact that a new industry or set of innovative firms may record strong employment growth ignores displacement in other industries. Overall, the empirical evidence suggests that no systematic long-run relationship is present between job creation and technological change (Cahuc and Zylberberg 2004, p. 583ff; Layard et al. 1991, p. 5). The strongest evidence for this is that unemployment rates do not exhibit long-run trends, despite ongoing technological change and accumulating knowledge. Aggregate unemployment and jobs growth should be seen as macroeconomic phenomena, not as the consequences of industry policy.

The rapid growth and development of China as a powerful industrial country has been beneficial for Australians. It has increased global productivity and improved the sales level and prices of our natural endowments. It has meant reduced prices of manufactured imports for Australian consumers and industry users.

It also generates structural changes within Australian industry that have reduced the relative importance of the manufacturing sector. This is why some consider that it is necessary to develop public innovation policies that transform and improve the economic prominence of that sector.

The argument has several limitations:

- Given our smaller and more specialised manufacturing base, it is likely that the future economywide effects of such structural change will be smaller than in the past.
- Resources cannot be allocated everywhere. The mining sector appears likely to play an enduring role in Australia's continued growth (Henry 2006). Australia's resource endowments are diverse and, contrary to some characterisations, the sector is innovative. It is true that as the economically exploitable reserves are depleted, resources will have to shift to other sectors, but why does this require transformation now?
- It assumes that government needs to orchestrate industry transformation with specific industry policies. In fact, resources are highly mobile and industries are always adapting to external and internal pressures, unless thwarted by policy. The role of manufacturing in Australia has dwindled over the last forty years from one in every four dollars in GDP to around one in eight, while income per person has risen dramatically (PC 2003b). Within manufacturing, relative price changes and comparative advantage have led to restructuring towards more capital and knowledge-intensive activities. Private innovation activity is an important part of that story, but the innovators have strong incentives to transform their firms because of the need to improve profits, lower costs or reduce threats. In other words, the imperative for transformation exists, but its details are driven largely by private sector incentives, backed by broad and flexible capabilities developed by governments, and occasional strategic opportunities (for example, CSIRO's investigation of titanium processing).
- The realistic scope for industry-specific innovation policies of the kind envisaged to transform Australia's industry structures appears weak. The transformative goal of past policies do not appear to have achieved their original aspirations. Moreover, the definition of innovation usually adopted when referring to transformation tends to place excessive weight on technological innovation, downplaying the arguably more important role of wider routes to doing things better. As noted previously, the most clearly transformed sector in Australia is the services sector, where technological innovation has played a relatively attenuated role in contrast to adoption and non-technological innovation.
- To conceptualise decreased prices for manufactures as a significant economic threat that requires transformative policies to promote alternative manufacturing capabilities is to return to the intellectual underpinnings of protectionism, which had exactly the same objective. In the past, policies that have resisted structural change, such as tariff and quota policies, have been damaging to Australia's

economic fortunes. Dr Ken Henry (2006), Secretary of the Australian Treasury notes:

> …despite the fact that the Australian economy is now operating at close to full capacity, with relatively few idle resources, many people think that industry policy should be doing something in response to higher terms-of-trade. The first test that should be applied to any proposal in this area is the following: Does the proposal seek to resist the change in resource allocation implied by the higher terms-of-trade, or is it empathetic with that change? Proposals that resist the changes … should themselves be resisted. My reasoning is straight-forward: Let's just suppose for the moment that we wanted to prevent the consequences of an increase in the terms-of-trade to which I have referred. What would be the best policy means of achieving such an objective? The answer is an across-the-board additional tariff on all imports at a flat rate of about 25 per cent. Now that would be absurd. But the point is this: absurd as it is, anything else would be worse. (p. 11)

Arguably, the best policy response to structural pressures that will assume unknown forms is the encouragement of a high-quality broad-based innovation system as part of a highly flexible economy, well functioning labour markets with high-quality labour endowments, and excellent and adaptive institutions. Innovation policy is a central part of a flexible capability, but arguably does not need to be directed to goals of transforming particular segments of (manufacturing) industry.

3.12 Evolutionary theories and the 'innovation system' approach

Evolutionary approaches originated from Schumpeter's theories, but were developed in their modern form by Winter and Nelson (1982). Evolutionary economics apply some of the ideas of evolutionary biology to the study of innovation. In this theory, heterogenous and boundedly-rational firms and other agents use constantly adapted, experimental processes in competitive contests. Entrepreneurs play an important role in evolutionary economics as a major source of innovation. Successful processes are discovered and then imitated through competitive processes. Firms that do not adapt well fail. The nature and speed of competition is influenced by the innovation system (chapter 1).

The most important policy-relevant features of the theory are:

- the value of variety, since this increases the likelihood that useful, novel processes will be discovered, and reduces the risk that an economy selects a poor technology pathway;
- high rates of diffusion of ideas among firms; and

- the importance of innovation systems that support entrepreneurial invention and competition. A significant focus of more recent development of evolutionary economics is analysis of innovation systems that assist rapid innovation. The central concerns are poorly developed linkages, inappropriate standards, poor regulations, inadequate infrastructure, network failures, and high exit and entry costs that reduce competitive pressures.

The evolutionary approach has several useful insights into innovation behaviour in firms, and is also useful for examining obstacles that may arise in the innovation system (chapter 5). The approach also recognises that science plays a useful role in the innovation system as an important source of knowledge and human capital that firms can draw upon in pursuing their innovations.

However, unlike some of the orthodox market failure arguments for public interventions, the evolutionary approach does not establish a welfare benchmark against which to gauge appropriate government policy. As Fagerberg (2002) notes:

> … from an evolutionary perspective there is no such thing as an 'optimal' rate of growth. Hence it is left to politics to decide whether or not the economic system is performing in a satisfactory way. If it needs to be invigorated there are two main mechanisms that follow from evolutionary reasoning. The first would be to attempt to increase the economic system's ability to generate new variety. For instance, rather than subsidizing R&D in well-established firms in traditional sectors, one might put the resources into new types of activities or actors, not necessarily with the expectation that these would do extremely well, but because the entire system (including the traditional sectors) might benefit from such increased diversity. The second would be to focus on the economic system's capacity to absorb innovations. (p. 42)

3.13 Empirical rationales for support

The previous sections have considered theoretical reasons for public funding support, and these are usually the only factors discussed when seeking a rationale. However, in many arenas of decision-making, including scientific discovery itself, emerging empirical regularities, rather than theory, is the basis for real world applications. For example, many pharmaceutical treatments arise through the observed consequences of compounds developed for other purposes. Penicillin is the classic example. More recent examples include Bupropion (*Zyban*) which was used as an anti-depressant, but was observed to reduce the craving for smoking; and sildenafil citrate (*Viagra*), which was originally a rationally selected molecule for the treatment of angina. Bio-prospecting — the search for new compounds in living things that may have medical applications — is a systematic application of this empirical approach.

Empirical approaches have advantages when theory is insufficiently developed. The expansion and elaboration of industrial organisation theory in economics has made it less clear about the circumstances and form of public support for firms (though not for public research agencies or universities). This is because firms are seen as complex strategic entities with incomplete information, whose behaviours are shaped by their (varying) technologies and by the actions of firms, industries and public agencies around them. It is possible in these contexts to get over-investment in R&D through patent races and duplication in one set of circumstances, yet re-invoke the conventional story of under-provision in another.

Given these theoretical uncertainties about the rationales for public support of business innovation, there are grounds to be at least open to empirical evidence that may help guide policy. Evidence about the impacts of innovation policy on the economy (chapter 4) may help do this.

3.14 Bottom lines

There are a plethora of rationales given for support, but only a few have strong relevance.

The strongest reasons for public support of science and innovation are:

- spillovers from innovation that cannot be captured by the innovator and that cannot be realised without support. The spillovers may arise through high quality human capital development, the development of basic knowledge capabilities, the resolution of public good problems and diffusion of new ideas among firms and others. They arise from research undertaken in universities, businesses and public sector research agencies;
- intangible factors such as national prestige and national identity. They relate mostly to scientific research in universities and public sector research agencies;
- the asymmetric tax treatment of highly risky investments, which mainly relate to R&D undertaken in businesses;
- with strong provisos, problems in capital markets that could affect the availability of finance to risky or uncertain investments in small firms and start-up companies; and
- problems in information provision by public sector agencies.

Some cited reasons for supporting the system, such as indivisibilities, business myopia, and the aspiration to achieve a transformation of Australia's industry away from its present structure have weak validity. In many instances, they would entail completely different support arrangements than those currently observed.

However, rationales for public support are based on implicit models of the behaviour of agents. With the advent of more complex models, it is harder to make clear rules about when support should be given or not, especially for business innovation. This suggests that it is important to be open to empirical evidence that may reveal unexpectedly effective policy initiatives.

DRAFT FINDING 3.1

There are strong rationales for the provision of public funding support for science and innovation.

4 Impacts

Key points

- Economywide productivity is closely linked with improvements in R&D. Evidence for this linkage within Australia includes:
  - aggregate time series studies;
  - panel data analysis across Australian States;
  - cross-country results;
  - models of innovation; and
  - case studies.
- It is not possible, given a host of measurement and methodological issues, to provide accurate estimates of the social rate of return on R&D for Australia, but spillover rates could readily lie between 35 and 100 per cent.
- The relevant issue for public policy is the magnitude of benefits from *public funding* for science and innovation, not science and innovation in general.
- Existing information suggests that government spending on R&D effectively increases national R&D and does not, to any substantial extent, substitute for privately-funded R&D. This is important because significant crowding out would reduce the potential for positive net impacts from public funding support.
- The Commission judges the benefits are likely to be high for R&D in universities and public sector research agencies, due to their greater orientation to public good research and their role in development of high quality human capital for the Australian economy.
  - This is backed by case studies and some econometric evidence, though the latter is not robust.
  - Other indirect indicators of academic quality suggest that Australian scientists are performing as well as in other advanced economies.
- Because of the nature and structure of business programs they are likely to have had smaller absolute impacts:
  - This is mainly due to the extent of public funding support, which is relatively (and appropriately) small-scale.
  - Considerable public support has been given to a few sectors that are contributing relatively less to the economy.
- The Commission judges that publicly funded science and innovation have produced important social and environmental benefits. It is difficult to enumerate these benefits, but research appears to have:
  - increased national preparedness and reduced risks in some areas; and
  - been widely adopted in a range of settings (public health, risk abatement in the environment and social and educational policy).

4.1 Introduction

Australian governments direct significant public resources to science and innovation (chapter 2). A key question posed by the terms of reference for this study is what Australians get from this spending. These impacts are not just the gains that end up in gross domestic product or other more tractable measures of the economy, but also broader social and environmental benefits to Australians.

This chapter brings together evidence on these impacts — from research undertaken by the Commission, as well as many useful studies undertaken in Australia, and to the extent that they may be applicable, from overseas. The impacts are explored from many perspectives because no single method is flawless. Some of this material is technical in character — especially section 4.3.

The chapter is structured as follows. Section 4.1 briefly describes the potential nature of impacts that should be assessed, of which the most important goal is to investigate the effects on Australians' well-being. It also explains briefly why it is necessary to use several methods when gauging impacts.

Section 4.2 assesses the extent to which broad public support makes a difference to the actual amount of R&D that is conducted (*additionality*). This issue stems from the fact that government support may, directly or indirectly, substitute for R&D that would otherwise be financed by others (*crowding out*). Additionality is important because beneficial impacts can only be generated by truly additional innovation, while the taxation distortions imposed by financing the transfers still produces costs.

Sections 4.3 considers the orthodox economic impacts of public support, applying a variety of quantitative approaches and drawing on evidence from overseas studies. Section 4.4 supplements this evidence with case study analysis. More detailed analysis is in appendices E to I.

While innovation in the market sector is the greatest source of national productivity growth, and a major indirect or direct target of public support, a key goal of public support is innovation outside the commercial sphere. The chapter uses several approaches to assess the environmental (section 4.5) and social impacts (section 4.6) of public support.

In many cases, it is only possible to derive indicators of the impacts of public support, such as its effects on patent counts and bibliometric measures and the goal, present in some industry programs, of growing highly successful Australian firms. While these have to be interpreted carefully, these may still provide useful information about the performance of the system and its potential impacts. These are briefly discussed in section 4.7 and specific aspects of these indicators are the subjects of appendices J and K, and ongoing review.

Section 4.8 draws some brief conclusions about the impacts of public support for R&D.

4.2 What is meant by 'impacts'?

In common usage, 'impacts' is a term that means effects of any kind. However, in this chapter a more narrow meaning is used, consistent with the framework in chapter 7. Impacts (or 'outcomes') are conceptualised as effects that are beneficial to Australians. The impacts could be:

- specific beneficial economic outcomes (such as new products or services, faster adoption of overseas technologies, the formation of rapidly growing high-wage industries, reduced costs, and increased consumer surplus). A summary measure of impacts will be their effect on aggregate productivity, if that is properly measured;
- beneficial social and environmental outcomes, some of which may only partly be visible in markets, such as reduced dry-land salinity or improved public health outcomes; and
- other intangibles (chapter 3), such as national prestige, contributions to the global common knowledge pool, implicit aid to developing countries and the development of capabilities that have future option values, even if they are not immediately useful (for example, a capacity to understand whether or when nuclear energy is a viable option for Australia).

Higher level impact measures have several desirable properties.

First, they should indicate the extent of the benefit, not just whether a particular beneficial objective was achieved. For example, in the case of a research program aimed at developing a vaccine for cervical cancer, it is preferable to know not just whether the project was successful, but whether that success translated to big or small benefits (such as, what is the likely effect of the uptake of the vaccine on reduced cervical cancer rates and the consequent improvement in well-being and reduction in health and other costs).

Second, if possible, measures should be commensurate across projects, so that the aggregate benefits of a suite of projects can be assessed. This is why measures of value expressed in dollars are useful.

Third, measures should take account of the indirect effects of projects or programs. Even a ‘failed’ project builds up human capital, indicates unprofitable research directions and adds to knowledge that may be useful in the future in many other ways. These indirect effects are just one manifestation of the non-linear nature of the innovation process.

However, it is often not possible to devise impact measures with these desirable traits, or in some instances any impact measures at all. In many cases, outputs are used as proxies for likely impacts. Some examples are high quality human capital, patents, academic papers and their citations (which reveals how widely the underlying knowledge may be diffused and gives an idea of their quality). Research outputs are mainly inputs into broader innovation processes and whether they produce outcomes depends on their character and the context in which they become available. There are many lower quality academic papers and lapsing patents, whose ultimate effects on Australians’ well-being are likely to be weak. Nevertheless, while the existence of outputs from public support is not sufficient to be assured of a subsequent outcome or impact, an output of some kind is at least necessary for that objective. Accordingly, carefully-interpreted outputs can sometimes be useful as proxy indicators of ultimate outcomes.

Moreover, it may be useful to measure outputs (and sometimes inputs) as well as outcomes because this can better indicate what kinds of policies are effective in generating outcomes/impacts. For example, a study of national multifactor productivity growth might show a high ultimate impact from the conduct of R&D, but it is also useful to know whether any separable effects stem from good quality human capital and problem solving capabilities, the diffusion of codified knowledge or particular areas of research. Gans’ analysis (sub. 10, pp. 12ff) of Australia’s innovation capacity proceeds along these lines (albeit looking at Australian patents granted by the US Patent and Trademark Office per capita, which is arguably an output measure rather than an outcome measure).

Another important facet of the impacts of public support is their distribution among Australians. This can be particularly pertinent to programs or projects that have low additionality or where the gains mainly come in the form of higher private returns, since these imply large transfers to relatively few shareholders. As noted by Baumol (2002, pp. 143ff), the usual assumption that non-distortionary lump-sum taxes can address this is improbable. However, while distribution is a relevant issue, it can only realistically be assessed on a program by program basis.

Where information is available, this chapter explores the above aspects of impact. In some cases, as in the human capital effects of the science and innovation system, the discussion is elsewhere in this report (chapter 5 and appendix L).

The distinction between economic and social/environmental effects

The terms of reference for this study separately examines economic, social and environmental impacts. In doing so, the chapter implicitly adopts the conventional, though not rigorous, view of economic benefits as those that are apparent in markets (and typically represented in official national accounts measures).

However, in fact, from an economic perspective, people's well-being is not just determined by goods and services that are counted in GDP. Since most people value peace of mind, good health and sustainable environments, these are also relevant to economic well-being, properly defined. They are also, in theory, measurable, since it may be possible to discover the tradeoffs people are willing to make between market-produced goods and others, such as biodiversity and reduced crime. In some cases, social and environmental impacts are, in any case, also standard economic benefits. For example, improved environments can increase productivity (for instance, reduced salinity raises crop yields), as can investments in animal and human health.

Where possible, the Commission draws attention to quantifiable measures of social and environmental benefits — whether in the market system or not. Nevertheless, in many instances, eliciting accurately people's aggregate preferences about such non-market goods is often difficult (and some people consider the preference-based approach to valuing such non-market goods is flawed in any case). Given these difficulties, assessment of the social and environmental impacts of R&D often use qualitative as well as quantitative approaches, and invariably involve more subjectivity (sections 4.5 and 4.6).

4.3 How much additional R&D does public support elicit?

Australian Governments commit around $6 billion in funding for science and innovation, mostly as funding for R&D. A key question is the extent to which this funding translates to R&D that would not otherwise have occurred (defined in appendix M). This is central to the concerns of this chapter since only genuinely additional R&D can even potentially have impacts that can be ascribed to government actions. The IPA (sub. 30) highlight this as a potential drawback of public support.

When considering the question of additionality, it is important to distinguish three types of publicly supported R&D — that mediated through tax measures; competitive grants to businesses; and through spending in PSRAs and universities.

In many discussions of this issue, the three modes are conflated, with the risk of misdiagnosis of the true effects.

The Commission has examined the existing large theoretical and empirical literature on additionality (appendix M). Three broad conclusions can be drawn from the Commission's analysis:

Public support for business R&D that lowers the price of R&D

First, policy measures that generally lower the price of business R&D, such as tax measures for business R&D, have been intensively analysed, though only recently has analysis attempted to differentiate empirically the degree of additionality associated with different designs of schemes. The evidence suggests that it is likely that every dollar of public support generates somewhat less than a dollar of new business R&D because it substitutes for R&D that businesses would otherwise undertake. This may well rise above one dollar for well-designed incremental schemes. Additionality rates of less than one can still produce sizeable net benefits, as explained in appendix M.

Competitive R&D grants for business

Second, competitive grants to business have been much less studied and not as much is known about their likely additionality. But additionality rates are probably greater than one dollar per dollar of revenue lost. However, poor program designs risk lower additionality than tax concessions because of selection biases in the application and merit award processes for grants. These biases can favour firms with projects that have strong commercial viability and which would probably still be financed in the absence of the grants.

The alternative risk is that flaws in the selection processes (reflecting the difficulties in technical assessments by grant committees of the quality of R&D) result in choices of projects with high additionality, but little likelihood of commercial or spillover gains. Consequently, outcomes from competitive grant programs depend on the nature of grant selection processes.

Public R&D funding for PSRAs and higher education

Finally, there appears to be little crowding out between government-funded R&D support for its own R&D activities in PSRAs and higher education institutions, and R&D performed and financed by business. The commonly reported findings of crowding out by public funding cited by some (for example, the IPA, sub. 30) is based on either *all* public funding (which includes public funding of business R&D) or is biased by the inclusion of results for the United States, where public funding of defence R&D does appear to crowd out private sector defence R&D. Such R&D is of little relative importance in Australia.

While the judgment of little crowding out in an Australian context may be true at the aggregate level, individual publicly funded projects with research applications that are likely to be used by relatively narrow groups of industry members may well crowd out private R&D investments. This may affect some industry-centred research activities by CSIRO and RRDCs and is discussed further in the appendix on case studies of R&D support (appendix I).

The other question is whether there are complementarities between publicly supported R&D in non-business entities and that in business. In theory, increases in R&D in one can actually stimulate, rather than crowd out, R&D in the other. There does not, however, appear to be much evidence of this. Of course, complementarities may take many years to materialise, so their usual absence in empirical analysis should not be regarded as definitive evidence against their existence. (It is unlikely that long-run crowding out is greater than short-run crowding out, so the same bias is probably not present for this issue).

The overall finding of no crowding out (or for that matter, complementarities) from public support of R&D in non-business settings is particularly important because of the emphasis of public funding support on R&D in universities and PSRAs (chapter 2).

4.4 The macro evidence on economic impacts

The aggregate economic impacts of R&D are usually assessed by examining the effects on productivity of R&D stocks *as a whole*. A link then needs to be made between the size of these aggregate effects and the likely impacts from R&D stimulated by public support. (This is why additionality, discussed above, is so important, as well as determining what parts of the publicly supported R&D are relevant to the market sector.)

This section first sets out how productivity is measured, its link to economic growth and the role of R&D stimulated by public support compared with other factors. It then shows the results of a semi-parametric method that illustrates the potential impacts of publicly supported R&D. These results are then compared with econometric results based on Australian and overseas time series and panel data.

Economic growth and multifactor productivity

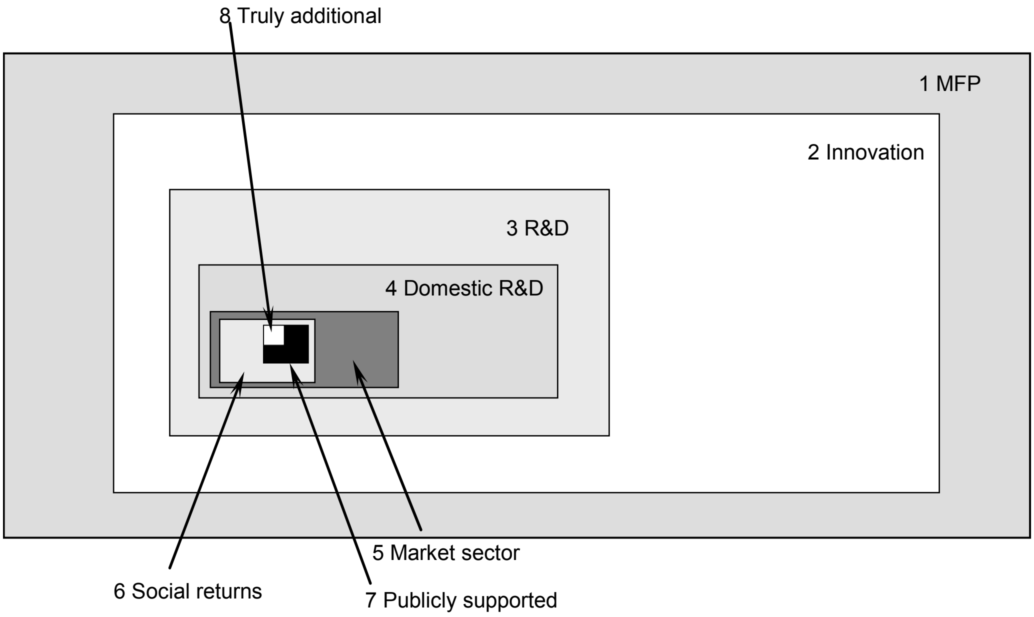
Australians' *material* well-being is determined by the capacity to consume more, or better quality, goods and services. With some qualifications, which are ignored here,[1] the long run determinant of that capacity is economic growth. A major goal in understanding economic growth is to attribute growth to its various sources. It is clear that an economy gets larger with capital accumulation and a bigger labour force. However, in all advanced countries, a substantial part of past per capita economic growth is due to factors other than labour or capital inputs. This residual source of growth is referred to as multifactor productivity (MFP) because its effect is to raise the productivity of capital and labour. From 1964-65 to 2004-05, around 65 per cent of economic growth per capita in Australia can be ascribed to MFP growth (appendix E). MFP rises due to better trained and educated labour; technological and non-technological innovation, of which R&D is just one contributor; regulatory reform; and reduced barriers to trade that increase competition and improve incentives.

Where does R&D fit among these sources of MFP growth? It is important to distinguish questions about the impacts of innovation, or even R&D more broadly, from the impacts of *publicly supported* R&D (which is the focus of government publicly funded support of the science and innovation system — chapter 1 and chapter 2). The R&D relevant to this narrower issue is smaller than the total stock of R&D that influences innovation. To address the issue of how much smaller, it is useful to progressively decompose R&D into its relevant constituent parts (figure 4.1), extending the categorisation used in chapter 1.

Just as innovation is one source of MFP growth, R&D is just one contributor to innovation. As noted in chapter 1, innovation results from many sources, including new technological and non-technological developments; catch-up; and the imperative to learn that arises from the constant pressure of competitive processes. It is likely that much of the improvement in productivity in Australia (particularly in the burgeoning service sector) arises from non-technological knowledge generation and copying of ideas from abroad and between firms within Australia (2 in figure 4.1). Developments in ICT has probably increased the capacity for generation and diffusion of knowledge of this kind.

[1] The terms of trade will affect the extent to which domestic production allows Australians to buy imports, and is ignored here. The IC (1997a, p. 26) has shown that, over the long run, declines in the terms of trade have had minor effects on per capita income.

Figure 4.1 **What matters for market sector multifactor productivity growth?**



R&D is most associated with technological development. But only a part of technological development can be ascribed to domestic R&D. Foreign stocks of knowledge may be the most important long-run contributor to new technological developments, given Australia's small size relative to other major generators of knowledge and the fact that knowledge is much more globally footloose than labour or physical capital (4 in figure 4.1). From a public policy perspective, the influence of foreign R&D stocks is only of interest to the extent that it has to be controlled for in estimating the impacts of domestic R&D; and to the extent that domestic R&D has to be undertaken to absorb its benefits.

And of domestic R&D, only a portion is relevant to developments that are likely to be included in MFP *in the market sector* (5 in figure 4.1). Domestic business R&D is important because it is aimed at improving market goods and services, but R&D undertaken by higher education and public sector research institutions often have broader objectives, such as inputs into public goods (chapter 3). These are valuable, but the test of their impacts has to look wider than the market sector. So only a portion of R&D stocks associated with HERD and GOVERD are likely to be relevant to measured MFP.

R&D is a cost that involves physical capital and specialised labour resources, so that it is already incorporated into labour and capital inputs. These inputs are weighted by their cost shares, assuming that inputs are paid their marginal returns (wages and rental prices of capital respectively). Accordingly, the private effects of (domestically-conducted business) R&D on value-added are already taken into account, and are not included in residual MFP growth. Any additional effects of R&D on MFP are therefore seen as picking up the social or spillover returns of R&D (6 in figure 4.1). These returns will contribute to innovation broadly, beyond the confines of firms that produce the knowledge in the first place.

Of domestic business R&D, a relatively small amount is supported by governments (7 in figure 4.1 and chapter 2).

Finally, as noted in chapter 3, part of public support for R&D is provided for activities that would have occurred anyway. The social benefits of these activities cannot, therefore, be ascribed to public support. Only the truly additional component is relevant (8 in figure 4.1).

Accordingly, while it is almost certainly the case that innovation is the key driver of MFP, the relevant stock of domestic R&D underpinning MFP is likely to be small relative to other influences and the stock of publicly supported R&D even smaller.

To get an indication of the magnitude of the spillover benefits from both the total market-sector domestic stock of R&D and its publicly supported component, the Commission developed a semi-parametric method (appendix G).

At the default values used in this model, R&D stimulated by public support (whether in business or elsewhere) had a gross spillover rate of return of around 65 per cent. There is some uncertainty in this result, since the semi-parametric method relies on judgments about some important parameters. However, even when uncertainty about the parameters is taken into account, rates of return are mostly above 35 per cent and below 100 per cent (figure G.1 in appendix G). Much larger values would imply that the huge flows of knowledge from overseas and from non-technological forms of innovation were unrealistically small relative to the flows from domestic R&D (even after accounting for absorption issues — see chapter 3 and appendix D). Much smaller values would risk ignoring the important role of domestic R&D as a generator of knowledge flows and in absorbing foreign flows of knowledge.

However, even though the social rates of return to publicly supported R&D may be high, the actual implications for long-run productivity growth are relatively modest compared with other factors. The appendix finds that around 5 per cent of conventional MFP change in the market sector from 1983-84 to 2002-03 can be attributed to R&D stimulated by public support, around 10 per cent to other market sector-relevant R&D and the remaining 85 per cent to other factors (table G.5 in appendix G). The figures could be slightly higher or lower than this, but it is hard, given the logic of figure 4.2 to see this judgment qualitatively altered.

Of the 5 per cent of MFP change attributable to publicly-supported R&D, a relatively small share can be ascribed to public support mediated through business R&D programs (as implied by table G.2 in appendix G). This reflects the (appropriately) small emphasis of public funding support for business R&D and the wastage associated with some crowding out. The calculations in appendix G also ignore the potential implications of the considerable emphasis in public funding support of business R&D in a relatively few large firms facing significant future adjustment pressures, such as those in the automotive sector (chapter 9). This may reduce the gains, albeit probably modestly.

The observation that many other factors are important drivers of MFP does not diminish the significant absolute gains from public support of market-sector relevant R&D (whether conducted in business or elsewhere). At a 65 per cent rate of return, the accumulated gross gains to market-sector GDP from R&D stimulated by public support over the roughly two decades from 1983-84 to 2002-03 are estimated to be around $54 billion in 2003-04 prices (table G.6 in appendix G). In 2004-05, the gains were around $6.5 billion (noting that this, in part, reflects the growth benefits of past supported R&D).

It might not be thought that this benefit is substantial given that governments invested around $6 billion on R&D in 2002-03 and have since increased spending (chapter 2). However, it should be recalled that these gains only relate to a part of that annual spending. About half the spending of PSRAs and two-thirds of public support through higher education R&D is focused on non-market applications. This R&D has less relevance for the market sector and so does not show up in market-sector GDP. But it still produces gains in non-market goods and services, such as better health and a cleaner environment.

The results demonstrate that it is possible to reconcile high social rates of return on R&D with a modest relative contribution to growth of market sector GDP. It is this modest relative contribution to MFP growth, against the background of the statistical noise in MFP models, that explains why econometric methods will generally find it hard to pin down the impacts of R&D on growth with any precision — the central finding of Shanks and Zheng (2006). The consequences of those difficulties is discussed next.

Past Australian aggregate studies

There are about a dozen studies of the links between aggregate Australian productivity growth and R&D (tables 4.1 and 4.2). Apart from the State-based panel studies that have exploited geographic as well as time series variations in productivity, the studies have considered the extent to which measures of R&D have affected productivity growth over time.

Most of the studies have sought to consider the links MFP and stocks of business R&D capital. The methods for constructing these and the theory that links R&D stocks to MFP is explained further in the companion Productivity Commission research study (Shanks and Zheng 2006, pp. 47–54; pp. 77–82).

Past Australian studies have had to use limited time series information (with the exception of studies that have used patents or panel data). The real position is worse than the apparent one. Studies have had to make up data for the many missing years when ABS surveys of R&D were intermittent. Two types of study were particularly affected by this problem:

- Earlier studies, because intermittent data only occurred from 1968-69 to 1983-84. For example, (1994b) (and the original Coe and Helpman study which it replicated) imputed more than half the data points on which their regressions were based.
- Studies based on quarterly data. Since, at best, only annual data are collected, these studies were forced to manufacture three out of four observations in years when annual data were available and 100 per cent when no annual data were available. In the case of Bodman (1998), nearly 85 per cent of observations on R&D stocks were imputed.

Of the national (not State and Territory panel) studies to date, the Commission's recent study by Shanks and Zheng (2006) have the least imputed data (about one in four). Large numbers of imputed data points undermine the precision of estimates from the regressions in a way that is not reflected in the standard errors of estimates (these are the statistical basis for assessing whether the estimated parameters of models are statistically significant or not). This should be borne in mind when interpreting results from these Australian studies, including those of the Commission.

Table 4.1 **Key features of prior Australian aggregate studies of the effect of R&D**

Study	*Dependent variable, period*	*Apparent Obs.*	*Real Obs.*	*Major data issues*	*Measure of R&D*
Dowrick (1994b)	Ln(MFP), 1971–90	20	9[a]	55% of the data was imputed	R&D stock
Industry Commission (1995)	Ln(Y) & Ln(MFP), 1976–77 to 1989–90	14	9	36% imputed	R&D stock
Rogers (1995)	Ln(MFP), 1972–1990	19	12	37% imputed	R&D stock
Bodman (1998)	∆ln(Y), 1968 Q1 to 1996 Q4	116	18	84% imputed; All quarterly R&D data interpolated, data source and type uncertain[b]	R&D stock
Crosby (2000)	∆ln(Y/hrs) and ln(Y), 1901 to 1997	97	..	..	Patents
Williams, Draca and Smith (2003)	Ln(MFP) 1984–85 to 1999–00	96	96	Interpolated of missing data	R&D stock
Burgio-Ficca (2004)	Ln(GSP) 1979–99	126	63	Interpolated of missing R&D series	R&D stock
Chou (2003)	∆Ln(Y/hrs), growth accounting, 1960–2000	41	20	51% imputed; Data on researchers is extrapolated for 16 years prior to 1976 and linearly interpolated for various missing years from 1976 to 2000	Researchers to employers
Connolly et al. (2004)	Ln(Y/L), Qtly data 1971Q2 to 2004Q3	134	25	81% imputed; All qtly R&D data interpolated	Share of ICT & R&D in total capital stock
Shanks and Zheng (2006)	Ln(MFP) & many other forms; 1968–69 to 2002–03	35	26	26% imputed	R&D stock mainly, but other forms tried

[a] Dowrick used Coe and Helpman's R&D stock, which was based on data from 1976-77 to 1988-89, with all other data imputed from the relationship between R&D, real output and investment apparent for years when data were available. Coe and Helpman's stock calculations imputed 11 of the 20 annual observations (not 7 as suggested by Dowrick p. 30). The imputation method creates the risk of endogeneity in any regression. [b] Bodman (p. 59) indicates that the quarterly R&D data are from the OECD's *Main Science and Technology Indicators* database, without specifying whether BERD, GERD or some other R&D measure is being used. Moreover, the R&D data in this OECD publication are annual, not quarterly.

Table 4.2 **Key results of Australian aggregate studies**

Study	*Domestic R&D elasticity*	*Foreign R&D elasticity*	*Implied rate of return on domestic R&D*
	coefficient	coefficient	%
Dowrick (1994b)	0.066	0.065	150
Industry Commission (1995)	0.119	0.086	149
Industry Commission (1995)	0.04	0.041	43
Rogers (1995)	often negative	0.04	<0
Bodman (1998)	0.13	None	>200[a]
Williams, Draca and Smith (2003)	0.056 (own state)[b]	0.039 (interstate)	173 in 1990; 116 in 1999
Burgio-Ficca (2004)	0.21 (non-HERD stock). For higher education, R&D elasticities were 0.262 (basic); -0.052 (strategic); 0.445 (applied) and 0.210 (experimental).	..	na
Crosby (2000)	na	None	na
	Increased patenting contributed to both labour productivity and output growth. Part of the decline in productivity in the 1970s might be attributable to declines in innovation (proxied by patenting applications) from the late 1960s. A one per cent increase in overseas resident patent applications in Australia reduces domestic long-run applications by 0.36 per cent.		
Chou (2003)	na	None	na
	42 per cent of Australian labour productivity growth attributed to rise in educational attainment, and 20 to 40 per cent to the increase in research intensity. Most of growth is associated with 'transitional dynamics'.		
Connolly et al. 2004	0.013[c]	None	150[c]
CIE (sub. 70) [d]	0.0571	0.0172	170
Shanks and Zheng 2006	Depended on the form of the R&D variable	Varied among specifications	Average of around 50 per cent gross rate and 35 per cent net rate for the most statistically adequate models[e]

[a] There is some uncertainty over the R&D stock used by Bodman and its underlying depreciation rate. But under any range of assumptions, the rate of return will likely exceed 200 per cent. [b] Elasticity for states. [c] Elasticity with respect to combined ICT and R&D stocks. The spillover rate is based on an average R&D and ICT stock to total capital stock of about 20 (p. 15) and a depreciation rate of 10 per cent per annum. Accordingly, the rate of return was calculated as 100*0.013*20-2.4 = 23.6 per cent on a quarterly basis and around 150 per cent annually. [d] The CIE study details are not shown in table 4.1 since the associated paper does not list them. [e] Shanks and Zheng used a variety of model specifications that covered endogenous growth rate as well as conventional models. The spillover rates are inferred from the steady state properties of the most statistically and theoretically adequate models described below.

Taken at face value, past Australian studies support the view that there are spillover returns to R&D. The returns are spillovers, not spillovers plus private returns, because the measurement of productivity already takes account of the private impacts of R&D (Shanks and Zheng 2006, p. 54). If it were assumed that the models were independent assessments of the data and were statistically and theoretically valid, then it would be appropriate to undertake meta analysis of the results. The resultant average of the rates of return of about 100 per cent (using a zero estimate for Rogers) is at the upper end of the spillover rates that are plausible for R&D obtained from the semi-parametric method described above.

However, some of the results represented in table 4.2 are based on statistically or theoretically inadequate models. For example, the conventional Coe and Helpman static model of R&D returns for Australia (on which Dowrick 1994b is based) misses out on some key variables. With more data, the model exhibits serious serial correlation that at best, indicates dynamic misspecification and at worst, the spurious regression problem. As demonstrated in appendix F, it is easy to find a highly significant positive relationship between trending variables such as MFP and R&D, with no underlying relationship being really present. The parameter results of this model are likely to be severely biased and are probably not useful. The implication of the model that rates of return are 150 per cent cannot be given weight.

The Commission has also been unable to replicate the findings of IC (1995) with new and extended data, and so, for present purposes, these results too cannot be given much weight now, though they were the best available at the time.

It is not possible to examine exhaustively the econometric properties of all of the various other models shown in table 4.2, but the other feature many share, at least in part, is their datasets. Where results use largely overlapping time series datasets, this means that they are not fully independent studies. Differences between studies with such overlapping data must therefore either reflect (a) different econometric specifications and/or (b) the effects of adding new observations and data revisions. The presence of differences due to (a) begs the question of which empirical specification is superior to the other,[2] while differences due to (b) raises the issue of parameter inconstancy, which is a sign of misspecification in its own right.

As a consequence of misspecification and non-independence, it is not appropriate to average across econometric results from the studies shown in table 4.2. At best, after excluding the clearly misspecified models, the remaining results should be seen as a very tentative indicator of what spillover rates might be.

[2] That is, 'encompasses' the other as in Hendry 1995.

In addition to the semi-parametric method discussed above, this study has chosen two other approaches to identify (spillover or excess) rates of return on R&D. First, the results of Shanks and Zheng (2006) provide a useful starting point for consideration of rates of return, because it uses the most up-to-date information, has the widest set of auxiliary variables and considers a broad spectrum of competing models. A second strategy is to develop some extension of those results.

In both instances, it is important only to consider adequate models out of the large group of models that can be estimated.[3] Adequate models are characterised by:

- including in general specifications the economic variables theoretically related to MFP growth that are available and well-constructed, thus reducing the risk of omitted variable bias; and
- excluding models that show signs of misspecification (such as integrated errors, serial correlation and unstable parameter coefficients).

A vexed question is whether models with 'incorrectly' signed, but statistically significant, R&D variables should be included within the set of comparison models. If it were possible that the focus variables — R&D capital stocks in this instance — could have positive or negative signs, then it would be appropriate to include such models within the comparison set. However, given what is known a priori about the function of R&D as a source of knowledge or as a vehicle for absorption of external knowledge that feeds into productivity growth, statistically significant negative coefficients must, at the national level, be taken as evidence of model misspecification.[4] The more highly statistically significant and larger in absolute size is a negative coefficient, the less credible are the results.[5] Of course, zero or negative, but not statistically significant, elasticities on R&D are not a sign of misspecification and should not be omitted from comparisons. To do so would bias

3 The CIE (for Standards Australia) (sub. 70 attachment) also used a meta approach based on the model findings of Shanks and Zheng (2006), but did not exclude statistically or theoretically inadequate models from their analysis.

4 In some industries for some periods, it is plausible that significant negative coefficients would occur due to patent races and wasteful forms of R&D duplication, but that appears very unlikely at the national level. It is possible to get roughly zero parameters. This could, for example, be associated with large inframarginal spillovers that have been exhausted at the margin. But that is not likely to show up as statistically significant negative coefficients.

5 That said, it is also appropriate and useful, as in Shanks and Zheng (2006) and Rogers (1995), to document those models where negative, statistically *significant* elasticities are found for R&D because these indicate the possible sources of the likely misspecification and do not hide it as a problem. In addition, were this repeatedly to be found as the best model on all other grounds, it would require some re-assessment of the role of R&D. Inconvenient results should not be hidden.

inferences and would amount to inevitably finding a significant positive effect for R&D.[6]

In this study, we exclude statistically-significant negatively-signed parameters on R&D from comparison models, but we consider whether the addition of control variables to a final preferred specification still results in statistically significant negative coefficients on R&D.[7] We also considered the extent to which models that have such negative coefficients statistically outperform the preferred model, and why that might be the case.

In addition to exploring the past Australian evidence, in this study the Commission has taken two other research approaches based on the Australian time series evidence. First, it has used the filtering criteria above to categorise the companion results to this study by Shanks and Zheng (2006). Second, it has undertaken some further estimates based on additional model specifications and econometric methods.

The 'best' models of Shanks and Zheng (2006)

On the criteria set up above, there are seven admissible models (table 4.3). Of these, two have negative coefficients on the domestic R&D variable, one a zero coefficient and four, positive coefficients. So, more often than not, the results show some positive effect of domestic R&D capital stocks on MFP. However, the t statistics on domestic R&D rarely exceed two, which means that against stringent testing criteria, all the results bar T7.3(Y5) and T9.3(Y3), cannot be distinguished from zero (or for that matter from a similar positive coefficient).

On close analysis of the short-listed models, one (S4) has an implausible coefficient on the index of communication services industry capital that reduces the credibility of that model. Another (S4LP) fits[8] the data more poorly than S3LP, after penalising for the additional explanators in S3LP. Accordingly, the two models with

6 It is possible that selection biases of this kind have affected the international and domestic literature, inflating the estimates of R&D spillovers that are published. A major way in which this can occur is through publishing bias. Journals may not publish, nor authors submit, results that have negative results for R&D elasticities. As the Congressional Budget Office (2005) noted, 'Time-series studies are also sparse, probably because significant results are hard to come by'.

7 The problem with excluding models with negative parameter values is that it amounts to imposing inequality constraints using non-linear least squares, with consequences for inference (Seck 2005). Averaging across models in which inequality restrictions have been imposed will tend to give an upwardly biased perspective on rates of return as well as too narrow confidence bands. This needs to be taken into account.

8 Using the Bayesian Information Criterion.

negative coefficients for R&D capital (S4 and S4LP) have some features, other than those considered by our initial model selection criteria, that make these models somewhat less compelling than the others. Moreover, Y5, S4 and S4LP use an R&D specification of log(ΔK/Y), which imposes strong restrictions on allowable rates of depreciation for R&D stocks to avoid taking logs of a negative number.[9] In that case, the weight of evidence shifts more towards positive rates of return.[10]

Table 4.3 **Best models from Shanks and Zheng (2006)**

Models meeting criteria[a]

Model	*Domestic*	*t stat*	*Growth effect (%)*	*Gross spillover rate*	*Foreign*	*Form of LHS*	*Form of domestic R&D variable*
	parameter	ratio	%	%	parameter		
T7.3 (Y4)[b]	0	(0.00)	0.00	0.0	0.079	Δlog (MFP)	log(K/Y)
T7.3 (Y5)[c]	0.018	(2.25)	0.17	26.8	0.014	Δlog (MFP)	log (ΔK/Y)
T9.3 (L1)[d]	0.019	(0.43)	0.18	60.8	0.042	log (MFP)	log (K)
T9.3 (Y3)[e]	0.027	(2.45)	0.26	86.4	0.153	Δlog (MFP)	log (K/Y)
T10.2 (S3LP)[f]	0.025	(1.56)	0.24	80.0	0.054	Δlog (LP)	log (K/(Y*hrs))
T10.2 (S4)[g]	-0.001	(0.25)	-0.01	-1.5	0.018	Δlog (MFP)	log (ΔK/Y)
T10.2 (S4LP)[h]	-0.005	(1.66)	-0.05	-7.5	0.028	Δlog (LP)	log (ΔK/(Y*hrs))

[a] The models are listed by table number (so that T7.3 is a model from table 7.3 in Shanks and Zheng, 2006) and by the model in that table (Y4 or Y5). All models use exhaustive control variables (described in Shanks and Zheng), though their parameters are not listed here. All models met statistical adequacy standards, through test procedures. The key variable of interest is the coefficient on the domestic R&D variable, though in Shanks and Zheng, it was also regarded as essential to include a foreign R&D variable, since foreign R&D is conceptually clearly important to Australian productivity growth. The t refers to the t statistic (in absolute value) for the domestic R&D variable. The growth effect is the deviation in the steady state growth of market sector output associated with a 10 per cent permanent increase in the capital to output ratio relative to the base case. For example, in model Y5 the effect of raising capital by 10 per cent above base for ever is a 0.17 percentage points increase in the economic growth rate. The gross spillover return on domestic R&D capital is calculated by multiplying the domestic coefficient by the ratio of output to capital (which ranges from to 32 depending on the depreciation rate). Special features of the models, other than those associated with the definition of the left-hand-side MFP measure or the right-hand-side R&D capital variables (which are shown in the table), are listed in notes for each model. [b] Uses time shift dummy and finite distributed lags (FDL). [c] Uses 5 per cent depreciation rate and several time shift dummies. [d] Uses United States Patent and Trademark Office (USPTO) patents for weights for foreign stocks and includes a linear time trend. This is the only conventional MFP model of the group. [e] Also uses USPTO patents. Includes three time shift dummies. [f] Uses intercept dummy, four time shift dummies and a two equation system approach. [g] Uses FDL, 5 per cent depreciation rate, intercept dummy, one time shift dummy and a two equation system approach. [h] Uses 5 per cent depreciation rate, intercept dummy, one time shift dummy and a two equation system approach.

Source: Shanks and Zheng (2006) and PC calculations.

[9] Depreciation rates must be 5 per cent or lower — which is below the usually accepted rates (Shanks and Zheng 2006).

[10] Against that, the use of four time shift dummies, as in S3LP, might be really evidence of underlying parameter inconstancy in that model, so the shift in the weight of evidence is slight.

If the two most problematic models are excluded, the overall effects of long run growth on increasing the R&D capital stock by 10 per cent range from effectively zero to around 0.25 percentage points a year and the associated gross spillover rates from around 0 to 85 per cent, with an average gross rate of around 50 per cent. The results are clearly imprecise — as could be expected — but the overall balance is nevertheless positive. None of the identified positive rates are implausibly large or small by the standards established by the semi-parametric analysis of appendix G.

New time series estimates by the Commission

The new approach involved estimating an error-correction model (ECM) of MFP. Such ECMs are now often used in empirical time series because it bridges the cointegration literature with realistic dynamics.[11] The economic interpretation is that there is some equilibrium relationship to which the economy returns when shocked away from it. This is consistent with the underlying hypothesis in the production function approach that there is a long-run relationship between levels in MFP and its various determinants, such as levels of R&D capital.

In the models estimated using this approach, it was difficult to find a statistically significant role for foreign capital stocks, and sometimes the coefficients were negative (though not significant). This was also a problem encountered by Shanks and Zheng (2006) for some types of models. While foreign stocks are theoretically important, it is not surprising that they might not be found to be significant when they are measured as smoothly changing stocks. In their measured form, they really act like trends and so will pick up any trending behaviour in other variables or residuals. This is suggested by the fact that introducing a trend in the model makes the negatively-signed foreign stock positive, but insignificant.[12] It is possible that the most important aspects of foreign R&D effects are being picked up by trade barriers (which tend to set up barriers to flows of knowledge as well as goods) and education. It does not appear that domestic R&D stocks — also a trending variable — is picking up the effects of foreign stocks (through absorption effects) because the domestic R&D elasticity actually rises if a foreign R&D stock is included in the model (table 4.4).

[11] And has been used in other MFP models, such as the panel estimates of Guellec, D. and van Pottelsberghe de le Potterie (2001).

[12] The long run elasticity on the foreign stock is 0.069, which is consistent with the elasticities found by Shanks and Zheng in some of their best models, described in table 4.3.

If the foreign stock is excluded from an ECM model, an adequate model of MFP was found (the *base* model):

$$\Delta \log MFP = 0.54\ \Delta Cycle + \text{other } \Delta \text{ terms } - 0.692\ (\log MFP_{-1} - 0.055 \log K_{-3} + 0.084\ LERA_{-1}$$
$$\quad (15.3) \qquad\qquad (6.4) \qquad\qquad (3.5) \qquad\qquad (3.3)$$
$$-0\ 175\ LEDUCATION_{-1} - 4.07 + 0.003\ TREND - 0.0244\ DUM85)$$
$$\quad (5.6) \qquad\qquad (5.5) \quad (3.5) \qquad\qquad (4.9)$$

$R^2 = 0.92$, 100SE = 0.542, DW = 2.81, tests for serial correlation, unit roots, cusum stability tests, reset misspecification were all adequate, estimation period is from 1971-72 to 2002-03.

All variables (bar the cycle variable) are in logs and subscripts indicate whether a variable is lagged. K is the domestic stock of business R&D capital (with a depreciation rate of 15 per cent). ΔCYCLE is a variable to control for business cycle effects and is measured as $\Delta(\{Y/HP(Y)\}-1)$, where Y is market sector GDP and *HP*(Y) is the Hodrick-Prescott filtered value of Y. This differs from the cycle term used by Shanks and Zheng. DUM85 is an intercept shift for 1985 and other variables are as defined by Shanks and Zheng.

The use of lagged R&D stocks is important because of the risk of endogeneity bias. R&D investment decisions are affected by output growth as well as affecting output growth itself. Consequently, if there is some unobserved shock that increases output and MFP, then it will also increase contemporaneous R&D investment and the R&D capital stock. This can bias the coefficient on R&D. Lagging the R&D capital stock is likely to alleviate this concern, and is, in any case, probably a more realistic treatment of the response lags that are required for spillovers to emerge.[13]

The role played by the CYCLE variable is important. The business cycle has no long-run effect on MFP growth, but it can mask the effects of factors, like R&D, that make small long run contributions and significantly affects the dynamic behaviour of the model.

The model compares favourably with the T(9.3) L1 model of Shanks and Zheng shown in table 4.3. The standard error of the estimate (over the same period) is about 30 per cent less for the new model compared with T(9.3) L1 and its better fit remains even after penalising the new model for its greater number of parameters. The gain is probably due to the dynamic specification of the new model.

The single most important problematic aspect of this regression is the high Durbin Watson statistic, which can suggest overfitting. Dropping the dummy shift removes

[13] If it were thought that the contemporaneous R&D stock was the right variable for using in the model, then instrumental variables estimation would be required. We have not pursued that approach.

this problem[14], but it also reduces the precision of the estimate of the R&D elasticity. An added foreign stock variable is positive, but not significant, so its inclusion in the model is rejected. The trend factor is a potentially questionable feature of the model, but it is the pattern that would be expected if hedonic price adjustment on physical capital stocks had overstated the economic value of the improvements made to those stocks. This is, at least, a tenable hypothesis. If the trend is dropped from the model, the coefficient on R&D is reduced, but not by much.

A concern in models with highly constructed variables, such as R&D capital stocks, is that the significance of the constructed variable is only picking up some other trend or time series behaviour of the variable, rather than its real economic information content. To test this, Box-Jenkins' methods were used to model the ARIMA characteristics of the domestic capital stock. Then an artificial variable with similar variance and the same ARIMA structure was created and used within the regression model as a substitute for the genuine domestic R&D variable. In repeated tests, such simulated artificial variables were not statistically significant in the model, which suggests that the significance of the R&D variable is not an artifice of its ARIMA characteristics. This further suggests in favour of the model results.

The interesting feature of the model is its long run, which is:

$$\log MFP = 0.055 \log K_{-2} + 0.084\ LERA + 0.175\ LEDUCATION - 4.07 - 0.003\ TREND - 0.0244\ DUM85$$

The long-run version of the model was estimated (in unrestricted form) and was found to be stationary, which provides evidence for a cointegrating long-run relationship even when the long term model is not nested within an ECM framework. The coefficients in the static model were very similar to those shown for the long run in the ECM form, providing further evidence for the adequacy of the model.

From an economic perspective, the long-run coefficients on education and openness agree with the findings of Shanks and Zheng and seem plausible. The model implies a long-run net rate of return on business R&D of 160 per cent. This is unrealistically high on the basis of the semi-parametric results in appendix G. However, the return is not accurately measured and could easily be half the rate shown.

It is also apparent that different specifications change the outcomes somewhat. The net rates of return are within the range 86 to 183 per cent when a variety of variable addition and deletion tests are undertaken (table 4.4).

[14] The Durbin Watson statistic becomes 2.2.

Table 4.4 **Effects of variable additions/modifications on the long-run elasticities and rates of return**[a]

Addition or deletion	*Elasticity*	*Gross return*	*Net return*	*Dep*	*Y/K*[b]
		%	%	%	ratio
Base case	0.0552	178	163	15	32.3
Drop DUM85	0.0476	154	139	15	32.3
Drop Trend	0.0362	117	102	15	32.3
Drop DUM85 and Trend	0.0312	101	86	15	32.3
Add Foreign (lagged) (10% depreciation)	0.0579	187	172	15	32.3
Add Foreign (lagged) (15% depreciation)	0.0584	189	174	15	32.3
Add Foreign (lagged) (USPTO measure)[c]	0.0529	169	154	15	31.9
Change to Domestic$_{-2}$	0.0613	198	183	15	32.3
Change to Domestic$_{-1}$	0.059	191	176	15	32.3
Change to 10 per cent depreciation rate	0.0541	128	118	10	23.7
Average	0.0514	161	147	..	..

a The t statistics for the elasticity are not shown but fall when the specification shifts away from the base case, sometimes becoming not statistically significant at the conventional level. Other variable addition tests were undertaken, but are not shown. They also had no marked effects, but were intended to assess whether in moving from a general to specific model, any of the dropped variables in the sequence of reductions, should really be added back. These additions included the variables TIOPEN and CENTBRG that were used in Shanks and Zheng. **b** Y/K is the ratio of market sector GDP to the relevant domestic R&D capital stock over the estimation period. **c** This uses USPTO patents for weights for foreign stocks. The Y/K ratio in this model is different from others due to the fact that the sample period over which the revised foreign stock is available is different.

Source: PC calculations.

An obvious missing element of the specification are non-business R&D stocks — those from public sector research agencies and the higher education sector. Additions of these to the specification did not change results qualitatively on the business R&D stock, but it was not possible to get reliable results for these two important R&D stocks by themselves. On the face of it, this is problematic for this study because most government funding support is provided to non-business research. However, in fact, this outcome may increase, rather than decrease, the credibility of the model findings. There are usually long lags before research in government or higher education institutions influences the market sector (Gans, sub. 10, pp. 6–7). Large amounts of their activities are also devoted to non-market impacts. Finding rapid effects from their research for the market sector would, therefore, be counterintuitive given these traits. The non-market impacts from research in government or higher education institutions is assessed separately in this chapter. The semi-parametric approach discussed above and in appendix G takes account of the effects of their market-oriented research.

Despite the overall stability of the model, parameters do, nevertheless, move over time, though within acceptable statistical bounds. As found in Shanks and Zheng, it appears that elasticities are steadily declining. This is consistent with the view that when R&D investment rates were much less, the marginal gains to productivity were more. This diminishing marginal effects might reflect large early catch-up gains from investing in R&D when a country is well behind the world's best technical frontier. Arguably, that gap has now closed somewhat, and with it, the marginal gains. As we discuss later, there is also some evidence of this phenomenon using international panel data. It is worth noting that even with a fixed elasticity, the implied spillover rates of return decline over time as the GDP to R&D ratio has fallen. With elasticities also trending slowly down, this implies more rapid reductions in spillover rates — though they remain high.

Overall, this new model appears to suggest strong returns to domestic R&D, though these may be falling over time. Its major strengths are that it:

- passes standard tests of statistical adequacy;
- uses a dynamic specification and its long run appears stationary;
- considers a reasonable number of other factors that might explain MFP growth and tests the final model by re-testing whether any omitted variables matter after all; and
- encompasses at least some of major alternative conventional models of MFP.

Its major deficits are the lack of statistical significance of a foreign R&D stock, the fact that, given other evidence, point estimates of the rates of return are unrealistically high, and evidence of overfitting. However, not too much weight should be attached to point estimates when the precision of the parameters is relatively low. With statistical uncertainty, the results could still be consistent with the credible bounds suggested in appendix G. Either way, the new model adds weight to the hypothesis that R&D produces significant returns to the economy through productivity increases that are not captured as rents by the firms undertaking R&D.

Panel data evidence for Australia

The Commission also used panel data for Australia to investigate possible rates of return (appendix H). The advantage of a panel dataset is that it can exploit two sources of variation in MFP growth rates — those that occur over time (as in the analysis discussed above) and that which occurs at any given time between Australian jurisdictions. The disadvantage of this approach is data scarcity. There are fewer observations on R&D, MFP, or for that matter some of the important control variables, so that the period of time considered is from 1990 to 2002 and more of the R&D data are interpolated than for the data set from Shanks and Zheng (2006).

The basic formulation used in this modelling (model 1 below) is similar to that used in the model above and includes similar controls for various factors other than domestic R&D stocks that might influence MFP. However, the panel data analysis also included a less restrictive model in which State Gross State Products are estimated directly, with capital and labour inputs included in the specifications. This allowed control for economies or diseconomies of scale (or better control for errors in national accounts relating to these measured inputs).

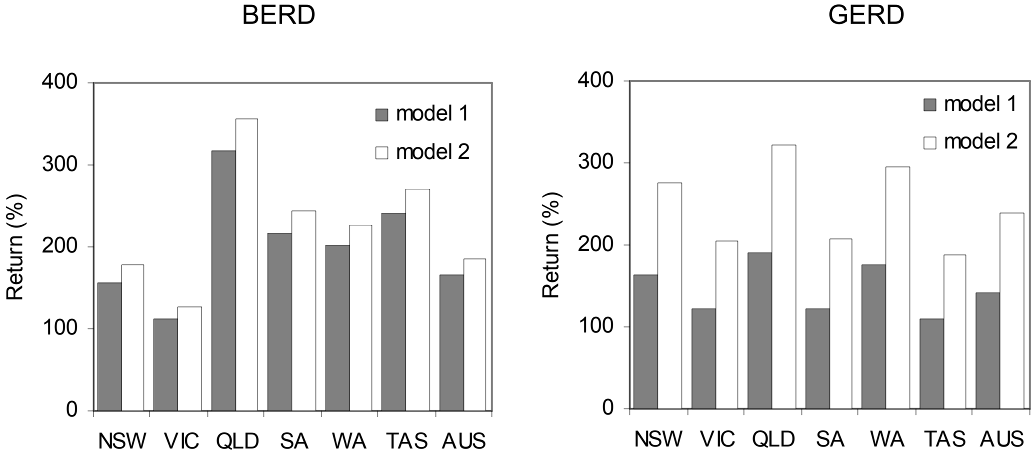
The implicit assumption in the panel data method used is that there are separate (fixed) effects for each State that account for State-wide variations in their average MFP levels, but that the R&D elasticities are the same. There are still variations in their rates of return on R&D (figure 4.2) because rates of return are a function of elasticities and GSP to R&D ratios (which vary considerably). The estimation find Australia-wide average gross rate of return is about 165 to 185 per cent for business R&D. This varied significantly by jurisdiction, though the precision of the models is too weak for this to be the basis for any policy action. The State differences could easily arise through misspecification biases or errors in variables.

The other major feature of the panel data estimation is that it suggested some impacts on economic growth from R&D undertaken in the public and higher education sectors These were not significant at the disaggregated level, although point estimates were positive. But they showed up as positive and significant rates of return for an aggregate measure of R&D (GERD), which combined BERD, GOVERD and HERD. It could be that the major reason for this is simply that BERD is the biggest contributor to GERD. The Australian rate of return for the GERD stock was, averaged over the period, from 140 per cent (MFP model) to 240 per cent (GSP model), showing some of the sensitivity of the model specification.[15] The latter result appears to be implausibly high given the observations made earlier about the focus of non-business R&D and the time it takes for any market-relevant R&D in these parts of the innovation system to have commercial implications. But the results support positive impacts of some kind.

15 The rate of return in the latest year was between about 100 (MFP model) and 150 per cent (GSP model).

Figure 4.2 **Gross rates of return for Australian States**

Panel data estimates, BERD and GERD[a]



[a]Model 1 is based on estimation of an MFP equation while model 2 is based on estimation of a GSP equation. That included controls for labour and capital inputs. The model specification included controls for the foreign capital stock (which had a high elasticity, as theory suggests, but was not statistically significant); a measure of the business cycle; union membership rates and educational attainment. Rates of return are estimated by multiplying the elasticity by the average of the yearly GSP to R&D ratios.

Data source: Appendix H.

International evidence

The existing Australian studies available represent a small sample of the many international studies into the effects of R&D. International studies have several major advantages. The data are often of higher quality or is available for longer. The international dimension also makes it possible to extend the panel data approaches the Commission used within Australia to exploit cross-country variations.

However, some of the differences between countries may need to be considered. Australia is geographically remote from other developed countries, which affects the prospects for trade-intermediated knowledge flows (Tunny 2006; Jaumotte and Pain 2005). To the extent that there are complementarities between returns from domestic and foreign R&D flows, this might lower the impacts of domestic R&D on MFP. Panel data methods can, at least in principle, draw out differences in country-specific factors that affect R&D elasticities and spillover rates.

There have been many major reviews of the international literature[16] so that it is not appropriate to undertake another comprehensive review. The reviews cover empirical analysis at the firm, industry and macroeconomic level. All review papers find excess private returns as a general phenomenon. But since spillovers, by their nature, spread beyond firms and industries, the best level of aggregation for determining average R&D spillover rates is probably whole economies, and so results at this level are the focus of this section.

The overall conclusions of these reviews is that spillover rates are likely to be high, but that the results are imprecise. For example, the Congressional Budget Office of the United States (2005) observed that:

> In summary, the available empirical evidence supports the idea that spillovers exist at the macroeconomic level and that they probably cross national boundaries. Indeed, it would be hard to believe that spillovers did not exist, considering the characteristics of knowledge and R&D capital that resemble those of public goods. But the challenges of measuring and estimating the impact of spillovers are formidable. Hence, it is not surprising to find considerable variation in estimates of the size of spillover effects and in the significance of those estimates across studies.

The CBO's judgment for the US was that aggregate R&D stock elasticities were in the range of 0.02 to 0.05. These implied rates of return of around 20 to 30 per cent for the US. The elasticities are at the lower end of the ranges suggested by the international literature and the new model estimated by the Commission for this study, but very close to those found by the more comprehensive study by Shanks and Zheng (2006).[17]

Apart from the reviews, which all support the importance of spillovers to economic growth, some of the more contemporary panel studies on economywide own rates of return are worth highlighting because such studies use more data and better methods. These studies suggest strong linkages between productivity growth (and therefore output growth) and R&D. Not all report spillover rates, with some instead just reporting the extent to which permanent increases in spending on R&D affects economic growth. Where spillover rates are reported, they tend, on average, to lie between 50 and 130 per cent. A recent panel data analysis by Gans and Hayes (Gans, Sub. 10, pp. 23ff) found a high elasticity for Australian business R&D, implying a spillover rate of around 300 per cent (table 4.5).

[16] Such as IC (1995); Congressional Budget Office (2005); Dowrick (2003); Commission of the European Communities (2005); Martin et al. (1996); and Scott et al. (2001).

[17] The rates of return implied for Australia by elasticities of between 0.02 and 0.05 are between 64 and 160 per cent because of Australia's higher ratio of output to R&D than the United States.

Table 4.5 **Recent international evidence on the effects of R&D**

Study	*Study type*	*R&D elasticities*	*Summary measure/comments*
Coe and Helpman (1995)	Panel of 22 countries, 1971–1990	0.247 for G7 countries and 0.107 for others	123% for G7 countries; 85% for the smaller countries.
van Pottelsberghe de le Potterie & Lichtenberg 2001	Panel of 13 countries, 1971–1990 business R&D	0.087 in G7 countries and 0.008 in small countries	68% in the G7 countries and 15% in the smaller countries
Lichtenberg & van Pottelsberghe de le Potterie 1996	Panel of 13 countries		51% in G7 countries; 63% in six small European
Frantzen 2000 cited in Commission of the European Communities (2005)	Panel of OECD countries from 1961–1991		About 60%
Luintel and Khan, (2001, 2003)	Panel of 10 OECD countries 1965–1999 Business & total R&D	Average around 0.27 for all R&D and 0.06 for business R&D	132% average for all R&D. Individual country results were: Ireland (453%), Denmark (183%), the US (175%), the UK (148%), the Netherlands (106%), Japan (100%), France (56.8%), Italy (4.9%) and Canada (-33.4%)
Guellec and van Pottelsberghe de le Potterie (2001)	Panel of 16 countries, 1980–1998; business & public R&D	Business R&D 0.132; Public R&D 0.171	The impact of business R&D on MFP is larger in countries where R&D intensity (the ratio of business R&D on business GDP) is higher.
Aiginger and Falk (2004)	Panel of 21 OECD countries, 1970–1999	Business R&D intensity 0.22	Measure is elasticity of R&D intensity with respect to long-run GDP per capita.
Bassinini and Scarpetta (2001)	Panel of 16 OECD countries, 1981–1998	GERD 0.14; BERD 0.13	Measure is elasticity of the R&D to output ratio with respect to GDP per capita growth. Implies a permanent 10% increase in GERD to output will raise GDP growth per capita by 1.4% per annum — a large return.
Luintel, K. and Khan, M. 2005a	Panel of 16 countries, 1980–2002; public, business & foreign R&D stocks	0.004 (UK) to 0.049 (Ireland) for business R&D	R&D elasticities are heterogeneous among OECD countries, so standard fixed effects models are probably invalid. Implies a business R&D spillover rate for Australia of about 40% (and a higher rate for public sector R&D)
Luintel and Khan, (2005b)	Panel of 19 countries, 1981–2000; Triadic patent stocks	0.048 (US) to 1.102 (Ireland) but patent stocks not R&D	Heterogeneity is important. Countries that already have an important R&D sector (such as the United States, Germany, Japan, the United Kingdom, Switzerland), the contribution of knowledge stocks to MFP appears very modest.
Gans and Hayes (2006) from sub. 10, pp. 23ff	Panel of 16 OECD countries from 1980–1998	0.11 Australia; 0.174 rest of OECD for business R&D stocks	Has significant foreign R&D effect. Introduces dummies for Australia to partly account for heterogeneity among the panel. Implied spillover rate of return for Australia is around 300%.

Many studies find (or implicitly impose) fixed elasticities of R&D with respect to R&D, with the implication that there will be higher average spillover rates for Australia. This is because Australia has less R&D intensive industries (and therefore higher output to R&D ratios in aggregate) and the spillover rate is defined as the ratio of output to R&D stocks times the elasticity.

Against this, there are two contrasting findings. First, some studies have found that there are economies of scale in R&D, and that the larger G7 economies have higher elasticities, whose effect is to actually elevate overall spillover rates for these economies. This was more typical of the earlier panel data studies, such as Coe and Helpman (1995).

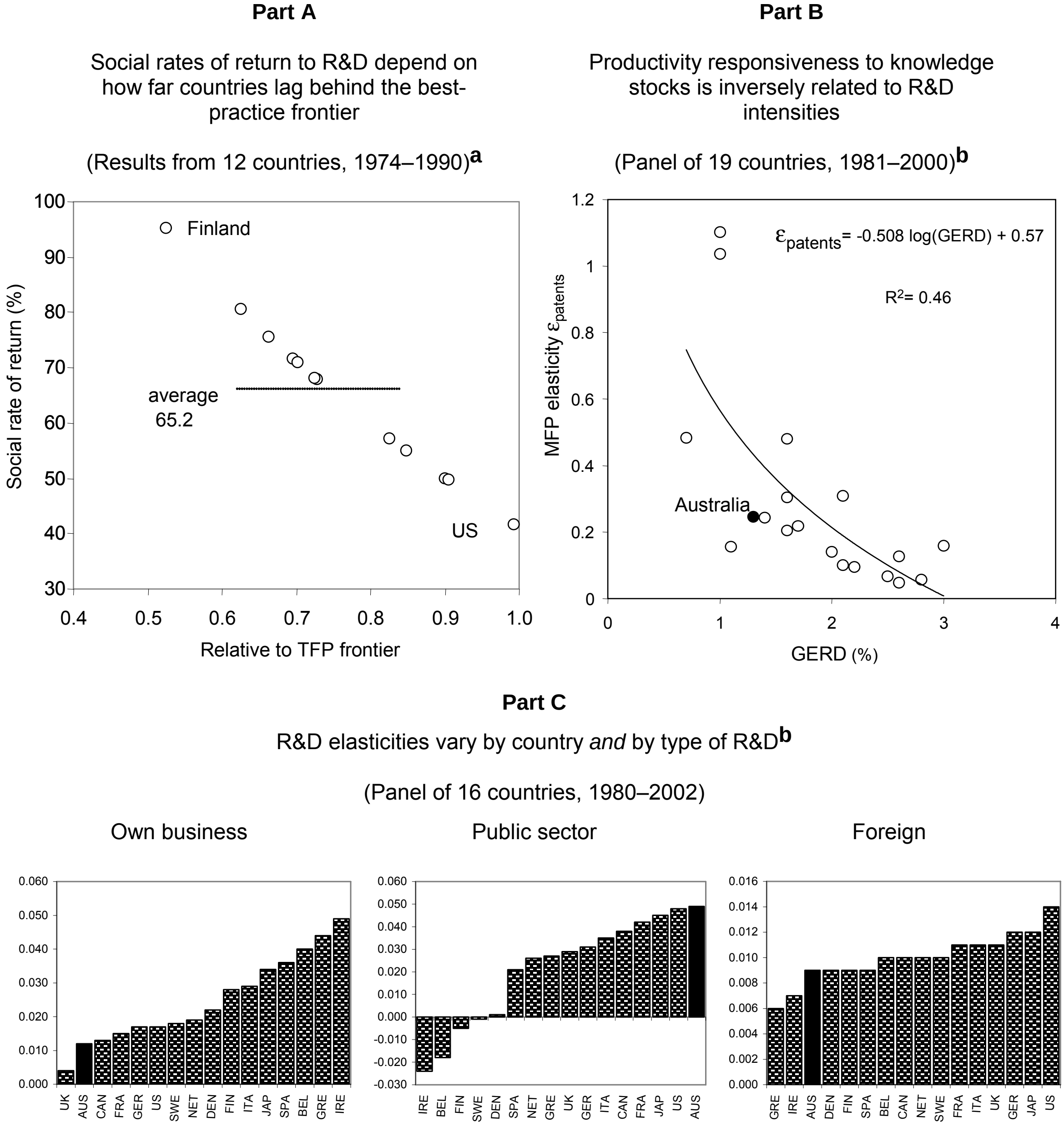
More recently, evidence has been mounting for the opposite hypothesis, which posits some exhaustion of the gains with the R&D size or sophistication of economies (as noted in this study and by Shanks and Zheng (2006) for time series evidence for Australia). For example, Griffith et al. (2000) suggest that the scope for technological catch-up plays an important role in determining the benefits of domestic R&D. Countries that lag more behind the global best-practice frontier experience higher rates of return from R&D (figure 4.3, part A). Rates of return, however, are still high (around 40 per cent) for those at the frontier, such as the United States.

Similarly, Luintel and Khan (2005b) considered the extent to which 'new-to-the-world' knowledge stocks[18] affected productivity growth. They find that countries that have large stocks of such novel knowledge (such as the United States, Germany, Japan, the United Kingdom, Switzerland) derive relatively small marginal benefits in productivity from new additions to that stock (part B of figure 4.3). Productivity growth in Australia exhibits a higher than average responsiveness to additions to new knowledge of this kind (and has historically had a relatively low rate of production of these novel knowledge flows). These results are important in that they suggest a relationship between one type of innovation — that resulting in patents — and productivity. However, despite the sophistication of the model estimated by Luintel and Khan, it is likely that much of the effect picks up the fact that patents pick up some omitted factors, not that single patents have as dramatic an effect on productivity as the results imply.

[18] Such stocks were measured as the depreciation of flows of triadic patents taken out. This is the set of patents at the European Patent Office (EPO), the Japanese Patent Office (JPO) and the USPTO that share one or more priorities.

Figure 4.3 **R&D has different effects on MFP for different countries**

Panel results



[a] Spillover rates of return relate to manufacturing. Note that rates of return and the R&D elasticities shown in the other two sets of graphs are associated, but different concepts. [b] The spillover rates are the multiple of the elasticity and the ratio of GDP to the R&D stock, which vary considerably by country. Accordingly, the spillover rates are not proportional to the elasticities shown here. Australia (AUS) is shaded black.

Data source: Part A chart derived from Griffith et al. (2000); Part B chart derived from data presented by Luintel and Khan (2005b); and Part C chart derived from data presented by Luintel and Khan (2005a).

A broader perspective on the heterogeneity of responses of MFP to R&D among different countries took account of R&D stocks of different types (Luintel and Khan 2005a — part C of figure 4.3). This panel data analysis suggests significant variations in elasticities across countries, particularly for business and public sector

R&D stocks. Such heterogeneity is much more intuitively appealing because it implies less dispersion in the associated spillover rates across countries than that automatically generated by fixed elasticities under imposed homogeneity. Australia is found to have a relatively low business R&D elasticity when the assumption of homogeneity is relaxed.[19] Taking into account Australia's very high GDP to R&D ratio in the business sector, this generates a more reasonable spillover rate for Australia (of around 40 per cent) than under homogeneity. The other revealing aspects of Luintel and Khan's (2005a) results are:

- the high elasticity on public sector research R&D in Australia; and
- the higher the stock of domestic R&D capital, the greater are the spillovers from foreign knowledge stocks, consistent with some value from domestic absorptive capacity (though this should be taken to imply that this is the only way of transferring foreign knowledge — appendix D).

What do all these numbers mean?

The Commission has considered many strands of econometric evidence about the effects of R&D on the market economy. These explore market-relevant R&D stimulated through various types of R&D. These macro approaches can only find effects of R&D that show up in goods and services sold in markets and cannot adequately capture the more long-run effects of basic research in higher education institutions. However, the overall consensus is that R&D stimulated by public funding support is likely to produce sizeable benefits for the economy, *though it is impossible to give accurate estimates* as highlighted by Shanks and Zheng (2006) on Australian data and every major international review of the effects of R&D

The imprecision is not surprising. It reflects:

- the complex causal pathways through which R&D affects productivity growth;
- an excessively short span of data;
- errors in data. The construction of capital stock estimates is particularly difficult. Choices of depreciation rates, initial growth rates used to form initial period R&D stocks, problems in interpolation of R&D data, and measurement issues associated with R&D survey data mean these errors could be large. For foreign R&D stocks, the problems are compounded by uncertainties over the correct weights to apply to R&D that originates from many different countries. Problems in the measurement of MFP are also appreciable;

[19] This varies from that found by Luintel and Khan's other study on patent knowledge sets (2005b), which also allows for heterogeneity. However, that model is concerned with only one kind of knowledge set, so the differences between the studies' findings may not be inconsistent.

- questions about the appropriate specification of models and the choice of estimation techniques;
- the potentially long lags from the conduct of R&D to ultimate benefits; and
- difficulties in controlling for the other factors that also influence productivity.

In fact, finding apparent precision in results — such as those suggested by high t statistics in some empirical studies — conceals the imprecision stemming from these measurement and methodological concerns. It is not possible, given the uncertainties outlined above, for any measures of ostensible accuracy to be anything other than artefacts.

But the overall qualitative story remains the same — domestic R&D matters for economic growth.

4.5 What do quantitative case studies suggest about the impacts of public support?

Another approach to measuring returns from publicly funded research has been to undertake cost-benefit studies. The treatment here draws on detailed Australian evidence reviewed in appendix I, as well as some of the international experiences and particular observations made by participants in this study. The focus is on case studies of publicly supported research undertaken within public sector research agencies, rather than industry, because of the relative abundance of the former and their greater sophistication.[20]

Cost-benefit studies have a number of advantages over the econometric methods discussed above. They focus on publicly supported R&D; provide lessons about the research investment decision processes; identify costs as well as benefits (and beneficiaries and losers); and provide insights into the mechanisms by which research produces benefits.

The approach has disadvantages too compared with the macroeconometric approaches. Three should be highlighted. First, projects selected for case studies are

20 There are, however, some analyses of Australian research in manufacturing industry, such as that of the BIE (1993). Dowrick (2003) draws attention to some international studies. There have been several Australian program evaluations that also provide estimates of benefit-cost ratios for portfolios of research projects supported by particular industry programs — such as the Productivity Commission's evaluation of the PIIP program (2003a). However, these impute spillover rates from the general literature, rather than estimating them from specific information provided by firms and consequently do not provide independent information about the magnitude of benefits from publicly funded R&D.

often not randomly selected, so they can give a biased indicator of the overall returns. Second, it can be hard to determine the magnitude of any impacts because of the difficulties defining a counterfactual and the complexities of attributing outcomes to projects when outcomes are the result of joint research (and past failures). Third, the studies usually do not provide measures of the impacts of marginal projects, but give information about average benefits and costs. Average net benefits in any one study do not provide evidence about whether more public support should be provided, only about whether that particular project was worthwhile.

Cost-benefit studies were identified for CSIRO, CRC and RRDC research projects. These are bodies which specialise in mission-oriented strategic and applied R&D projects, with the goal of generating public good or commercially-useful outcomes:

- A variety of CSIRO research areas were the subject of studies including: agricultural crop research; entomology; wool manufacturing technologies; automated mining equipment; industrial processing; advanced vehicle technologies; visual processing for road maintenance; pharmaceuticals; and animal health research. Portfolio reviews covered some social and environmentally-oriented research agendas, such as preventative health and water management. The latter are also discussed in a later section from a more qualitative perspective.
- The latest CRC program evaluations (Allen Consulting 2005 and Insight Economics 2006) provided information on identified returns from a number of CRCs and compared the identified returns with the overall cost of the CRC program.
- RRDC programs covered agricultural and animal research. Detailed information was obtained for the grains research area.

There are few detailed Australian cost-benefit studies of university projects (except where they are part of CRCs). The virtual absence of university-based case studies is neither surprising nor problematic. Universities concentrate more on curiosity-driven research and applied social research, rather than on large mission-oriented research projects suited to analysis by cost-benefit methods. Existing university research evaluations have usually focused on the efficiency with which research outputs (mainly publications) are produced (appendix K). The ARC (sub. 6, pp. 20ff) describe some instances of very successful university research and has commissioned analysis of the collective market sector benefits of ARC-funded research (described later under social impacts), but the latter reflects assumptions rather than the aggregation of detailed empirical analysis of individual cases.

The coverage of the case studies considered in this report was small compared to the total research output of the relevant agencies. For example, CSIRO successfully produced, on average, 81 new technologies or products per year in the three years from 2002-03 to 2004-05 (while these technologies or products were not yet at the utilisation or commercialisation stage, a significant proportion of these are likely to become utilised/commercialised). In contrast, less than 50 cost benefit studies were identified for CSIRO research conducted over the 1980s and 1990s.

Quality of estimates made in selected cost-benefit studies

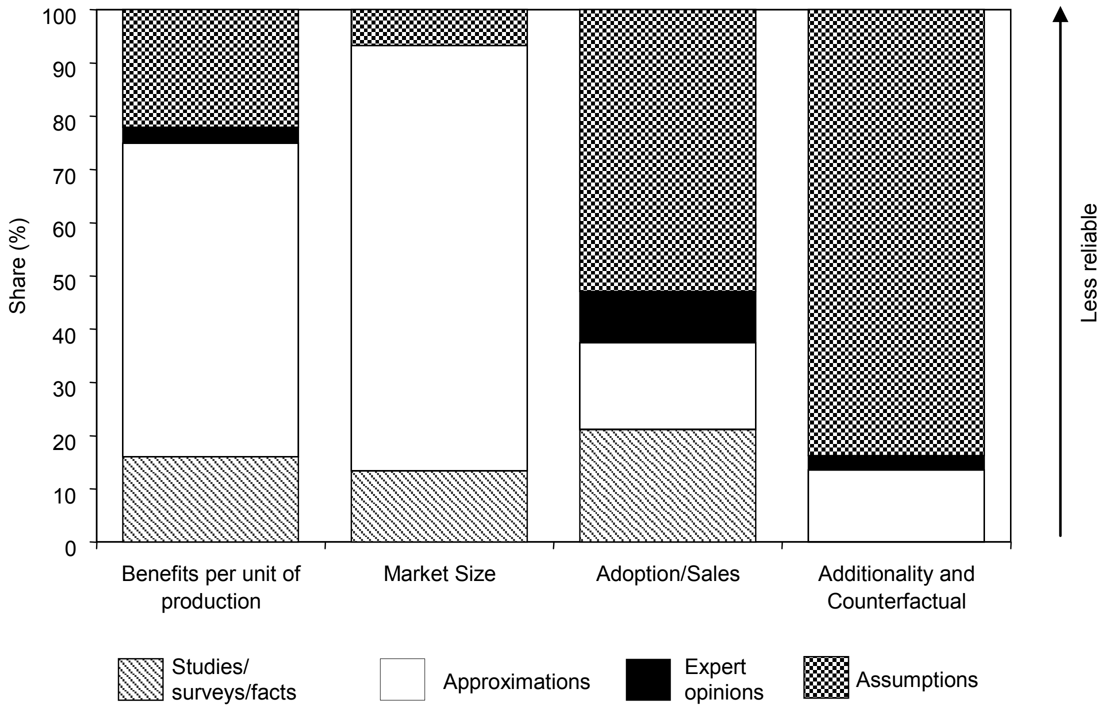
The quality of information used in calculating the benefits of the selected projects is mixed (figure 4.4), which reduces the reliability of any estimates. In projects that aimed to reduce production costs (a common objective in many of the projects), judgments about benefits per unit of production were reasonably well-based, but judgments about market size, adoption and counterfactuals/additionality became increasingly subjective. Judgments about the latter were mostly hunches.

Part of the reason for the mixed quality of the information underpinning the studies was that many of the case studies were undertaken on at least a partly ex ante basis (before prolonged application in the field), sometimes to serve planning and research management processes in public sector research agencies. Inevitably, evaluations that are undertaken on an ex ante basis must make more assumptions than those that consider ex post outcomes.

This does not necessarily imply that such ex ante studies produce biased results, just ones with very high noise-to-signal ratios. In fact, ex post studies may face a greater risk of bias because the projects are more likely to be chosen on the basis of proven commercial success. Though this has not been investigated for Australia alone, the large meta study by Alston et al. (2000) has examined this question and found that, internationally, ex post case studies tended to increase reported rates of return by about 18 percentage points (reflecting a ‘picking the winners’ selection bias).

Figure 4.4 What is the quality of the case studies?

The role of hunches versus information in reaching conclusions[a]



[a] Information was collected across case studies of the basis for judgments made about four different aspects of the benefits: the benefits per unit of production; market size; adoption or sales and the nature of additionality and technological displacement. Higher quality sources included scientific trials (examples include studies that show yield increases for new crop varieties) and company surveys (often used to determine sales volumes). Approximations were considered as slightly less reliable but still fairly reliable (examples include estimates of yields or prices of new crop varieties based upon yields or prices of older crop varieties). In some cases, the opinions of researchers or industry experts were sought where hard data was not available. The least reliable form of estimation were assumptions made with little supporting data (examples include assumptions of likely market adoption rates where sales have not yet started).

Data source: Appendix I.

Estimates of returns from individual case studies

Around 70 individual case studies were initially selected for examination. These covered agricultural research in the CSIRO, RRDC and State agricultural departments; research undertaken by CSIRO for industrial, mining, transport, animal health and pharmaceutical applications; and research undertaken in CRCs. Older projects analysed by the IAC showed high average returns, but were ultimately omitted from the meta analysis because it was considered that they may be too dated. Several project results were omitted on the basis of concerns about ambiguity of the published results. Overall, appendix I discusses around 50 projects across various PSRAs. The available case studies were biased towards agriculture — probably reflecting the greater ease of estimating returns for this sector.

The Commission's analysis focused on the projects' benefit-cost ratios (BCRs). A BCR exceeding one meets the minimum standards for projects to be socially worthwhile. Additional costs associated with raising taxes to fund the projects are not taken account of in the results. A bigger deficiency, discussed later, is the generally inadequate treatment of additionality in the studies. This means that the results should be interpreted as the possible private and public returns from the projects, but will not, in many cases, indicate the returns to research that was genuinely induced by public funding support.

The simple average of project BCRs was high — with benefits exceeding costs by an average of 45 to 1 (table 4.6). Given that some projects were estimated to provide extreme BCRs — with a maximum of 557 to 1 — the average will give a biased perspective. A graphical depiction of the rates of return underlines the strong skewness of the BCRs (figure 4.5), even among projects selected on the basis of commercial success. The extreme returns associated with a few projects pushes the bulk of the density leftwards. The graphical depiction of the distribution of the log of the BCR provides much more information about the observations otherwise cramped together in the unscaled graph.

Table 4.6 **Major characteristics of benefit-cost ratios**

Selected publicly supported R&D projects

Statistical measure	*Results*
Mean	44.8
Median	8.5
Standard deviation	85.1
Skewness	29.4
Minimum	557.0
Maximum	0.0
25th percentile	4.9
75th percentile	68.5

a Based on data derived in appendix I from 47 projects.

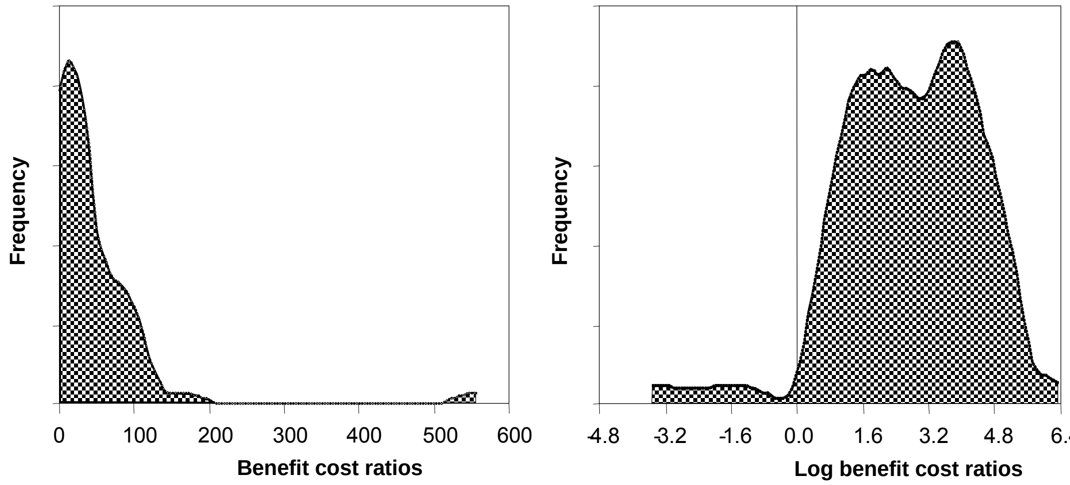
Source: Appendix I.

When returns are as skewed as this, other measures of central tendency can be useful. It is notable that the median (or middle) rate is lower at 8.5 to one, though this is still high. The weighted average can also sometimes constitute a better measure since it takes account of the varying scale of projects and considers the return on the overall portfolio. The weighted average of the BCR (formed by aggregating the present value of the benefits and costs to a single base year) is around 21.

A rough translation of the BCR to the internal rate of return is *i* times the BCR, where *i* is the discount rate (Alston et al. 2000). This suggests that the internal rates of return have a median value of around 40 per cent and an average of 225 per cent.

Figure 4.5 **Distribution of benefit cost ratios**

Selected public sector projects, 1970s–2000s



[a] Based on 47 projects, reviewed in appendix I. The benefits and costs are expressed in present value terms and then a ratio formed to give the BCR. The density functions are estimated using a Epanechnikov function. The first is the density of the raw BCRs, while the second is the density of the natural logs of the ratios. In log terms, those studies with returns below zero fail the minimum project selection criterion.

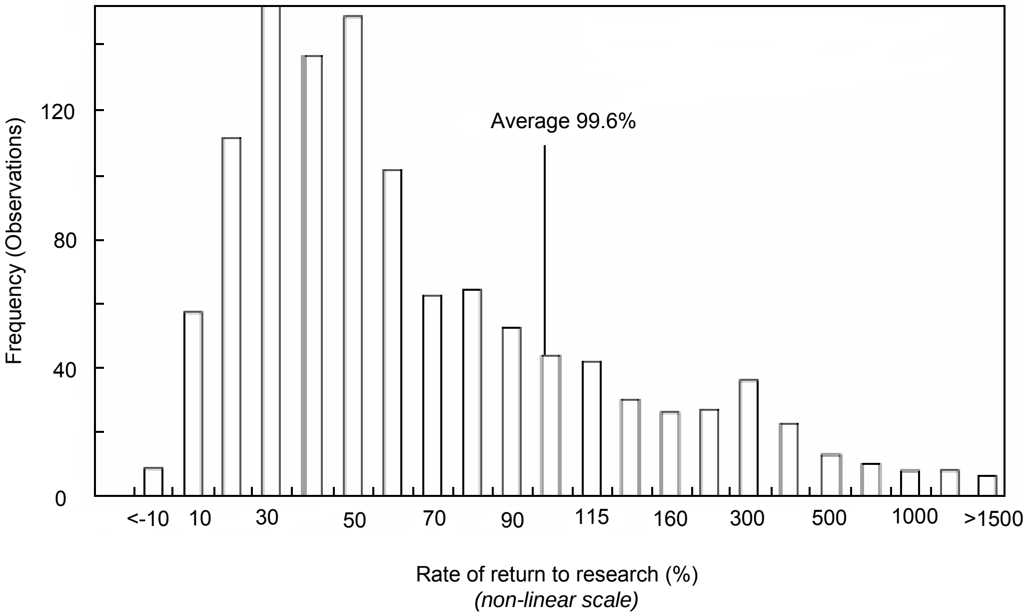
Data source: Appendix I.

The high rates of return implied by these case studies is characteristic of the literature on case studies. For example, in a large meta study Alston et al. (2000) were able to estimate the returns on over 1000 agricultural R&D projects conducted world-wide (of which around 10 per cent were performed in Australia). They found an average rate of return of 100 per cent (figure 4.6).

The other characteristic feature of the case studies reviewed by the Commission is the large dispersion in results. The 50 per cent middle range of BCR estimates (that is, those between the 25th and 75th percentile of the distribution) was 4.9–68.5. The corresponding 50 per cent middle range in the rates of return was 24–340 per cent. Alston et al. (2000) found the same phenomenon in their much larger (and therefore, more reliable) study, observing that the usual assertion that most R&D projects had returns within the range 40–60 per cent was poorly based, with only 25 per cent of case studies in their analysis falling within this narrow band. This degree of dispersion is a consequence of the real variability of returns to R&D projects and the large variations between case studies in their conceptual underpinnings and data accuracy. It underlines why seemingly precise figures from individual cost-benefit analyses should be regarded as being as imprecise as those generated by the macroeconometric methods described earlier. Some case studies make this uncertainty transparent. For example, ACIAR have used assumptions about the distribution of gains to estimate probabilities on returns (sub. 81).

Figure 4.6 **The international literature on agricultural returns reveals similarly high rates**

Results of a meta study



[a] Based on averages of 1144 international case studies. Studies that examine extension services are excluded.

Data source: Alston et al. (2000).

The Commission attempted to discover any feature of case studies that would suggest where returns were lowest or highest, but no reliable patterns were apparent:

- There was no evidence that later studies exhibited lower rates of return, as might be expected if there were diminishing returns to knowledge accumulation in the sectors in which the research was focused (agriculture and natural resources). Alston et al. (2000) also found no diminution of returns with a larger sample, over a longer period and in agriculture alone, which provides even stronger evidence that returns can be sustained over time.[21]

[21] This does not imply that the gains, *at any one time*, from further R&D would also stay constant were the amount of R&D funding to increase. There is an implicit investment demand schedule for public R&D that, at any given time, represents the opportunities for profitable investments. If investments were increased in this given time period, it could be expected that the returns would fall as the best prospects were exhausted. Of course, in another time period, there may be fresh opportunities for investment — with as good a set of average returns as in past periods. So stable

- There was some evidence that returns were high in agricultural applications, but the significance of the result was sensitive to data omissions and the sample size was too small for this to be a reliable inference.
- Larger initial scale of R&D projects were associated with smaller average BCRs, but the effect could easily have been due to noise in the data and was not statistically significant.

Counterfactuals: additionality and displacement

The treatment of counterfactuals — what would have happened to technology in the absence of the publicly funded research — can exert large influences on the outcomes of the cost-benefit analyses. Counterfactuals in case studies have two dimensions.

- First, the publicly funded research might have large expected private returns such that in the absence of public funding, the same research project might have gone ahead at the same time, even being performed by the same researcher (albeit funded from a private source) — the concept of low additionality.
- Second, even if no other private firm would have immediately invested in the particular research project, it is typical in research for at least several agencies around the world — private and public — to be exploring different research approaches to the same problems. This means that the absence of a particular project is unlikely to deny the world the benefits of a given research application for long periods. This implies usually fleeting periods over which the benefits of any publicly funded project should be counted.

While both of these are aspects of the counterfactual, in appendix I and this sub-section, we refer to the first as *additionality* and the second, temporary nature of benefits, as technological *displacement*.

Additionality

Few of the studies made a rigorous assessment of additionality, with the most common assumption being that the projects would not have proceeded without public support. This may be a reasonably realistic assumption for projects that focus on problems that have management or technological solutions largely specific to Australia. These include research projects of various divisions of CSIRO's Institute of Plant Production and Processing and the RRDCs that targeted plant diseases affecting Australian crops.

average rates of returns *over time* says nothing about the slope of the investment demand schedule at any *particular time*.

However, as noted in chapter 10, the existence of voluntary levies among rural industry groups enables them to internalise a significant share of the benefits when the R&D is focused on industry-specific goals. This at least raises the question of whether, in the absence of public support, levies might in some cases be increased voluntarily and some projects might still proceed.[22] In other cases, there may be farm intermediaries, such as a seed wholesalers, that may be potential financiers in the absence of public support (this could apply to the cotton breeding project discussed in appendix I). In non-agricultural contexts, the potential beneficiaries are sometimes relatively few in number, and the potential private returns high, *at least after a certain stage in project completion*. This implies that the assumption of additionality and prospective benefit-cost ratios should be re-assessed as projects evolve and the prospects for full private funding increase. This may hold, for example, to the technologies developed by CSIRO's Light Metal Flagship, though the initial research may have had reasonable additionality.

Consequently, the ongoing assessment of additionality has subtle effects on the measurement of BCRs. More importantly, from a policy perspective, the ongoing decisions by public research agencies on whether to seek greater or full funding from industry of further stages of research (or whether even to proceed with the research at all) will depend on dynamic evaluation of the prospective costs and benefits. Undertaking continuous evaluation of this kind increases the initial option value of public research projects because it reduces the future risks of low additionality (and, for that matter, the risks of failure, since early failing projects can be terminated). This is an area where case studies, and particularly those that adopt an options approach (ACIL Tasman 2006e), have policy insights that extend beyond the macroeconometric impact analysis discussed earlier.

How temporary are benefits?— displacement

The Commission considered the effects of this aspect of the counterfactual in several ways.

First, the average BCRs of studies that made an assumption of temporary benefits were compared with those implicitly assuming effectively infinitely long periods of technological advantage, while controlling for several other influences (such as scale and industry of project). While the latter assumption generally could be expected to elicit significant positive biases to benefit-cost rates, surprisingly this was not reliably evident in the regression analysis undertaken by the Commission.

[22] This condition could still hold even if there were some spillovers outside the industry (chapter 3).

This may reflect the offsetting effects of other omitted biasing factors, the small sample[23] and data errors.[24]

Second, the potentially large effects of different assumptions about potential displacement may be gauged by comparing studies that examine the same project using different methodologies. The automated mining research project[25] was one of these. It was initially estimated to produce $4.5 billion of benefits for $47 million in costs — a BCR of about 100 (CIE 2001a) — with the implicit assumption of infinitely realised benefits. In contrast, a recent ACIL Tasman (2006a)[26] study considered that the project brought forward by five years a technology that would eventually have been discovered by another research agency. With that assumption and a slower adoption rate than envisaged, the benefits fell to $273 million, but so to did the costs (to $26 million), with an overall BCR of 10, or around one tenth of the original estimate (albeit still high).

Estimates of returns from portfolio cost-benefit studies

The majority of the benefits of research are often generated by a few successful projects. In the case studies analysed by the Commission, four out of the nearly 50 studies generated about two thirds of the cumulative gains (in present value terms). And as noted earlier, many research projects fail to produce any tangible applications and are not even analysed in case studies, generating a selection bias. For example, in CSIRO, the Wool Technologies Division undertook 109 projects from 1993-94 to 1997-98, of which eight were adopted in industry (Collins and Collins 1999). Accordingly, for more insights into the returns from public research it is useful to offset highly successful projects against less successful ones, and to also count the resources used in projects that failed to produce any apparent social or economic returns.

The portfolio results across eight broad research areas (table 4.7) reveals more modest BCRs than those suggested by considering individual published case

[23] It was not possible to determine the assumptions used in all studies — cutting the effective sample size in two. The Commission will see if it can increase the sample size of the analysis in the final report.

[24] For example, counterfactuals may more often be investigated properly in studies where commercial success has been gauged to be particularly successful, so this selection bias offsets the adverse expected effect of a proper counterfactual on the aggregate return.

[25] A project undertaken in CSIRO, but with large co-funding by industry partners. The two studies differed also in when they were done, so the first involved more assumptions and the second could use more observed data. However, the judgment was that the differing treatment of the counterfactual was the decisive difference.

[26] Forthcoming. Provided to the Commission by CSIRO.

studies, probably reflecting the importance of selection biases. The weighted average BCR is about two. However, this approach probably produces biases of the opposite direction because it omits some projects that produce benefits.

Table 4.7 **Minimum portfolio cost-benefit estimates**[a]

	Authors	*Comparison period*	*Dis-count rate*	*Base year*	*Expend -itures*	*Benefits*	*BCR*
					$m	$m	
Ex post utilisation studies							
CSIRO divisions for soils, plant industry, horticulture and tropical crops and pastures	Jonston, Healy, I'ons and McGregor (1992)	1970–1990	5	1990	2526.6	2039.7	0.8 (7.9)[b]
CSIRO Entomology Division	IAC (1980)	1960–1975	5	1975	107.2	475.1	4.4
Ex ante utilisation studies							
CSIRO Wool Technologies Division	DJ and BA Collins (1999)	1993-94 to 1997-98	6	1999	288.9	582.0	2.0
CSIRO Preventative Health Flagship[c]	ACIL Tasman (2006d)	2003-04 to 2006-07	6	2006-07	87.0	376.4	4.3
CSIRO Light Metals Flagship[c]	ACIL Tasman (2006c)	2003-04 to 2007-08	6	2006-07	15.0	466.0	31.1
CSIRO Water For a Healthy Country Flagship[c]	ACIL Tasman (2006e)	2003-04 to 2007-08	6	2006-07	around 175	around 900	At least 5.1
General equilibrium models							
CRC Program[d]	Allens Consulting (2005)	1991–2005	..	..	1 920	3 062	1.6
CRC Program[d]	Insight Economics (2006)	1991–2005	..	..	2 331.5	3 488.5 to 5 028.5	1.5 to 2.16

[a] The details regarding these portfolio studies is in appendix I, including discussions of assumptions underpinning them. [b] The BCR of 0.8 is potentially misleading. It is based on the costs of all the relevant CSIRO divisions, but the benefits for only eight of 22 successful research projects over the comparison period. The costs of the 8 projects were $257.8 million (and the benefits of $2039.7 million) giving a BCR of 7.9 for that group of projects. Since there were another 14 successful projects that were not evaluated, the 0.8 figure is clearly an underestimate of the BCR for the divisions collectively. However, the portfolio analysis does show that just 8 out of 22 projects can almost realise enough benefits to pay for the divisions as a whole. [c] Studies use an options approach. That is, possible outcomes are weighted by probability of success and project expenditures are weighted by their probability of being incurred (which take into account scenarios where projects are cancelled). [d] Based on general equilibrium modelling (appendix I).

Source: Appendix I.

Other evidence

Case studies from submissions

The submissions to this study also provided many detailed qualitative/quantitative case studies that provide insights into the nature and magnitude of benefits from publicly funded research. These included the CSIRO (sub. 50); the Department of Agriculture, Fisheries and Forestry (sub. 100, p. 51); the State Government of Victoria (sub. 84, pp. 46–47); the NSW Government (sub. 91, pp. 26ff); DCITA, (sub. 101 attachment) and the Rural R&D Corporations (sub. 94).

Some of these discussed formal benefit-cost results (sub. 91, sub. 94 and sub. 100), while others noted the broad nature of the benefits (sub. 84) or specific qualitative examples (sub. 101). The results for the NSW Department of Primary Industry's evaluations are shown in table 4.8, but are not included in the Commission's meta analysis at this stage as we have not gathered some of the required data from these studies or confirmed potential overlaps with studies that have already been included. The RRDC and Department of Agriculture, Fisheries and Forestry submissions also suggested similarly high average benefit-cost ratios, commensurate with those identified by the Commission in its own meta study.

Table 4.8 **Recent evaluations by the NSW Department of Primary Industry suggest large public benefits**

Evaluations 2003 and later

Investment area	*Cost for DPI*	*Share of total cost*	*BCR*	*Environmental impact*
	$m	%	Ratio	
Evaluations in 2003				
Net feed efficiency in beef cattle	13.9	70	4.9	Greenhouse gas reductions
Annual weeds in temperate pastures	8.7	67	22.2	Reduce accessions; better water quality
Wheat breeding	43.0	45	8.4	Reduced chemical dependence
Conservation farming in northern NSW	29.0	68	20.5	Reduce soil erosion; soil structure gains
Extension in water use efficiency	19.8	100	4.5	Environmental water savings
Total	114.4		11.5	
Evaluations since 2003:				
Ricecheck	3.8	67	18	Water use efficiency
Beef CRC III	3.8	9.5	66	Greenhouse gas savings
Sheep CRC	n.a.	n.a.	8.1	Reduced chemical dependence
Fox control	0.024	4.9	12.4	Save native species

Source: NSW Government (sub. 91, p. 26).

An important set of benefits are realised overseas

Some Australian publicly funded research explicitly aims to provide benefits overseas. Generally, within an economic framework, spillovers that flow overseas are irrelevant to judgments about the net benefits of funding for Australians. However, this is not always true. First, there are intangible benefits associated with Australia's contribution to the global knowledge pool (chapter 3) and goodwill from overseas partners.

Second, sometimes research applied overseas can be perceived as a form of foreign aid. In this role, it may be more effective than alternative forms of aid. It engages positive incentives, unlike some other aid forms, is resistant to expropriation, is enduring and can have large benefit-cost ratios. As noted by Alston et al. (2000) and ACIAR (sub. 81), it has been shown that R&D undertaken in developed countries for applications in developing countries have higher rates of return than those undertaken in the developing countries themselves. There is good evidence of the nature and magnitude of these returns. The submission by Innovative Research Universities Australia (sub. 54, p. 9) cited the successful introduction of a novel (beer-based) fruit fly management technology in Vietnam, which has lowered the costs of managing this problem, as well as environmental and human health benefits from lower pesticide residues. More comprehensive evidence of large benefit-cost ratios from foreign R&D aid in which Australian research was central was provided in the meta study by Alston et al. (2000) and by ACIAR (sub. 81) for more recent research (table 4.9).

A third dimension of benefits are spillovers from R&D undertaken for developing countries by Australia that flow back to Australia, for example through reduced pest incursion (University of New England, sub. 17, p. 10 and ACIAR, sub. 81, p. 18). ACIAR examined 20 projects for which these benefits had been quantified, with total benefits of an estimated $735 million (relative to costs of $60 million) and a BCR of 12.

Table 4.9 **Benefit-cost ratios from Australian R&D aid abroad**

Examples given by ACIAR of projects

R&D type	*Benefits*	*Costs*	*BCR*	*Source cited*
	$m	$m	Ratio	
Sample research activities partly attributable to ACIAR				
Conservation tillage for dryland cropping in China	>1000	5	205	Vere (2005)
Breeding and feeding of pigs in Vietnam	878	4.9	118	Tisdell and Wilson (2001)
Controlling Phalaris Minor in the Indian rice-wheat belt	422	1.5	275	Vincent and Quirke (2002)
Bio-control of the banana skipper pest in Papua New Guinea	555	2.1	258	Waterhouse, Dillon and Vincent (1998)
Analysis of socioeconomic and agribusiness developments in the Chinese beef and cattle industry	..	..	60	Pearce (2005)
Raw wool production and marketing in China	..	..	40	McWaters and Templeton (2004)
Emergence and integration of regional grain markets in China	..	..	6 to 30	Watson (1998)
Establishment of a protected area in Vanuatu	..	..	4.5	McMullen (2004) and CIE (1998)
Overall attributed to ACIAR research program[a]	3500	134	26	CIE (2006) forthcoming

[a] This includes research projects not listed above.

Source: ACIAR (sub. 81).

Conclusion

Overall, the case study approaches suggest high rates of return to publicly funded research, consistent with a large overseas literature. These results are influenced by the availability of the case studies, which focus on research projects that are successfully utilised and where the benefits are more readily quantifiable. Modifying the results for the omission of failed research projects by considering whole portfolios of research reduced the benefits, but average benefit-cost ratios were found to be still high — of the order of two to one. The case study approach also provides useful lessons for the management of research and in particular, the insights afforded by an options approach.

The existing case studies, with a few exceptions, tend to accentuate R&D that is aimed at increasing productivity and, consequently concentrate on measuring effects that show up as higher GDP. Some types of research — particularly in the social and environmental fields — have effects that are more diffuse than this. This research can affect the market economy, but it is often mainly aimed at achieving unpriced, but still valuable, outcomes. The impacts of research in these areas are considered next.

4.6 Environmental impacts

The hybrid nature of environmental impacts

Investments in R&D can often produce benefits for the market economy and the environment simultaneously:[27]

- Reductions in salinity, pesticide use and invasive weeds/pests — all areas of substantial publicly funded research in Australia — can increase agricultural productivity, as well as generate less easily measured environmental and social benefits.
- Similarly, research about the potential impacts of climate change affects investment timing, pricing and technological decisions by businesses and government-owned utilities.
- Research into improved energy efficiency increases abatement of carbon and sulphur dioxide with environmental benefits, but also has large potential economic gains.[28]
- Biodiversity can have unexpected benefits. For example, the State Government of Victoria (sub. 84, p. 40) noted the discovery of an antimicrobial protein in Tammar wallaby milk.
- Research by CSIRO in agribusiness will boost growth rates, but also reduce methane production by cows (CSIRO sub. 50), a gas with a larger global climate warming potential. The NSW State Government also observed benefits of this kind, suggesting that the adoption of new genetics in the NSW beef herd would save methane emissions worth around $28 million over the 25 year simulation period, which was around 10 per cent of the private benefits of the research.

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[27] This list ignores a subtle, but important source of benefit flowing from the market system to the environment. Gains in market-sector productivity stemming from market sector innovation reduce environmental damage in its own right, as well as generally relaxing national budget constraints and creating higher preferences for environmental amenity (Pearce and Palmer 2001). This shows up as a strong correlation between measures of spending on the environment per capita and GDP per capita (in PPP terms). Similar relationships between GDP per capita and more general environmental performance (the Environmental Performance Index — described later) are apparent (Esty et al. 2006, p. 26).

[28] Indeed, the private economic benefits can mean that achieving additionality with public funding in this area represents a challenge.

- An improved understanding of water management and flows can increase the likelihood of properly timed investments in water infrastructure, potentially savings hundreds of millions of dollars (box 4.1).

Despite the links between environmental benefits of R&D that are realised as market-benefits, aggregate macroeconometric measures are not adequate for revealing them.

- Business R&D — the basis for the results of Shanks and Zheng's (2006) models in table 4.3 and for the new specification of this study — largely excludes publicly funded environmentally-oriented R&D. In any case, market sector MFP excludes gains in productivity in several industries, including government services, where some of the benefits of environmental R&D would be realised.
- GERD does include such spending and is used in the Commission's State-based estimates of the returns from R&D. However, the separate effects of environmental research could not be inferred from these results.
- Shanks and Zheng (2006) have produced estimates of around a 25 per cent rate of return to public R&D realised as productivity gains for the Australian agricultural sector.[29] This will include some gains that occur through environmental improvements, but obviously also include gains that are not generated in this way. Moreover, the gains for agricultural productivity from R&D may sometimes be adverse for the environment, as noted by Alston et al. (2000, p. 29).

The deficiencies in aggregate approaches suggest alternative approaches. These often have the advantage that they also consider some of the non-market benefits of environmental research. Case studies of particular projects or streams of projects (of which the Water for a Healthy Country Flagship is an example — box 4.1 and table 4.7 in the previous section), suggest substantial gains in particular instances.

[29] The gains are also to the total of public sector R&D, not just public R&D directed at agriculture (Shanks and Zheng, pp. 142–3).

Box 4.1 **CSIRO Water for a Healthy Country Flagship**

Current water policy by Australian governments is focused on managing competition between alternative uses for increasingly scarce water, including optimal investment strategies.

The CSIRO Water for a Healthy Country Flagship continues a long history of public sector research into Australia's water and related natural resource systems. Established in 2003, its current budget is $125 over the next four years.

The flagship aims to increase efficiency of water use through better decision rules and tools for investors and policymakers (including better information to use as inputs for decisions), lowered costs of provision and better allocation of water among users with different values for the resource. The flagship is conducting research in six themes: Urban Waterscapes; Murray River Region; South West Western Australia Region; Great Barrier Reef Catchments; Australian Water Systems (concerned with the extension of lessons across regions); and Water Resources Observation Network (concerned with developing the water accounts and data needed to allocate water to its highest value use). The flagship brings together a range of skills ranging from: hydrology, climate assessment and modelling; wider complex-systems modelling; to natural resource economics.

Many State Governments are also active in these areas, so that there are attribution problems in determining the role of the flagship in achieving better efficiency. Nevertheless, ACIL Tasman (2006e) considered that the there were sizeable gains that could be attributed to the research, albeit with judgment being the basis for many of the estimates.

One of the key potential economic gains from the flagship is the development of specialised decision-making and information tools (for example, computer modelling software) that may avoid or defer inappropriate investments in high cost, irreversible, investments. ACIL Tasman noted that currently around $2.5 billion is spent annually by water utilities on water infrastructure, so even modest savings in this area can be valuable.

Overall, it was estimated that the flagship would return at least $900 million in cost-savings and community benefits in present value terms. It was estimated that the urban waterscapes theme could produce cost-savings of the order of $200 million over the next few years, with around half of this being capital cost savings. The development of advanced computer modelling tools for the Murray River Region could produce risk-weighted community benefits of $100 million from the restoration of environmental river flows. Over the longer term it was estimated that advanced computer modelling techniques could advance the development of water property rights systems and reduce monitoring costs with the potential to return a risk weighted value of $600 million.

Source: ACIL Tasman (2006e).

Table 4.10 **Impacts by types of environmental spending**

Organisation	*Investment*	*Example of Impacts*	*Source*
CSIRO Sustainable Energy and Environment Group	$170m from government $246.53m total	Direct Impacts: Estimated average cost benefit ratio of 8:1. This represent the average of 12 backward looking CBAs on environmental projects Indirect Impacts: Of the 52 other manufacturing, mining and agricultural projects examined, 13 were found to have at least a 'minor' impact on environment.	CIE (2001)
CRCs in the environmental sector	Program funding $55.7m $242.1m total (compiled from CRC directory)	Impacts: There is a diverse set of outcomes for environmental CRCs, but outputs typically take the form of information provision and policy influence through: expert advice; influence over policy documents; publicly available research; journal articles; and conferences and public awareness activity.	
Antarctic Division	$94.6m (DEST statistical snapshot)	Indirect Impacts: Output contributes to knowledge of Antarctic ecosystems, resources and climatic change. The Antarctic Division produces 150–200 refereed papers per year	
Land and Water Australia	$12.5m from government $27.9m total (annual report)	Direct impacts: Cost benefit ratio of 1–3.5 This is the aggregates triple bottom line CBA estimate for 25 innovations (covering 278 projects) and representing 25% of LWA's R&D investments. 17 of the 25 case non-exclusively contain environmental benefits. Estimates were based on 'willingness to pay' surveys in 10 cases and projected cost savings in 8 cases.	Schofield (2005)
Greenhouse Gas Abatement Program	$16.m from government (DEST statistical snapshot)	Direct impacts: Reduction of greenhouse emissions of 17.9 million tonnes. This is a projected outcome based on a selection of 10 GGAP projects over the period 2008 – 2012. Lifecycle funding of these projects amounts to $67m which implies a return 0.26 tonnes per dollar of GGAP investment.	GGAP webpage[a]
Bureau of Meteorology Research Centre	$11.8m	Indirect impacts: Outputs are information relating to atmospheric modelling, climate change, air quality analysis used generally as an important basis for private and public investment decisions (farm investments; land-use decisions, insurance premium settings; infrastructure and technology decisions).	

[a] http://www.greenhouse.gov.au/ggap/index.html.

As noted in the cost-benefit literature examined earlier, some benefits to Australian publicly funded research accrue overseas, and these nevertheless can produce incidental environmental benefits for Australians, such as reduced pest incursions in Australia. For example, ACIAR (sub. 81, p. 16) noted that an estimated 47 per cent of the (sizeable) spillover benefits to Australians from Australian R&D for overseas applications were from direct or indirect benefits in reducing pest incursions. Such pest problems often have environmental as well as agricultural productivity effects.

Uncertainty is high

The basis for estimates of some kinds of environmental benefits is likely to be more uncertain than those for research activities directed at economic benefits. For example, the valuation of technologies that abate carbon dioxide and reduce climate change depend critically on the likely benefits of successfully achieving that objective. A recent meta study of 28 studies by Tol (2005) gave a 90 per cent confidence interval of the value of carbon reduction at between -$2 per tonne (a loss) to $165 per tonne, with a mean, median and mode of $93, $14 and $1.50 respectively.[30] Similarly, the present best estimates of the marginal costs of achieving reductions vary by similarly large margins. Despite the uncertainty, Tol's (2006) conclusion is that a portfolio approach to global risk warrants sizeable investments in new technologies, but the problem for cost-benefit analysis means that reliable rates of return are particularly hard to formulate in this area.

The potential costs of global warming also mean that the long-run returns from conventional long-lived energy infrastructure is now also increasingly uncertain. This is why some of the research aimed at estimating the costs, as well as mitigating them, has large option values.

The fundamental issue here is that uncertainty has two edges and these apply beyond the case of climate change risks. Uncertainty makes it harder to give precision to standard cost-benefit analyses, but it also provides a value to preparedness (Mathews sub. 83) and to delay in making costly long-lived legacy investments (for example, a new dam).

Are there any other ways of looking at this issue?

The case study information is useful, but clearly partial. This raises the question of whether there are any other ways of looking at this issue.

[30] Other studies confirm the uncertainty of benefits per tonne and observer that there is also variation across regions (Downing et al. 2005).

An MFP equivalent?

One possibility is to estimate the role of research capabilities, particularly in the environmental area, in contributing to some measure of gains in environmental quality. This is akin to the MFP approach adopted for the market economy, but extended to environmental benefits. Two reputable measures of environmental quality and management are:

- the Environmental Sustainability Index (ESI) (Esty et al. 2005) The ESI utilises 76 variables combined into 21 environmental indicators to calculate an overall index value for each of the 146 countries examined (figure 4.7).
- the Environmental Performance Index (EPI) (Yale Center for Environmental Law and Policy et al. 2006), which uses a similar approach to the ESI, but is more focused on factors affecting the environment that are within the control of governments.

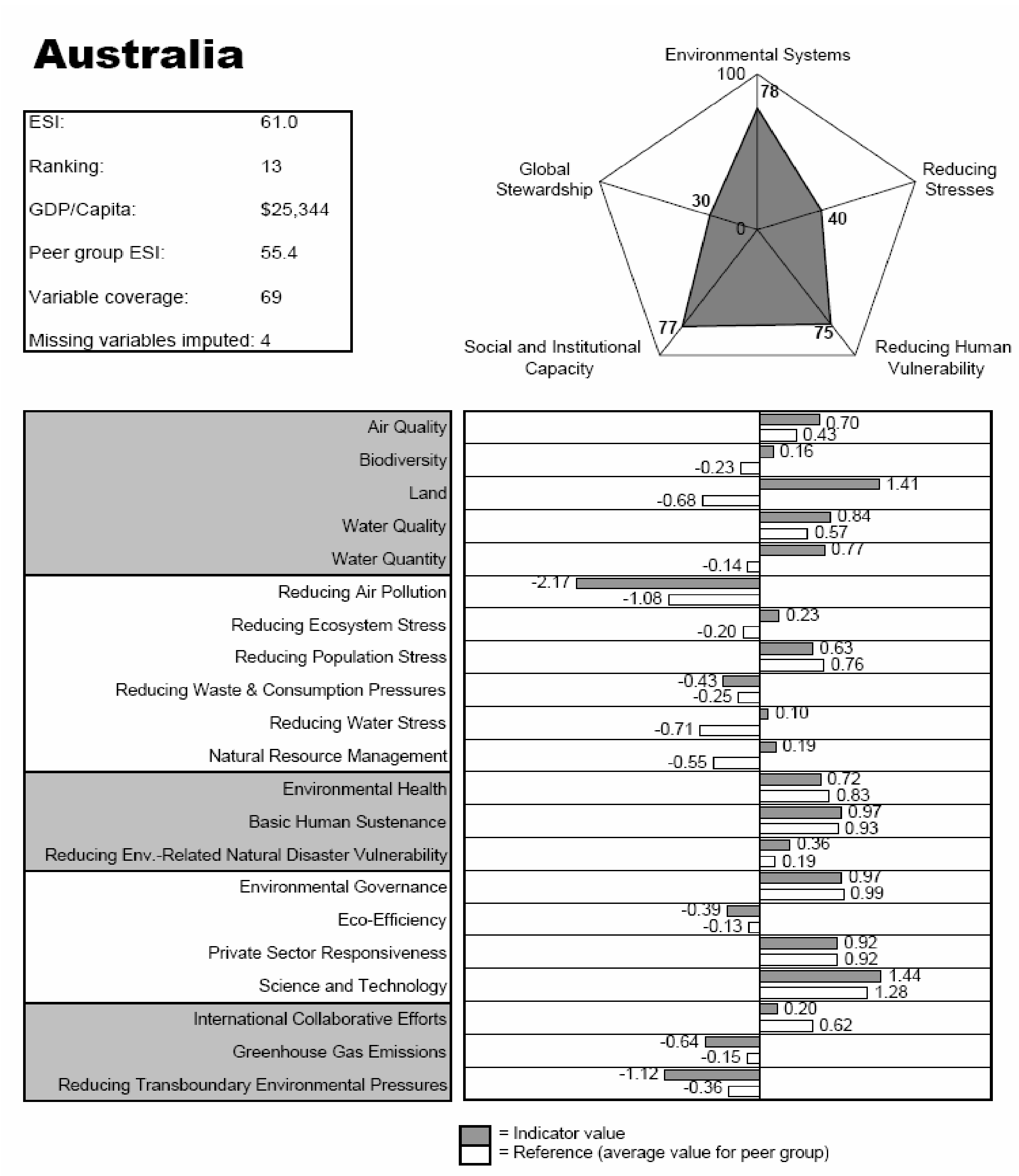
The most useful aspects of the ESI and the EPI are the particular environmental indicators that can be derived from them rather than the summary measures themselves.

To probe the links between these environmental indicators and various measures of research capability, a suite of regressions were run:

$$log(E_i) = \alpha_1 + \alpha_2 \, log(\text{Income per capita}_i) + \alpha_3 \, log(\text{Research capability}_i) + \alpha_4 \, log(\text{Quality of research}_i) + \alpha_5 \, log(\text{R \& D care \& control}_i)$$

where E_i are various environmental indicators — components of the ESI and EPI (and the summary measure EPI itself) (table 4.11). The selection of indicators to be used was based on whether they had a sound theoretical link to research capabilities, which only extended to a handful of the components. Many components were excluded on the basis that they were clearly exogenous to research capabilities — such as the total fertility rate (a component of the ESI). In that regard, for the purpose of considering the environmental impacts of research capabilities, the ESI is less satisfactory as a summary measure of potential environmental outcomes than the EPI or various appropriate components of the EPI and ESI.

Figure 4.7 **The composition of Australia's ESI**
2005[a]



a It should be noted that Australia's high relative Science and Technology score is not specific to the environment, and so should not be seen as a measure of capability in this area. The per capita PPP spending on R&D on care and control of the environment and bibliometric measures probably provide better measures of that general relative global capacity.

Data source: Yale Center for Environmental Law and Policy et al. (2005) available from http://www.yale.edu/esi/.

Research capability is the number of researchers (including outside the environmental area) per capita. *Quality of research*[31] is a bibliometric measure of the quality of environmental research. *R&D care and control* is spending per capita (PPP) on R&D devoted to care and control of the environment. The latter data item was only available for a selection of OECD countries and is, in any case, a narrow measure of government spending on environmental R&D.[32] The regressions, while simple, controlled for GDP (PPP) per capita (*Income per capita*) which might otherwise hide or exaggerate the relationship between environmental indicators and research indicators.

Table 4.11 **Environmental indicators used**[a]

Description	*PC code*
Quality of environmental governance — based on WEF survey questions on several aspects of environmental governance: air pollution regulations, chemical waste regulations, clarity and stability of regulations, flexibility of regulations, environmental regulatory innovation, leadership in environmental policy, consistency of regulation enforcement, environmental regulatory stringency, toxic waste disposal regulations, and water pollution regulations (From ESI: WEFGOV).	*GOVNCE*
Quality of private environmental innovativeness — based on WEF survey questions on private sector environmental innovation covering environmental competitiveness, prevalence of environmental management systems, and private sector cooperation with government. (From ESI: WEFPRI)	INNOV
The share of missing data from a major index of the environment (the CGSDI 'From Rio to Johannesburg Dashboard'). The index covered facets like fuel emissions, urban air pollution, use of pesticides and withdrawal of ground and surface water that may require environmental expertise to collect. A lower value of MISS is preferred cf all other indicators in this table. (From ESI: CSDMIS)	MISS
Quality of resource management based on sustainable forestry, fishing and agricultural policies. (From EPI: RESOURCE_MGT)	RESRCE
Wilderness protection based on an overlay of areas that are wild and areas that are protected. (From EPI: PWI)	WILD
Ecoregion protection: extent to which unique ecologies are sufficiently protected. (From EPI: PACOV)	ECORGN
Water quality management as measured by oversubscription to water resources and nitrogen loading per average flow of river basins (From EPI: WATER)	WATER
Environmental Performance Index: index of environmental performance based on indicators of the quality of the environment that are amenable to policy action. (EPI aggregate)	POLICY

a WEF = World Economic Forum; CGSDI = Consultative Group on Sustainable Development Indicators.

Source: Esty et al. (2005) and Yale Center for Environmental Law and Policy et al. (2006).

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31 In the ESI database, this corresponds to the inverse of KNWLDG. In the ESI database KNWLDG has a value that is lower for higher quality knowledge generation. By taking its inverse, a more easily interpretable measure is derived.

32 The amount spent on R&D for 'control and care of the environment' is one of the few internationally comparable indicators of environmental science and innovation spending. It is available for most OECD countries. The Frascati manual (2005) defines this spending category as the amount of R&D that is directly used to promote an undestroyed physical environment including: the identification and analysis of the sources of pollution and their causes; the dispersal of pollutants in the environment; the effects of pollutants on man, fauna, flora, micro-organisms and the biosphere; and the elimination and prevention of all forms of pollution in all types of environment. It is not a comprehensive measure of R&D devoted to environmental issues, as shown by comparing expenditures with ABS data on spending in environmental R&D — but is at least available on a reasonably consistent basis for many OECD countries.

Table 4.12 **Regressions of environmental outcome indicators against research capabilities (models 1–8)**

	Environmental outcome indicators (1) to (8)							
	(1) GOVNCE	(2) INNOV	(3) MISS	(4) RESRCE	(5) WILD	(6) ECORGN	(7) WATER	(8) POLICY
Dependent variables								
OECD countries								
Income per capita	**0.21**	**0.09**	-0.35	0.04	0.78	**-1.86**	**-0.27**	-0.01
	(2.8)	*(1.7)*	*(0.9)*	*(0.1)*	*(0.8)*	*(2.2)*	*(1.9)*	*(0.1)*
Research capability	**0.12**	**0.15**	-0.06	-0.35	**0.90**	**1.07**	**0.15**	0.02
	(2.6)	*(4.4)*	*(0.2)*	*(1.4)*	*(2.3)*	*(2.4)*	*(2.0)*	*(0.8)*
Quality of research	-0.01	0.01	-0.05	**0.10**	0.09	**0.36**	0.02	0.01
	(0.8)	*(0.5)*	*(0.7)*	*(1.6)*	*(0.4)*	*(1.6)*	*(0.4)*	*(1.4)*
R&D care & control	0.01	0.01	**-0.24**	**0.09**	0.28	0.17	-0.01	0.01
	(0.3)	*(0.8)*	*(2.4)*	*(1.5)*	*(1.3)*	*(0.7)*	*(0.5)*	*(1.1)*
All countries								
Income per capita	**0.23**	**0.14**	**-0.41**	**-0.21**	-0.26	-0.30	**0.08**	**0.12**
	(4.5)	*(3.6)*	*(5.4)*	*(3.9)*	*(1.1)*	*(1.4)*	*(1.5)*	*(6.6)*
Research capability	0.01	-0.01	0.04	**0.04**	0.03	0.08	-0.01	0.01
	(0.3)	*(0.4)*	*(1.2)*	*(1.5)*	*(0.2)*	*(0.8)*	*(0.4)*	*(0.6)*
Quality of research	0.01	0.01	-0.04	**0.07**	**0.49**	**0.55**	-0.01	0.01
	(0.5)	*(0.6)*	*(0.5)*	*(1.6)*	*(2.0)*	*(3.1)*	*(0.1)*	*(0.6)*

a Coefficients that are statistically significant at approximately the 10 per cent level or better are boxed. Statistics in brackets are the absolute values of robust t statistics. Sample size vary by regression.

Source: Commission calculations.

The regression results (table 4.12) suggest that scientific capacity and R&D have some associations with environmental outcomes:

- General research capabilities were associated with improved levels of government environmental governance; private sector environmental innovativeness; eco-region and wilderness protection; and water policy for OECD countries. There was a weakly significant link between such capabilities and improved resource management for the all-country dataset.
- Per capita spending on R&D care and control of the environment in OECD countries has a weakly significant effect on environmental resource management and a strongly significant improvement in the availability of environmental data used to make policy decisions. The latter is an important, if obvious, benefit from environmental R&D.
- Environmental research quality is weakly positively related to resource management for both the OECD and 'all-country' datasets. It is also associated with higher eco-region protection for both the OECD and the all-country datasets and for wilderness protection in the all country dataset.

The results above must be regarded as tentative. The various indicators of environmental outcomes, with the possible exception of information adequacy (MISS), will have complex, dynamic relationships with research capabilities, and the causality may run both ways. Cross-sectional data analysis, such as that above, also ignores the cross-country variations in the various environmental indicators that are generated by historical circumstances. For instance, some country's values of eco-region protection may be low due to historical exploitation. Through environmental R&D and mitigation, such countries may improve the level of protection above what it would have been otherwise, but the positive impacts will not be apparent in simple cross-sectional data. Fixed effects or other forms of panel data analysis (for which there is currently insufficient present data) is required to address this methodological concern.

Moreover, it is not clear that per capita R&D inputs — as in *R&D care and control* — would be a good measure of the effect of R&D capability on the various environmental indicators. While aspects of the Australian environment are population-dependent (air quality, water pollution), other aspects may be better captured by land and adjacent water resource areas and global location (for example, biodiversity). In that instance, spending per capita is not an appropriate metric for the right-hand side of a regression against environmental indicators. Factors such as spending per square kilometre; spending per unique species; and a whole range of other possibilities may be more appropriate.

These issues highlight some of the subtleties of links between measures of environmental effort and environmental outcomes. These conceptual and measurement issues, combined with limitations in the availability of data, suggest that the challenges presented by an MFP-type approach appear too formidable at the moment, but in future such modelling strategies could be trialed.

Policy needs and the option value of environmental science

Another way of measuring the impact of environmental R&D is to re-visit the concept of option values raised previously under the rubric of uncertainty. Just as insurance has a value (or impact) because it provides future options (such as replacement of a stolen car), knowledge and analytical skills in science may also provide options or values associated with preparedness. An indicator of the size of the existing option value of environmental science is captured by three complementary dimensions:

- the degree and complexity of Australia's future potential environmental problems and needs;
- the quality of present environmental scientific resources; and

- the quantity of existing resources.

Weaknesses in any of these three dimensions reduce the option value and impact of environmental science.

Starting with the first issue, countries with complex environmental problems — potential or existing — need to gather objective information for evidence-based policy decision-making. R&D is also required to develop solutions that reflect local circumstances and opportunities. For example, the viability of geosequestration depends on its technical and economic feasibility, but also on the availability of suitable geological conditions, which are country-specific.

The Environmental Sustainability Index provides some useful objective indicators in this sense, suggesting that Australia does have complex and emerging needs (table 4.13). As an illustration:

- Australia has the sixth highest degrees of species abundance (biodiversity) in the world, reflecting the size, climatic variation and isolation of its landmass. It is also somewhat vulnerable, with a high risk of extinction threats to mammals relative to other countries.
- Various emissions — sulphur dioxide, carbon dioxide and nitrogen oxides — are relatively high by world standards given the populated land area and population — a result of legacy technologies.
- There are potential problems associated with present agricultural sustainability, that needs to be investigated and may be potentially addressed with new technologies or management practices.

On the second and third issues, it appears that Australia has high quality environmental science capabilities relative to other countries and devotes considerable national resources to research in this area:

- Australia was ranked third best of 78 countries (for which evidence was available) on the excellence of its environmental knowledge by Esty et al. (2005).
- Australia contributes just a little less than one in every 20 global publications on ecology and the environment and more than this share in plant and animal sciences (with which there are significant complementarities). This is much higher than Australia's average scientific contribution. Overall, about 20 per cent of the R&D budgets of PSRAs and 6 per cent of higher education budgets are directly related to environmental science.

Taken together, these indicators suggest that environmental science has a relatively high option value for Australia.

Table 4.13 **Australia-specific risks requiring environmental knowledge**[a]

Measures[a]	*Australian score*	*Mean*	*Median*	*Country rank*[b]
	Index	Index	Index	Number
Biodiversity index	0.85	0.55	0.55	6th of 160
Threatened mammals species as a share of known species	24.23	14.91	11.19	17th of 155
Anthropogenic emissions of:				
Nitrogen oxides (NOx) per km of populated land	14.28	3.32	0.56	6th of 157
Sulphur dioxide per km of populated land	11.86	56.18	0.64	5th of 151
Volatile organic compounds (VOC) per km of populated land	12.79	5.0	1.65	9th of 159
Metric tons of carbon emissions per capita	18.32	5.14	2.59	10th of 197
Hectares of biologically productive land required per capita	7.09	2.55	1.73	8th of 145

a High values equal more. **b** Country numbers for the ranking vary due to missing values for some countries. The ranks refers to rank from highest to lowest among the relevant countries. For example, Australia has the 6th highest biodiversity index among countries.

Source: Esty et al. (2005) based on the ESI index of Yale Center for Environmental Law and Policy (Yale University); and the Center for International Earth Science Information Network (Columbia University) in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission.

Summary

The challenges in capturing, in any summary measure, the environmental impacts of R&D appear to be currently insurmountable (and in any case may be an unrealistic aspiration).

However, there is abundant case study evidence that public funding support for environmental R&D is associated with positive environmental impacts and, in many cases, associated economic gains. There is also aggregate quantitative evidence from cross-sectional international evidence that suggests links between scientific capacity and positive environmental outcomes, though that evidence is only tentative due to deficiencies in the data and methodological concerns. There are also strong arguments on the grounds of increasing preparedness to continue to make substantial investments across a wide diversity of environmental concerns, especially given Australia's unique ecosystems; the particular concerns about water scarcity and climate change risks; and one of the largest marine assets per capita in the world.

4.7 Social and health impacts

In this section, the Commission has interpreted social impacts to include health, as well as broader social impacts, a view that is in generally reflected in submissions from participants in this study.

As in the case of environmental impacts, it is important to distinguish between research with social and health impacts from social and health research that has impacts, social and otherwise.

Many social impacts are, as in the case of the environment, as much a consequence of broad innovation in the market economy, as they are of research specifically directed at social outcomes. For example, strong economic growth is probably the most important single determinant of lower poverty and unemployment, which are also important goals of social research. More broadly, many of the most pervasive social trends — female labour force participation; population ageing; urbanisation; fertility; and changing leisure patterns — have foundations that reflect, in part, economic and technological innovations.

And much social and health research have implications for economic growth, such as development of medicines that increase productivity and workforce longevity; new management methods; macroeconomic research and so on.

Indeed, the only Australian assessment of the aggregate return to research that encompasses social science concentrated on market sector impacts. The study was an evaluation of the impacts of competitive funds distributed by the ARC, which cover the spectrum of research areas, including a considerable contribution to the social sciences (Allens Consulting Group 2003). The evaluation claimed that the research permanently increased in GDP, with overall returns to ARC funding of around 40 per cent. However, these impacts:

- are too narrow, given that many of the social impacts of R&D are not counted in the market sector, so missing one of the key factors that it would be desirable to assess;
- are the result of assumptions about effects, rather than empirical estimates; and
- have been elusive in standard econometric analysis of market sector impacts, for reasons that have been set out in section 4.3, so raising the question of the reliability of the inference that they might be around 40 per cent.

While undoubtedly social research has economic impacts, the principal concern of this section is on the social impacts of research that is not focused on economic gains. A substantial share of publicly funded R&D is intended to produce social impacts, including research activities in health and in the humanities and social sciences. There are strong a priori grounds for significant publicly-funded research into such areas because of the prominent role played by government in the provision of services in health care; education; community services; social welfare; urban planning; policing and community safety and so on. Research can play a large potential role in increasing innovation in the provision of these services, generating resource savings for governments or improving outcomes for Australians.

There are many individual cases of social research with large potential qualitative social and economic impacts. A small sample includes:

- the development of new public health initiatives — such as sudden infant death syndrome research undertaken in Tasmania and discussed in chapter 1;
- many technical evaluations of government social and educational programs that are undertaken by academics in universities or informed by their expertise;
- research into the dynamics of families, youth suicide and management of difficult children;
- identification of people at higher risk of unemployment, as a basis for case management in unemployment management;
- research into indigenous health, employment and communities to achieve better outcomes;
- research into social problems, such as problem gambling problems; substance abuse; and youth suicide;
- understanding the public's behavioural responses to public health initiatives; and
- development of large social research databases that have had large impacts on public policy — the HILDA social and economic longitudinal data; the Longitudinal study of Australian Youth (fundamental in a large series of research activities in education and youth unemployment); and the large, comprehensive, datasets collected and managed by the ABS.

This list is at the applied end of the social sciences, but there is a counterpart to basic physical sciences in the social sciences. For example, new statistical procedures are initially developed as basic science, but may eventually widely spread to applied practitioners.

No systematic inventory of case studies is feasible, given the large quantity of projects that are undertaken. Unlike research in PSRAs, less social research takes place in large themed sets of projects. It tends to be more diffuse and is harder to categorise into a few taxonomies.

The gains from research in these areas are not measured in existing national accounts measures of productivity in the provision of government services because the current assumption in these parts of the economy is that outputs are equal to inputs. Consequently, improvements in the quality of outcomes, which conventionally are translated to output increases, are not measured. For example, long-term improvements in literacy rates and hospital care, and reduced vehicle fatality rates and crime rates do not show up in the national accounts as 'service improvements', though research activities have almost certainly contributed to these positive outcomes. As noted by the Australian Business Foundation (sub. 72), the ABS has proposed an alternative to orthodox economic measures. This is a broad framework for assessing innovativeness that would include measurements of social cohesion, demographic patterns, health status, crime levels and income distribution as metrics of social gains.

In the health sciences, development of metrics of social impacts is probably more advanced than elsewhere, because this area lends itself to greater causal attribution and more quantitative measures of outcomes. For example, a particular intervention may lower incidence of a disease by a given margin, reduce costly side-effects, increase quality adjusted life years, and allow carers to work, all of which are subject to some degree of quantification and valuation. The ACIL Tasman (2006d) evaluation of the CSIRO Preventative Health Flagship represents an example of an options-based appraisal of the overall benefits of a particular stream of health research (box 4.2), which indicates the nature of some of these benefits.

At the broader level, Access Economics has estimated returns of between 100-500 per cent on Australian health R&D, with the base case delivering a 240 per cent return. While it is difficult to ascertain the reliability and validity of measures that are fundamentally driven by assumptions, it highlights an important point about the impact of health R&D. Even if health R&D is only a very small contributor to health outcomes, and Australian R&D is only a very small contributor to world health R&D, the returns are still likely to be reasonable. This is because people attach a very high value to quality of their lives and to longevity. In addition to being intuitively obvious, numerous studies (Viscusi 1993; Nordhaus 1999; and Cutler and Richardson 1998) consistently find that people value their own life beyond their lifetime earning power (Access Economics 2003, p. 60).

Box 4.2 The CSIRO Preventative Health Flagship

The Preventative Health Flagship was launched in 2003. The flagship's budget for the three years to 2006-07 was $61 million, with roughly equivalent external revenue and in-kind support. The flagship concentrates on the development of early detection and prevention approaches, rather than cures per se. The research is conducted in several, sometimes overlapping, areas: colorectal cancer and gut health; neurodegenerative diseases with an emphasis on Alzheimer's disease; cardiovascular diseases (CVD); and health data systems (data integration, imaging and sensing diagnostics and health informatics). The main emphasis was on research into colorectal cancer, using novel approaches such as preventative foods. (Australia and New Zealand have second highest male rates of colorectal cancer in the world and the highest female rates.)

ACIL Tasman estimated that the total option value for the colorectal cancer research was $138.6 million in 2006-07 present values. The option value for neurodegenerative disease was estimated to be at least $237.8 million. Contributing to these gains were reductions in health care costs, values attributed to improvements in the sufferer's quality of life, savings in carer payments, increases in earning capacities and values attributed to prevention of deaths.

The major benefits from the Alzheimer's research are derived from the potential development of early detection techniques. However, even if it is technically successful, the ability for the flagship to achieve benefits will also depend upon advances by external health researchers. New diagnostic technologies will only be beneficial if better treatments for Alzheimer's are also found. The benefits will also only be achieved if competing global technologies find solutions ahead of Australia. ACIL Tasman considered that there is still a 98 per cent chance that researchers in the rest of the world will solve the problem first. The fact that positive net option values are still realised with such risks is testimony to the enduring costs of the disease.

The other notable finding of the ACIL Tasman research was that there can be significant gains in achieving solutions to large national (or international) problems from the application of a different set of skills to the norm.

Source: ACIL Tasman (2006d).

Beyond applications in health, systematically tracing pathways from the diverse array of specific social science research efforts are even more problematic due to:

- the nature of advancement in social science:
  - it is not obvious how to value research work that reinforces conventional wisdom;
  - the valuation must consider the case where research is not only fruitless, but also the case where it has adverse effects on people — referred to as a 'poisoned well' effect in the literature on the impacts of the social sciences (Ryan 2002); and

  - the majority of social science work is incremental by nature.
- difficulties establishing a link between inputs and outcomes:
  - socioeconomic indicators are influenced by a wide range of factors, of which social science research is only a minor contributor; and
  - there is a large amount of variation in the time it takes social science research to influence socioeconomic indicators. When the research is demand driven (by policy makers), effects are likely to be more rapid, but be less revolutionary. However when research is supply driven, the findings may not be acted upon for decades.

The International Food Policy Research Institute has recently made some preliminary attempts to devise a methodology to measure the impact of social science research (Ryan 2002). The focus of this methodology is economic research that elicits policy change, but nevertheless, it yields some insights that can be generalised to the social sciences more generally. The techniques centre on systematic analysis of case studies, although bibliometrics and econometric methods are also considered as useful tools.

The most specific methodology (Alwang 1998) includes a framework for measuring the benefits of social policy research that effectively mimics the cost-benefit framework described in appendix I, but with social impacts. The most important aspects of the methodology are clear specification of the expected social impacts; collection of data on the outcomes that the research aims to achieve; the use of interviews to attribute the extent to which the research may have contributed to these outcomes compared with other influences; and measures of outcomes that can be compared across successive case studies. The latter presents the greatest conceptual difficulty since it invariably requires monetisation, for which tools such as 'willingness to pay' are still highly contested and unreliable. In any case, these methods are most suited to demand-driven social and health science research with relatively specifiable impacts. Their cost is too great too apply except across a sample of projects.

The Council for the Humanities, Arts and Social Science (CHASS 2005) has attempted a more holistic approach to measuring the quality and impact of social science research. Research output is assessed according to its quality, impact and capability, with the institution or individual having some discretion as to the weights applied to each area. Performance in each area is ultimately determined by peer review guided by appropriate metrics. CHASS (p. 39) lists 25 impact indicators, the majority of which are concerned with academic rather than other impacts. Of the non-academic impacts, the most directly measurable are economic, such as patents, commercial licenses and commercial uptake, rather than social impacts.

Other specific frameworks are probably appropriate for measuring specific types of social impacts, such as the poverty measurement issues described by ACIAR as part of its consideration of the impacts of Australian-performed R&D in developing countries (sub. 81, p. 23).

For the broad social impacts of applied social science R&D, it may be that policymakers' subjective judgments about portfolios of research can give as reliable an indicator of value as more costly alternatives.

Ultimately, the nature of social science research currently precludes its *collective* impacts from being adequately measured. However, there are several compelling reasons to believe that public support for social science research does have significant impacts:

- Individual case studies in any area of social impacts reveals high quality social research in Australia and well-recognised local research capabilities.
- The R&D conducted in this area is unlikely to be undertaken in the absence of government support so that the challenges presented by additionality in other areas of research are not as prevalent.
- Given the unique natures of cultures and societies — there is often a need for Australia to invest in research into its own social institutions and challenges. For example, regional and indigenous issues in Australia are often distinctive.
- Social science research plays an important role in complementing the other forms of R&D that occurs within Australia's innovation system.
- The social sciences focus on areas of large importance to people, such as the quality of their education, mental well-being, security and social cohesion.

4.8 Other impacts

As noted previously, there are several measures that may provide useful indicators of impacts of public support, while not being impacts themselves. Given their indirect quality, this chapter does not deal with these at length, but they are considered in appendices to this report or are still under study. Three broad measures were considered.

The first were measures of academic papers and citations, which provide indicators of the quality — on a peer reviewed basis — of Australian science by world standards. This is important because it provides a measure of research capabilities, and to some extent, given the links to training, of the development of advanced problem-solving human capital. While the limitations of such impact measures are well known (such as citation rings), the evidence suggests that Australian science is high quality by world standards. The details are discussed in appendix K.

Second, the Commission considered innovation indicators. These suggest the extent to which R&D can be translated into particular forms of commercialisable knowledge. The evidence suggests Australia is a middle tier performer on this metric, but is improving (appendix J).

Thirdly, the Commission considered the extent to which firms receiving commercialisation assistance have, as a result, been able to grow successfully. From an economic perspective, other impacts (such as the broad ones discussed above) are more relevant for Australians' overall well-being. However, from the perspective of the programs concerned, a desired impact of these programs was the growth of globally competitive, commercially successful Australian firms. A reasonable question then is whether these desired program impacts can be confirmed. The Commission has formed a large longitudinal database of firms that have received Australian Government R&D grant assistance with a commercial orientation to try to assess that question. The analysis has not been completed so that metrics cannot be provided yet.

4.9 What are the implications of good returns to public support?

This chapter has used a variety of quantitative and qualitative indicators that suggest that, on balance, Australia obtains good returns from its public funding support of R&D. The broad implication of this finding is that, at the aggregate level, existing levels of public support are warranted.

It should not, however, be assumed that good returns necessarily imply that more should be spent:

- the Commission's estimates of benefits are imprecise. They could not reliably indicate the marginal gains from expanding support. In any case, it is likely that the apparently marginal returns suggested by the empirical analysis also include some gains that are made at investment rates lower than current levels (inframarginal gains).
- more investment may reduce marginal benefits, as suggested by some of the most recent empirical assessments of the impacts of business R&D;

- in the short-run at least, there are resource constraints that apply to R&D spending, because this spending utilises specialised, highly talented research expertise that is in finite supply. This is one reason for incremental approaches to aggregate public support for R&D; and
- new spending measures have transaction costs associated with compliance and unexpected incentive effects, as well as the costs of raising finance through distortionary taxes (or displacement of other areas of public spending). A decision to spend more has to balance the marginal benefits against the marginal costs.

This chapter suggests Australians are well served by public funding support for R&D. As emphasised in chapter 8, decisions about increments to spending or alteration of the mix should be made against the backdrop of well-established budget processes that take into account the tradeoffs.

DRAFT FINDING 4.1

Taking account of multiple sources of evidence, the Commission considers that there are significant positive economic, social and environmental impacts from publicly supported science and innovation.

5 Impediments to the functioning of the innovation system

Key points

- Participants identified a range of possible impediments to the operation of the innovation system. These mainly related to perceived deficiencies in public support programs. Remaining identified impediments focused on skills development, intellectual property rights, research infrastructure, privacy and ethics regulation, and scientific publishing.
- There are recognised shortages in engineers and science and mathematics teachers. The shortages in engineers have been reflected in rapid growth in salaries. In the case of science and mathematics teachers, such price signals have not operated as effectively due to inflexible pay levels and structures. These shortages may have been accommodated by using teachers without adequate skills in science and mathematics, which may adversely affect student interest and competence as well as decrease future university enrolments. Introducing greater flexibility in teacher pay levels and structures would make teaching more attractive to prospective entrants, including those with science and mathematics qualifications. It would also provide greater scope to attract and retain skilled teachers, not only across the board, but in areas of particular shortage.
- Legal uncertainty about the use of patents for research has the potential to impede knowledge dissemination. One option proposed by the Australian Law Reform Commission and the Advisory Council on Intellectual Property is to introduce an experimental use provision in the Patents Act. However, the extent to which legal uncertainty actually acts as an impediment is unclear, as are the costs and risks of implementing the proposed option.
- There is poor utilisation of research infrastructure. This could be improved through owners of major research infrastructure charging to recover marginal operating costs (supplemented as appropriate with a congestion charge) and enabling third party access or, at least, making access entitlements transferable. Enhancing information about the existing stock of research infrastructure could also improve utilisation.
- Privacy regulation is having adverse effects on medical research due to the complexity caused by the intersection of Australian Government and State and Territory laws. National consistency in privacy regulation of health information should be progressed by the Australian Health Ministers' Conference as a matter of priority.
- The ethical review processes of human research ethics committees are impeding health and medical research, particularly, across multiple institutions. State and Territory health agencies should seek to streamline ethical review processes as expeditiously as possible. National consistency could also be beneficial.
- There is scope for the ARC and the NHMRC to play a more active role than they currently do in promoting access to the results of research they fund. They could require as a condition of funding that research papers, data and other information produced as a result of their funding are made publicly available such as in an 'open access' repository.

5.1 Introduction

The terms of reference to the study ask the Commission to identify impediments to the effective functioning of Australia's innovation system including knowledge transfer, technology acquisition and transfer, skills development, commercialisation, collaboration between research organisations and industry, and the creation and use of intellectual property. They also ask the Commission to identify any scope for improvements.

Participants' views on what constitutes an 'impediment' (or a 'barrier' or a 'weakness') to the functioning of the innovation system vary widely and, collectively, comprise a long list.

- Many alleged problems with public support for science and innovation such as insufficient funding, poor program design, onerous reporting requirements, inappropriate performance measures, and poor coordination across governments and programs.
- Some perceived problems within other areas of government activity such as intellectual property protection and privacy regulation.
- Some claimed problems in markets such as skills shortages in the labour market and deficiencies in the venture capital market.
- And yet other participants identified as impediments such economic structural and cultural factors as declining numbers in schools of students of mathematics and science, the structure of the Australian economy including the preponderance of small to medium-sized enterprises, Australia's geographical size and location, the size of the domestic market, the lack of 'critical mass', the lack of a culture of risk taking and leadership, and the lack of effective communication between academics and businesses.

In the ABS Innovation Survey 2003, businesses were asked to list 'the factors that hampered them in developing or introducing new goods or services, or developing or implementing new processes' (2006a, p. 20). The most commonly reported barriers for both innovating and non-innovating businesses related to costs, of which 'too high direct costs' followed by 'government regulations or standards' were the most significant. Of the market-related barriers, most businesses reported 'potential market already dominated by established businesses' (table 5.1).

Table 5.1 **Barriers to innovation, 2001 to 2003, all businesses**[a]

Type of barrier	*Innovating businesses*	*Non-innovating businesses*
	%	%
Cost-related barriers	**62.3**	**34.2**
• Excessive economic risk perceived by the business	24.4	8.7[b]
• Excessive economic risk perceived by financiers	6.7[b]	4.0[b]
• Direct costs too high	36.2	19.3
• Cost or availability of finance	19.2[b]	9.7[b]
• Government regulations or standards	28.1	15.7
Market-related barriers	**47.6**	**26.3**
• Potential market already dominated by established businesses	30.1	14.8
• Lack of customer demand for new goods or services	17.9	12.0[b]
• Unable to appropriate benefits from intellectual property	8.4[b]	2.7[b]
• Inability to secure strategic partnerships	5.6[b]	2.3[c]
• Market too small or unknown	12.7[b]	6.7[b]
• Lack of information on technology	2.9[c]	1.8[c]
Lack of skilled staff	**25.6**	**16.2**
No barriers	**24.5**	**52.6**

[a] Businesses could select more than one factor. [b] The estimate has a relative standard error of 10 per cent to less than 25 per cent and should be used with caution. [c] The estimate has a relative standard error of 25 per cent to 50 per cent and should be used with caution.

Source: ABS (2006a, *Innovation in Australian Business 2003,* Cat. no. 8158.0, revised, March).

That participants have wide-ranging views on impediments is not unusual. As CSIRO noted, the ‘reality of discussing impediments is that different parts of the innovation system have their own perspective on possible limiting factors, depending on their own roles, responsibilities and stakeholder interests’ (sub. 50, p. 97).

The Commission has taken an economywide approach to defining impediments. It considers an impediment to the effective functioning of the innovation system to be any factor that distorts the allocation of Australia’s resources such that too few or too many resources are devoted to innovation, resources are misdirected among competing areas of innovation, or there is a failure to capitalise on foreign or domestic innovation adequately.

Impediments, thus, could include:

- ‘market failures’ in the innovation system — where the market fails to provide or allocate goods and services to their most efficient use (that is, allocation is not one that maximises overall community wellbeing) ; and
- ineffective or inappropriate government regulations, policies, programs and administrative decisions. These are government actions where the costs to the community outweigh the benefits.

Some areas of government activity which were seen as impediments by participants include:

- competition policy (Business Council of Australia, sub. 58, p. 6);
- corporate governance (Business Council of Australia, sub. 58, p. 6);
- taxation policy (such as the treatment of personal income and capital depreciation) (Business Council of Australia, sub. 58, p. 6);
- the ‘state’ of the nation’s infrastructure (Business Council of Australia, sub. 58, p. 6).
- the regulatory regime in which the health and medical industry operates including that relating to clinical trials (NHMRC, sub. 80, p. 6; Medicines Australia, sub. 99, p. 34; the NSW Government, sub. 91, p. 10)
- regulations governing the use of chemicals, precursors for drugs, and explosives and therapeutic substances (Science Industry Australia, sub. 22, p. 10);
- regulation of biotechnology including of genetically modified organisms (Institute of Public Affairs, sub. 76, p. 10 and CRC for Beef Genetic Technologies et al., sub. 85, pp. 35-6);
- regulation of nuclear energy (Institute of Public Affairs, sub. 76, p. 11); and
- regulation of stem cell research (Institute of Public Affairs, sub. 76, p. 11 and Victorian Government sub. 84, p. 12).

While recognising the importance of these participants’ concerns, for the purposes of this study, the Commission has confined its attention to impediments to the functioning of the innovation system, rather than to particular industries, products or technologies. This chapter addresses, in particular:

- skills development;
- intellectual property;
- research infrastructure; and

- other areas such as privacy regulation, ethical review and scientific publication practices.

Related issues covered elsewhere in the report include:

- the main market failure rationales for public support for science and innovation (chapter 3);
- deficiencies in public sector programs, including issues about coordination as well as institutional decision making and governance, and performance benchmarking (chapters 7, 8, 9, 10 and 11); and
- ineffective or inappropriate government actions affecting commercialisation and collaboration (chapter 6 and chapter 9 on CRCs).

5.2 Skills development

Human capital is an important component of the innovation system. It not only provides Australia with the capability to pursue scientific knowledge and undertake research and development type activities, but also to utilise and adapt the innovation flowing from research and development undertaken in other countries.

Participants' concerns about skills development nearly all relate to ensuring that there are adequate numbers of appropriately trained scientists, engineers and related professionals. These concerns are encapsulated in the ongoing concern that skill shortages will ultimately affect Australia's ability to create and absorb scientific knowledge and undertake innovative activities.

The following discussion focuses on concerns about shortages and what, if anything, should be done in these areas. Other concerns surrounding the adequacy of this workforce including declining enrolments in science and mathematics in high schools, the emigration of skilled and educated workers, problems with career pathways and workforce satisfaction are discussed further in appendix L.

Skills shortages

Australia's science and engineering workforce has grown strongly in the last decade with large increases in graduate completions between 1990 and 2000 and net migration flows. In addition, the number of PhD graduates has increased in both science and engineering. However, there has been a decline in graduate completions in some areas since 2000. Against this backdrop of increasing supply, employment for science and engineering professionals has also generally been strong (appendix L).

There do not appear to be shortages of scientists at present, although there are significant shortages in certain engineering occupations. For example, civil, chemical, mining and petroleum engineers have been identified by the Department of Employment and Workplace Relations as being in ongoing national shortage for the skilled migration program and placed on the Migrant Occupation in Demand List. The recent Audit of Science, Engineering and Technology Skills undertaken by DEST (2006c) noted that employers were having difficulties in recruiting engineers. A shortage in engineering skills was confirmed by Engineers Australia (sub. 65, p. 11).

Most jurisdictions have reported ongoing shortages and difficulties in recruiting mathematics and science teachers according to the national reports on teacher supply and demand (MCEETYA 2003 and 2004). More recent analysis indicates that these problems continue. The Department of Employment and Workplace Relations skills in demand list for September 2006 (DEWR 2006b) identified shortages of mathematics and physics teachers in Victoria and recruitment difficulties in respect of science and mathematics teachers in nearly all other jurisdictions. Moreover, there are concerns that the extent of these staffing problems may have been hidden through the reliance on unqualified teachers to teach in these subject areas (appendix L).

This has been of particular concern given the importance of these subjects in the final years of high school as providing the platform from which to undertake tertiary study in these areas and for delivering broader scientific and mathematical literacy in the wider population. The Business, Industry, and Higher Education Collaboration Council said:

> Investment in primary and high school science education, and in training and retaining high quality science teachers is an important part of long term capacity building. It appears that the quality of science, engineering and technology teaching in schools may act as a limiting factor in the long term capacity to graduate students suitably qualified to meet the high expectations of industry. Quality high school maths and science teaching has a critical flow on effect on student's choices and success at university. Investment in world class higher education courses in the enabling sciences is also critical to recruiting and retaining students. (sub. 55, p. 13)

Of course, shortages or recruitment difficulties are not unexpected in the current strong overall labour market and there have been shortages in a variety of professional, technical and trade occupations. To the extent that such shortages are cyclical, rather than structural, any policy response is likely to have a limited impact.

In most labour markets, shortages of labour generate price signals in the form of higher earnings to attract additional labour. In the case of engineers, unlike teachers, this shortage has been reflected in the rapid growth in salaries for graduate and experienced engineers (DEST 2006c).

While market mechanisms are important in addressing shortages, governments have also intervened to increase the supply of these workers. The Australian Government has done this through its funding of higher education places and the skilled migration program. For example, teaching places at university have been funded as a national priority and additional places have been made available. The Australian Government has also announced that there will be additional university engineering places (Bishop 2006c). The skilled migration program has been changed to provide a more immediate response to shortages whereby additional points are attached to those occupations assessed as being in shortage.

Information provided by governments can also play a role in maintaining the ability of the system to adjust now and in the future. For example, ensuring school leavers and other potential university entrants are aware of employment prospects for different fields of study can assist the operation of the labour market by signalling to students areas where there are shortages and this can avoid adding to oversupply in other occupations.

One area in which governments could further improve the ability of the labour market to adjust to meet any shortages is to address certain price rigidities.

Teacher shortages

In the teaching profession, particularly in the public sector, price signals have not been able to reflect the shortages due to the inflexible nature of teachers' pay structures.

Webster, Wooden and Marks (2004) argued that there should be changes to teachers' pay structures. They found that fewer science and mathematics graduates, compared to humanities graduates, were attracted to tasks involved in teaching children. However, as attraction was a matter of degree, higher earnings could be used to attract and retain these teachers. They concluded that higher salaries and extended career paths should be formalised in teaching wage agreements to ensure such incentives were signalled to mathematics and science graduates, as well as existing teachers in these areas.

The level and structure of teachers' pay was seen as a negative by year 12 students contemplating a career in teaching in a survey of these students undertaken by Lewis and Butcher (2002). It found that there was a critical awareness on the part of year 12 students of the issue of teachers' pay and, while acknowledging the benefits of the starting salary, teaching was considered not to provide an adequate financial future. Moreover, the year 12 students were conscious of the incremental levels of pay and the lack of career pathways. Concerns with promotional pathways and salary levels were expressed by senior secondary school students and parents in an attitudinal study for DEST (2006b).

Leigh and Ryan (2006) found that as teachers' pay relative to other professions had declined over time, teaching had become less attractive to high aptitude students leading to a decline in overall teacher quality.

The Review of Teaching and Teacher Education (DEST 2003b) noted that teaching salaries plateau after around 10 years from entering the profession and that this generated considerable dissatisfaction among experienced teachers. Around 70 per cent of teachers in New South Wales public schools were at the top of the scale (NSW Auditor General 2003). Highly accomplished teachers were disadvantaged in comparison to other professionals by their inability to access pay commensurate with their performance. It recommended that career progression and salary advancement be based on merit and teacher performance rather than years of service and that remuneration for those teachers who perform at advanced levels be increased significantly.

To attempt to reward more experienced teachers, most jurisdictions have put in place advanced teacher classifications, known as senior, master or leading teachers, which provide for a limited number of additional steps on the salary scale. In some jurisdictions, access to the advanced teaching classification is based on meeting specific criteria, providing an undertaking to perform higher duties and/or meeting satisfactory performance benchmarks. In other jurisdictions these positions have been rolled into the normal incremental salary scale (AEU—ACT Branch 2005). However, while such measures have added a number of additional steps, there are no further rewards for those teachers at the top of the scale. For those seeking further rewards the only option is to progressively move out of the classroom and seek promotion through the administrative stream.

Providing greater flexibility in pay structures, which would involve increasing pay rates for some teachers relative to others, would make teaching more attractive to prospective entrants, including those with science and mathematics qualifications, and provide education departments with greater scope to retain skilled and experienced teachers across the board and attract teachers into areas of shortage. Importantly, credible methods to assess teacher performance would need to be developed that are acceptable to both management and staff in the teaching profession as they have been in other areas of the workforce.

A number of incentive measures have been proposed or put in place to overcome teachers shortages. For example, the action agenda arising from the Review of

Teaching and Teacher Education (DEST 2003b) raised the issue of separate incentives for prospective science and mathematics teachers including removing all student contributions, providing scholarships and/or paid internships for those qualifying in these fields who take up teaching appointments. It also recommended that those students with science qualifications who then went on to teach through a graduate teacher program be subject to the same rate of HECS-HELP as education students.

State and Territory Governments have implemented a number of scholarship arrangements for science and mathematics teachers and retraining schemes for teachers currently teaching in other areas. For example, the Queensland Government offered up to 25 scholarships to an accelerated Bachelor of Education course. The Victorian Government has offered a $4000 up-front payment to attract final year trainee teachers to difficult to staff subject areas and the Western Australia Government has offered a HECS reimbursement scheme of up to $6000 to physical science graduate teachers upon taking up employment (MCEETYA 2004).

Given the fairly low sensitivity of student response to changes in HECS-HELP contributions — due to both the higher income that a graduate receives and the payment being deferred to the future — such differentiation would need to be significant to influence students and other prospective entrants into teaching. Further, as the scope of the problem is so profound and endemic, Webster, Wooden and Marks (2004) considered that attraction schemes such as scholarships and extra advertising are unlikely to have sustained effects.

In sum, shortages in science and mathematics teachers are exacerbated by the inflexible nature of teachers' pay structures. Greater flexibility would make teaching more attractive to prospective entrants, including those with science and mathematics qualifications. It would also provide greater scope to attract and retain skilled teachers, not only across the board, but in areas of particular shortage.

Greater flexibility may have an associated fiscal impact on governments, although any such impact would have to be considered against the need to attract and retain these teachers.

5.3 Intellectual property rights

Intellectual property (IP) rights — such as patents, trademarks and copyright — confer legal ownership to the creator of IP. As with any other legal property rights, IP rights exclude others from freely using the IP, can be bought and sold, and can be licensed to others for a royalty.

The main areas of concern about IP rights expressed by participants are their impact on knowledge sharing and dissemination and their interaction with competition policy. Concerns about the management of IP in universities, publicly funded research agencies and CRCs are covered in chapters 6 and 9. Other concerns raised by participants and commentators relate to the costs and speed of acquiring patents, the breadth of patent protection, dispute resolution and the impact of IP-related provisions in international agreements: these matters have been well-traversed in the public policy arena. The IP system itself is described in appendix N.

Common to all these concerns is an inherent underlying tension associated with IP rights. In making IP excludable, IP rights increase the incentives for business to invest in innovation and commercialisation. Without the protection given by IP rights, and because of the 'public good' nature of IP (that is, its use is not capable of being excluded and is 'non-rivalrous' in that its use by one person does not diminish the amount that can be used by others), businesses are less likely to invest if there is a risk that others would freely use their IP. However, if IP rights are cast too restrictively, they can confer undue monopoly power on the owners. This could, for example, manifest in owners of IP rights extracting excessive licensing royalties or placing unnecessary restrictions on knowledge dissemination with further knock-on effects for the rest of the innovation system.

In assessing participants' concerns, it is useful to remember there are market-based alternatives to IP rights. Businesses can exploit or protect their IP through first mover advantage, marketing and product differentiation, confidentiality agreements, technological solutions and the like. The importance of market-based alternatives to IP rights should not be understated. In 2003, 21.5 per cent of innovating businesses claimed to use a formal protection method, while 36.6 per cent claimed using informal methods, the most common of which was secrecy (ABS 2006a, p. 57).

Open source

Some participants have expressed a broad concern about the adverse impacts of IP rights on the sharing and dissemination of knowledge and, thus, on further research. For example, Rooney and Mandeville noted that 'overly strong IP can block the knowledge flow and thereby block new knowledge creation as well' (sub. 2, p. 9). In a similar vein, Prof. Fitzgerald considered that IP rights can in some instances 'stifle the flow and spontaneity of an innovation system' (sub. 21, p. 1). The Business, Industry and Higher Education Collaboration Council observed that 'unused intellectual property has no value explicitly' (sub. 55, p. 5).

These participants have advocated an 'open source' (or 'open science' or 'open innovation') approach to IP. The underlying premise of the approach is the free sharing of knowledge, particularly, for research purposes. Although there are different ways in which this approach could manifest itself, it could encompass:

- holders of IP rights freely licensing their IP to researchers and only extracting royalty payment where the IP is commercialised; and
- researchers in universities and publicly-funded research agencies making their research freely available rather than seeking IP rights or royalties.

It may well be that an 'open source' approach to IP works better for some industries, and research areas, than others. Many of the examples of the application of open source derive from the ITC industry. The Business, Industry and Higher Education Collaboration Council, for example, observed that many ITC companies such as IBM undertake open source licensing (sub. 55, p. 6). The Department of Agriculture, Fisheries and Forestry noted that the adoption of agrifood R&D outputs is largely achieved through an 'open-source non-competitive extension approach'. That said, the Department noted that food producers need to achieve a competitive advantage, 'often through exclusive access to IP or the ability to exploit some particular knowledge' (sub. 100, pp. 25, 26). For industries where R&D takes a longer time, is more expensive and involves greater risks — such as the biotechnology and pharmaceutical industries — the application of an open source approach to IP rights may have more limited appeal. That said, there are emerging signs of an open source approach being applied in these types of industries; CAMBIA's Biological Open Source Initiative is one example (sub. 42, p. 3).

Incorporating an open source approach to IP would require careful analysis as to the effects as well as the precise manner of implementation. For example:

- an approach which involved changing IP laws such that IP rights were freely licensed to researchers could adversely affect firm incentives to invest in innovation and acquire the resultant IP rights, even though dissemination of the knowledge embedded in the IP may be enhanced; and
- whether research produced by universities and publicly-funded research agencies should go straight into the public domain has implications for their commercialisation strategies but also affects the ability of others to gain commercial advantage and, hence, be willing to use that research — this is discussed further in chapter 6 on commercialisation.

Experimental use of patents

A subset of the broad concern about the impact of IP rights on the sharing and dissemination of knowledge is the capacity of researchers to access patents for 'experimental use', particularly in the area of biotechnology. Experimental uses of patents could include:

- testing an invention to determine its sufficiency or to compare it to 'prior art';
- tests to determine how the invention worked;
- experimentation on the invention for the purpose of improving on it or developing a further patentable invention;
- experimentation for the purpose of 'designing around' the patented invention;
- testing to determine whether the invention met the tester's purposes in anticipation of requesting a licence; and
- academic instructional experimentation with the invention (in ACIP 2005, p. 10).

There is currently legal uncertainty about whether such experimental uses are permitted under the *Patents Act 1990.* The Act does not expressly exempt experimental use of patented inventions from liability for infringement. And there is no case law as to whether an implied experimental use defence to patent infringement exists (ACIP 2005, p. 2; ALRC 2004, p. 317).

Jensen, Palangkaraya and Webster referred to the problem that this creates for researchers:

> Historically, most industrialised countries have not deemed university research on a patented invention as an infringement of the rights of the patent-holder. However, the *Madey v. Duke* case in 2002 changed the perception of this [discussed in box 5.1]. Without an exemption, it is possible that scientists and universities may be sued for infringement when the work they are doing is for scientific progress generally. As a result, there is now widespread concern that the absence of a research exemption in patent law may have serious long-term effects on scientific progress. (sub. 9, p. 9)

The experimental use of patents has been considered in two public reviews in recent years.

The Australian Law Reform Commission (ALRC 2004) considered experimental use within the context of gene patenting. It expressed the view that the legal uncertainty has the 'potential to result in underinvestment in basic research; and to hinder innovation if researchers become concerned that their activities may lead to legal action by patent holders' (p. 331). It recommended amending the Patents Act to incorporate an experimental use provision for 'acts done to study or experiment on the subject matter of a patented invention' (for example, to investigate its properties or improve upon it such as when a patented genetic sequence is being used to investigate the function of a gene, or its association with disease) (p. 335). It further recommended that the provision makes it clear that: the exemption is available only if study or experimentation is the sole or dominant purpose of the act; the existence of a commercial purpose or objective does not preclude the application of the exemptions; and the exemption does not derogate from any study or experimentation that may otherwise be permitted under the Act (p. 335).

The Advisory Council on Intellectual Property (ACIP 2005) effectively found there were no major impediments to experimental use of patents in Australia. It noted this was not a result of formal protection but, rather, of a convention in Australian industry of not pursuing patent infringement that is the result of experimentation. It went on to say however that this will change and there could, thus, be merit in introducing an experimental use provision:

> Although there is some anecdotal evidence, there is no strong empirical evidence that the current situation is adversely affecting the balance between the incentives to innovate and the ability to use innovations for research and development. However, ACIP considers that this situation will change. There is evidence that more assertive IP practices are developing in Australia. Without clarification of the law, this would increase inefficiencies and lost opportunities. Also, new case law may determine the category of allowable uses of patented invention be very narrow. ACIP therefore considers that, if an experimental use provision can be drafted into patents legislation which prevents a damaging situation without introducing an even greater set of costs, then it should be introduced. (p. 2)

Its preferred option was to introduce an experimental use provision in the Patents Act to ensure that the rights of a patent holder are not infringed by acts done for experimental purposes relating to the subject matter of the invention that do not unreasonably conflict with the normal exploitation of a patent. Acts done for experimental purposes relating to the subject matter of the invention include: determining how the invention works; determining the scope of the invention; determining the validity of the claims; and seeking an improvement to the invention (p. 3).

Although there are various points of difference between the Australian Law Reform Commission and the Advisory Council on Intellectual Property's recommendations — such as whether experimentation is *on* an invention or relates to the *subject matter* of an invention, and as to the existence of a commercial purpose — both come to the same broad conclusions that there is a need for an experimental use provision in the Patents Act to provide certainty for researchers and to foster research.

Since the release of the Advisory Council on Intellectual Property report, an interdepartmental committee has been established to draft the Government's response. A public consultation paper has been issued by the committee seeking submissions.

Provisions exempting experimental or research use of IP rights are not new. Experimental use provisions exist in the patent legislation of other jurisdictions such as the United Kingdom and Japan. New Zealand is also about to introduce a new experimental use provision based on the Advisory Council of Intellectual Property's recommendations (box 5.1). Also, other areas of Australian IP law have exceptions for research purposes.

- The *Plant Breeder's Rights Act 1994*, for example, provides an exception for the use of a protected variety in experiments or plant breeding (section 16). Rights cannot be granted for any new variety unless it is 'clearly distinguishable' from the original variety (section 43(2)).
- And the *Copyright Act 1968* contains special provisions which allow for use of copyright material for the purpose of research or study provided that the use is 'fair'. What is 'fair' depends on the circumstances such as the purpose and character of the dealing, the nature of the work, the possibility of obtaining the work within a reasonable time at an ordinary commercial price, and the effect of the dealing on the potential market for, or value of, the work.

Box 5.1 **Experimental use in other jurisdictions**

New Zealand

The NZ *Patents Act 1953* does not provide an express exemption for experimental use of a patented invention. In at least two cases, New Zealand courts appear to have accepted that such a defence is available. However, although the courts have drawn distinctions between experimental use and commercially-directed research, the law is said to remain 'uncertain as to where the line actually falls between pure research and research for gaining a commercial advantage'.

Following a recent review, the NZ Government decided to incorporate an experimental use provision in the Act. The wording of the provision is to be based on the wording proposed by the ACIP in its final report. It is expected that draft provisions will be introduced late in 2006.

United Kingdom

An experimental use defence was enacted in the UK *Patents Act 1977* in part to ensure that UK law conformed to the Community Patent Convention (ratified by the United Kingdom and eight other European Union states). The UK provision states that 'An act which, apart from this subsection, would constitute an infringement of a patent for an invention shall not do so if — a) it is done privately and for purposes which are not commercial; b) it is done for experimental purposes relating to the subject-matter of the invention' (section 60 (5)).

These exceptions appear to have been interpreted rather narrowly. For example, in *Monsanto v. Stauffer Chemical,* it was found that the underlying purpose of the experiments must be technical — 'to discover something unknown or to test a hypothesis' relating to the patented invention.

(Continued next page)

Box 5.1 **(continued)**

United States

As in Australia and New Zealand, there is no explicit experimental use exemption in the US Patents Act. US case law recognises a limited experimental use defence. For example, in *Roche Products v. Bolar Pharmaceutical,* the US Court of Appeal for the Federal Circuit found that the defence was dependent on the experiments involved being for 'amusement, to satisfy idle curiosity, or for strict philosophical inquiry' and not for business reasons. In *Madey v. Duke University,* the Court emphasised that the defence is very narrow and strictly limited and that, in particular, 'use in keeping with the legitimate business of the alleged infringer does not qualify for the experimental use defence'. The Court found that the non-profit (or educational) status of the alleged infringer does not determine the availability of the experimental use defence. Rather the focus should be on whether the act was in furtherance of the alleged infringer's legitimate business.

The *Madey* decision has been widely regarded as narrowing the experimental use exception in the US to the point where most organisations carrying out research or experimental work involving patented inventions could find themselves liable for patent infringement.

Japan

There is an express provision in the Japanese Patents Act, dating from 1909, that states that 'the effects of the patent right shall not extend to the working of the patent right for the purposes of experiment or research'. The Act does not define 'experiment'. Japanese courts have held that the testing of generic pharmaceuticals for the purpose of obtaining regulatory approval during the term of the patent on the original pharmaceutical falls within the experimental use exception.

Sources: ACIP (2005); ALRC (2004); NZ Ministry of Economic Development (2006).

Incorporating an experimental use provision in the Patents Act raises a host of complex issues at the heart of which is the need to strike an appropriate balance between ensuring that patent holders are rewarded for their investment and ensuring that research that relies on patents is not unnecessarily stifled.

Neither the Australian Law Reform Commission nor the Advisory Council on Intellectual Property has made a strong case for the introduction of such an exception. Indeed, both noted that the evidence of a problem existing appears to be anecdotal, though the mere existence of legal uncertainty itself is a sufficient basis for further legislative change. Moreover, it is not clear as to what are the costs and risks of either of their recommendations.

IP rights and competition policy

There has been a long-standing debate about whether IP rights should continue to be exempted from the pro-competitive provisions of the *Trade Practices Act 1974* (TPA). Specifically, section 51(3) exempts certain conditions in licences and assignments of IP from some of the provisions of Part IV.[1] (Another complex issue, not considered here, relates to the impact of the TPA on collaboration among firms for the purpose of undertaking research and development.)

On the one hand, because of the public good nature of IP, IP rights are said to be needed to encourage innovation and, thus, should be exempted from the TPA. In supporting the exemption, the National Competition Council considered that, given few owners of IP rights have the market power necessary to substantially lessen competition, there was no inherent clash between IP rights and competition policy (NCC 1999, p. 13). The US Federal Trade Commission observed that both 'competition and patent policy can foster innovation' when a proper balance between the two is achieved (FTC 2003, p. 1).

On the other hand, as IP rights restrict access to IP, they can potentially have anti-competitive effects including impeding further innovation and, thus, some argue that they should be subject to the TPA. Lawson observed that, the regulation of IP is 'just another regulatory measure to promote economic development', it should be treated the same as any 'other legislation with potential anti-competitive effects' (sub. 5, p. 1).

The Australian Government's main review of the interaction of IP rights with competition policy was undertaken in 2000 by the Intellectual Property and Competition Review Committee. It considered the current IP rights exemptions in the TPA to be 'seriously flawed' as 'the extent and breadth of the exemptions are unclear, and may well be over-broad' (IPCRC 2000, p. 11). It recommended that section 51(3) of the TPA be amended such that anti–competitive conditions (specifically, contraventions of Part IV or section 4D of the TPA) by reasons relating to the imposition of an IP statute do not constitute a breach, so long as those 'conditions do not result, or are not likely to result in a substantial lessening of competition' (p. 11). What constitutes a breach would be determined by the Australian Competition and Consumer Commission. Although the Australian Government has stated its intention to further explore the implementation of this recommendation, it has yet to legislatively deal with this particular matter. It has,

[1] The section provides that conditions that 'relate to' the subject matter of patents, registered designs, copyright, trade marks and circuit layouts are exempt from sections 45, 45A, 47, 50 and 50A. It does not exempt licensing and assignment conditions from the operation of sections 46 or 48.

however, introduced legislation to deal with other recommendation of the IPCRC (IP Australia 2006b).

In its review of National Competition Policy, the Commission was of the view that IP laws should ‘continue to be scrutinised to ensure they are not unduly restrictive’ (PC 2005d, p. 285). This would be achieved through the retention of a legislation review mechanism, including provision for periodic review (also recommended in SCSI, 2006, p. 125). In conducting such reviews, however, there needs to be consideration of the appropriateness of Australia’s IP laws within the constraints of its international obligations.

5.4 Research infrastructure

Research infrastructure is an important input to science and innovation. The Mapping Australian Science and Innovation report noted that:

> Access to world-class research infrastructure is critical to the capacity of Australia’s scientists, engineers and technologists to perform high-quality research. In particular, the competitive position of a nation’s science base … depend[s] upon access to research equipment which is sufficiently technically advanced to enable scientists to carry out the experiments required to keep up with the leading-edge of research and advances in the technologies which underpin scientific research equipment have driven and continue to drive increases in the quality, quantity and breadth of experimental data that can be gathered by scientists. (DEST 2003c, p. 173)

Research infrastructure embraces such items as research facilities and equipment (and the services that support them); libraries and ITC networks for storing, moving and accessing research information; and collections, archives, large/complex data sets and records (Australian Government 2006a, p. 35). A taxonomy of research infrastructure capturing such factors as cost, complexity and extent of collaboration required in its provision is given in box 5.2.

Most research infrastructure in Australia is funded by governments, with the Australian Government being the main source of funds. Total public support is estimated to be around $1 billion in 2005-06 (appendix O). A key form of public support is ongoing research infrastructure programs as distinct from one-off expenditures (box 5.3). For the Australian Government, these include the Department of Health and Ageing’s Medical Research Infrastructure Projects ($215 million in 2005-06) and DEST’s Research Infrastructure Block Grants ($200 million), Systemic Infrastructure Initiative ($61 million) and Major National Research Facilities Programme ($42 million). The National Collaborative Research Infrastructure Strategy (NCRIS, box 5.4) is another major program ($542 million from 2004-05 to 2010-11). More information on public support for research infrastructure is given in box 5.3 and appendix O.

Box 5.2 **A taxonomy of research infrastructure**

In its 2004 report, the National Research Infrastructure Taskforce described five broad categories of research infrastructure to capture such factors as cost, complexity and extent of collaboration required in its provision.

Australian foundation facilities are basic, systemic infrastructure such as broadband communications, high performance computing and major data repositories and services.

Australian landmark facilities are large scale research facilities, such as synchrotrons and research vessels, typically involving funding in excess of $100 million.

Australian major research facilities are used to pursue regional, institutional and thematic groups' research priorities, typically requiring funding of $1 million to $100 million.

Australian research sector facilities facilitate regional and institutional strategies and priorities, require regional and institutional collaboration and access, and are implemented in a coordinated way, typically requiring funding of $0.15 million to $1 million.

Institutional research facilities usually facilitate institutional research priorities, are of relatively low cost, are site specific in nature, and are funded entirely from the institution's resources.

Source: DEST (2004e, p. 9).

Box 5.3 **Public support for research infrastructure**

The array of public support for research infrastructure includes:

- Australian Government and State and Territory Government research infrastructure programs involving either recurrent or one-off expenditures;
- Australian Government funding of public sector research agencies such as CSIRO and ANSTO, as well as of universities — these institutions then allocate funding to research infrastructure; and
- State and Territory Government support for 'in-kind' research infrastructure provided, for example, to cooperative research centres and major national research facilities.

Funding under research infrastructure programs — which presents a lower bound on total public support for research infrastructure — amounted to around $1 billion for public support for science and innovation in 2005-06.

Source: Appendix O.

Box 5.4 National Collaborative Research Infrastructure Strategy

Concerns relating to large and systemic infrastructure have been the ad hoc nature, inadequacy and lack of strategic direction of funding, particularly under the Systemic Infrastructure Initiative and the Major National Research Facilities program.

The Australian Government established a National Research Infrastructure Taskforce in 2005 to develop a national research infrastructure strategy framework to inform it of investment in research infrastructure for universities and publicly-funded research agencies. The Taskforce issued its report at the end of 2005.

The Government accepted the Taskforce's central finding that there is a need to 'strengthen, plan and prioritise research infrastructure needs' (DEST 2004e, p. ix). It committed $542 million from 2004-05 to 2010-11 to NCRIS, which seeks to bring greater strategic direction and coordination to national research infrastructure investments. NCRIS will replace the Systemic Infrastructure Initiative and the Major National Research Facilities program. A Roadmap and Investment Framework have been released in 2006: the Roadmap identifies the principles underpinning NCRIS as well as priorities for investment (in 'emerging fields' such as biotechnology, nanotechnology, biosecurity and environmental monitoring), and the Investment Framework sets out in more detail how NCRIS is to be implemented. Funding proposals are to be prepared and assessed, and funding agreements negotiated by the end of 2006.

The Minister for Education, Science and Training recently noted that while NCRIS 'will do much to serve the infrastructure needs of Australian scientists' more needs to be done, particularly in the area of international collaboration due to the escalation of the cost and complexity of research and facilities in recent years (Bishop 2006a, p. 5).

Sources: Australian Government (2006b); Bishop (2006a); DEST (2004e).

Several participants (such as the AVCC, sub. 60, p. 37; the University of New England, sub. 17, p. 15; Baker Heart Research Institute, sub. 40, p. 5; and the Australian Society for Medical Research, sub. 36, p. 4) expressed concerns about the public support for research infrastructure. They claimed various deficiencies such as: the failure of funding to keep pace with the costs of provision; in the types of costs funded by research infrastructure programs; underutilisation of some types of research infrastructure; the ageing of research infrastructure; and inconsistencies across research infrastructure and other programs. They said that such deficiencies had adverse consequences for the type and quality of research.

What follows is a consideration of the key concerns about research infrastructure funding and provision identified by participants.

Costs funded under research infrastructure programs

Participant concerns about the types of costs funded under research infrastructure programs focused, among other things, on the short term duration of funding under many research infrastructure programs (for example, funding is available on a calendar year basis under DEST's Research Infrastructure Block Grants program and up to five years under the ARC Linkage Infrastructure Equipment and Facilities program), their lack of funding for ongoing costs (which then have to be funded from other sources), and their disconnection from research funding programs.

Existing research infrastructure programs typically fund upfront infrastructure costs, with ongoing costs recovered elsewhere in the system such as from research programs, from institutional block funding arrangements (such as the Institutional Grants Scheme for universities) or, indeed, from the Operating Grant provided to universities.

Another source of research infrastructure funding is for institutions that own infrastructure to charge for access or use. There is currently no consistent approach in Australia. Some institutions such as the Australian Partnership for Advanced Computing and ANSTO have charging regimes augmented by peer review. Others such as the Australia Telescope National Facility provide access freely but based on peer review. And yet other institutions (Adelaide Microscopy, University of Adelaide) provide access freely on a 'first come first served' basis.

The National Research Infrastructure Taskforce, which focused on large and systemic research infrastructure, identified four basic options for setting access charges:

- full cost recovery of capital and operating costs;
- full cost recovery of operating costs;
- free to designated users, except for marginal operating costs;
- free to designated users (DEST 2004e, p. 31).

The Taskforce recommended that funding of research infrastructure provide both capital and 'standing' operating costs, with marginal operating costs being recovered from designated users (p. 32). It argued that:

> The first two market-driven models place large market and financial risks on the host of the facility. Unless the current arrangements for research funding are changed to a more market-driven, fully funded model, they may place at risk the ongoing viability and relevance of the facilities. These models for charging also introduce additional complexities for management of cash derived from recovery of capital charges by facility hosts, and for the creation of usage models which may be at odds with national, regional, institutional and thematic groups' strategies and priorities. (p. 31)

It also recommended that access charges for users outside the research sector be on a full cost recovery basis, but be flexible (p. 3). These recommendations were echoed in later implementation advice by the NCRIS Advisory Committee and set out in the NCRIS Investment Framework.

For infrastructure where a commercial rate of return is sought — such as electricity and urban water infrastructure — efficient utilisation and investment would require that charges to users expressly reflected the long run marginal costs of provision including operational, overhead and capital costs. Of course, variations to this basic principle would be required depending on the particular circumstances, for example, where there is congestion as opposed to underutilisation.

However, such a commercially-oriented approach to charging is only partly relevant to research infrastructure. Research infrastructure is an input to research and, as such, the main rationale for public support for research — namely, to capture external benefits or spillovers from innovation — also applies to public support for research infrastructure.

That said, the Commission considers that there are aspects of charging to seek a commercial rate of return that could be usefully applied. In this respect, the Taskforce recommended that charges be set to recover marginal operating costs alone. Such an approach would provide a useful signal to funding agencies of the demand for research infrastructure and, therefore, provide some guidance of future investment in capacity. Where utilisation exceeds capacity, the charge could also incorporate a congestion component.

For research infrastructure funded and provided through a collaboration of domestic and/or international institutions, it would appear that there is less scope for such a modest approach to access charging. Here, a protocol typically applies whereby access is allocated to an institutional partner based on the proportion of its contribution to the costs as well as the scientific merit of that partner's research. However, for effective utilisation of capacity, it would be desirable if the initial access entitlement were transferable, not only among partners, but to third parties, with the transfer fee reflecting underlying infrastructure costs.

Payments by users for accessing research infrastructure could be recovered from research funding and, indeed, was recommended by the National Research Infrastructure Taskforce (DEST 2004e, p. 32). In its submission to the NCRIS Advisory Committee, the Australian Academy of Science (2005) favoured 'expensing' access to research infrastructure in research grants such as those provided by the ARC and NHMRC:

> A line item in [ARC and NHMRC] research grants for access to centralised research infrastructure will guarantee that facility users have the means to contribute adequate funds to operate these national research assets. In turn, these funds should support

> dedicated technical support for the facilities, for the facilities to keep abreast, and indeed contribute to, cutting edge technologies. Competent technical support is essential for efficient and effective use of the facilities and this in turn will be an inducement to researchers to collaborate with the centralised facilities and will help avoid fragmented national research infrastructure. (pp. 4-5)

Some ARC research funding programs already incorporate some research infrastructure costs. The Discovery Projects and Linkage Projects programs, for example, allow for a small proportion of research funding to be directed to purchasing equipment, or to maintenance and operating costs. If a research facility is not available internally within the university where lead researchers are employed, support may also be provided under the programs for researchers to use outside facilities. The Centres for Excellence program also provides funding to researchers for the purchase, building, maintenance and operation of equipment and facilities.

Such an approach does not have to imply an increase in funding for research, but a recalibration of existing funding arrangements. For example, some programs that currently support funding of research could be augmented with funding to cover the cost of access of research infrastructure with offsets from existing block funding programs for universities and publicly-funded research agencies (such as the Research Infrastructure Block Grants Scheme). However, any implications arising from adjusting the balance of block versus competitive funding would need to be considered (for example, see chapter 11 in relation to higher education funding).

Inconsistencies in public support for different institutions

Another concern expressed by participants was inconsistencies in the way in which research infrastructure is publicly provided and funded for different institutions. Funding or support is provided to:

- universities under DEST's Research Infrastructure Block Grants program and the ARC's Linkage Infrastructure Equipment and Facilities program (appendix O);
- public sector research agencies under their block funding arrangements;
- health and medical research institutes under Australian Government research infrastructure programs such as the Department of Health and Ageing's Medical Research Infrastructure Projects, NHMRC programs such as the Independent Research Institutes Infrastructure Support Scheme as well as from the States and Territories (appendix O); and
- CRCs from the States and Territories (treated as 'in-kind' contributions under the Australian Government's CRC program).

The implementation of NCRIS (box 5.4) will help to coordinate the funding and provision of large and systemic infrastructure across institutions as well as across jurisdictions. Incorporating the recommended charging approach of the National Research Infrastructure Taskforce to research infrastructure funding would also help to reduce inconsistencies. Further discussion of coordination issues is given in chapter 8.

Knowledge about the stock of research infrastructure

According to the Western Australian Department of Industry and Resources, there is a lack of knowledge about the current stock of research infrastructure. This extends to what infrastructure exists, where it is kept, its operational state, its current rate of utilisation, and its accessibility. The Department called for a 'national audit of R&D and innovation infrastructure' (sub. 82, p. 5).

A lack of knowledge would make it difficult for potential users to access suitable research infrastructure, thereby exacerbating any problem of under-utilisation of existing capacity. Moreover, it would affect the ability of governments to provide effective public support for new infrastructure.

A national audit would help to overcome any such problems. By identifying existing capacity, it would enhance utilisation as well as improve the effectiveness of public support for new infrastructure. As Hϕj et al. (2004) noted:

> Such knowledge would point researcher X in the right direction and assist funding agencies make decisions about the merits of applications as well as assessing the opportunity for transfer of equipment from location A to B or simply grant researcher X at location B access to the required equipment at location A. (p. 3)

However, care would be required to ensure that the national audit is not needlessly costly. It would thus need to build on existing information to hand by universities and publicly-funded research agencies.

5.5 Privacy regulation

Privacy regulation generally involves limits or conditions on the collection, storage, access, use and disclosure of personal information. The main source of regulation is the Australian Government's *Privacy Act 1988* (hereafter referred to as the Privacy Act) (appendix P). Some States and Territories also have privacy legislation that either apply generally to personal information or specifically to health information (appendix Q). Under the Constitution, Commonwealth legislation prevails over State or Territory legislation to the extent that these laws are inconsistent. In addition to privacy legislation, there are privacy, confidentiality and/or secrecy obligations embedded in other legislation — such as in freedom of information legislation, telecommunications interception legislation, and 'spent' (or previous) convictions legislation — as well as under common law and industry codes.

While not disputing the objective of privacy regulation, the NHMRC raised concerns about its impact on the conduct of health, medical and other areas of research. The main concern was complexity stemming from both the intersection of Australian Government and State and Territory privacy legislation applying to health information and medical research as well as from different provisions under the Privacy Act applying to the public and private sectors. The NHMRC said:

> The privacy regulation framework is a complex, patchwork of Commonwealth and State/Territory legislation, administrative decisions and codes of conduct which can hamper health and medical research as it has the potential to act as a barrier to the exchange of information. (sub. 80, p. 15)

In addition, there were concerns about the obligations placed on human research ethics committees under the Privacy Act to weigh the balance of the public interest in the protection of privacy against the public interest in research as well as reporting obligations. These concerns are explored later in relation to the ethical review of health and medical research.

Specific adverse impacts of privacy regulation on health and medical research were said to include the following:

- the ability of agencies or organisations that hold personal or health information to make effective decisions about using or disclosing that information for research was unduly hampered;
- the administrative/compliance burden on researchers, particularly if data is required from multiple jurisdictions, had increased unnecessarily thereby reducing the amount of public funds directed to actual research and/or preventing certain types of research from occurring;
- the ability of researchers to obtain a more randomly selected and/or larger sample were restricted, thereby adding to standards of error in sample estimates; and
- the ability of researchers to undertake data linkage or matching were unduly restricted (NHMRC 2004b, 2005d).

Some examples of these impacts are given in box 5.5.

Box 5.5 Examples of how privacy regulation affects medical research

Added compliance costs for researchers

A primary health care research evaluation and development research fellowship in the University of Melbourne undertook research which involved mailing a survey to Victorian general practitioners (GPs). The Health Insurance Commission (HIC), an Australian Government public sector agency that collects GP data, provides representative datasets of randomly-selected GPs. To maintain anonymity of potential respondents for this particular research, the HIC required that research materials (for example, surveys and plain language statements) be forwarded to it, from where they are remailed to respondents. The HIC further required that: research materials need to be approved (and altered if required) by its privacy department, despite prior approval from a university ethics committee; there be a limit of two reminder mail-outs (whereas usual protocols for maximising response rates require up to four mail outs); and each mail out be sent with the same HIC covering letter. Additional HIC requirements involved sending envelopes, surveys and plain language statements in bulk to Canberra (numerous times); printing HIC covering letters; and charges for ‘preparing business rules, extraction specifications, project manage processes to completion …’. These requirements, imposed by the HIC to comply with the Privacy Act, increased costs (including adding four weeks in compliance time).

Smaller sample populations

The Vaccine and Immunisation Research Group within the University of Melbourne conducts community-based vaccine trials. It attempted to use school enrolment lists to mail information to parents about a study. Despite approval from the Royal Children’s Hospital human research ethics committee, one major governing body of Victorian public schools rejected the proposal on privacy grounds, as did several independent schools. The main concern expressed was that the use of this information for health research was not related to the primary purposes of collection, and families had not consented to this use. Only a small number of schools raised no privacy concerns at all. The Group claimed that the net result was substantially reduced access to the population eligible for recruitment.

Sources: Brice and Priotta (2006); O’Grady and Nolan (2004).

In countering these concerns, particularly in relation to medical research, the Australian Government Office of the Privacy Commissioner considered that strong privacy provisions are essential for sustaining the community confidence needed to make medical research viable. Referring to the Privacy Act, for which it had administrative responsibility, the Office said:

> The Privacy Act, by placing controls on the flow of health information, provides a structure to support individual’s confidence in how their information will be handled. Far from obstructing research, the Privacy Act provides a valuable control on the flow of information, helping to support its long-term viability. (sub. 63, pp. 7–8)

In support of this view, the Office referred to research that it and others had conducted which showed that many individuals were sensitive about the use of their health information. Of its own research, it noted that:

- 21 per cent of respondents reported a reluctance to provide their medical history or health information to any organisation and 11 per cent reported a reluctance to provide genetic information; and
- 64 per cent of respondents considered that their permission should be sought before de-identified information is used for health research purposes.

Several options have been raised in recent government reviews (such as that by the Senate Legal and Constitutional References Committee in 2005 on the Privacy Act, the Office of the Privacy Commissioner in 2004 on private sector provisions of the Privacy Act, and the Australian Law Reform Commission in 2003 on human genetic information) as well as by the NHMRC, to improve the application of privacy regulation to health information and medical research. Many of these proposals have focused on improving national consistency, improving consistency between public and private sectors, and removing significant barriers to the conduct of medical research.

One option proposed is a national privacy regime governing health information and medical research alone. This could involve:

- the adoption by governments of template legislation (such as the draft National Health Privacy Code prepared for the Australian Health Ministers' Advisory Council — box 5.6); or
- the Australian Government enacting a single piece of legislation with national effect under a constitutional head of power.

Box 5.6 **Draft National Health Privacy Code**

The draft Code was first prepared in 2002 by a working group of the Australian Health Ministers' Advisory Council (which in turn reports to the Australian Health Ministers' Conference). Among other things, the Code seeks to achieve national consistency in the handling of health information between the public and private sectors. A revised version of the Code, draft mandatory guidelines for research, and draft explanatory notes for the use or disclosure of genetic information were considered by Health Ministers in late 2004. However, since then, no further progress in implementation has been made.

A second option that has been proposed is to enact specific changes within the Privacy Act including:

- combining the information privacy principles and national privacy principles into a single set of privacy principles that apply to all relevant public sector agencies and private sector organisations;
- removing distinctions between different types of research;
- clarifying what is meant by 'impracticality of consent';
- providing for a single set of guidelines that apply to the collection, use and disclosure of health information without consent for the specific purpose of medical research by public sector agencies and private sector organisations; and
- simplifying the reporting arrangements applying to human research ethics committees.

In assessing such options there is a need to take account of several factors. One is ensuring that the balance between protecting individual privacy — which is the primary purpose of the regulation — and using personal information for the benefit of others, including medical research, is appropriate.

A second factor is the wide reach of privacy regulation. The Privacy Act, for example, governs activities other than health information and medical research such as consumer credit reporting, the administration of personal tax file numbers, law enforcement, and information sharing during overseas emergency situations. Care is needed, therefore, that any specific options under the Act relating to health information and medical research do not perversely affect other areas of the Act.

A final factor to take account of is the constitutional division of powers, with the States and Territories primarily responsible for health matters. Any options involving national consistency in the application of privacy regulation to health information and medical research are likely to involve complex negotiations between the Australian Government and the States and Territories regarding implementation. This would be the case whether negotiations concerned the adoption of template legislation or the referral of power to the Australian Government to enact uniform legislation.

It is anticipated that these options, and the concerns driving them, will be comprehensively considered by the Australian Law Reform Commission in its current review of the Privacy Act (for example, see its recently released issues paper — ALRC 2006). The terms of reference require it to address, among other things, Australian Government, State and Territory practices, the need of individuals for privacy protection in an 'evolving' technological environment, and the desirability of minimising regulatory burden on business. It is expected to report in March 2008.

In the meantime, there would be merit in governments through the Australian Health Ministers' Conference progressing national consistency in privacy regulation governing health information as a matter of priority. It would help reduce complexity and thus mitigate adverse impacts on health and medical research. Nationally consistent provisions should seek to be as cost-effective as possible.

5.6 Ethical review of health and medical research

A framework of research governance, including ethical review, is one in which 'institutions are accountable for the scientific quality, ethical acceptability and safety of the research they sponsor or permit' (Walsh et al. 2005, p. 468). In Australia, it consists primarily of a series of NHMRC guidelines issued under the *NHMRC Act 1992*, where compliance is a condition for research funding (NHMRC 2000, 2001). In addition, there are legislation, other guidelines and codes of conduct relating to such matters as privacy, confidentiality, consent, biosafety, professional standards and radiation safety.

The key NHMRC guidelines are the National Statement on Ethical Conduct in Research Involving Humans (the National Statement) — a central feature of which are provisions requiring the establishment of human research ethics committees (HRECs) (box 5.7) — and the Joint Statement and Guidelines on Research Practice (the Joint Statement) (box 5.8). Both are currently being reviewed by the NHMRC, the ARC and the AVCC with consultation drafts being released. The joint nature of these reviews implies that the guidelines will eventually cover a much wider field than just health and medical research.

Participant concerns have been expressed about ethical review processes particularly in relation to clinical trials. Research Australia, for example, was of the view that complex ethical approvals processes were hampering such trials (sub. 33, p. 5). Many of the concerns of its members related to the performance of individual HRECs as well as to difficulties in obtaining ethical approval for multi-centre research (sub. 102).

The performance of HRECs

The National Statement sets out provisions for the establishment and role of HRECs. A central provision is that research proposals must be reviewed and approved by HRECs, which are established by institutions to provide advice regarding ethical approval of research projects. Other provisions go to such matters as the composition of an HREC, appointment of members, working procedures, recording of decisions, monitoring, complaints mechanisms, and compliance reporting to the NHMRC. There are over 200 HRECs of which about 60 per cent are in health care institutions. Membership is by volunteers drawn from the community or research institution.

Participant concerns about the performance of individual HRECs largely focused on the delays experienced in obtaining ethical approval. A study sponsored by Merck, Sharp and Dohme (Australia) found that the average HREC approval cycle time in Australia based on a review of 18 protocols was 78 days compared with 44 days in New Zealand (sub. 102, p. 3). Dr Maccarrone of GlaxoSmithKline noted the following instances of delays:

- One study with a diabetes drug took over eight months to gain approval at one centre in contrast to best practice of two months.
- One study in a hospital took six months to be cleared by the hospital's legal advisors (which had nothing to do with the science or ethics of the clinical trial).
- An Alzhiemer's disease study at a hospital will be delayed by a further two/three months due to relocation of the ethics committee office.
- A study in overactive bladder disease in women is still awaiting approval after eight months. (sub. 102, p. 5)

Box 5.7 National Statement on Ethical Conduct in Research

The National Statement seeks primarily to protect the 'welfare and rights of participants in research'. It sets out:

- principles of ethical conduct that institutions and researchers must have towards participants of research. These principles reflect basic ethical values of integrity, respect for persons, beneficence and justice. These are incorporated in provisions on consent, research merit and safety, as well as ethical review and conduct of research;
- provisions relating to the establishment and role of human research ethics committees (HRECs).
- provisions relating to different types of research such as multi-centre research; research involving particular types or groups of people (such as children and young people, persons with an intellectual or mental impairment; and Aboriginal and Torres Strait Islander peoples); research involving the use of particular technologies (ionising radiation and assisted reproductive technology); clinical trials; innovative therapy or intervention; epidemiological research; the use of human tissue samples; human genetic research; and privacy.

Source: NHMRC (1999); Walsh et al. (2005).

Box 5.8 Joint Statement and Guidelines on Research Practice

The Joint Statement seeks to ensure the quality and integrity of research such as to maintain the community's confidence in the research findings, the reputation of researchers and research institutions, and the safety of all those associated with the research.

It sets out a number of general principles as well as specific provisions covering such matters as data storage and retention, authorship, publication, supervision of students and research trainees, conflicts of interest and research misconduct.

The general principles are that:

- Institutions must establish procedures and guidelines on 'good research practice' and on steps to be followed if suspicions or allegations exist regarding research misconduct.
- Institutions must establish and maintain practices and policies which promote the 'highest possible' standards and discourage misconduct and fraud. These policies should encourage the open presentation and discussion of results via peer review.
- Institutions must have 'clearly formulated' policies on the maintenance of records, retention of data, publications and authorship, management of intellectual property, research training (where appropriate), confidentiality and conflict of interest.
- Researchers have an obligation to achieve and maintain the 'highest' standard of intellectual honesty in the conduct of their research.
- Researchers must be aware of and adhere to ethical principles of justice and veracity and of respect for people and their privacy and avoidance of harm to them, as well as respect for non-human subjects of research.
- Where research procedures are of a kind requiring approval by a human or animal experimentation ethics committee, or by other safety or validly constituted regulatory committees, research must not proceed without such approval.
- Institutions should ensure that a person with appropriate authority is responsible for monitoring the observance of the guidelines.

Source: NHMRC and AVCC (1997).

Factors affecting the speed in which HRECs are able to make decisions were said to include:

- slow HREC administrative processes;
- required 'sign offs' from other departments in an institution (for example, pathology, radiology and pharmacy departments in a hospital);
- referral of contracts and indemnity agreements to lawyers with little experience of clinical trials; and

- the need to resolve issues arising from the content of patient information and consent forms (such as patient compensation, privacy and risk) (for example, Dr Bootes of Roche Products, Merck Sharp and Dohme (Australia), Dr Davies of George Institute, and Prof. Horne of Howard Florey Institute, sub. 102).

In addition, concerns were expressed about the burden placed on researchers in making submissions to HRECs including the 'cumbersome and lengthy ethics submission forms' (for example, Dr Bootes of Roche Products, sub. 102, p. 5).

The approach that some institutions take to establishing and resourcing their HRECs can prevent them from performing their role effectively. It has been said, for example, that:

- HRECs are overloaded, under-resourced and insufficiently skilled;
- HRECs are lacking in accountability and transparency;
- HRECs' capacity to monitor research is minimal;
- most institutions provide minimal orientation or training for new HREC members; and
- many institutions have come to rely too heavily on HRECs to do tasks beyond ethical review for which they are not well equipped (NHMRC 2005b, pp. 8–9; Walsh et al. 2005, p. 469).

Poor performance by HRECs in undertaking ethical review can undermine the primary objectives of the NHMRC's guidelines. Moreover, it can impede the way in which research involving humans proceeds.

Some options for improving upon the current research governance framework, including improving the performance of HRECs, were put forward in an NHMRC discussion paper (2005b):

- promoting a wider appreciation and understanding amongst institutions and researchers of the existing research governance framework;
- embodying the current obligation on institutions to comply with the National Statement on Ethical Conduct in a deed of agreement (or memorandum of understanding);
- basing the reporting or auditing process around the entire institution and not just on HRECs;
- using the deed of agreement as a 'pathway for assuring sensible provisions' for the review of multi-centre research proposals;

- being proactive in setting standards, encouraging the development of educational services and providing education on research ethics and methods for researchers and for HREC members; and
- fostering openness of HRECs (by permitting observers) (pp. 16 – 17).

The current joint reviews of the NHMRC guidelines present a good opportunity to consider these options further.

Multi-centre research

The National Statement contains provisions relating to the ethical review of multi-centre research (which includes a research project conducted at more than one institution such as a clinical drug trial) with a view to minimising 'unnecessary duplication' and facilitating 'prompt and efficient consideration'. It encourages HRECs to ascertain whether the same research proposal has been reviewed by another HREC, including reviews conducted overseas. In particular, an HREC may:

- communicate with, and give advice to or receive advice from, any other HREC;
- accept a scientific/technical assessment of the research by another institution or organisation;
- review and, where the same research project is conducted at two or more institutions or organisations, adopt the reasons for ethical approval or disapproval of another HREC in reaching its own decision; or
- adopt other administrative procedures to accelerate timely consideration and avoid unnecessary duplication.

In practice, however, the National Statement's provisions have not been as effectively implemented by institutions and HRECs as initially intended. The Victorian Government noted that 'multi-site trials' face a 'slow and complex' ethical review and approval process, involving several HRECs (sub. 84, p. 57). Also Dr Maccarrone of GlaxoSmithKline noted that:

> The current ethical review process for multi-centre trials can be slow, resource intensive (both internally and externally), inefficient and costly. There is a wide range of variance in speed (and quality) of review of clinical trials by ethics committees. The duplication of effort (wastage) is also considerable. Administrative issues and resourcing is often the reason for delay; and not questions related to the scientific and ethical appropriateness of multi-centre trials. (sub. 102, p. 4)

Box 5.9 provides an example of the challenges faced by researchers in obtaining ethical approval of a multi-centre project.

Streamlining ethical review by HRECs, which is catered for under the National Statement, can help to overturn these problems and reduce compliance costs for researchers. Such streamlining need not require rationalisation in the number of HRECs. It could involve a system of mutual recognition of ethical approval, whereby the approval of one HREC is capable of being recognised by others. Or it could involve a group of HRECs agreeing to nominate one to undertake the review. One participant suggested mutual recognition could extend to approvals by North American and European ethics committees (Prof. Hartman, University of Western Australia, sub. 102, p. 1).

Box 5.9 An example of the problems of obtaining ethical approval of a multi-centre project

A multi-centre project in New South Wales was being conducted on the outcomes of hypertensive pregnancies in a cohort of 1620 women. The project was to be a retrospective review of medical records and did not require the participation of the women. Ethics approval was sought and gained from the New South Wales Department and one other area health service involved in the study. The bulk of the medical records (85 per cent) were held by this area health service and a smaller proportion by eight others. The process of gaining ethics approval from the eight area health services was ‘fraught with obstacles’ at every stage. After eight months work, approval was finally received from the HREC of each area health service. The table illustrates differences between the area health services in their approach to considering the project.

	Area health service							
	S	*T*	*U*	*V*	*W*	*X*	*Y*	*Z*
No. of pages of application form	19	20	19	20	12	23	2	11
No. of copies of form required	1	1	17	15	20	16	1	14
No. of hospitals in area health service covered by approval	2	2	4	1	3	5	3	5
Whether approval covered private hospitals	na	na	Yes	No	No	na	No	na
No. of contacts (letter, email, phone) made to gain approval	20	15	20	15	20	30	10	20
Time taken to gain approval	3 months	5 months	4.5 months	8 weeks	6 weeks	6 weeks	1 week	3 weeks
Approved after first submission	Yes	No	No	Yes	Yes	Yes	Yes	Yes

na not applicable

Source: Roberts et al. (2004).

Although the application of such approaches is by no means widespread nor without difficulties (for example, it has been suggested that mutual recognition of ethical approval may make it difficult for some institutions to obtain insurance and medical indemnity for clinical trials), there are signs of progress. Prof. Rosenthal of the Royal Melbourne Hospital noted that a Mutual Acceptance Program applies to Cancer Trials Australia sites where a standard primary site review is mutually accepted by the HRECs of the other sites (sub. 102, p. 8).

Also some State and Territory health agencies, notably in New South Wales, Victoria and Queensland, have examined the scope for streamlining their ethical review processes. In New South Wales, for example, a model of single ethical review is being considered by NSW Health whereby a multi-centre research project is reviewed by a lead HREC, representing existing HRECs, which is then recognised throughout NSW Health.

The issue of a national approach by health agencies towards the ethical review of multi-centre research was considered by the Australian Health Ministers' Advisory Council in June 2005. The Council agreed to form a working group to develop a report on achieving a streamlined approach, while having regard to the initiatives of individual jurisdictions (NSW Health 2005, p. 2). It is understood that a report was prepared for Council's October 2006 meeting. This issue in turn will need to be considered by the Australian Health Ministers' Conference.

The efforts of Australian Health Ministers to achieve a national approach should not deter individual jurisdictions from streamlining their own ethical approvals processes as expeditiously as possible. That said, a national approach would reduce the compliance costs of researchers seeking ethical review for multi-centre research across jurisdictions.

5.7 Scientific publishing

The importance of scientific publications (such as journals, monographs and databases) to the innovation system lies in their role in disseminating and providing access to knowledge and, thus, in turn, on contributing to the stock of knowledge and economic wellbeing. As the OECD (2005a) noted:

> Scientific publishing is an important mechanism for providing dissemination and access to a wide range of scientific, technical, medical, economic and social information. Scientific publishing also plays an important role in making research more efficient. … Dissemination of findings helps other researchers define their research work, minimises duplicative activities and may provide data which might otherwise have been collected again. Moreover, as an evolving process of building on findings, rapid publication and dissemination help to accelerate the advancement of science and, thereby, economic development. (p. 17)

There has been considerable interest in recent years, internationally and in Australia, amongst government agencies, universities and other organisations in enhancing access to the results of publicly-funded research. This has been prompted, in part, by the high and increasing cost of scientific publications and changes to ITC including the use of the Internet over the last decade. This issue is similar to that of open source discussed earlier in relation to IP rights

The OECD Committee for Science and Technology Policy adopted a Declaration on Access to Research Data from Public Funding in January 2004, which sets out members' commitment to the establishment of 'open access' regimes for digital research data from public funding in accordance with specific objectives and principles such as openness, transparency, legal conformity and the like. A working group has since been exploring commonly agreed principles and guidelines.

The Australian Government has sought to enhance access to the results of publicly funded research through the:

- development of an Accessibility Framework for Publicly Funded Research; and
- allocation of funding under the Systemic Infrastructure Initiative to build technical information infrastructure that supports the creation, dissemination of and access to knowledge, and the use of digital assets and their management (box 5.10).

Box 5.10 **Australian Government actions to enhance access to the results of publicly-funded research**

Accessibility Framework

One aspect of Backing Australia's Ability — Building our Future through Science and Innovation — announced in May 2004 is the establishment of Quality and Accessibility Frameworks for Publicly Funded Research. (The Research Quality Framework has been considered elsewhere in this study.)

The Accessibility Framework will be an agreed system-wide approach for managing research outputs and infrastructure so that 'they are discoverable, accessible and shareable', in order to improve the quality of research outcomes, reduce duplication and better manage research activities and reporting. It is currently being developed by DEST in consultation with universities and publicly-funded research agencies.

Issues that the Framework is seeking to address include:

- common standards and protocols for storing, curating, cataloguing and disseminating information;

(Continued next page)

Box 5.10 **(continued)**

- technology infrastructure capable of supporting rapid access to information and facilities;
- a regulatory environment that both enables and encourages the population of repositories and information sharing; and

Systemic Infrastructure Initiative projects

The Australian Government has given $12 million in funding to universities and institutes — under the Backing Australia's Ability – An Innovation Action Plan for the Future 2001 — for projects to build technical information infrastructure that supports the creation of, dissemination of, and access to knowledge, and the use of digital assets and their management.

Four major projects are the:

- Australian Partnership for Sustainable Repositories, which establishes a centre of excellence for the management of digital collections;
- Australian Digital Thesis Program Expansion and Redevelopment, which creates a national collaborative distributed database of digitised theses produced at Australian universities;
- Meta Access Management System, which supports the development of prototype middleware/common technical services to enhance national research effectiveness; and
- Australian Research Repositories Online to the World, which identifies and tests software solutions to support best practice institutional digital repositories comprising e-prints, digital theses and electronic publishing.

Source: DEST (2006a).

In a recent report to DEST, Houghton et al. (2006) estimated net gains from improving access to publicly-funded research across the board and in particular research sectors (table 5.2).

- The estimated benefits from an assumed 5 per cent increase in access and efficiency and level of social rate of return were between $2 million (ARC competitively-funded research) and $628 million (gross expenditure on R&D).
- Assuming a move from this level of improved access and efficiency to a national system of institutional repositories in Australia over twenty years, the estimated benefit–cost ratios were between 3.1 (NHMRC-funded research) to 214 (gross expenditure on R&D).

Table 5.2 **Estimated annual benefits of enhanced or open access, 2003**

Research sector	*Annual benefit of national system*	*Annual benefit of 5% increase in access and efficiency*[a]	*Benefit-cost ratio associated with move to national system*[b]
	$m	$m	
Gross expenditure on R&D	12 250	628	214
Government expenditure on R&D	5 438	139	47
Public sector expenditure on R&D	5 912	151	51
Higher education expenditure on R&D	3 430	88	30
ARC-funded research (NCGP)	481	2	4.1
NHMRC-funded research	250	9	3.1

a The social rate of return assumed for gross expenditure on R&D is 50 per cent and for other research sectors is 25 per cent. **b** These are calculated over 20 years for a full system of institutional repositories in Australia costing $10 million a year and achieving a 100 per cent self-archiving compliance.

Source: Houghton et al. (2006, table A2).

Houghton et al. suggested a range of measures to improve access to publicly funded research (box 5.11).

Of interest, is whether funding agencies themselves could become more actively involved in enhancing access to the results of the research they fund. A rationale for them to do so is that publicly-funded researchers, if left to themselves, would have little incentive to make the results of their research publicly available, such as in an ‘open access’ journal (these are typically peer-reviewed journals which are freely available online but whose costs are met by authors rather than subscribers). For example, researchers may prefer to publish through more costly and, thus, less accessible journals because they:

- generally do not bear the costs directly — subscribers do; and
- consider that their reputation and, thus, the citation impact of their research, would be enhanced.

Neither of the Australian Government’s key funding agencies, the ARC and the NHMRC, currently require researchers to make the results of their research publicly available. For example, under the ARC funding agreement for discovery projects commencing in 2006, there is only a requirement for data or specimens or samples to be lodged with an appropriate museum or archive in Australia (provision 18).

Box 5.11 **Some suggestions for improvement**

In their recent report to DEST, Houghton et al. (2006) made a number of suggestions to improve access to and dissemination of research including:

- developing a national system of institutional or enterprise-based repositories to support new modes of enquiry and research;
- encouraging higher educations and research institutions to develop enterprise-wide digital repositories for the storage, preservation, curation, access, registration and management of their intellectual property;
- ensuring that the Research Quality Framework supports and encourages the development of new, more open scholarly communication mechanisms, rather than encouraging 'a retreat' by researchers to conventional publication forms and media, and a reliance by evaluators upon traditional publication metrics (for example, by ensuring dissemination and impact are an integral part of evaluation);
- encouraging funding agencies (for example, ARC and NHMRC) to mandate that the results of their supported research be made available in open access archives and repositories;
- encouraging universities and research institutions to support the development of new, more open scholarly communication mechanisms, through, for example, the development of 'hard or soft open access' mandates for their supported research; and
- providing support for a structured advocacy program to raise awareness and inform all stakeholders about the potential benefits of more open scholarly communication alternatives, and provide leadership in such areas as copyright (for example, by encouraging use of 'creative commons' licensing) (pp. xii-xiii).

In contrast, funding agencies in the United States and the United Kingdom are encouraging access to the results of publicly funded research.

- The US National Science Foundation makes it a general condition of its grant that the grantee is responsible for assuring that the cognisant program officer is provided access to, either electronically or in paper form, a copy of every publication of material based on or developed under the grant promptly after publication.
- The US National Institutes of Health (NIH) have a Policy on Enhancing Public Access to Archived Publications Resulting from NIH-Funded Research, which took effect in May 2005. The Policy 'requests and strongly encourages' all researchers to make their NIH-funded, peer-reviewed, authors' final manuscript available to other researchers and the public through PubMed Central, which is an open access repository operated by the National Library of Medicine.

- The UK Medical Research Council (MRC) requires from 1 October 2006 that, for new funding grants, any research papers supported in whole or part by MRC funding should be subject to open access (box 5.12).

Given this international precedence, there appears to be scope for the ARC and the NHMRC to play a more active role than they currently do in promoting accessibility to the results of research they fund, such as through their funding conditions. However, they would need to define what satisfies accessibility including identifying suitable open access repositories. This identification could link to the work currently done by the Australian Government on the Accessibility Framework and under the Systemic Infrastructure Initiatives.

Box 5.12 **UK Medical Research Council guidance on open and unrestricted access to published research**

- From 1 October 2006, the UK Medical Research Council will require that, for new funding awards, electronic copies of any research papers that have been accepted for publication in a peer-reviewed journal and are supported in whole or in part by MRC funding are deposited at the earliest opportunity — and certainly within six months — in PubMed Central. When UK PubMed Central is established, the requirement will be to deposit papers in that repository.
- This applies to all award holders, including MRC staff.
- Deposition of a research paper into PubMed Central (or UK PubMed Central) does not prevent authors from also depositing a copy in their own institutional or another subject-based repository should they choose to do so or be required to do so by their employing institution.
- The MRC also encourages, but does not formally oblige, all award holders and MRC staff to ensure the deposition of articles arising from grants awarded as a result of applications before 1 October 2006.
- The MRC strongly encourages authors to publish in journals that allow them (or their institutions) to retain ownership of the copyright. Requests for ‘author pay’ charges associated with publishing may be included in applications for MRC funding.
- If author/institution ownership of copyright is not permitted by the publisher, authors should publish in journals that permit deposition of the published paper in PubMed Central/UK PubMed Central within six months of publication. If a researcher wishes to publish a paper in a journal that is unwilling to agree either to author/institution-ownership of copyright, or to deposition in PubMed Central/UK PubMed Central within six months, the MRC may, in very exceptional cases, grant permission for authors to submit the paper for publication in such a journal. This position will be reviewed in 2008.

(Continued next page)

Box 5.12 **(continued)**

- The MRC will work with publishers to put in place mechanisms for publishers to deposit publications directly, on behalf of authors, where this is possible.
- The MRC's grant conditions will be amended to reflect the above changes.
- From 1 January 2006, all applicants submitting funding proposals to the MRC are 'expected' to include a statement explaining their strategy for data preservation and sharing. MRC Data Sharing policy indicates that, where possible, published results should provide links to the associated data.

Source: MRC (2006).

DRAFT FINDING 5.1

Several impediments to innovation should be addressed:

- *major publicly funded research infrastructure should be priced to maximise utilisation, while avoiding congestion;*
- *there should be national consistency in the application of privacy regulation and in ethical review of multi-centre research;*
- *published papers and data from ARC and NHMRC-funded projects should be freely and publicly available; and*
- *there should be greater flexibility in pay structures for teachers to help address science and maths teacher shortages.*

6 Commercialisation and utilisation

Key points

- There is often a degree of pessimism about Australia's commercialisation performance. However, Australia's economic performance over the last fifteen years suggests that such concerns may be overstated.
- Australia's commercialisation performance should not be seen as dependent on growing any particular set of knowledge-intensive industries or transformational high-tech firms. Australia's success in commercialising knowledge and technology is often in areas that are close to its traditional comparative advantages in the mining and agricultural sectors.
- There is a wide range of perceived obstacles to commercialisation, such as: size and distance; financing; incentives within universities; cultural barriers; a lack of effective linkages between research organisations and firms; intellectual property management; and skill shortages.
  – Some of these apparent impediments do not provide a compelling basis for intervention. Governments are generally already taking steps where needed.
- One possible exception is addressing the impediments within universities that constrain the transfer, diffusion and utilisation of knowledge and technology.
  – Flexible arrangements should be developed to allow universities to draw on the commercial expertise they need in the most efficient and cost-effective way.
  – There may be a case for providing universities with some additional funding to support knowledge transfer to non-academic communities. However, there is a number of options for supporting such transfer that do not involve a new dedicated funding stream.
- Ultimately, in terms of community wellbeing, it is the transfer, diffusion and utilisation of knowledge and technology that matters. Commercialisation is only one of the pathways along which this can occur.
- The Commission does not support increasing the level of public support for business commercialisation.
  – Generally, there is not a strong case for government intervention on public good grounds.
  – It is not the role of government to 'de-risk' highly risky commercial ventures.
  – Governments may end up subsidising projects with poor commercial prospects.

There is a perception that Australia is not good at exploiting the commercial potential of the knowledge and technology it generates and, consequently, is missing out on opportunities to create wealth and prosperity. This has led to calls for governments to address potential impediments to commercialisation and increase the level of support for business commercialisation.

This chapter critically assesses the view that Australia's commercialisation performance is poor. It then analyses the factors that are commonly identified as impediments to commercialisation. Based on this analysis, the chapter canvasses some practical steps that could be taken to improve the transfer, diffusion and utilisation of research undertaken by universities. Finally, it considers the case for providing increased public support for business commercialisation.

6.1 What is commercialisation?

Commercialisation is the process of transforming knowledge and technology into marketable products, services or processes. It is a subset of the broader innovation system, being one of the pathways along which knowledge can be developed into some form of practical application. The commercialisation process is usually characterised as being expensive relative to any initial investment in research, complex and inherently risky.

Consistent with the approach to innovation outlined in chapter 1, the Commission has adopted a broad definition of commercialisation, one that encompasses the commercial benefits arising from R&D and the adoption, integration and adaptation of existing knowledge and technology. Fundamental to the concept of commercialisation is the notion of firms and others utilising intellectual property to create additional value, where value is ultimately determined by the market. A focus only on research commercialisation (particularly the commercialisation of transformational 'breakthroughs') runs the risk of failing to recognise the importance of firms and others creating value by utilising existing knowledge and technology to make incremental improvements to products, services or processes. From the community's perspective, both are potentially important sources of increased wealth and prosperity. Ms Catherine Livingstone, in her submission noted:

> Australia has tended to have a science-centric view of innovation and one which has emphasised transformational or breakthrough innovation, often diminishing the importance of incremental innovation. This has resulted in a technology push model of innovation tending to predominate and a view that Australia is not good at commercialisation. (sub. 56, pp. 6-7)

The factors that are commonly identified as necessary for successful commercialisation include: demanding customers; centres of academic excellence; entrepreneurship (including the ability to match new products, services or processes with market opportunities); effective linkages between researchers and firms; adequate capital; the protection of intellectual property; integration into value chains (networks of research organisations, manufacturers, service providers and customers); access to the infrastructure necessary for experimental product development; an adequate supply of skilled labour; and a supportive regulatory environment (that is, one that does not impose high transaction costs or unnecessarily slows the process of taking new products, services or processes to market).

6.2 What is the perceived problem?

There is a perception that Australia is not good at commercialising the intellectual property it generates and fails to fully capture the economic and social benefits from its investment in science and innovation. Such concerns are often expressed in relation to product innovation — in particular, a perceived failure to harness Australian research to make new or improved products that could be sold to the rest of the world. From this perspective, the sale of Australian intellectual property overseas is sometimes seen as a 'lost opportunity' rather than as a mark of success.

William Ferris AO (2001), a former chairman of the Australian Trade Commission (Austrade) has observed:

> There has been a proud tradition of self-sufficiency, one bred out of the necessities of Australia's time and distance from the rest of the world. However, Australians have demonstrated a less remarkable record of commercialisation, that is, of profitably bringing such innovations into the market place, and especially into world markets. (p. 47)

An article that appeared in the 2004 innovation issue of the *Business Review Weekly* likened Australia's innovation system to a 'leaky pipeline' and argued there is a need to 'shore up' the commercialisation end of the innovation process:

> If Australia is a nation of inventors, it is not adept at reaping the rewards. Fewer than 5% of inventions ever make it to market, and fewer still are selling after five years. This need not be cause for concern: many deserve to fail. But some great ideas never get to market because of Australia's poor commercialisation processes. (Gome 2004)

Seemingly adding weight to this view are apparent examples of Australian breakthroughs that were commercialised overseas. These include the black-box flight recorder, the ice maker, xerography (the forerunner of the Xerox copy), X-ray crystallography, atomic absorption spectrophotometry, and microsurgery (Ferris 2001, p. 47).

Typically, commentators explain Australia's alleged poor commercialisation performance by pointing to a wide range of potential impediments (see section 6.4). As a result there are calls for government to:

- improve the commercialisation of publicly funded research; and
- increase the level of support provided to firms attempting to commercialise intellectual property.

Australia's alleged poor commercialisation performance is often seen as having significant implications for the community's wellbeing through weaker innovation capabilities and long run economic growth.

6.3 What does the evidence show?

Given such concerns it is timely to consider the evidence on how well Australia is performing in terms of utilising knowledge and technology to create wealth and prosperity. Evidence of the commercialisation performance of firms and of public sector research agencies and universities is considered.

Commercialisation performance of firms

Over the last decade and a half Australian firms have responded to stronger incentives to develop better products and services and find better ways of doing things. The details of Australia's improved economic performance, and the productivity surge that underpinned it, have been well documented (for example, Parham 2002 and Banks 2003). As a result, living standards have steadily improved and now surpass all G7 countries except the United States (OECD 2006d).

The influence of economic reform

Microeconomic reforms have been an important driver of Australia's improved economic performance (for example, Parham 2002). One way microeconomic reform has influenced commercialisation is by increasing competitive pressures in the economy (for example, through reductions in tariffs and the national competition policy reforms). Increased competition has sharpened incentives for Australian firms to look for ways to reduce costs, grow markets, and improve their competitiveness and productivity over time (Bassanini et al. 2000).

The fact that this process of reform has not elicited the creation of and rapid growth in any particular set of 'knowledge-intensive' industries should not be seen as diminishing the success of Australian firms in commercialising knowledge in other ways. Microeconomic reform, if anything, has more strongly revealed where Australia's present industry advantages lie, in particular, a strongly growing and innovative service sector backed by advantages in traditional resource endowments.

Some evidence of this success has been the rapid uptake and utilisation of information and communications technologies (ICT). The Commission's research suggests that compared with their overseas counterparts, Australian firms have been particularly active in their uptake of ICT and successful in their efforts to turn it to productive advantage such as by developing and introducing new value-adding and efficiency-enhancing products, processes and organisational structures (PC 2004).

Further evidence is provided by a recent study that analyses data from the 2003 ABS Innovation Survey (Trewin and Paterson 2006). The study was undertaken jointly by the ABS and DITR and seeks to provide a broad overview of the main patterns of innovation in Australian businesses, the general characteristics of innovators and an analysis of expenditure on innovation. The report found that 35 per cent of Australian businesses had introduced new goods and/or services; operational and/or organisational/managerial processes. Moreover, the study found that this activity is occurring across the economy rather than being confined to particular sectors.

In terms of 'novelty' the study suggests that for goods or service innovation, the highest degree of novelty of innovating businesses was new to the *business* product innovation (56 per cent), with only 9 per cent engaged in new to the world activities (p. 17). Similarly, in terms of operational process innovation, very few businesses are introducing new to the world processes (about 3 per cent), and 75 per cent of innovators were focusing on new to the business activities (p. 18). As the authors acknowledge, this pattern is not unique to Australia, with a strong emphasis on 'new to the business' innovation appearing to be a general characteristic of innovation at the global level.

This picture is consistent with Australian firms responding to stronger incentives to commercialise knowledge and technology in order to narrow the gap with the international productivity frontier largely through incremental improvements to products, services and processes. As Ms Catherine Livingstone observed in her submission:

> What Australia has repeatedly demonstrated is its world class capability as a technology integrator. That is, an ability to combine early stage technologies, domestically developed and/or acquired internationally, using innovative design

> approaches, to produce competitive product/service bundles which command a value added premium in the market place. (sub. 56, p. 2)

The influence of the commodity-led terms of trade boom

It is also clear that Australia has significantly benefited in recent years from the commodity-led terms of trade boom, the likes of which has not been seen since the early 1970s. This favourable shock is largely a consequence of big rises in the price of some of Australia's mineral exports, such as iron ore and coal. A rise in the terms of trade is an increase in a country's real income (in the sense of being able to purchase a larger quantity of imports for a given quantity of exports). The Reserve Bank has estimated that, on average, the rise in Australia's terms of trade increased our real income by an amount equivalent to about 1 ½ percentage points of GDP in each of the two years prior to June 2005 (Macfarlane 2005, p. 3).

However, from a commercialisation perspective there is much more to the success of the Australian mining industry than the recent surge in international demand for some of our key mineral exports. Over time the Australian mining industry has built up a competitive advantage by applying leading edge technologies, which have improved mining practices, reduced costs and increased productivity (Tedesco and Curtotti 2005, p. 5). This illustrates an important general point — namely, that Australia's success in commercialising knowledge and technology is often in industries that are not popularly thought of as being high-technology. Other examples are to be found in Australia's agricultural sector, including aquaculture and the wine industry. The Winemakers Federation of Australia noted that:

> Wine industry research is in general characterised by a large number of small improvements aimed at reducing cost through either improved management practices in the vineyard and/or winery, minimising problems in viticulture and oenology and/or improving the cost per quality unit ratio. (sub. 14, p. 5)

The Australian manufacturing sector

Concerns about Australia's commercialisation performance are often focused on the manufacturing sector and draw attention to the relative decline of the sector, a relatively small and shallow base of high-tech manufacturing industries, high profile examples of Australian breakthroughs that were successfully commercialised overseas, and the failure to create a 'transformational' high-tech manufacturing firm of the likes of Finland's Nokia.

While it is true the Australian manufacturing sector has declined in relative terms, this trend is a common feature of higher income countries. Despite this, the sector continues to play a major role in the Australian economy in terms of output and employment, and as the dominant source of technological innovation in the business sector (PC 2003b). Further, manufacturing is a heterogeneous sector with a number of high growth niches — for example, manufacturing activities linked to Australia's natural endowments and products that are differentiated, and those with higher skill levels and R&D intensities (including medicinal and pharmaceutical goods, and scientific and medical equipment). The sector has also become increasingly globally oriented.

In its submission, the Australian Electrical and Electronic Manufacturers' Association (AEEMA) emphasised there are many positive dimensions to the recent performance of Australia's manufacturing sector and new opportunities are emerging. For example, AEEMA observed that:

> Australia, with its comparative advantages of a solid R&D capability base (particularly in the areas of new and advanced materials), its well educated skills base, its excellent research infrastructure (e.g. the Australian Synchrotron) can be viewed in a more favourable light in the emerging area of 'minimal manufacturing'. In addition, Australian designers are innovative and creative, and our engineers excel at technology integration; our contract electronics manufacturers are agile and globally competitive in small volume, complex product systems. (sub. 51, p. 10)

The performance of the Australian manufacturing sector has to be seen in the context of an economy that has become increasingly oriented towards the service sector and generally does not enjoy a comparative advantage in manufacturing (except in particular niches). It is therefore not surprising perhaps that Australia was ranked 24th among OECD countries (2002 data) in terms of the share of value-added by technology-intensive manufactures in total gross value added, but was ranked 5th for the same measure of knowledge-intensive 'market' services (DEST 2005a).

It is also not surprising that Australian breakthroughs are sometimes commercialised overseas rather than locally, especially given the relatively small size of the Australian domestic market, Australia's distance from overseas customers, and Australia's relatively small and shallow base of high-tech manufacturing industries. Moreover, 'lost' opportunities are effectively part of an overall beneficial process of global information flows.

The Commission does not consider that the success of public policy in this area hinges on whether Australia produces a 'transformational' high-tech company, such as Nokia, or grows any particular set of knowledge-intensive manufacturing industries. As Gans and Hayes (2005) point out:

> Ultimately, policy should not be judged on whether a particular company or industry flourishes but on whether, taken as a whole, Australian firms are increasingly able to develop and commercialise innovation for global competitive advantage and as a source of prosperity for Australia going forward. (sub. 10, appendix B, p. 15)

There are some important qualifications

While the Commission sees little evidence from an economywide perspective of a problem with firms not fully exploiting knowledge and technology to add value, there are two important qualifications.

First, the aggregate picture may mask problems in particular sectors and industries. In such cases there may be scope for policymakers to address sector or industry-specific impediments to commercialisation. For example, the Australian Government has developed an action agenda for Australia's science industry (DITR and DEST 2005).[1] Amongst other things, this agenda makes a number of recommendations to address impediments within the industry such as: harmonising regulations and standards relevant to the science industry across Australian, State and Territory governments, and aligning them with relevant international standards; improving the entrepreneurial skills of the industry's company executives; and taking steps to address skills shortages.

A further example was provided by the University of New England, which highlighted the need to 'up skill' the farm workforce to take advantage of new technology (such as decision tools software).

> Based on 2001 data, 68 per cent of Australian farm-sector employers and self-employed were aged 45 and above and 27 per cent were aged 60 and above ... Given this age profile, it can be expected that without some pre-conditioning work such as extension or education, the uptake of innovations will be low. (sub. 17, p. 8)

Secondly, the aggregate picture does not indicate the extent to which Australia could be leveraging more from public investment in science and innovation.

The commercialisation performance of publicly funded research organisations

Given the relative importance of government expenditure on R&D in terms of Australia's overall R&D effort, it is not surprising that considerable attention has focused in recent years on the commercialisation performance of publicly funded research organisations (such as PSRAs and universities). In this regard, a number of recent studies have sought to measure and benchmark this performance against international performance.

[1] The science industry is defined as R&D, design, production, sale and distribution of laboratory-related goods, services and intellectual capital used for the measurement, analysis and diagnosis of physical, chemical and biological phenomena (DITR and DEST 2005, p. 9)

Attempts to measure this activity have been hampered by a lack of data. The most common metrics used are: invention disclosures, such as patent applications filed and patents issued; licences executed and income arising from licensing; and start-up companies formed. These measures only provide a partial picture of the level of commercialisation activity. Moreover; these measures do not capture the full range of commercial benefits flowing from publicly funded research. For example, they miss the benefits arising from: consultancy work carried out by researchers; theses on commercially relevant topics carried out by higher degree students; and the economic contributions made by people with research training who move into industry (DEST 2004d, p. 39).

Nevertheless, significant steps in improving the measurement of research commercialisation have been taken, including the development of the national survey of research commercialisation by DEST (building on previous work undertaken by the Australian Research Council, the National Health and Medical Research Council and CSIRO). In its submission, DEST noted that the most recent survey, covering 2003 and 2004, is due to be released in late 2006. This survey will be more comprehensive than past surveys, with DEST indicating that:

> The scope of the survey has been broadened in response to the report of the Coordinating Committee on Science and Technology's Working Group on Metrics of Commercialisation (2004), which recommended gathering data on research contracts and consultancies, as well as skills development and transfer. The Working Group also recommended a broadening of the definition of 'research commercialisation' to encompass commercial benefit in the broad sense, not merely the generation of financial returns to the research institution. (sub. 87, p. 61)

Overall, there appears to be a widespread view that while research commercialisation in Australia has improved in recent years, there is scope to leverage further commercial benefits from the work being done by publicly funded research organisations.

Sometimes the scope for leverage is seen in ambitious terms. For example, a working group convened by the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) (2001) looked at the performance of five commercialisation 'success stories' (ResMed, Cochlear, GroPep, Vision Systems and Radiata) and argued that if Australia could grow 200 to 250 more research-based companies like these over a five year period 'the prize would be around $20 billion added to our annual export earnings. Australia would be well on the way to reducing the national debt and the cost of servicing it' (2001, p. 3).

In most other instances, it is recognised that the existing commercialisation performance of publicly funded research organisations has been satisfactory, but uneven in parts. A paper commissioned by DEST from the Australian Centre for

Innovation et al. (2002) on best practice processes for university research commercialisation argued that:

> Australian universities have significantly strengthened their research commercialisation capabilities and performance in the past five years. The research-intensive universities (predominantly the Go8) display a level of performance well above the average of American universities, and approaching that of the highest performers in America and Europe. However there is great variability in performance. (p. vi)

Similarly, the Science and Innovation Mapping Task Force (2003) found that:

> While commercialisation performance in universities, government research agencies and medical research institutes has improved, it is uneven across and within these sectors. (p. 15)
>
> In the publicly funded sector … we lag behind the US and Canada in terms of US patents issued and licences executed per $US1 billion in research expenditure, but perform more comparably on start-up companies and adjusted gross income from licences. (p. 136)

In reaching these conclusions the Task Force drew heavily on data from the first national survey of research commercialisation. This survey was conducted in 2002, collecting baseline data for the year 2000, and covered universities, government research agencies and medical research institutes (MRIs). The Task Force highlighted the unevenness of commercialisation activity across the research organisations surveyed by noting that at that time, six universities accounted for 90 per cent of gross licence income by public research entities and four universities for 59 per cent of invention disclosures (Science and Innovation Mapping Task Force 2003, p. 121).

In a report commissioned by the Australian Vice-Chancellors' Committee and the Business Council of Australia, the Allen Consulting Group noted that:

> Recent studies suggest that the research commercialisation performance of Australian universities, and for that matter the CSIRO, has been improving and is in fact not too far away from the performance levels demonstrated by the top 100 US universities. The challenge, however, is to create conditions in which Australian universities research commercialisation performance can expand and potentially reach levels seen in the top 20 US universities. (2004, p. ix)

The report estimated that if Australian universities had been generating licensing revenue at the level of leading US universities in 2000 'overall licensing revenues would have been around double those that actually were accrued in that year' (p. 13).

The DITR conducted a study in 2004 of the levels of university patent protection and commercialisation for the period 1995 to 2002 (Singhe et al. 2005). The study was based on surveys and interviews with staff of university commercialisation offices. The survey accounted for 99 per cent of patents granted to Australian Universities over the period of interest. Amongst other things the study found that:

- the number of Australian patents granted to Australian universities over 1995 to 2002 shows annual fluctuations with 41 patents granted in 1995, reaching a peak of 72 in 1998, and declining to a low of 30 in 2000;
- the proportion of patents commercialised was remarkably consistent during this time, averaging 70 per cent;
- there was no evidence of the existence of a large body of unused patents within Australian universities. However, the study did not quantify the extent to which there is university R&D that has commercial potential, but is not being patented or otherwise commercialised; and
- the Group of 8 universities accounted for 89 per cent of total patents granted and 90 per cent of the commercialisation activity. (Singhe et al. 2005, p. iii)

The Commission notes that the findings from the latest national survey of research commercialisation are broadly consistent with those of earlier studies (see box 6.1). An interesting dimension of the survey is that it confirms that a relatively small number of research organisations account for the bulk of commercialisation activity. In 2002:

- three universities accounted for 48 per cent of all university disclosures; one MRI accounted for 42 per cent of all MRI disclosures; and one CRC accounted for 79 per cent of all CRC disclosures;
- six universities accounted for 64 per cent of all university Australian and United States patent applications, and three accounted for 62 per cent of all university patents issued worldwide; three MRIs accounted for 46 per cent of MRI patent applications, and three accounted for 67 per cent of MRI patents issued; four CRCs accounted for 70 per cent of CRC patent applications and two accounted for 61 per cent of CRC patents issued; and
- three universities accounted for 82 per cent of total university adjusted gross income from licences; five MRIs accounted for 88 per cent of total MRI adjusted gross income from licences; and three CRCs accounted for 87 per cent of CRC adjusted gross income from licences. (DEST 2004d, pp. 8, 9 and 19).

Box 6.1 **The national survey of research commercialisation**

In October 2004 DEST released the results of the latest national survey of research commercialisation for years 2001 and 2002. The survey is based on information provided by publicly funded research organisations in surveys commissioned by DEST and conducted on its behalf by the Australian Institute for Commercialisation. It updates and extends an earlier survey for the year 2000 which was undertaken by the Australian Research Council, the National Health and Medical Research Council and CSIRO.

Among the key messages from the survey were:

- The stock of income-yielding licences held by Australia's publicly funded research organisations has increased, as has the active stock of start-up companies formed by them and the overall value of organisations' equity holdings.
- Income earned from licences has remained reasonably steady, after taking account of a single, very large transaction reported in the 2000 survey which inflated the figure reported for that year.
- Universities earned about 59 per cent of total licence income in 2002, compared with medical research institutes (22 per cent), CSIRO (13 per cent), CRCs (5 per cent) and other publicly funded research agencies (1 per cent). Licence income as a proportion of research expenditure was higher for medical research institutes (6 per cent) than for the publicly funded research sector as a whole (1.7 per cent). A striking feature of the results is that, across all sectors and all measures used, a small number of organisations accounted for the bulk of the commercialisation activity reported.
- Employment of commercialisation and commercialisation support staff is increasing.
- The number of new invention disclosures grew between 2000 and 2002, but there were declines in the number of new patents applied for and issued.
- Overall, the international comparisons of patenting, licensing and start-up company formation activity suggests that, relative to their peers in the United States, Canada and the United Kingdom, and taking into account differences in levels of research expenditure and countries' GDP, Australia's universities:

– have fewer US patents issued to them than the United States or Canada;
– execute fewer licences than the United States, Canada and the United Kingdom;
– earn income from licences at a rate which is greater than the United Kingdom, roughly comparable to Canada but less than the United States; and
– form more start-up companies than the United States, but fewer than Canada or the United Kingdom.

These findings are subject to a range of qualifications and do not purport to capture the full range of commercial benefits flowing from publicly funded research.

Source: DEST (2004d, p. xvii)

What can we take from this picture?

These recent studies suggest that research commercialisation in Australia has improved in recent years, although the available metrics only provide, at best, a partial picture of the commercialisation performance of publicly funded research organisations. While Australia's performance still appears to be below that of some other countries (at least in terms of some measures), a doubling of revenue from commercialisation activities would still have only a small impact on research organisations' bottom lines.

An important aspect of Australia's performance in this area is that a relatively small number of publicly funded research organisations appear to dominate research commercialisation. This suggests there may be gains from improving the commercialisation performance of others, while recognising that there may be limited potential. In particular, the metrics are likely to be biased against smaller regional universities whose role in commercialisation is largely in the provision of advice and consulting services. Moreover, some degree of concentration could simply reflect performance hierarchies among Australian universities, which may be an optimal outcome.

Evidence of a performance gap says little about the net benefit to the community from governments taking steps to reduce it. Careful consideration still needs to be given to the scope for governments to improve research commercialisation and the best way of doing this, in particular, by removing or effectively dealing with any impediments.

6.4 What are the impediments to commercialisation?

Although participants generally acknowledged that governments have taken steps to facilitate and encourage commercialisation in Australia, there is a perception that obstacles remain.

However, the identification of barriers is not, of itself, sufficient to justify government intervention. Such barriers are often natural features of markets rather than market failures warranting action. For example, the ABS 2003 Innovation Survey found that major barriers were lack of customer demand for new goods or services (18 per cent of innovating businesses), high direct costs (19 per cent) and perceptions of risk by the innovator (9 per cent) (ABS 2006a, p. 22). These 'barriers' are general features of markets and are not usually seen as policy relevant.

Further, government intervention has both costs and benefits, and it is important to ensure that any policy intervention delivers a net benefit to the community. The choice of policy instrument is thus very important. In the case of many of the impediments discussed below, there is already a range of government policies and programs in place to lessen their impact. This puts an onus of proof on those seeking further government intervention to establish why these existing measures are insufficient.

The remainder of this section is structured around a discussion of the following potential impediments:

- size and distance;
- the structure of the Australian economy;
- cultural barriers;
- impediments within firms;
- impediments within universities;
- the lack of effective linkages between research organisations and firms;
- the 'innovation gap';
- intellectual property management; and
- public policy failure.

The issue of skill shortages is discussed in chapter 5.

It is also worth noting that some of the impediments discussed in this section are also relevant to the issues of research collaboration and intellectual property creation. As the National Health and Medical Research Council (NHMRC) observed, (sub. 80, p. 14), many impediments to commercialisation also affect non-commercial pathways of knowledge and technology development. And, by implication, addressing these impediments may have wider benefits.

Size and distance

Australia has a relatively small domestic market for niche manufactured goods and services and is geographically distant from major centres of knowledge creation (for example, biotechnology research centred around Boston in the United States) and overseas customers (especially markets for knowledge-intensive products and services).

The relatively small size of the Australian market is a potential barrier to firms building scale through domestic sales growth before attempting to break into international markets. This means that to be successful, some Australian firms have to be internationally focused at an early stage in their development. This is likely to expose these firms to increased risk, expense and complexity. For example, given the importance of the US market for pharmaceuticals, Australian firms developing new drugs have to focus on US Food and Drug Administration (FDA) approval processes and US patenting laws.

The Australian Academy of Technological Sciences and Engineering (ATSE) noted in its submission:

> By global standards, Australia is an affluent, but relatively small market. However, accelerating global integration is changing forever the volume and composition of international trade. To achieve international competitiveness, many Australian organisations must produce for the global market to achieve the necessary economies of scale and scope. Focusing on the domestic market not only limits growth opportunities, it can handicap competitiveness. (sub. 27, p. 2)

The Institute of Public Affairs drew attention to how the size of the Australian market and other factors influence opportunities for commercialisation in the biotechnology sector.

> While much is made of biotech applications in the medical fields, the truth is that the scope for full-scale commercialisation of biomedical product in Australia is greatly limited by the size of its market, the absence of large, local firms and barriers to overseas markets. Most local biomedical discoveries will be developed overseas particularly in the US where the market is huge, prices not regulated or capped by government and where local regulatory approval is essential to worldwide success.
>
> Australia's greatest potential lies in the application of biotechnology to agriculture and food. Here the local markets are large and there are many large firms that export to the world. In addition there is a large local research base, a body of expertise and an industry with a long track record of innovation and a need to continue innovative developments. (sub. 76, p. 8)

In recent years there has been considerable debate in the literature about the influence of geographic distance on firms' access to the resources needed for innovation (including knowledge, skilled labour and venture capital). Put simply, does distance matter?

One way distance may matter is by making it harder to establish and maintain the personal and institutional relationships that are often crucial to becoming integrated into global value chains (that is, networks of firms, research organisations, individual researchers and customers). These networks are important for the dissemination of the 'resources of innovation' (including knowledge, skilled labour and venture capital) (Rutten and Boekema 2005). However, multinational enterprises operate globally, including in Australia, by using a variety of network arrangements, including personal networks. So it is not clear how large these barriers are. In any case, these barriers do not generally constitute a strong basis for policy action.

The structure of the Australian economy

A number of structural features of the Australian economy are likely to contribute to there being a smaller pool of businesses capable of absorbing and commercialising the knowledge and technology generated by research organisations, particularly in those cases where commercialisation involves developing knowledge-intensive products, services or processes. Compared with other developed countries Australia has a relatively high proportion of small and medium sized enterprises (SMEs). This is also true of Australia's high-tech manufacturing sector (including industries such as electronics, aerospace and pharmaceuticals), which is both smaller and shallower than countries such as the United States and Japan.

In a recent study by DITR of the levels of university patent protection and commercialisation, discussions with the staff of university commercialisation offices suggested that:

> … the Australian industry structure is not conducive to take-up of university patents for commercialisation. This is mainly due to the small size of many companies, inadequate resources and the associated poor capacity to absorb university inventions. In addition, most Australian firms are low-technology based and these firms do not have adequate resources to conduct R&D and adopt new technology, especially high-technology, as part of their business growth strategy. (Singhe et al. 2005, p. 6)

The Australian Business Foundation (ABF) drew attention to two further potential structural impediments. First, Australia is one of the most dependent OECD countries on the operations of firms headquartered overseas. The ABF contended that the bulk of R&D conducted by transnational enterprises in Australia 'is focused on product modification for the Australia market, not the creation and diffusion of new knowledge' (sub. 72, p. 12). Second, in many sectors Australia has few home-grown world-class 'platform' firms (such as Nokia, Ericsson or Phillips) that are capable of 'capturing and holding the economic 'value-added' from their innovative technologies and global brands and bringing a stream of both novel products and entirely new businesses to the market' (sub 72, p. 13).

Similarly, a working group convened by PMSEIC (2005) to consider the growth of Australian technology-based SMEs argued that '… we are constrained by the limited number of Australian MNEs [multinational enterprises], which means fewer opportunities for SMEs to leverage large-company knowledge and to access international markets' (p. 77).

It is particularly important to have regard for the influence of the structure of the Australian economy on key metrics when making international comparisons. As a report by the Allen Consulting Group (2004) recently observed:

> … the relative lack of high technology industries in Australia, which do tend to be the drivers of commercialisation and university-business research collaboration in the US, is something that should be kept in mind when comparing Australian returns from the commercialisation of university research with those obtained in countries with bigger and deeper high technology industry bases. (p. 42)

In the Commission's view the structure of the Australian economy should be seen as an important factor shaping the demand-side of the commercialisation ledger rather than a constraint *per se*. While there may not always be strong local demand for the knowledge and technology generated by research organisations, the community can still benefit from the sale and licensing of intellectual property to overseas buyers.

Finally, it is important to recognise that the structure of the Australian economy is unlikely to change in the short to medium-term (see chapter 3). By diverting resources away from products with the best long-term potential to add value and prospects for growth and exports, industry creating policies can be a drain on productivity growth and living standards.

Cultural barriers

Some argue that there are various cultural traits that impede commercialisation, namely that Australians tend to be more risk averse and have a lower tolerance for failure, and do not value science, innovation and creativity as much as some other societies. For example, the Australian Research Council (ARC) (2000) has contended:

> It has been frequently observed that Australia lacks the cultural attributes of the US in providing the desire, incentives and facilitation of processes for academic researchers to generate knowledge and technology based enterprises. We do not accept readily that research and new technology based companies sometimes fail, in contrast to the American view that values failure as an important learning experience. (p. 13)

Similarly, a working group convened by PMSEIC (2002) to consider the issue of management skills for high-growth start-up companies observed that:

> … Australia needs to foster a culture that does not view business failures as personal failures rather, we need to change our perspective of failure to one that places entrepreneurs in high regard for having a go. The Working Group considers that far too many good entrepreneurial managers are lost because of one failure whereas it is not uncommon in the United States for entrepreneurial managers who have failed to come back, learn from their mistakes and ultimately be successful. (p. 11)

In its submission, the Western Australian Department of Agriculture and Food noted:

> A common view among the senior management of DAFWA was that one impediment to greater innovation was the apparent absence in Australian society of an underlying culture that greatly valued science and the creativity of innovative science. To rapidly and successfully develop leading edge innovation systems, it was felt that Australia needed to build and maintain a society that valued more, science and creativity. (sub. 44, p. 7).

Attempting to alter cultural traits that potentially impede commercialisation is difficult in the short-term but may be amenable to policy initiatives in the medium to longer-term. In this context, the Commission notes the considerable effort going into developing an awareness and appreciation of entrepreneurship and science in Australian secondary schools. There are many initiatives in this area, including the following.

- As part of *Backing Australia's Ability* the Australian Government announced it would provide $38.8 million over the seven years to 2010-11 to strengthen science, technology and mathematics education in Australian schools.
- Austrade is continuing to develop a range of secondary school teaching and learning resources in its 'Exporting for the Future' program — covering topics such as international trade, business enterprise, exporting and marketing, globalisation and the global economy (Austrade 2006).
- Questacon (Australia's National Science and Technology Centre) runs the Questacon Smart Moves Program. This is an outreach program that aims to raise awareness of science and innovation among young Australians living in rural and regional areas and inspire them to purse careers and opportunities in science, mathematics, engineering, and technology.
- There are a number of competitions for science teachers and students including: the Australian Academy of Science Teacher Awards; the Prime Minister's prize for excellence in science teaching in primary schools and science teaching in secondary schools; The Rio Tinto Big Science Competition; and the Australasian Schools Science Competition.

In an appendix to its submission, DEST provided information on the current suite of science awareness programs (sub. 87, p. 83).

For the most part, such initiatives have only been in place a relatively short time and it is too early to tell how significant an impact they may have on the community's attitude towards entrepreneurship, science and creativity or the extent to which this may influence commercialisation. It is worth noting, however, that many attitudes to science, as well as mathematics, are shaped in the school classroom. In this regard, limitations in the quality of some teaching will have long term impacts (chapter 5).

At an institutional level, participants pointed to cultural differences between research organisations and firms that can create barriers to their effective interaction. In terms of commercialisation, the key cultural differences are likely to relate to research timeframes; work practices; and attitudes towards the acquisition, use and sharing of information and knowledge. The Australian Institute for Commercialisation (AIC) has observed that:

> There are still significant challenges in matching the ethos and culture of researchers and their institutions within the time frames and economic imperatives of the business community. (Jonson 2002, p. 9)

Similarly, Science Industry Australia argued that ‘cultural issues at the organisational and researcher level in universities and PFRAs impede the transfer of research IP to industry’ (sub. 22, p. 8).

Cultural differences of this nature may be a cause for concern when they impose excessive transaction costs, increase risk and uncertainty or are a barrier to resolving key issues. For example, AIC highlighted the significance of research organisations and firms having different expectations concerning the ownership of intellectual property.

> When a business engages another business to provide expertise in the form of ‘paid services’, it is customary that the business paying for the services ultimately owns any IP [intellectual property] that is developed through the provision of such services. However, when businesses engage ROs [research organisations] to provide expertise in the form of ‘paid services’, they are often shocked to find the RO expects more than just a fee for service or provision of expertise. It has become the norm for ROs to demand either full or part ownership in any new IP developed through the provision of their ‘paid services’, as well as royalties or other forms of success fees. It is often at this point where collaborative discussions simply fail. (sub. 6, page 3)

Up to a point, cultural differences between organisations are a fact of life. As Howard Partners (2005b) has observed ‘… long held values and cultures of business, government and higher education are fundamentally different and unlikely to change, at least in the short term’ (p. 3). Often where there are significant cultural differences between the parties to a transaction a market for intermediaries will develop to reduce the cost of engagement. For example, AIC TechFast program aims to facilitate technology transfer between research organisations and SMEs.

Overall, the Commission sees only a limited role for government in addressing wider cultural barriers to innovation. Governments are already taking steps to encourage more positive community attitudes towards entrepreneurship, science and creativity. Governments are also supporting the development of stronger linkages between research organisations and firms.

Impediments within firms

In recent years, there has been an increasing view that some impediments to commercialisation are to be found within firms themselves. Attention in this area particularly focuses on the availability and quality of entrepreneurial, management and leadership skills. The literature also highlights the importance of incentive structures within organisations, the design and delivery of training programs and corporate attitudes towards risk and failure.

For example, a working group convened by PMSEIC (2002) to consider management skills for high growth start-up companies noted that:

> The large majority of businesses fail in Australia not because of technical reasons, but because entrepreneurial managers lack the skills and experience to effectively respond to management, financial, human resource and legal problems (p. 14)

Further, Australia is seen as lacking a base of 'serial' entrepreneurs — that is, people who have an established track record of successfully commercialising knowledge and technology (Jonson 2002, p. 8). Serial entrepreneurs can be role models and mentors for those starting-out.

The Australian Business Leadership Survey (a joint research project undertaken by the Australian Institute of Management and Monash University) found that the least extensive culture for Australian organisations was innovation (Sarros et al. 2005, p. 43).[2] The survey also found that in terms of the climate for innovation within organisations, Australian managers are most supportive of creativity, but least supportive of providing sufficient resources for innovation (p. 59).[3]

Perhaps reflecting concerns about the quality and depth of entrepreneurial, leadership and management skills in Australia, it is sometimes suggested that Australian firms tend to adopt a defensive rather than strategic approach to innovation and commercialisation. For example, Roos et al. (2005) have observed that:

> … Australian businesses, especially SMEs, seem very good at tactical problem solving as opposed to strategic innovation. … This can pose an additional barrier to building an effective national innovation system, since it might create an attitude of complacency believing that 'we are good at innovating because we are good at finding solutions'. In fact, this approach is one of tactical problem solving as opposed to strategic innovation.

[2] Seven descriptors of organisational culture were used in the survey: social responsibility; competitiveness; performance orientation; supportiveness; emphasis on rewards; stability and innovation.

[3] The dimensions of climate for innovation were: support for creativity; non-conformity; support for innovation; and resource supply.

> Practical problem solving is mostly a defensive tool, whereas strategic innovation is an offensive tool with corresponding differing impacts on economic growth. (p. 22)

Engineers Australia also emphasised the importance of leadership for innovation and risk taking.

> Whether funded publicly or privately, leadership is a vital influence in a company's decision to be innovative and to undertake R&D. Leadership is required to drive and influence management culture and practices so as to seek continuous improvement and excellence. As well, there must be continuing determination to support development of new products and services. The lack of risk taking and leadership within management constraints innovation. Other constraints include the tendency to 'when in doubt-don't' and conservative 'risk' management. (sub. 65, p. 5)

Several participants noted the importance of building entrepreneurship, leadership and management skills as an essential part of developing human capital (see for example, Society for Knowledge Economics sub. 53, and Business Council of Australia sub. 58). Some participants also drew the Commission's attention to the Karpin Report (Industry Task Force on Leadership and Management Skills 1995), arguing that there is still considerable need to focus on building an enterprise culture in Australian management. This report included a number of recommendations around five key challenges: developing a positive enterprise culture through education and training; upgrading vocational education and training and business support; capitalising on the talents of diversity; achieving best practice management development and reforming management education.

Since the Karpin Report, the number and range of management development programs offered by tertiary, industry and professional bodies has expanded considerably. However, in a recent study, D'Netto and Bakas (2005) found that the effectiveness of management development within Australian organisations is mediocre. The study makes a number of recommendations on how Australian organisations could improve the effectiveness of management development (pp. 3-4).

Overall, participants' comments suggest possible deficiencies in firms' entrepreneurial, management and leadership skills. The key question is what should be done to improve the availability and quality of these skills? The government already undertakes measures in areas over which it has prime control, such as developing skills in the education sector. It has also established a more competitive environment for firms, which has strengthened incentives for firms to develop their human capital. In relation to SMEs, the Australian Government funds the Small Business Entrepreneurship Program, which provides competitive merit-based grants to foster an entrepreneurial small business culture, particularly in developing business skills for young entrepreneurs and succession planning for business continuity.

Perceived impediments within universities

This section outlines factors within universities that participants felt impede the commercialisation of university research. In the Commission’s view, to the extent that they are valid, these impediments may also be relevant to the broader issue of trying to maximise the social return from the transfer, diffusion and utilisation of university research.

Australia’s universities are an important source of knowledge, technology and skilled and capable people. In addition to the traditional roles of teaching and research, there has been an increasing focus on research commercialisation (through the development and encouragement of science-based entrepreneurship). Pressure to improve research commercialisation has come from governments and from inside universities themselves (Harman and Harman 2004). As a result, some universities have devoted significant resources to developing their capabilities in this area, particularly the research-intensive universities.

> Major efforts have been made by a large number of universities to enhance technology transfer capabilities, with the allocation of additional resources to support commercialisation activities, new specialist staff appointments, and revision of institutional policies with regard to the ownership and commercialisation of intellectual property, contract research, and consultancies. Other efforts have included investment of university funds in CRCs and other research centres, and the development of research parks, either by individual universities as with Macquarie University, or by groups of universities as with the Australian Technology Park in inner Sydney, which includes three major universities. (Harman and Harman 2004, p. 159)

Notwithstanding these efforts, there are various claims (some questionable) about barriers to research commercialisation within universities. This section first sets out these claims, before a brief assessment by the Commission.

At an overarching level some have questioned whether the traditional governance structures and frameworks of universities are conducive to commercialisation. For example, in a report commissioned by DEST, the Australian Centre for Innovation et al. (2002) argued that:

> One aspect of universities that may be particularly challenged by their involvement in research commercialisation is their governance. Their Acts, State Government auditing requirements, and the structure, authority, membership and practices of governing bodies may each raise, and in some cases have raised, evident inefficiencies, tensions and conflicts. (p. 48)

The governance structures and financial, legal and administrative frameworks of universities are important in shaping decision making and behaviour within these organisations and their interaction with the public and private sectors. Several participants argued that there was a need for universities to put in place governance structures and frameworks that would allow them to be more responsive. For example, the Council for the Humanities, Arts and Social Sciences argued that commercialisation was impeded by:

> … rigid university structures that prevent researchers responding in a more agile manner to the needs of industry: for instance, the rapid finalisation of contracts to conduct research, and flexibility in the conduct of these contracts. (sub. 52, p. 13)

And, Macquarie University observed that there is ‘no national mandate to undertake commercialisation activities (cf. the US *Baye Dole Act*)’ (sub. 47, p. 5).

Other study participants considered that commercialisation is still seen as lacking the legitimacy of teaching and research and claimed that incentive structures primarily rewarded researchers on the basis of their publication rate and success in securing external research grants rather than commercial development of a discovery or invention. The Baker Heart Research Institute contended that:

> … Universities and Medical Research Institutes should recognise research income derived from commercial activities equally with that of grant income. Thus, a scientist attracting $1 million of commercial research into a laboratory should enjoy the same recognition and privileges enjoyed by a scientist that attracts an equal sum through competitive grants. (sub. 40, p. 7)

The CRC for Spatial Information argued that the incentive structures within universities particularly discourage researchers to engage with SMEs because this kind of speculative/research-assistive activity does not attract adequate recognition:

> … Australia operates with a reward structure for individual researchers at universities that works against engagement with SMEs. This is a fundamental structural impediment to collaboration with SMEs for the purposes of research. Moreover, the university itself is not rewarded for permitting its staff to allocate this speculative time. (sub. 32, p. 2)

There was a view from some study participants that the preferences of researchers themselves might also affect prospects for commercialisation within universities, for example because of fears of a tradeoff between academic freedom and commercial secrecy. Further, the NHMRC claimed that there was ‘a negative perception of commercialisation and research application generally among many Australian scientists working at the basic end of the spectrum’ (sub. 80, p. 16).

There was also a view that, unlike some other countries, researchers working in Australian universities generally do not have experience working in the business sector with consequences for understanding between the two sectors. For example, CSIRO observed that:

> … in Australia very few researchers or university scientists appear to have had experience working in business. This can make it more difficult to produce scientists and researchers with a broader understanding of how business works and the ways in which science can contribute to business development. It is not easy to see how to address this problem. It may in part reflect a risk averse attitude on the part of academics here compared to those in some other countries, where it can be more common for scientists to try setting up their own business and later return to research or academia. (sub. 50, p. 103)

Universities offer a range of incentives to encourage research commercialisation. These incentives include: arrangements to share the financial returns from successful commercialisation between the university, the research centre or faculty and the researchers (typically, the returns are shared equally between these parties); providing business development staff and resources to help identify commercialisation opportunities and financial support in the early stage development of an invention; provision of pre-seed and seed funding for technology development, funding support for intellectual property protection and assistance with developing a business model (Karingal Consultants 2005).

However, there have been concerns about their practical application. DEST commissioned an evaluation of incentives for commercialisation of research in Australian universities (Karingal Consultants 2005). The study focused on the thirteen universities comprising the Group of Eight (Go8) and the Australian Technology Group (ATN). On the basis of some 'best practice' criteria the report suggested that:

- About one third of the universities satisfied or came close to satisfying all the best practice criteria identified. …
- Around a third of the universities provided inadequate support and incentives to their researchers to get involved in the commercialisation of their research outcomes. …
- Almost all the universities had difficulty in making available adequate finance and human resources to achieve the best practice criteria identified. (pp. 10-11)

The report claimed that there was a number of structural weaknesses to the commercialisation of research within the universities surveyed:

- Many researchers were unaware what incentives were available ….
- Among researchers, there was quite widespread lack of trust in university administrations that the incentive reward would be paid as expected, particularly where changes had been made post hoc, generally to the disadvantage of the inventors or people involved in the consultancies and research contracts.

- In many universities financial commercialisation support was inadequate. There was little or no access to small amounts of pre-seed finance, often not enough to pay for intellectual property (IP) protection up to the Patent Cooperation Treaty (PCT) stage, usually about $50,000.
- The smaller research profile universities had difficulty in finding the financial and other resources needed to deploy suitably qualified and experienced business development staff, and had been unable to establish their own internal critical mass of commercialisation support.
- Trust was seen as being a critical issue for some universities. There was no benefit to be gained from offering increased financial incentives to researchers if the potential beneficiaries lacked trust in the willingness and ability of the university management to deliver them. (Karingal Consultants 2005, p. 9)

Several participants argued that the commercialisation activities of universities are not adequately resourced. Universities do not currently receive dedicated government funding to support their research commercialisation activities. The Business, Industry and Higher Education Collaboration Council (BIHECC) pointed out that this means 'funding for engagement, knowledge transfer, and research commercialisation activities is usually drawn from discretionary revenues and weighted against other spending priorities' (sub. 55, p. 10).

The Australian Vice-Chancellors' Committee (AVCC) argued that:

> A key barrier here has been a view that universities should be able to secure revenue through their own commercial enterprise, rather than providing universities with sufficient resources to facilitate processes of knowledge transfer to firms, whereby the market will ultimately deliver economic benefits. Resourcing 'Third Stream' activities to promote knowledge transfer has been recognised elsewhere as the most efficient and effective method of improving knowledge transfer and realising benefits. (sub. 60, p. 34)

Similarly, the Go8 universities contended that:

> Universities currently receive public funding to support their teaching and research activities. Very limited dedicated funding is available, however, to support the research commercialisation activities of universities — even though governments increasingly expect universities to improve their performance in this area. (sub. 68, p. 11)

This issue is taken up later in this chapter (section 6.5).

Closely related to the issue of funding, several concerns were raised about the performance of university commercialisation arms. For example, the Commonwealth State and Territory Advisory Council on Innovation (CSTACI) considered that the 'commercialisation arms of Australian universities, with one or two notable exceptions, may not be operating as effectively as possible' (sub. 98, p. 2). Professor Michael Vitale (2004) has argued that those employed in commercialisation and associated support activities are spread relatively thinly across Australian research organisations:

> Only about 300 people are employed in commercialisation and commercialisation support activities across all of Australia's major research institutions and CSIRO. At many universities, a small handful of staff — and in some cases no-one at all — is responsible for the commercialisation of research flowing from thousands of academic staff across multiple faculties. (p. 18)

AIC drew attention to a number of other issues affecting the performance of university commercialisation arms:

> Many commercialisation offices are still very much in 'start-up' mode themselves and are significantly under-resourced for the massive tasks they face. Many also complain of unclear organisational goals and policies for commercialisation, and lack of real commitment from institutional leaders. Frequently, they have limited knowledge or understanding of what IP the organisation actually has because the research may be emergent and not conveniently packaged for specific applications. IP disclosures are rarely formalised, and maintaining in-faculty development managers to seek out and understand 'hidden' IP is expensive. As such, commercialisation offices are often inefficient at being able to market their goods. (sub. 6, p. 6)

The issue of university commercialisation arms is considered in section 6.5.

A further claimed impediment to commercialisation is the extent to which there are differences across Australia's research organisations in their approach to intellectual property management and commercialisation.

A working group convened by PMSEIC (2001) to examine the commercialisation of public sector research observed that 'our research organisations have many different approaches to knowledge and IP management. As a result, investors are left to deal with myriad approaches to dealing with these institutions. The effort required is a serious disincentive' (p. 19).

AIC considered that inconsistencies within and across research organisations act as a significant barrier for SMEs attempting to engage with the sector:

> Many of the 130 publicly-funded ROs [research organisations] have now set up commercialisation offices or subsidiaries to serve as 'shop fronts' for their people and technology assets. Unfortunately for SMEs, there is neither a single model for interaction with a particular institution, nor a single clearing house representing them all. Therefore, the task for SMEs in identifying, contacting, learning how to deal with and successfully negotiating collaboration or technology transfer deals with a particular RO is too time consuming for most to justify. (sub. 6, p. 3)

The BIHECC also advocated greater consistency in approaches to managing intellectual property:

> The Australian Research Council has defined a set of *National Principles of IP Management* for publicly funded research, however many different models of IP management are being applied by Australian research organisations with varying results. There may be value in developing more uniform national approaches to IP ownership, transactions and licensing to encourage greater technology diffusion. (sub. 55, pp. 18-19)

The Commission's assessment

Participants have identified a range of possible barriers to the commercialisation of university research. However, in some cases, governments are already taking steps to address these issues.

- The Australian Government has announced a Commercialisation Training Scheme to fund around 250 awards for research students undertaking higher degrees to study full-time for a semester to obtain graduate qualifications in areas relevant to the commercialisation of research and the management of intellectual property (DEST 2006d).
- In response to the House of Representatives Standing Committee on Science and Innovation report *Pathways to Technological Innovation*, the Minister for Education, Science and Training has requested the BIHECC develop a business case for providing universities with some additional funding for knowledge transfer (sub. 55, p. 10). This is discussed further in section 6.5.

And universities are also pursuing a range of initiatives to improve community engagement and the commercialisation of research (for example, Macquarie University sub. 47, p. 1).

Other perceived barriers to commercialisation within universities are questionable. For example, as discussed later, the Commission questions whether decision-making within universities in relation to the transfer and diffusion of knowledge and technology should be driven by the objective of commercialisation (see section 6.5). There are also risks in addressing the preferences of, and apparent disincentives faced by, researchers in relation to commercialisation activities within universities if these reduce the non-pecuniary benefits that such researchers derive from the conduct of curiosity-driven, openly discussed and published research activities.

That said, it would appear sensible for universities to address inconsistencies in the management of intellectual property within their organisations.

Lack of effective linkages between research organisations and firms

Linkages within the innovation system are essential for the flows of information, knowledge, technology, people and capital on which the system relies. The importance of such linkages has grown over time as the innovation process has become more interactive, with the literature particularly emphasising the importance of value chains. These networks can connect participants across diverse fields of activity and national borders. In part this reflects that, in many areas, the creation and commercialisation of knowledge and technology has become increasingly complex — requiring a greater variety of knowledge across multiple disciplines and functional areas. At the same time, participants within the innovation process have tended to become more specialised and thus more reliant on being part of networks that are geared towards creating value.

From a commercialisation perspective the linkages between research organisations and firms are an important subset of the connections that define these broader networks. These linkages between research organisations and firms can take many different forms including, research collaboration, teaching services, consultancy services, conferences, seminars, student placements and advice. They provide the means for knowledge transfer, diffusion, learning and technology development. They also allow firms to feed back to research organisations practical problems that need solving, and influence the education and training of future employees.

Over the last decade and a half governments have encouraged stronger linkages between research organisations and firms — most notably through the CRC program (chapter 9).

Nevertheless, there are concerns about the extent, depth and quality of the linkages between research organisations and firms. In this regard, the Commission notes two observations by the Australian Business Foundation:

> If a country is to enjoy a trend of private innovation and robust productivity growth on the one hand, and increasing flows of aggregate income on the other, it must consciously develop a socio-economic system that links private and public agents of innovation in ongoing and purposeful relationships. (sub. 72, p. 10)

> While Australia has strong knowledge infrastructure through grants and tax concessions for research and development, support to universities, publicly funded research institutes and Cooperative Research Centres, it has relatively weak knowledge diffusion mechanisms. (sub 72, p. 12)

Specifically, participants drew attention to two perceived problems. First, weak linkages between research organisations and SMEs. Secondly, that Australia lacks a base of intermediaries that can bring research organisations, firms and others together.

Linkages between research organisations and SMEs

Several participants argued there is a need to develop stronger linkages between research organisations and SMEs. The BIHECC said that roughly 34 per cent of Australian SMEs used new technologies to improve their business or develop new products compared with 85 per cent of their European and US counterparts (sub. 55, p. 15). The BIHECC argued that this is partly due to Australian SMEs not always being aware of the latest developments in the R&D sector.

Similarly, Engineers Australia argued that:

> … there needs to be an increased focus on encouraging collaboration between small and medium enterprises with universities, TAFEs, and other publicly funded organisations, such as the CSIRO.
>
> Most small and medium enterprises know nothing about assistance packages for collaboration or what facilities are available within research organisations. If this collaboration was better understood and utilised by small and medium enterprises, and taken further by the universities, TAFEs, and government R&D organisations, it would be another source of income for all concerned. (sub. 65, p. 3)

Concerns about the linkages between research organisations and SMEs are focused on the transfer of 'cutting-edge' science. In this area linkages in the form of research collaboration and high level technical advice and support are likely to be particularly important. Other potential linkages include the services of 'entrepreneurial' scientists and researchers who operate in both the scientific and business communities and help build ties between firms and research organisations.

However, only a relatively small proportion of SMEs are likely to be capable of commercialising cutting-edge science. A PMSEIC working group (2005) on growing technology-based SMEs, reported results from the May 2004 Sensis Business Index (p. 74). A sample of 1800 SMEs were asked to identify whether they were high, medium-high, medium or low technology-based businesses. The results suggested that 70 per cent of SMEs have a low technology profile, 17 per cent have a medium technology profile and only 13 per cent have a medium-high and high technology profile (p. 74).

In terms of the transfer of cutting-edge science, it is not clear there is a problem with the linkages between technology-based SMEs (as noted above, around 13 per cent of SMEs) and research organisations. These are the SMEs that are most likely to be capable of commercialising the knowledge and technology generated by research organisations. The evidence suggests that these SMEs devote considerable resources to R&D, with the PMSEIC working group reporting that technology-based SMEs spent around 72 per cent of the level of R&D expenditure spent by large technology-based firms in 2001-02 (p. 75). It is reasonable to expect that an R&D effort of this magnitude would provide a good basis for ongoing formal and informal linkages with research organisations. Further, some of these SMEs are likely to be university spin-off ventures.

The PMSEIC working group sought to identify through its research and interviews with the CEOs of leading Australian technology-based SMEs the factors that critically influence the growth of these firms. The four factors identified were: the ability to export; a focus on developing innovative solutions to customer problems; having access to domestic expansion capital; and possessing experienced and skilled management (PMSEIC 2005, p. 66). Notably, 'linkages with research organisations' does not appear in this list. Either technology-based SMEs are unaware of how the work of research organisations could help their growth prospects (which seems unlikely given the nature of these firms) or other factors were perceived as being a more significant constraint on growth.

Of course, this is a particularly science-centric view of the scope for SMEs to benefit from the knowledge and technology generated by research organisations. There is considerable potential for SMEs to utilise knowledge from non-scientific areas (such as design, marketing and management) to improve product differentiation, business models and organisational structures. In these areas, the technology profile of SMEs may not be as important in determining whether these firms are able to absorb and utilise knowledge. Further, collaborative research projects and high level technical advice may be less important forms of linkages than education and training services, consultancy services, conferences, seminars and other forms of advice.

However, for some SMEs, linkages would matter. For these, there are several conjectures about the source of barriers:

- SMEs may have insufficient information about the research being undertaken by research organisations and its potential commercial value as well as about the programs already in place to encourage collaboration.
- SMEs may face high transaction costs in dealing with research organisations, reflecting many of the issues raised earlier in this chapter, including: cultural differences between research organisations and SMEs; differences in the commercialisation policies and approaches to intellectual property management within and across research organisations; and a lack of experience and expertise in commercialising intellectual property on the part of both research organisations and SMEs.
- As noted earlier, the incentive structures within Australian universities may be a disincentive for researchers to engage with SMEs.

- Research organisations may be poor at identifying SMEs that could potentially commercialise their research. In a recent report on knowledge exchange networks in Australia's innovation system, Howard Partners (2005b) argued that:

  > … research organisations need to know much more about the business and commercial environment and where contributions can be made and be in a position to *engage* more effectively with SMEs in relation to how knowledge can firstly be developed and then applied. Universities and research organisations need to identify the attributes of SMEs with whom they want to commercialise their research and seek them out. However, research organisations have an approach to risk that makes working with SMEs very difficult to initiate. (p. 42)

A number of proposals have been canvassed to improve the linkages between research organisations and SMEs.

The CSIRO Australian growth partnerships model

The model, developed by CSIRO, and endorsed and widened by the House of Representatives Standing Committee on Science and Innovation (2006), aims to encourage demand driven collaborative arrangements between SMEs and PSRAs. The proposal includes several features:

- provision of funds to SMEs with a track record of commercialisation to acquire technologies and technical advice; and
- repayment of funds if the project is successful.

The Commission discusses a more flexible arrangement for supporting collaboration in chapter 9.

Subsidies to reduce search and assessment costs

AIC advocates a subsidy to reduce the cost and risk faced by SMEs in identifying and assessing new opportunities arising from the research sector (sub. 6, p. 9). It argues that providing funding to help SMEs cover the costs of essential external services to undertake opportunity identification, assessment, negotiation and commercialisation planning would have two benefits:

> Firstly, it encourages SMEs to look to the research sector as a catalyst for innovation and growth. If SMEs were left to fully fund this activity themselves it is likely many would just see this as an additional cost of research sector engagement and would simply avoid it. Given the significant investment in the public research sector, many SMEs rightly expect that appropriate mechanisms are also provided to help them engage with the entire research sector without employing experts to help them access this public asset.

> Secondly, it can assist SMEs to follow best practice in undertaking due diligence and subsequent commercialisation, as the costs in doing so is more affordable. It is the failure to adequately undertake such due diligence and commercialisation planning that currently leads to sub-optimal technology transfer outcomes by SMEs. (sub. 6, p. 9)

However, it would be difficult to design a subsidy of this nature to ensure a high degree of additionality. In the event an SME is successful in identifying and commercialising technology, the proposal does not include any requirement for firms to repay the value of the subsidy. Moreover, while a subsidy would induce some increased search and assessment activity by SMEs that would not otherwise occur, much of this activity may not lead to increased commercialisation. There is also some concern that those SMEs requiring a subsidy to engage in search and assessment activity may be more marginal in terms of their ability to successfully commercialise the knowledge and technology coming out of research organisations.

The Commission's assessment

Effective linkages between research organisations and SMEs are undoubtedly important for the transfer, diffusion and utilisation of knowledge and technology. However, perceptions about these linkages in Australia appear to be coloured by concerns about the transfer of cutting-edge science. This 'supply-push' perspective has several limitations:

- It seemingly gives little regard to the needs and capabilities of the majority of Australian SMEs, which for the most part have a low or medium technology profile. Importantly, it is not clear whether there are weak linkages between research organisations and the relatively small pool of technology-based SMEs capable of developing cutting-edge science into marketable products, services or processes.
- It implicitly characterises the remaining group of knowledge-intensive SMEs as passive in their relationships. This has generally not been established using convincing evidence. If such SMEs eschew public sector sources of knowledge, it may be because other firms and customers are more important sources of knowledge.

The impediments that have been identified in this area are relevant to the linkages between research organisations and firms in general. For example, these apply to disincentives within Australian universities to commercialise knowledge and technology. Further, there appears to be scope to address these impediments directly rather than relying on government subsidies to particular types of firms. Policy should improve the transfer, diffusion and utilisation of *all* forms of knowledge and technology generated by research organisations (that is, not just those related to the hard sciences). Subsidies carry the risk of distorting decision-making about the optimal path of commercialisation. In saying this, the Commission recognises that many commentators argue that SMEs have a particularly important role to play in the innovation system. For example, the PMSEIC working group (2005) on growing technology-based SMEs argued that:

> Technology-based SMEs are critical for Australia's success in the global economy. OECD and Australian research suggests these firms are fast growing, create high value jobs, have high export potential, renew established industries and help create new industry sectors. They contribute directly to economic growth by being catalysts for knowledge diffusion and by introducing new technology products in response to market demands. (p. 75)

Similarly, Walsh and Kirchhoff (2002) commenting on the situation in the United States observed:

> Within the last 20 years, evidence has appeared that suggests that small firms are better at commercialising disruptive technologies into discontinuous innovations thereby creating increased competition, better product/service performance and greater economic benefits to society. Thus, the paucity of small firms involved in the transfer of technology from government labs to private sector firms is a cause for concern to the national laboratory community in the United States and undoubtedly to other nations. (p. 134)

However, the Commission considers that decision-making should be focused on maximising the social return from public investment in research — taking into account the costs and benefits of alternative pathways of developing knowledge and technology into some form of practical application. In relation to commercialisation, this may mean that sometimes knowledge and technology are best commercialised by SMEs, but in other cases the optimal commercialisation path may be through large Australian firms or even foreign firms.

Intermediaries

A report by Howard Partners (2005b) for DEST on knowledge exchange networks in Australia's innovation system noted that in recent years there has been an expansion in the market for knowledge, 'built around the production, distribution and exchange of what are often termed 'intellectual products'' (p. 24). As the market for knowledge has developed the report found there has been a proliferation of intermediaries, such as early stage venture capital investors; commercialisation advisers and consultants; lawyers; corporate and taxation advisers; and patent attorneys who advise on corporate law, business planning, marketing, taxation structures, and intellectual property (p. 25). As the report observes, these intermediaries stand between buyers and sellers of intellectual products as brokers, advisers, and arbitrageurs.

Intermediaries are seen as playing a useful role in facilitating the transfer of knowledge and technology in the context of a market that has become increasingly sophisticated. The report by Howard Partners observed:

> Business models for knowledge exchange networks based on adverstising, marketing and hopefully selling technologies without the involvement of intermediaries are unlikely to succeed. People do not acquire technologies like they purchase a book. They want to know how it works and ask questions (and expect answers) in relation to issues such as scalability, security of IP and its relationship to a company's own IP suite, cost of development, safety and other business related matters. (p. 42)

Some participants were concerned about the availability of intermediary services in Australia and argued that the development of this market niche should be supported. For example, AEEMA contended that:

> The weak link in the innovation chain is often the piece of infrastructure that can link technology with business and capital. By strengthening these links, then we can deliver the assured, secure path for commercialising and potentially industrialising the initial creative concept. There exist a few 'facilitators' in Australia for welding the combination of technology, business and capital through linking appropriate strategic partners. This industry niche needs fostering in a way that delivers fast, efficient and economic outcomes. (sub. 51, p. 5)

The report by Howard Partners argued there was a strong case for supporting the development of technology brokers, who are knowledgeable about university and business research and can work with business in an independent intermediary role. The report argued that this should not displace the market oriented role of a growing industry of professional technology advisers (p. 30).

The Commission considers that intermediaries can play a useful role in the market for knowledge and technology. However, any public support for intermediaries would need to be based on evidence that there are regulatory or other market failures to justify policy intervention.

The 'innovation gap'

Several participants argued a significant impediment to commercialisation in Australia is the lack of public and private funding for taking completed research through to the early stages of commercialisation, including proof-of-concept.

For example, the Association of Australian Medical Research Institutes (AAMRI):

> The major gap between public investment in basic research and private sector investment in downstream, 'de-risked' opportunities must be addressed. Rather than there being competition and crowding out of private investment by public funds there is in fact a major gap in required funding that is currently not being filled by either sector.

> As a consequence this gap has created a serious market failure and the frequently experienced 'valley of lost opportunity'. (sub. 41, pp. 18-19)

Conceptually, the presence of a gap in the market does not necessarily constitute a problem requiring government intervention (see chapter 3). To some extent the innovation gap may reflect rational decision-making on the part of investors (especially in view of the resource and other constraints they face). In any case, the evidence suggests that the market for knowledge and technology in Australia has become increasingly sophisticated. For example, Howard Partners (2005b) has observed that evidence of the increasing sophistication of this market includes:

- The growing interest in the sale and/or licensing of Intellectual Property;
- The emergence of the technology 'start-up' as a vehicle for the marketing of knowledge products;
- The emergence of a financial asset class for investment in knowledge companies;
- The emergence of a business for knowledge brokers and technology advisers;
- An increasing role for university Technology Transfer Offices within universities and research organisations;
- A proliferation in the number and scope of data bases relating to discoveries and inventions that are thought to have commercial potential;
- The increasing of third party agents in packaging and marketing programs for fee-paying students. (p. 25)

The extent of any impediments to the early stages of commercialisation is explored below.

A proof of concept metric

Science Industry Australia noted that the science industry is collaborating with commercialisation intermediaries and peak bodies in the research sector to develop a set of guidelines for a proof of concept metric:

> These guidelines are aimed at assembling the evidence necessary to demonstrate the technical and commercial viability of a research idea to potential investors. The metric would, if implemented appropriately by universities and PFRAs [publicly funded research agencies], encourage researchers to develop their ideas to a stage where they are of more interest to industry, particularly Australian industry. (sub. 22, p. 7)

The Commission considers that voluntary collaboration of this nature has merit, especially for high-tech niche industries. This reflects that investors often have to assess a large number of potential investment projects to find ones with commercial potential. For example, the latest ABS (2005d) survey of venture capital in Australia found that the 140 venture capital managers 'reviewed 10,199 potential new investments during 2004-05 and conducted further analysis on 1,094 of those, with 176 being sponsored for venture capital' (p. 5). Establishing the level of evidence likely to be required by potential investors could reduce search and transaction costs and improve the level of analysis of projects.

Funding of universities and medical research institutes

Some participants were concerned that universities and medical research institutes find it difficult to cover the costs associated with developing their research to the point of being 'investment ready'. These costs include further research and experimental development to establish the commercial potential of a discovery and patenting the intellectual property. This appears to be particularly an issue in areas such as the life sciences, where establishing the commercial value of a discovery can require an extended period of research and experimental development.

Failure to develop research projects to the point of proof-of-concept can impede commercialisation, particularly where commercialisation is dependent on attracting outside funding. Professor Jonathan West (2004) has observed in regard to venture capital that:

> … like all other risk-management vehicles, venture capitalists are expert in only certain types of businesses and certain types of risk. They specialise in understanding market and managerial issues. They are rarely qualified to assess or cope with technical risk. Unlike companies, therefore, most venture capitalists attempt to remove or substantially reduce technological risk before committing to an investment. Discussions between technological entrepreneurs and venture capitalists typically begin with at least 'proof-of-concept': demonstration that the device, software program, or service will actually function as claimed. (p. 26)

The Go8 has identified a lack of funds to support proof-of-concept activities as one of the key constraints on university research commercialisation (2006a):

- Public funding for university research typically stops at the point when the research question has been answered, or the funding runs out.
- Industry requires proof of the commercial potential of the IP before it will invest.
- This why initiatives such as the Pre-Seed Fund, run under BAA [Backing Australia's Ability], have not led to much increase in investment at the proof-of-concept stage of the process. Those in charge of the funds see it as too commercially risky to invest at this early stage.
- Universities are obliged to target their teaching and research funding on these activities — many of which promise more immediate returns on investment and are financially less risky than investment in research commercialisation.
- In Australia there exist a number of funds specifically set up to invest in technologies emerging for publicly funded research organisations (eg, UniSeed, the ANU/MTAA

> fund, the WestScheme Fund). However, these too tend to invest following proof-of-concept because of the risk factor (2006b, p. 1).

Reflecting these concerns, the Go8 has proposed a new proof-of-concept funding mechanism — the 'Innovation Stimulation Fund'. Under its proposal the Australian Government would provide $45 million over three years on a competitive basis to encourage universities to invest in research of commercial potential at the proof-of-concept stage.

The House of Representatives Standing Committee on Science and Innovation (2006) recommended the Australian Government introduce such a scheme (p. 162).

A number of participants argued that medical research institutes face similar problems. The Australian Society for Medical Research noted that NHMRC Development Grants provide an avenue for early stage development of commercially promising projects but argued there are limited funds beyond that (sub. 36, p. 2). For its part, AAMRI argued that the funding gap is exacerbated by medical research institutes being unable to access the Pre-seed Funds (sub. 41, p. 19).

As in the case of universities, participants generally saw a need for additional government funding. The Baker Heart Research Institute argued that patent expenditure could be made an eligible expense in normal grants or the development grant system could be expanded to accommodate intellectual property protection as well as proof-of-concept research (sub. 40, p. 7). And AAMRI argued that the Australian Government could fund research commercialisation more effectively by:

> … providing pro-rata commercialisation infrastructure funding similarly to the way it currently block-funds scientific infrastructure funding (though this should be extended to medical research institutes to capture biotechnology investments). (sub. 41, p. 5)

In the Commission's view, these matters could be considered in the broader context of universities receiving some additional funding to support knowledge transfer to non-academic communities (section 6.5). If considered appropriate, a similar approach could be taken to medical research institutes.

Access to capital by start-up and early stage firms

The innovation gap in Australia is also said to reflect the difficulties start-up and early stage firms face in accessing capital. These firms are often working to validate a technology or invention to attract the downstream investment and partnerships needed to develop marketable products, services or processes. The risk at this early stage of commercialisation can be considerable. Initially these firms may be able to rely on informal sources of finance (for example, family and friends). They may also attract the interest of business angels (high net worth individuals willing to invest their own capital). However, often these firms need to access formal sources of high risk capital if they are to continue to commercialise their intellectual property.

The main options for financing the early stages of commercialisation for start-up and early stage firms include banks and other financial institutions and the venture capital sector.

For such start-up and early stage firms, venture capital is an important source of finance for commercialisation.

- Venture capital is a subset of the private equity market. Private equity covers professionally managed pools of funds seeking investment in high risk/high return opportunities in unlisted companies or situations. Venture capital covers seed, early stage and expansion stage investment in emerging businesses, usually intellectually property based, with prospects for rapid growth, and with a higher risk/higher return profile than later stage private equity investment (such as leveraged buyouts, management buyins and management buyouts).

Venture capital brings with it not only access to finance but management expertise and contacts as well. Firms can also benefit from being able to tap into the established network of relationships venture capitalists have built up over time. In these ways venture capitalists may significantly improve the probability that start-up and early stage firms succeed in commercialising their intellectual property.

The Australian Government has provided considerable support to the development of the venture capital sector (box 6.2).

However, despite considerable government assistance over the last decade, there is a strong perception that the venture capital market in Australia remains relatively shallow and very much an emerging market.

Moreover, several participants argued the funds that are available in the Australian private equity market tend to be skewed towards later stage development. For example, AAMRI argued that one of the reasons the funding of venture capital consortia to identify commercial opportunities in academia has not worked well is because 'such consortia necessarily take a very short term approach to liquidity and therefore identify only late stage projects' (sub. 41, p. 5).

Limited access to venture capital was claimed to seriously constrain the ability of start-up and early stage firms to commercialise knowledge and technology:

> Research Australia's Beyond Discovery report examined the competitiveness of 100 Australian biotechnology companies and reveals important barriers to success. A key

Box 6.2 **Government support for the venture capital sector**

The main Australian Government initiatives in this area include:

- Innovation Investment Fund (IIF): a competitive investment program with the government investing funds alongside funds from private investors up to a maximum ratio of two to one. Licensed private sector fund managers administer the pool of investment capital. An important aim of the IIF is to develop fund managers with experience in the early-stage venture capital industry.
- Pre-Seed Fund program: a portfolio of four venture capital funds that invest in projects or companies spinning out from universities or Australian Government research agencies. The fund managers acquire an equity interest in each project or company, and provide management and technical advice to develop the commercial potential of the technology. Once the project has reached maturity, the managers divest their interest in the project or company to later stage investors.
- Venture Capital Limited Partnerships (VCLP): this vehicle is intended to attract certain non-resident tax exempt funds for investment in high risk start-up and expanding Australian businesses. VCLP registration provides flow-through taxation treatment for gains made on eligible venture capital investments. For an eligible partner of a VCLP, these tax gains are exempt from capital gains tax.
- Pooled Development Fund (PDF): PDFs raise capital and make equity investments in Australian SMEs. PDFs and their shareholders receive tax benefits on the income derived from their equity investments.

In the 2006-07 Budget, the Australian Government announced a number of further measures to stimulate activity in the venture capital sector.

- The establishment of an Early Stage Venture Capital Limited Partnership (ESVCLP) investment vehicle providing flow-through tax treatment and a complete tax exemption for income, both revenue and capital, received by its domestic and foreign partners. This initiative will progressively replace the exiting PDF program (which will be closed to new registrations after 31 December 2006).
- The operation of the existing VCLPs will be enhanced by: removing a range of restrictions including allowing investment in unit trusts and convertible notes as well as shares; relaxing the requirement that 50 per cent of assets and employess must be in Australia for 12 months after making the investment; and removing restrictions on the country of residence of investors.
- The Australian Government has committed $200 million for a further round of funding of the IIF program.

This is in the context of a broader suite of government programs at both the Commonwealth and State and Territory level that support the early stages of commercialisation. For example, the Commercial Ready Program; Commercialising Emerging Technologies; and the Renewable Energy Equity Fund.

finding was a serious lack of funding for emerging biotechs. (Research Australia sub. 33, p. 3)

Too often the Board witnesses companies going offshore simply because they cannot secure the type of support (the risk money) needed in Australia. Whilst large companies use earnings (or in some instances capital raising) to finance innovation, start-ups do not have such reserves as a source of finance. (Industry Research and Development Board sub. 77, p. 5)

It is often suggested that lack of funding leads to other undesirable outcomes as well, such as firms: issuing public offerings earlier than similar firms overseas; seeking to license their knowledge and technology relatively early (which can mean the value of the intellectual property is heavily discounted); and adopting a cautious approach to patenting because of the difficulty of covering the cost of protecting their intellectual property.

The AIC has proposed that superannuation funds be required to invest 0.1 per cent of their assets in early stage venture capital.

An early-stage capital base of $1 billion (equivalent to 0.1 per cent of total assets) could build a pipeline of hundreds of new opportunities every year, and would significantly increase the capital available to start-up and early stage businesses. (sub. 28, p. 2)

The Commission's assessment

The size of the private equity market in Australia is continuing to expand. The 2004-05 ABS (2005d) survey of venture capital in Australia reveals that as at 30 June 2005 investors had commitments of $11.2 billion in 210 private equity investment vehicles. This is compared with commitments of $9 billion in 195 private equity investment vehicles as at 30 June 2004; and commitments of $7.5 billion in 177 private equity investment vehicles as at 30 June 2003. The ABS survey reveals that in the five years to 30 June 2005, the amount of commitments by investors in the private equity market has more than doubled ($5 billion to $11.2 billion).

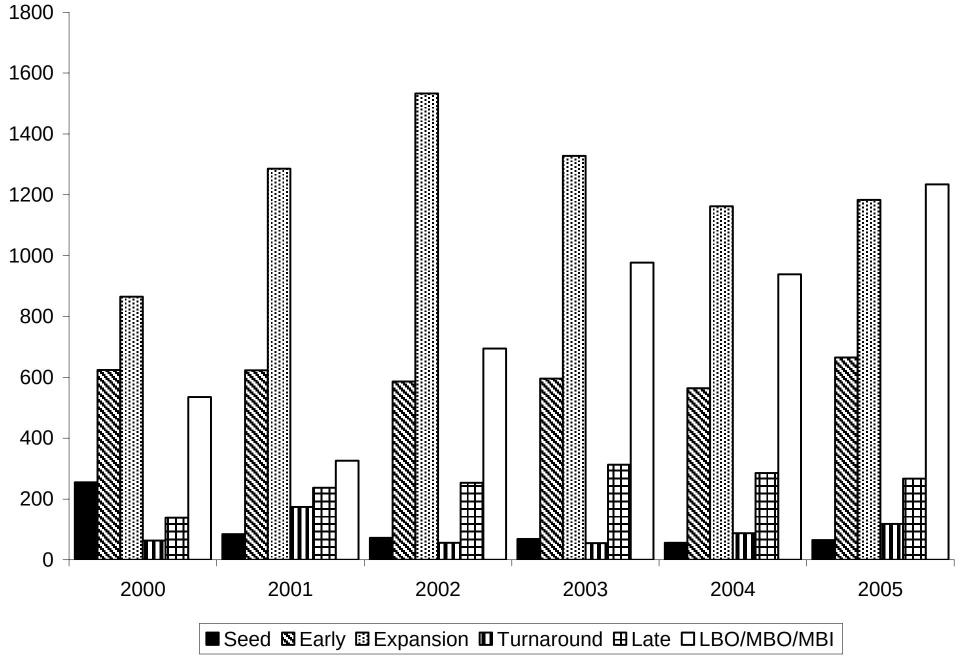
However, the commitment figures include both the venture capital market and the later stage private equity market. In that sense, the overall picture could be misleading in terms of the strength of the venture capital sector. Anecdotally, the Commission understands that in the wake of the dot.com boom, most of the growth in the private equity market has occurred in the later stage private equity segment of the market.

Investments in investee companies has been more stable in recent years. The 2004-05 ABS survey reveals that as at 30 June 2005, $3.5 billion was invested in

912 investee companies. This is compared with $3.1 billion invested in 909 investee companies as at 30 June 2004; and $3.3 billion invested in 889 investee companies as at 30 June 2003. Figure 6.1 shows investment in investee companies, by stage of investee company. For the last five years, expansion capital comprised on average 65 per cent of venture capital (defined as seed, early and expansion). Thus even within the venture capital segment of the private equity market, a significant proportion of funds goes to the expansion of existing ventures rather than emerging commercialisation ventures.

A well functioning and self-sustaining venture capital market potentially provides a relatively efficient mechanism for identifying, screening and funding the most promising early stage commercialisation ventures. However, the general consensus appears to be that Australia still has some way to go in achieving this goal. The most significant impediments to the development of the venture capital sector in Australia are considered to be the scale of the existing venture capital industry, the relatively small pool of investment managers and the lack of a strong track record in delivering the kind of returns needed to attract major institutional investors to this high risk market.

Figure 6.1 **Investment in investee companies, by stage of investee company (as at 30 June, $million)**



Data source: ABS (2005d), *Venture Capital Australia 2004-05*, Cat. No. 5678.0.

Conceptually, market failure in the venture capital market could occur because of agency costs, asymmetric information or spillovers. However, as discussed in detail in chapter 3, in financial markets the agency costs and information asymmetries are largely dealt with through the development of sophisticated contracts, monitoring mechanisms and governance frameworks. And, as canvassed in section 6.6, the existence of spillovers generally does not provide a strong rationale for government intervention in relation to commercialisation. Consequently, it is not clear whether market failure lies behind the impediments that are typically identified as constraining the development of the venture capital sector. In this environment it is important that the costs and benefits of any intervention to promote the development of this sector are carefully assessed.

Thus, government programs in this area should be subject to periodic independent review to ensure that they are delivering a net benefit to the Australian community. While the Commission accepts that a sustainable venture capital sector is likely to require patient government investment over a number of years, continued support should at least be conditional on evidence that a sustainable venture capital sector is in fact developing.

It is also important to recognise that while the Australian venture capital market may be relatively shallow, Australian firms have developed a number of strategies for working within this constraint. For example, in the biotechnology sector, firms are raising money and/or establishing commercial presences in foreign capital markets; developing a revenue stream by leveraging aligned products and services; and merging with or partnering a foreign company (Herpin et al. 2005).

The Commission does not support mandating that superannuation funds invest a percentage of their assets in venture capital. The interests of the community are best served by fund managers autonomously making investment decisions with a view to maximising the return to members.

Intellectual property management

Ultimately, the commercialisation of publicly funded research relies on the involvement of the business sector. How well intellectual property is managed by research organisations can affect the level of interest from firms. Generally, firms prefer intellectual property to be well-defined and properly protected. Accordingly, the quality of decision-making in this area affects the transfer, diffusion and utilisation of knowledge and technology. Thus, the management of intellectual property within publicly funded research organisations and universities is critical to maximising the social return from public investment in R&D.

Even at the research stage, researchers need to be aware of the intellectual property implications of their work. In its submission, CAMBIA noted that problems can arise if researchers knowingly or unknowingly use patented technologies in their research.

> Funders of research, investors and lenders may be increasingly understandably reluctant to invest in research projects that, while interesting, may never be delivered to the public, even for humanitarian uses, because any scale-up or commercial-scale implementation can be prevented by any of the multiple patent-holders whose patents were infringed during the research phase. (sub. 42, p. 2)

Typical of participants' concerns about university management of intellectual property were those raised by the National Committee for Mathematical Sciences, which observed that:

> … universities and academics were quoted as believing that an idea represented IP, whereas industry people see this as only the very beginning of the research and development process. Universities are seen as possessive and rigid about IP. Moreover Universities have problems recruiting suitably trained people with real knowledge of R and D in industry to assist with negotiations. (sub. 25, p. 3)

The increasing complexity of the intellectual property landscape is exemplified by the difficulties of negotiating the ownership and use of intellectual property in collaborative research arrangements (such as CRCs). In a combined submission, CRC for Beef Genetic Technologies; CAST CRC; CRC for Innovative Dairy Products; CRC for Forestry; CRC Mining; CRC for the Australian Poultry Industries; the Australian Sheep Industry CRC; and Vision CRC argued that:

> One of the major issues in R&D undertaken by CRCs is user-application of IP. These IP issues take many forms. Where the ideal business model is lacking, CRCs often find it difficult to negotiate ownership of IP rights with other CRC participants. This causes problems in the delivery of technology to industry, where delivery is sometimes best achieved through CRCs making exclusive licences available to third party delivery service providers. Leaving aside the question of the availability of commercialisation funding for CRCs, without ownership of these IP rights, licensing by a third party is not possible unless negotiated with the participants who own the IP. (sub. 85, p. 33)

There is also the ongoing debate about the protection of intellectual property versus the free dissemination of knowledge for the public good. The BIHECC argued it is critical Australian intellectual property laws keep abreast of these types of emerging issues.

> Management of intellectual property (IP) is a critical part of successful knowledge transfer and research commercialisation. There is an ongoing international debate regarding the protection or 'propertisation' of intellectual property versus the free dissemination of knowledge for public good. It is critical that Australian IP laws that are able to deal appropriately with emerging developments in knowledge transfer. It is important to review Australian IP laws to keep abreast of rapid technological

> development. Australian IP laws and policies need to promote engagement, knowledge transfer and research commercialisation and to clearly outline what level of experimentation and development can be conducted on and around new intellectual property without infringing on protected rights. (sub. 55, p. 18)

Similarly, the Victorian Government observed that:

> IP arrangements that lock up knowledge and prevent broader use constrain the flow of knowledge transfer. Australia's intellectual property protection regime has been seen as cumbersome and costly. Other approaches to IP management — for example, the creative commons and open source approaches — provide greater opportunity for knowledge flows and innovation by offering permissible use. Consideration of the most appropriate form of IP management in view of the nature of the intellectual capital and intended purpose might broaden the potential for knowledge sharing that drives innovation. (sub. 84, p. 13)

While the intellectual property landscape has become more complex over time, the work of IP Australia ensures that Australia's intellectual property laws and policy settings are periodically reviewed and refined to reflect the latest developments. The Commission did not find any evidence to suggest this process is deficient.

Public policy failure

Several participants argued that, in some cases, government policies and programs are themselves an impediment to commercialisation. Generally, concerns in this area fell into four broad categories: inconsistent and sometimes conflicting government policies and programs; regulatory issues; tax issues; and the general proliferation of government programs in this area.

Inconsistent and conflicting policy government policies

Some argue in looking across the current suite of government policies and programs in relation to commercialisation that there are examples of inconsistencies and even conflicting policies. Professor Michael Vitale (2004), argued as follows, in relation to the commercialisation of Australian biotechnology research:

> For example, the Commonwealth Department of Industry, Tourism, and Resources uses the BIF grant program to encourage company formation, while the Australian Taxation Office treats share options in a way that makes it difficult for new companies to recruit the staff that they need in order to grow. The Department of Education, Science, and Training gives universities money for research, but does not require them to devote any effort to the commercialisation, or even to the protection, of the intellectual property that the research generates. (p. 29)

The policy landscape in relation to commercialisation is complex and across the suite of government policies and programs in this area there may well be examples of apparent inconsistencies. However, it is important to recognise that sometimes policy settings necessarily reflect tradeoffs against broader policy objectives. For example, tax policy settings in relation to commercialisation have to be carefully considered in the context of the integrity of the tax system as a whole.

Government regulation

Participants raised a number of concerns about the effect of government regulation on commercialisation. Some of these were of a general nature, for example those raised by Science Industry Australia (sub. 22, p. 10) and AEEMA (sub. 51, p. 13). However, there were also concerns that regulation may restrict opportunities to commercialise knowledge and technology in particular areas. The Institute of Public Affairs cited government restrictions on the commercialisation of genetically modified organisms, the development of nuclear energy and stem cell research (see sub. 76). And, in a combined submission, CRC for Beef Genetic Technologies; CAST CRC; CRC for Innovative Dairy Products; CRC for Forestry; CRC Mining; CRC for the Australian Poultry Industries; the Australian Sheep Industry CRC; and Vision CRC argued that:

> Government regulations also create impediments to commercialisation and the utilisation of CRC-developed technologies. One example is in the area of Genetically Modified Organisms (GMO), where the current regulatory review pathway causes impediments to efficient research in immunobiological products. This issue is relevant to most CRCs dealing with plant and animal health … . (sub. 85, p. 33)

The ABS Innovation Survey (2006a) found that about 30 per cent of innovating businesses considered government regulations or standards were a barrier to innovation (p. 22). The Commission has explored specific regulatory problems raised by participants that adversely affect innovation in chapter 5. But it is beyond the scope of this report to consider the efficacy of the regulatory environment generally that may impinge on commercialisation. These issues would need to be carefully considered using an appropriate cost-benefit framework. That said, the Commission agrees that there is a risk that excessive or poor-quality regulation may divert resources away from the generation and commercialisation of knowledge and technology. In some areas (such biotechnology), successful commercialisation depends on the speed with which firms can take new or improved products, services or processes to market. Regulations that unnecessarily impede this process can potentially impose substantial costs on firms and the wider community.

Australian governments are already taking steps to reduce regulatory burdens on business. The Australian Government announced in response to the recent report by the Taskforce on Reducing Regulatory Burdens on Business that it has agreed in full or in part to 158 of the 178 of Taskforce's recommendations (Australian Government 2006c). In its submission, the Victorian Government highlighted the steps it is taking to reduce the regulatory burden on industry. This includes reducing the compliance burden of regulation by funding government departments to conduct hot-spot reviews and providing incentive payments to reward progress in this area (sub. 84, p. 13).

Moreover, at the Council of Australian Governments' meeting of 10 February 2006, governments agreed to a new National Reform Agenda. The regulatory stream of this agenda focuses on reducing the regulatory burden imposed by the three levels of government (see COAG 2006).

Tax issues

A recent report, released by the Intellectual Property Research Institute of Australia (IPRIA), examines the tax treatment of the commercialisation of intellectual property with a particular focus on spin-off companies (Rider et al. 2006). The general conclusion of this paper is that the 'current tax law presents considerable obstacles to the efficient commercialisation of intellectual property, and these obstacles will also negate the effect of the R&D concessions and the CGT concessions which are intended to encourage increased investment in intellectual property' (p. 105).

Based on their examination of the Australian income tax system, the authors argue that the income tax law reveals a sub-optimal tendency to impose taxation of unrealised gains, and double taxation of realised gains, from intellectual property commercialisation. Areas the authors identified as causing problems include:

(a) up-front tax liabilities imposed on the initial contribution of intellectual property to commercialisation vehicles such as spin-off companies;

(b) inappropriate tax liabilities imposed on employee shares in start-up companies;

(c) unfavourable tax treatment of start-up losses where the commercialisation vehicle is a limited liability company;

(d) denial of tax deductions for many intellectual property commercialisation cost items, such as confidential information, trade secrets, trade marks, brands and good will;

(e) features of the general tax law which negate the intended benefits of specific concessions such as deductions for research and development and the venture capital and pooled development fund concessions;

(f) tendencies in the tax law to encourage relocation of intellectual property ownership and control to more favourable overseas jurisdictions; and

(g) tendencies in the tax law to discourage investment in entrepreneurial risk activity as an alternative to passive low-risk investment activity. (pp. 2-3)

The report makes some suggestions on how the tax treatment of the commercialisation of intellectual property could be improved through amendments to the Income Tax Act.

The authors acknowledge that considerable additional work is required to evaluate these reform options, including further investigation of the options of the US tax law provisions.

The proliferation of government policies and programs

As governments have focused more on encouraging and facilitating commercialisation the number of policies and programs in this area has increased. In this regard, one of the notable developments over the last decade has been the States and Territories taking a more active role in fostering science and innovation, including encouraging the commercialisation of knowledge and technology in their jurisdictions. Moreover, it is likely that perceptions of firms about the policy landscape in relation to commercialisation would include the broader suite of science and innovation policies.

As discussed in chapter 8, diversity in government programs can have benefits. For example, diversity can reduce the possibility of there being significant gaps in the overall suite of programs. Programs offered by different levels of government may sometimes be complementary. For example, some States and Territories target their programs to 'fill in the policy gaps' or offer assistance of cash and in-kind support to help firms access Commonwealth programs (see NSW Government sub. 91, p. 6). Moreover, diversity can provide scope for a degree of experimentation in policy development, which may reveal better ways of doing things.

However, a proliferation of programs, and their constant change, can increase costs to business in attempting to navigate through the assistance on offer and satisfy various reporting requirements. For example, AEEMA argued that:

> But perhaps the most crippling obstacle to effective support for innovative processes and products in Australia is the overwhelming belief in industry that the multiplicity of policy programs, their attendant application processes and the myriad details sought by government for successful innovation assistance are far too time-consuming, costly and onerous. (sub. 51, p. 8)

The issue of coordination across jurisdictions is discussed in chapter 8.

An overall assessment of the impediments to commercialisation

This section has surveyed a wide range of potential impediments to commercialisation. In isolation or combination these impediments may significantly constrain the development of knowledge and technology into marketable products, services or processes. The Commission considers that there is sometimes a role for government in addressing these impediments. However, governments are already taking a range of measures to address these constraints on commercialisation and public sector research agencies and universities are also undertaking their own initiatives. As noted at the beginning of this section, it needs to be established why existing government policies and programs to address these impediments are insufficient before additional measures are contemplated. The Commission considers that in most cases this threshold test has not yet been satisfied.

That said, the Commission considers that one possible exception is addressing the impediments within universities that constrain the transfer, diffusion and utilisation of knowledge and technology. This includes working to improve the interface between universities and the business sector.

6.5 Improving knowledge transfer, diffusion and utilisation

Focusing on the social good, not commercialisation *per se*

Over the last two decades considerable attention has focused on the development of scientific entrepreneurship and research commercialisation to better capture the economic and social benefits arising from public investment in research and on giving research organisations access to additional sources of revenue.

More recently, there have been attempts to develop a broader and more comprehensive framework for understanding research commercialisation and knowledge transfer (Howard Partners 2005a, PhillipsKPA 2006). Such work has usefully highlighted that the commercialisation activities of publicly funded research organisations encompass a wide range of activities (such as consultancy work and contract research, staff and students working on interchange with industry, university-appointed ‘visitors’ from industry, policy advice, seminars and conferences).

However, the Commission questions whether decision making within universities in relation to the transfer and diffusion of knowledge and technology is now too driven by the objective of commercialisation. Some participants appear to share this concern. For example, Griffith University argued that:

> Recently all Australian governments have pressed universities to commercialise their intellectual property as a way of both further diversifying their revenue and ensuring that full economic benefit is obtained from universities' research. However, this policy may be counter-productive. First, the potential for universities to generate revenue from intellectual property may be overstated: it seems that even highly research intensive and entrepreneurial universities in Canada, the UK and the US earn no more than 3%-4% of their revenue from intellectual property sales and licensing. Secondly, it places too much emphasis on research in the innovation value chain, encouraging universities to overvalue their research. … Thirdly, it may impose obstacles to the transfer of research to application since formal legal agreements have to be negotiated and implemented. (sub. 7 p. 9)

Ultimately, in terms of community wellbeing, it is the transfer, diffusion and utilisation of knowledge and technology that matters. The social return from public investment in R&D depends on: whether knowledge and technology is transferred out of universities (that is, whether it sees the light of day); how fast and widely the knowledge diffuses among potential users; whether the knowledge and technology is developed into some form of practical application (that is, whether it is taken up in some form or other that is welfare enhancing); and how widely the resulting innovation is utilised.

It should not be assumed that commercialisation will always be the optimal pathway in terms of maximising the social return from public investment in R&D.

Indeed, commercialisation is only one of the pathways along which knowledge transfer, diffusion and utilisation can occur. Non-commercial pathways are also very important, such as the transfer of knowledge to the public sector and the general community. For example, university research can be a significant input into public policy development. In its submission, Griffith University cited the Pathways to Prevention Project as an example of research based innovation that has demonstrated economic and social benefits, but is not commercialisable (sub. 7, p. 10). Developed under the leadership of Professor Ross Homel, Pathways to Prevention is a universal, 'early intervention', developmental prevention project that has become the template for the new Australian Government Communities for Children program.

Further, an over emphasis on commercialisation potentially carries with it some significant risks:

- poor choices about where best to allocate research resources;

- unnecessarily slowing the transfer, diffusion and utilisation of knowledge and technology, which may involve substantial costs for firms and the wider community; and
- locking-up potentially valuable intellectual property in small ventures that lack the organisational structures, management expertise and capital needed to survive and grow.

The rest of this section is structured around a discussion of the need to:

- consider the decision making priorities within universities; and
- ensure universities are adequately resourced to efficiently transfer and diffuse knowledge and technology to non-academic communities (firms, public sector organisations and the general community).

DRAFT FINDING 6.1

Decision making within universities in relation to the transfer, diffusion and utilisation of research outputs should not focus unduly on an objective of commercialisation to the detriment of maximising the social return from the public's investment.

The decision making priorities within universities

The Commission considers that two of the most promising areas for action are the management of intellectual property and the commercialisation institutions of universities.

The management of intellectual property

Universities already have their own policies and procedures for managing intellectual property, guided by the National Principles of Intellectual Property Management for Publicly Funded Research (ARC et al. 2001). These principles aim to ensure that researchers, research managers and their organisations have access to best practices for the identification, protection and management of intellectual property, and therefore, to maximise the national benefits and returns from public investment in research (ARC et al. 2001, p. 2).

For the bulk of university research, centralised management of transfer and diffusion is unnecessary. Academics themselves manage this process and it appears to work quite well. This reflects that most university academics try to ensure the potential economic, social and environmental benefits arising from their work are realised. Moreover, academics generally have informal and formal contacts with potential users of their work that facilitate knowledge transfer and diffusion. A report commissioned by DEST from the Australian Centre for Innovation et al. (2002) on best practice processes for university research commercialisation found:

> The great majority of academics with a substantial research performance (on average about half) have a very strong interest in seeing the potential outcomes of their research being realised. This realisation may take the form of a new course, a book, a performance, a new scientific theory, or a technology, such as the computer or the Internet, which will change the world. Some can generate direct commercial returns, while from others the economic return is indirect, and the social return considerable. (p. vi)

In many cases, as already happens, the most appropriate course of action is for research to be written-up and diffused through journal articles, conference papers and seminars.

What appears more contentious is when research is potentially commercialisable. Commercialisation arms naturally face financial incentives to try and maximise the financial returns to the university from its research activities. These incentives are likely to be even stronger in those cases where commercialisation arms themselves face financial constraints. Where commercialisation is appropriate, such incentives can enhance social returns. For example, if commercialisation is very expensive, requires highly specialised technical expertise and/or facilities, involves more than one firm in the development process and carries with it considerable risk for the commercialising firm or firms, universities should protect the intellectual property. In these circumstances, firms are only likely to be interested in pursuing commercialisation if they can protect their competitive position through restricted access to the intellectual property.

However, an undue focus, or unquestioning focus, on commercialisation can reduce the social return from the transfer, diffusion and utilisation of knowledge and technology. Again to illustrate, if the knowledge or technology is generally applicable to a wide range of firms and the costs of further development and replication of the resulting innovation are low, the intellectual property should arguably just be given away. In this case, seeking to protect the intellectual property and sell or license simply delays its transfer and diffusion, potentially imposing substantial costs on firms and the wider community.

Even when the intellectual property has already been protected, consideration could be given to whether the potential use of the knowledge or technology would be maximised by giving the intellectual property away. The Commission considers that when the most appropriate pathway for ensuring the utilisation of knowledge or technology involves transferring the intellectual property to foreign firms, universities should seek to license or sell the intellectual property. In this way, Australia shares in the rents from the development of the intellectual property into a marketable product, service or process.

Decision making needs to take into account whether patents are likely to be effective, and this will vary across different fields. The literature suggests that patents are unlikely to be effective if they can be 'invented around' at low cost, are unlikely to be held valid if challenged or are otherwise difficult to enforce, if the technology is moving so fast that patents are irrelevant, or if patent documents require disclosure of too much proprietary information (Shane 2002). If patents or some other form of intellectual property protection are unlikely to effective, then again the best course may be to give the research away.

There has been pressure on universities to create spin-off ventures. However, transferring intellectual property to existing firms (including foreign firms) in many cases is likely to offer the best prospects of ensuring that the knowledge or technology is commercialised. Existing firms may have more appropriate organisational structures, entrepreneurial and management skills, market knowledge and access to the financial resources necessary for commercialisation. Spin-off ventures may have a role where continued involvement of university researchers or access to university research facilities is necessary for the commercial development of the research.

University commercialisation institutions

The focus of universities in recent years on commercialisation has been reflected in the development of various institutional arrangements, usually favouring a specialist unit of some kind for each university (Harman and Harman 2004). These typically, identify, package and commercialise university expertise and technology. To successfully fulfil these functions, commercialisation institutions have to draw on a wide range of skills and expertise including in the areas of contract law, intellectual property, venture capital, spin-off development and marketing. Further, a key role of these bodies is developing effective linkages between universities and firms to facilitate the transfer of knowledge and technology. Generally, the literature suggests that the scale of commercialisation arms is important in terms of developing sufficient critical mass to be effective in this role (Debackere and Veugelers 2005).

However, the Commission questions whether the existing institutional arrangements are necessarily the best use of resources for all universities. In practice, this will depend on the context and capability of individual universities. Dedicated units for each university are resource intensive to establish and maintain, and generally promote the transfer and diffusion of only one part of a university's research output. As the BIHECC noted:

> Commercialising research is a complicated and demanding process, which requires highly skilled staff with strong commercial backgrounds. Skilled commercial managers are highly sought after internationally and are expensive to both attract and keep. Unless sufficiently resourced, university knowledge transfer and commercialisation offices will struggle to employ the calibre of staff required to deliver on the commercial potential of their portfolios. (sub. 55, p. 12)

It seems unlikely that such dedicated units can be self-sustaining for all but the large research-intensive universities. In 2003, across all universities, income from royalties, trademarks and licences was only $34.9 million or 0.3 per cent of total university income (Howard Partners 2005a, p. 17). This is not surprising, since to be self-sustaining, commercialisation units would require an ongoing through-put of commercialisable intellectual property. While universities are repositories of a great deal of knowledge, commercialisable intellectual property is a rarer asset, shaped as it is by market opportunities and user preferences.

The Commission considers that there should be no expectation that universities will each have a dedicated unit. Rather it favours the development of flexible arrangements that allow universities to draw on commercial expertise in the most efficient and cost-effective way. For the large research-intensive universities this may mean maintaining an in-house commercialisation capability. In other cases, however, the best approach may be to purchase this expertise as and when required. To some extent this is already happening such as through the commercialisation collaboration between UniQuest and the University of Wollongong. The Commission sees merit in such arrangements.

Another option may be to encourage research organisations that have built-up effective commercialisation arms to consider the costs and benefits of spinning-off these ventures. This could encourage the development of a number of independent specialist service providers and avoid any perceptions of conflict of interest associated with commercialisation specialists being affiliated with a particular research organisation.

The resourcing of knowledge transfer

As noted in section 6.4, some participants claimed that universities are not adequately resourced to facilitate knowledge transfer to non-academic communities and that the Minister for Education, Science and Training has requested the BIHECC develop a business case for knowledge transfer. In its submission, DEST considered that:

If any case is to be made for additional funding for knowledge transfer it needs to be:

- Located somewhere midway between the extremes that have tended to emerge from the debate so far (that is, research commercialisation versus public interest community engagement).
- Aimed at economic outcomes, both directly and indirectly through, for example, support for social imperatives such as health and stronger communities that ultimately flow through to the wider economy.
- Centred on the practical application of research.
- Encompass both original research and the research of others that can be adapted and applied in new and productive ways.
- Built on effective two-way relationships between institutions and their stakeholders. (sub. 87, p. 63)

As this chapter has argued, it is important for universities to promote the transfer, diffusion and utilisation of the knowledge and technology arising from their research activities. Greater support for this important goal could be provided in a number of ways, including:

- the provision, as requested, of additional funding through a third stream funding program earmarked for this goal, but with competition between universities for the capped funding;
- supplementation of existing block grants that would provide universities with the funding to exercise their discretion for such transfer activities, but would not force them to do so if the opportunities were less attractive than other spending priorities; and/or
- no funding supplementation, but the introduction of measures that address the possible impediments within universities that frustrate the allocation of funding to such knowledge transfer activities. This could involve requirements for institutions to set aside an appropriate proportion of their existing funding for this purpose or other measures aimed at altering incentives within universities.

Essentially, the choice hinges on three particular aspects: whether or not additional funding should be provided; whether that should be provided competitively or through block funding; and, if through block funding, whether its use should be restricted to transfer, diffusion and utilisation purposes. Each approach has advantages and disadvantages.

- In relation to additional earmarked funding, universities currently receive over $3 billion per annum for research and it is arguable that they should already have set aside an appropriate share of this to promote research impacts.
- The design of any competitive programs should minimise gaming opportunities and maximise additionality.

- Competitive funding would discriminate against institutions that choose to concentrate their efforts in areas that require relatively less effort or expense to promote and provide an incentive to commercialise, merely to obtain additional funding.
- Hypothecated block funding could also engender such undesirable outcomes. Moreover, universities already face implicit and explicit hypothecation of block funds to particular purposes (such as matching competitive funds awarded through the ARC). On the other hand, an untied addition to block funds (for each institution) may achieve little additional in terms of transfer, diffusion and utilisation.

These are difficult considerations to balance and reaching a final judgement is not easy — as noted in chapter 8, there are no 'correct' answers to the questions of the optimal public funding levels and mix for science and innovation or for R&D.

At this stage, the Commission considers it best to await the outcomes of BIHECC's deliberations and analyse the resulting proposals against the program design guidelines set out in chapter 9.

6.6 Public support for business commercialisation

The perception that Australia's commercialisation performance is poor sometimes leads to calls for increased public support for business commercialisation. However, the Commission does not support moving in this direction.

The rationale for public support of business commercialisation is weaker than in relation to business R&D. As outlined in chapter 3, the strongest rationale for public support of science and innovation are spillovers that cannot be captured by the innovators and that cannot be realised without support. The commercialisation of knowledge and technology by firms can result in spillovers and in some cases these may be significant. However, it is not the existence of spillovers *per se* that matters in terms of determining whether government intervention is justified. The issue is whether the private returns from investment in commercialising knowledge and technology are sufficiently large to ensure that the investment will proceed. Generally, if successful, firms are in a much stronger position in terms of capturing the returns from commercialisation than they are in relation to investments in R&D. Consequently, there is much less risk from a community-wide perspective that investment in commercialisation will be significantly below what is socially optimal in the absence of government intervention.

In this environment, the problem of achieving genuine additionality from government subsidies to encourage business investment in commercialisation is larger than in relation to R&D. As firms are generally better placed to capture the returns from their investment in commercialisation, provided these private returns are above the required rate, the investment will proceed.

Ex ante, a firm that commits to R&D has already signalled its intention to commercialise. So if there is a systemic impediment to commercialisation, it will generally be revealed as an absence of R&D, not a failure to commercialise pre-existing R&D (the commonly claimed failure).

The Commission also notes that it is sometimes argued that there is a role for government in 'de-risking' highly risky commercial projects. This appears to rest on the view that the parameters of risk-taking in relation to commercialisation are more numerous and more severe than regular economic activity. Professor Jonathan West (2004) has noted in relation to innovation risk that:

> … attempts to innovate induce a far greater level of risk than is present in routine production. Innovation necessarily implies grappling with the unknown, not only because prices and quantities of given commodities cannot be predicted in advance, but also because the technical qualities and very feasibility of yet-to-be-created products or processes cannot be known or even described with confidence. Markets that don't yet exist cannot be analysed. (p. 13)

There is no doubt the commercialisation of knowledge and technology is inherently risky. Moreover, the closer to the knowledge and technology frontier the development of new or improved products, services or processes is occurring — the greater will be the associated risk. However, the issue is not simply what level of risk firms must bear in commercialising knowledge and technology. Consideration also has to be given to what return they can expect from their investment. Generally, firms will only invest in high risk ventures if they consider that the expected return from their investment is sufficiently large to justify the associated risk. It is a commercial reality that sometimes firms make the wrong decision. If firms are reluctant to invest in high risk commercialisation ventures this may simply reflect rational decision-making in the face of uncertainty and the operation of market forces in allocating resources to their most productive use.

De-risking highly risky commercial ventures simply involves transferring commercial risks from firms to taxpayers. Moreover, program administrators who are removed from the market are less likely to be able to assess the risks. There is also the danger of distorting the efficient allocation of resources across the economy.

The Commission considers that a stronger rationale for public support for business commercialisation may lie in the asymmetric treatment of tax losses. This issue is explored in chapter 3.

7 Performance evaluation and benchmarking

Key points

- Effective performance evaluation and benchmarking helps to achieve a number of important goals, particularly in relation to the allocation of public (and private) funds firstly to programs and, secondly, to projects within those programs.
- Various types of measures can be useful including effectiveness measures which assess a program's outputs and outcomes in terms of its defined objectives, and efficiency measures which assess resource use.
  – Measures can be usefully applied in three ways: backwards looking evaluation of results; monitoring of current progress; and estimation of future performance.
- With some activity, for example basic research, suitable output measures can often be used as helpful proxies for measures of outcomes.
- Performance evaluation is enhanced by: specifying desired outputs and outcomes (that is, objectives) consistently; factoring performance measurement into initial program design; considering how best to assess quality and impact; providing appropriate independence and transparency of assessment; and ensuring measurement results feed back into program design.
  – Isolating the effects of public support from the many other factors which can affect outputs and outcomes is important but difficult.
  – Performance measurement system design should trade off the advantages of greater sophistication and precision against additional administrative and compliance costs.
- The adequacy of existing performance evaluation and benchmarking is mixed. There are some notable shortcomings, particularly in relation to business and rural programs. As well, the outcomes from higher education block funding are not transparent and thus difficult to assess. Some arrangements appear very sound in principle, but scope remains for further improvement.

Previous chapters have explored the evidence relating to the nature and extent of the economic, social and environmental impacts of public support for science and innovation. This chapter is more concerned with *frameworks* for performance evaluation and benchmarking. In particular, there is a focus on assembling information relevant to whether public support returns a net community benefit.

The terms of reference request the Commission to report on 'whether there are adequate arrangements to benchmark outcomes from publicly supported science and innovation and to report on those outcomes as measured by the benchmarks'. The chapter assesses the extent to which, in an individual program context, adequate arrangements have been established to monitor, measure and report on the effectiveness and efficiency of public support for science and innovation. 'Benchmarking' can also be interpreted in a 'best practice' framework — through comparing, for example, the performance of a firm with others or, at a broader level, in comparing the performance of countries (chapter 8).

The relevant terms of reference focus on 'outcomes' from publicly supported science and innovation. As discussed further below, however, much performance evaluation will beneficially be, or necessarily have to be, related to program and project 'outputs'. (The distinction is explained below.)

The outputs of research programs and the outcomes that result should ideally be assessed in the context of objectives. These can be set at various levels — for instance, at an economywide or community-wide level; for broad programs such as Backing Australia's Ability; for narrower programs such as the business R&D tax concession; and for individual projects. Given this, performance evaluation should take account of the level at which it is pitched.

- The broader the level, the more necessary it will be for evaluation to trace the direct and indirect positive and negative flow-through impacts of public support on economic, social and environmental outcomes, including the opportunity costs of providing that support.
- At the narrower level, it will be more appropriate for evaluation to concentrate on the direct and immediate positives and negatives of a particular form of support for a particular program or project, leaving aside many of the more indirect and wider impacts. (In the terminology used in this chapter, funding for the CSIRO, for example, would be considered as *program* funding, which that organisation itself would then allocate as *project* funding.)

The following discussion proceeds largely, but not entirely, in the context of performance evaluation for the more narrowly defined programs and projects.

Given that public support is extended in the belief that it will influence outputs and outcomes, a central issue concerns how to establish useful performance measures that isolate, as far as possible, the effects of such public support from the many other factors which can also affect those outputs and outcomes.

7.1 The importance of evaluation

Economic theory can provide rationales for the provision of public support to science and innovation activity in general (chapter 3) and, at a more detailed level, to particular programs and projects. However, theory provides little if any practical guidance about how much support is appropriate in aggregate and how that support should be distributed (chapter 8). Assessment of these matters can be facilitated by performance evaluation and benchmarking.

Indeed, appropriate and effective performance evaluation of the outputs and outcomes from public support can help to achieve a number of goals.

- It provides a guide to the success, or otherwise, of public support in achieving the objectives sought.
  - In turn, this allows evaluation of whether support for particular objectives could profitably be increased, or should be reduced.
- Where comparable data for other countries is available, guidance can be given about whether Australia is achieving 'best value for money' from available funding and whether there is scope for improvement in outcomes.
- Comparisons between programs within a country are facilitated, thus guiding the allocation of funding between them.
- At a project level, benchmarking of expected outcomes could guide the initial allocation of funds to projects by recipients of public support. Setting performance indicators and targets can provide impetus to researchers to perform well. Evaluation of actual project outcomes could then assess whether expected outcomes had, in fact, been achieved and whether funding should be reallocated within the program.

Performance measures can be most useful when they can be used to infer information about the marginal impacts of public support — the change in net benefit that is, or would be, occasioned by a change in the level of public support. Then, theoretically, public support could be allocated in such a manner as to maximise the overall net benefit from its provision (chapter 8). But although measurements over time can sometimes proxy for marginal effects, in practice, measurement of marginal impacts, either for public support in aggregate (chapter 4) or through performance measurement of particular programs, is very difficult. Nevertheless, much useful information can be garnered from average measures.

7.2 A conceptual framework

A simple framework is used below: a science and innovation program is established in response to a set of objectives; the program transforms a set of inputs (including public support) into a range of outputs; and these influence outcomes. Outputs and outcomes may also be affected by a range of influences 'external' to the science and innovation program. (In this chapter, the term 'impact' can usually be used interchangeably with the term 'outcome'.)

Although this model separates 'outputs' and 'outcomes', the Steering Committee for the Review of Government Service Provision (SCRGSP 2006) notes:

> Outcome indicators provide information on the impact of a service … and on the success of the service area in achieving its objectives. Outputs, on the other hand, are the services delivered.
>
> While the … focus [is] on outcomes, they are often difficult to measure. The Report therefore includes measures of outputs, with an understanding that there is a correlation between some outputs and outcomes, and that measures of outputs can be proxies for measures of outcomes. (p. 1.13)

Two broad categories of performance measure are defined.

- Effectiveness measures assess how well the outputs and outcomes achieved meet program objectives. Of course, the weaker the links the less meaningful effectiveness measures will be.
- Efficiency measures assess how well resource inputs are used.

Each category can be applied in three separate ways: backwards looking evaluation of results; monitoring of current progress; and estimation of future performance. (And, conceptually, each could be targeted at average or marginal impacts.)

These detailed performance measures need to be supplemented by high level review of the rationales for public support and their translation into objectives for particular programs.

A significant criticism of the way such frameworks are applied to performance evaluation and benchmarking centres on the narrow interpretations often given to the concepts of outputs and outcomes — for example, a focus on measurable outputs and economic outcomes to the exclusion of wider social and environmental influences, which may be more difficult to measure. These include papers produced and their quality, patents registered, students trained, conferences attended, new products developed, the extent of cost reduction and productivity growth.

However, Graeme Pearman, for instance, considered that in the context of science, 'the concept of wealth needs to include such components as public scientist/technological literacy, international awareness, policy sophistication and inclusiveness …' (sub. 86, p. 11). In the Commission's view, the evaluation framework should embrace, where relevant, social and environmental outcomes, reduction of risk, preparedness to meet uncertainty, and the maintenance of strategic capability and infrastructure.

7.3 Improving evaluation

This section briefly discusses a number of criteria useful to the assessment of the adequacy of current performance evaluation arrangements and how they might be improved.

Given the rationales for public support for science and innovation (chapter 3), program and project objectives should focus on such things as overcoming market failures, capturing spillover benefits, dealing with social and environmental risks, and making a contribution as a global citizen. As well, public support can help to build the human capital and infrastructure bases necessary to pursue these objectives. In turn, effectiveness measures and key performance indicators should be developed in accordance with those rationales and objectives.

As an example, an objective of *increasing expenditure on R&D by business* has no merit in itself. This is because it does not reflect the rationales for public support and thus obscures important evaluation issues, such as causality. An alternative objective of *increasing spillover benefits available to the community through enhancing levels of business R&D* would be more useful. This would serve to focus evaluation on the net community benefits of public support, while treating enhanced business R&D expenditure as just an output which contributes to the underlying goal.

Further, the nature of activity accorded public support and the form in which that support is provided should also influence performance evaluation.

Basic research, for example, focuses on investigation for the sake of curiosity, improving the community's stock of knowledge and the development of new experimental techniques. Outcomes from such work are not necessarily expected in the short to medium term and its practical usefulness can often be manifested in unforeseen and serendipitous ways. Indeed, often such basic research is undertaken on the understanding that there may well be 'failure' from a short to medium term viewpoint. When evaluating such activities, the focus is more appropriately on outputs, including quality, rather than outcomes, as well as, of course, assessing the efficiency of the use of resource inputs to achieve those outputs.

With applied research, in contrast, practical outcomes are usually expected in a reasonably short timeframe. Evaluation should focus more on achieved outcomes, rather than outputs. It should specifically attempt to address the causality issue — in effect, to demonstrate that public support has 'caused' the desired outcome. Support for BERD, rural research, the CRCs and such programs as ACIS provide examples of where, after appropriately defining objectives, it is reasonable to focus more on outcomes than outputs — and, in particular, on the extent to which public support has been a factor in enhancing outcomes.

Assessing causality

According to the OECD, four basic problems affect the relationship between research outputs and its outcome effects (box 7.1) — these can be broadly summarised under the term 'causality'. Dealing with this issue is central to appropriate and useful effectiveness measurement.

Box 7.1 **Complexity of relationship between research and its effects**

According to the OECD, exploring why the relationship between research and its effects is complex highlights four 'basic' problems.

- *Timing* — the effects of research are often manifested long after the research has been completed and the connections obscured.
- *Attribution* — a given innovation may draw upon multiple research projects and a given research project may impact upon multiple innovations. In drawing pathways between them it is also the case that an innovation depends upon many inputs other than research before market or social effects are realised.
- *Appropriability* — the beneficiaries of research may not be the same people or organisations who performed it so it may not be obvious where to look for effects.
- *Inequality* — the distribution of impacts in a given project portfolio is typically highly skewed. A small number of projects ('blockbusters') may account for the majority of effects, while around half often do no more than advance knowledge in a general way. This has implications for sampling strategies.

Source: OECD 2006a, p. 4.

Ideally, it would be preferable to develop a range of effectiveness measures that can directly measure the effect of public support on outputs and achieved outcomes. However, a range of influences can make it difficult to assign attribution to public support (or, indeed, to any other factor(s)). Using business R&D as an example:

- an increase in total R&D activity (with enhanced spillovers) might reflect an underlying trend, developing technological opportunities, more favourable economic conditions, or an improvement in profitability and the ability of firms to invest, just as much as public support; whereas
- a decrease in total R&D might disguise a situation of even lower R&D activity in the absence of public support.

Further, achieved outcomes depend not only on the effects of immediate public support, but also on such influences as the existing 'stock' of relevant R&D (domestic and/or foreign), the competitive environment, and institutional and regulatory factors. Elapsed time between program inputs and achieved outcomes can be lengthy. For example, it has been estimated that in the CRC program there is an average lag of some 9 years between funding support and achieved outcomes (Allen 2005, p. ix). Some basic research may only pay dividends in the form of measurable impacts after many years, if at all.

In commenting on such issues, the New South Wales Government considered that:

> Performance measures must recognise the long-term nature of the impacts from research, and that many benefits, especially environmental and social impacts, are difficult to track and measure. A measurement system will also have to resolve the issue of attribution and the broad span of the commercialisation or adoption pathways. (sub. 91, p. 15)

Indeed, some forms of outcomes may not be apparent to external observers, being internalised within the individuals, firms or institutions receiving public support. This does not mean that such outcomes are not valuable — they can form the building blocks to future gains for particular groups or for the community generally — but just that they cannot be reliably measured or estimated.

Given this attribution difficulty, there can be incentives for recipients of funding to ascribe changed outcomes almost 'automatically' to the support program, thus falling for what is described by the OECD as the 'project fallacy' (OECD 2006a, p. 42). However, this leads to inaccurate and misleading performance measurement and assessment.

The causality problem is less intractable that it might first appear, however.

- Appropriate professional judgment such as peer review can assess output quality and the impacts of public support. Similar professional judgment is drawn on in many fields, including education and medicine. Appropriate ground rules for such judgment, including moderation where appropriate, can build confidence in the rigorousness of the process.

- Some categories of science and innovation activity are predominantly funded by government — for example, some public sector research agencies (PSRAs) and much of the basic research of tertiary institutions. Of course, this does not necessarily make the identification and measurement of particular outcomes much easier nor eliminate the causality problem entirely — external factors would still need to be accounted for.
- Similarly, much research undertaken to maintain scientific capability and to address defence and environmental risks may simply not be undertaken without public support.
- Finally, as discussed in more detail below and in chapter 9, another approach is to provide public support in a form which inherently evokes additionality of outcomes — for instance, if the program objective is to encourage useful additional spillovers for the community, then support could be conditional on recipients demonstrating that additional R&D had been or would be made.

Assessing quality

The assessment of 'quality' has assumed greater importance in the evaluation of many programs of support for science and innovation in Australia. Quality evaluation may become even more central in future, through developments such as the proposed Research Quality Framework (RQF), for example (see below and chapter 11).

Although quality, of course, is relevant to both outputs and outcomes, it is best to regard it primarily as an output characteristic. Even though there will always be legitimate interest in promoting research efficiency and quality, good outcomes may sometimes be obtained almost irrespective of the quality of program activity through serendipitous discovery, for example. Further, treating quality as an outcome characteristic could lead to this important dimension of activity being overlooked in performance evaluation in basic and strategic research where no particular short or medium term outcomes are targeted (see below).

A benefit–cost framework

As discussed in chapter 11 in relation to funding for higher education research, performance evaluation and measurement systems themselves need to be considered in a benefit-cost framework, assessed against a number of possibly conflicting criteria. To put it simply, it would be counterproductive to establish detailed and expansive systems to assess quality and impact if the gains compared to simpler systems were to be outweighed by extra administrative and compliance costs, greater opportunities for gaming or even more intrusiveness.

Forms of assistance

In many cases, choosing forms of support which most directly target assistance rationales not only improves program outcomes but also facilitate useful performance evaluation. For example, as the 175 per cent tax expenditure deduction for additional R&D relates more directly to the underlying rationales for public support than the 125 per cent deduction for *base* R&D, performance evaluation measures can more readily deal with the causality issue.

Further, evaluation will be enhanced if program rules are structured to maximise the incentives for participants to contribute to the intended outputs and outcomes while minimising their opportunities to manipulate the funding allocation rules to the detriment of program objectives. For example, assistance simply based on the number of research publications produced would overlook the more important quality and efficiency dimensions.

These issues are discussed more in chapter 9.

The role of project case studies

Many programs, including for example the CSIRO, the RRDCs and the CRCs, include case study evaluations of the impacts of selected projects as part of their performance evaluation arrangements. As summarised in box 7.2 (also see appendix I), however, there are significant issues in using such analyses as indicators of the community benefits of public support. Indeed, in that context, they may well only be useful as a supplement to more focused program-wide evaluation.

Aggregation and weighting issues

As noted, performance evaluation can proceed at various levels, including for the assessment of rationales for public support, prospective and/or retrospective evaluation of broad funding mechanisms, the programs themselves and for individual projects within programs.

Often, questions of aggregation and weighting will arise. For instance, higher education institutions and research agencies such as the CSIRO may literally have hundreds of projects proceeding at any given time. Further, with business programs, each firm could be considered a separate 'project' in a sense. How should performance in relation to such individual projects be aggregated to give a measure of overall program performance, particularly where occasional ‘failure’ at a project level can be expected and where separate but concurrent projects often deliver their outputs and outcomes at different periods of time?

Box 7.2 **Relevance of selective project case studies**

A number of agencies measure the economic impacts of particular projects in terms of such measures as the social rate of return, net present value and/or benefit–cost ratios. Essentially, although their expression varies, all such measures attempt to measure benefits net of costs.

But there are a number of problems in using such measures as indicators of the *net community benefits of public support*.

- If measurement focuses on those projects with the highest net returns it gives a misleading picture of program impacts. Most programs could be expected to have a share of ‘failures’ or low/negative return projects ex post.
- Such measures may not address the impacts of the marginal dollar either — that is, the net benefits of extra spending at the program level.
- They often measure the impact of total project funding, rather than just those impacts consequent on public support. That is, they often fail to deal adequately with causality/additionality issues.
- Often, they do not factor in opportunity costs, including the efficiency costs of taxation.

Even as indicators of the net benefits of particular projects, such measures can have problems.

- Benefits are difficult to judge and measure, particularly those for future years. The time for which an outcome will be inherently useful — for example, before it is overtaken by outcomes from other projects or ‘depreciates’ in some other way — is often uncertain. Difficult judgments need to be made about how much of an outcome to attribute to the project, how much to attribute to forerunner projects and how much to attribute to external factors. There can be a tendency to over-attribute benefits to the project (the ‘project fallacy’) — for example, to attribute all profit arising from the production and sale of a new product to its R&D genesis, ignoring the contribution of other factors of production. The bottom line is that benefits can be easily overestimated.
- There can be problems on the costs side as well — for example, in judging which overhead and indirect costs to include.

In summary, selective economic impact evaluations can be quite useful as indicators of the net benefits from particular projects, if done well, even if they do not directly assess the impacts of public support, per se. But they must be used with considerable care as indicators of the net community benefits of public support associated with particular programs.

The answer partly depends on the nature of activity undertaken. In some cases, simple counts of successful outcomes falling within range (possibly against pre-specified targets) may suffice. In others, more sophisticated summation and weighting measures may be appropriate. Frequently, however, informed professional judgment will be required.

Performance assessment of programs which receive funding from more than one source can be complex — particularly where a variety of funding criteria are used with different conditions attached — as it will not always be possible to ascribe outcomes to particular buckets of money.

Retrospective or prospective assessment

As noted, performance assessment and evaluation can take place in three different timeframes — looking back, looking forward, and monitoring. There is a role for all three forms.

Much evaluation relates to ex post evaluation, in terms of rationales/objectives, funding methodology and at the program level. As noted, this can then be used to inform such decisions as future funding levels, revisions to assistance mechanisms and changes in administrative and compliance rules. As such, ex post evaluation is critically important.

However, there is also a place for ex ante evaluation/estimation, particularly in the allocation of funds to projects. For example, the ARC/NHMRC processes assess likely outputs/outcomes in advance through peer review of proposals and allocate funding according. Similarly, some business programs also use an evaluation of likely outputs and outcomes in allocating funds to particular firms.

Further, there is obviously a critical role for monitoring work in progress, especially in large organisations such as higher education institutions and the CSIRO, where there is a multiplicity of projects under way at any one time.

Frequency

While it is reasonable to expect that efficiency of resource use should be kept under annual or more frequent review, a number of considerations will need to be balanced in considering how often comprehensive effectiveness evaluation should be undertaken.

- Outcomes may take years to emerge (even though outputs should be observable more frequently).

- Evaluation can be expensive, particularly where extensive data and information has to be collected, special methodologies need to be employed or the review workload is otherwise likely to be high, for example when extensive peer review might be required.
- And comprehensive review itself can take considerable time.

On the other hand, in some circumstances, effectiveness evaluation can be relatively simple and quick, especially where forms of public support are compatible with outcomes sought; and where substantial reliance can be placed on output measures rather than outcomes.

The New South Wales Government stated that it:

> … recognises that the recipients of public sector research funds should be required to undertake submission and reporting activities that demonstrate prudent management of funds, and outcomes from the investment. However, the quantity and frequency of reporting should be in step with the funding levels, and the projects' scale. (sub. 91, p. 13)

In summary, it is difficult to be prescriptive about the optimum frequency of performance evaluation, especially for effectiveness measures of outcomes. However:

- the evaluation of a program's past performance, rationales, objectives, future desired outputs and outcomes, and future levels of public support, should be undertaken periodically — consistent with the costs and benefits involved — major programs, for example, should be reviewed every three to five years;
- individual projects should be monitored with sufficient frequency to reassure the program sponsors that satisfactory progress is being made; as well, they should be assessed after completion for their effectiveness and efficiency; and
- relevant institutions should report on their own performance at least annually.

Independence and transparency

A major purpose of performance evaluation is to assess the net benefits for the community as a whole of public support provided for science and innovation. Thus, there is a strong case that performance evaluation, at least at the program level and above, should be conducted independently with reports and recommendations being made available to the public.

Independence of evaluation is not always easy to achieve in practice. Sometimes evaluation will necessarily have to draw on the experience of program participants or rely on the assessments of expert peer reviewers, for example. While review procedures can usually minimise the risk of bias, it is hard to eliminate completely. This makes transparency all the more important. (Of course, it is recognised that in particular instances questions of privacy/security, commercial confidentiality, and so on, may arise.)

The quality and transparency of program evaluation can be reinforced through such procedures as establishing independent steering committees to guide evaluators, agreement up front on a timetable for publication of the evaluation, and through independent third party peer review of the evaluation report.

Feeding assessment back into improvement

Finally, performance evaluation and benchmarking will only be useful if the findings are drawn on to enhance the future benefits of public support for science and innovation. With major reviews, this requires governments to commit to a public response to any relevant recommendations for change. And at a lower level, the results of performance evaluation can be used for fine tuning program arrangements.

7.4 Adequacy of current arrangements

This section responds to the terms of reference which request the Commission to report on whether the benchmarking and reporting arrangements for the outcomes from public support are adequate. (Some of the programs discussed below are described in more detail elsewhere in this report.)

Broad level programs and arrangements

National Research Priorities (NRPs)

Australia’s NRPs and their associated priority goals, developed in 2002 and enhanced and refined in 2003, are listed in chapter 8.

The priorities and priority goals are not ranked in importance in any way. Neither are they prescriptive, nor do they provide quantitative goals in measurable terms (for example, in terms of expenditure targets). Further, they do not apply to industry R&D programs or to university block grants.

However, ‘all Australian Government research and research funding bodies are expected to contribute to the national research priorities, within their existing mandates and missions'. Each of these bodies was expected to prepare an implementation plan to 'describe how they propose to implement national research priorities'. Each plan in turn was required to 'identify performance measures to enable the impact of the national research priorities initiative to be assessed. Performance measures should include outcomes, outputs and inputs components' (quoted from DEST website).

Research and research funding bodies are required to report progress against these plans in appropriate documents, including in the annual *Innovation Report*, and to report annually to the Government. These reports typically assess how the funding body's activities line up in broad qualitative terms against the national priorities. As well, they usually objectively report expenditure and trends in expenditure classified by research priority and also, sometimes, by simple measures such as numbers of projects.

Given the purpose and nature of the current NRPs it is not surprising that performance reporting against them is relatively simple. This is all the more so given their current non-prescriptive nature, their lack of specification of the expected public benefits arising, and their non-quantitative expression (in the broad and at an agency level).

As discussed in chapter 8, the Commission considers that NRPs should continue to be expressed as high level direction statements of the areas in which the Australian Government considers science and innovation activity in Australia should be focused. In the Commission's view, there are advantages in avoiding the added prescription that a move towards greater specificity in Australia's NRPs would bring. Accordingly, there is little to be gained from attempting to enhance the 'sophistication' of performance evaluation and reporting associated with them.

Backing Australia's Ability

The terms of reference refer to the Backing Australia's Ability (BAA) program, established in 2001. Funding levels under the BAA umbrella were boosted in 2004 — the original program provided some $3 billion over a five-year period from 2001, while the revised arrangements provide for some $8.3 billion over the 10 years to end 2010-11. In total, BAA now annually accounts for some 20 per cent of Australian Government funding for science and innovation.

BAA was implemented in a number of ways, including by the establishment of new programs with associated funding allocations, the cessation of, or significant revisions to, some existing programs, and by augmenting funding for many existing arrangements.

The Government's objective has been to 'support … innovation by boosting funding to key areas and introducing significant new initiatives' (BAA 2001, p. 14). According to the initial strategy document:

> *Backing Australia's Ability* has been developed with full understanding of our current strengths and weaknesses, recognition of relevant national and international factors and a comprehensive assessment of likely conditions in the future. … This strategy supports the essential ingredients for a dynamic and productive innovation system. It focuses on the Government's commitment to three key elements in the innovation process: strengthening our ability to generate ideas and undertake research; accelerating the commercial application of these ideas; and developing and retaining Australian skills. (BAA 2001, p. 14)

However, while the 2001 plan, and its 2004 successor, draw on previous reports and studies, the plan documents themselves do not explicitly link funding provision, either for individual programs or in total, to those general goals.

The terms of reference note that the Commission's research study 'will complement the ongoing and planned reviews of BAA programs'. The Commission understands that this refers to a planned review of BAA as a whole, following the Commission's report, as well as to ongoing reviews of the individual programs that are supported, at least in part, by BAA funding. Current BAA progress is commented on in general terms in the annual Innovation Report.

The general nature of BAA's objectives, and the lack of any linkage between these objectives and specific programs and funding allocations, make detailed performance evaluation of the program very difficult. Nevertheless, there would be value in undertaking, at a suitable time, a broad level assessment of BAA with a view to rebalancing its various components and revising funding levels if found beneficial.

Such broad review, however, would have to draw heavily on more detailed reviews of each component program. This emphasises the importance of working towards overcoming the present inadequacies in performance evaluation in several of those programs (see below).

Public sector research agencies

As with higher education institutions (see below), public sector research agencies (PSRAs) operate under a 'hybrid' funding model, involving block grants from governments together with monies attracted on the basis of performance, or likely performance, both from governments and private sources. The extent of funding that is directly based on performance varies over time and among agencies.

It could be expected that a PSRA should focus on work of a public good nature. However, a focus on such work is necessary but not sufficient for the ongoing maintenance of such a public sector organisation — this depends on the particular nature of the research issues addressed as well as how it performs relative to the possible alternatives (such as contracting out). Hence, continuing performance evaluation of effectiveness and efficiency is crucial for such an organisation, especially for the publicly funded component.

The following discussion draws on, as one example, the CSIRO, which is Australia's major PSRA, and which in 2005-06 received public funding of some $600 million from the Australian Government. Such appropriations make up about two-thirds of the organisation's revenue. A second illustration concerns the DSTO, the R&D arm of the Australian Defence Organisation. In 2005-06, its government funding, delivered as an integral part of the defence budget, totalled some $350 million. (Further information about both these organisations is presented in chapter 10.)

CSIRO

CSIRO's performance measurement framework is based on a number of performance indicators under 24 objectives clustered under 6 strategic goals (see CSIRO 2003, 2005b). Targets are set for many, but not all, of the performance indicators. Five elements of performance are distinguished: strategy implementation; program performance; science highlights; organisational health; and outcomes.

In the CSIRO context, program performance relates to the achievement of annual performance goals detailed for each of its many 'programs' (these are better described as 'sub programs' in the terminology used throughout this chapter, the organisation itself being the 'program'). Input and output measures are generally reported under the organisational health element, whereas outcomes are reported under the outcomes heading. The organisation conducts a 'science assessment review' process, aimed at assessing the quality of its scientific capabilities and the impact of its research performance (box 7.3) — there are similarities between this process and the proposed RQF (see below and chapter 11). It also assesses the 'economic impacts' of selected research projects. Collectively, this performance framework guides the CSIRO in setting strategies and priorities, allocating funds to sub-programs and to projects, monitoring progress of research and measuring outputs and outcomes. Much of the resulting information is reported publicly.

Box 7.3 **The CSIRO's Science Assessment Reviews process**

As part of its 2004-07 triennium funding agreement, the CSIRO undertakes reviews of the quality of its scientific capabilities and the impact of its research performance. These are currently done on a divisional basis, with each division to be assessed once over the three year period. To an extent, the proposed RQF mirrors processes already undertaken in these reviews — however, in contrast to the proposed RQF, these existing CSIRO reviews have no immediate broad funding implications, although they do inform internal resourcing allocation decisions.

In brief:

- the relevant division provides information on the basis of which assessments can be made, grouped by appropriate subdivisional units (groups);
- the assessments are undertaken by panels of 3–5 external (to the CSIRO) experts, predominantly from overseas, including at least one member from an end-user organisation, plus the CSIRO's executive director of science planning; and
- groups are assessed on two criteria — research community impact, and industry/community impact — each against a five point scale.

A range of other processes are used by the CSIRO in monitoring and assessing its research quality and impact. These include citation based analysis, benchmarking performance against other organisations, and formal benefit–cost evaluations.

Source: Information provided by the CSIRO.

DSTO

As noted, DSTO is the R&D branch of Australia's defence organisation (ADO) and funded through it. Indeed, about 90 per cent of DSTO's income comes from the ADO. The nature of its work is somewhat different from that of a PSRA such as the CSIRO. Such a direct ownership relationship has implications for performance assessment.

A recent external review of DSTO commented that:

> DSTO's role in securing Australia cost effectively means its primary output is a more cost effective defence capability — not the supply of public good-based research outcomes of direct value to the wider community. Accordingly, this output should be its primary basis for accountability. (Trenberth 2004, p. 99)

The review considered that as it is 'intimately connected to the ADO', DSTO 'is more like an industry research group than a university' (Trenberth 2004, p. 1).

As a result of that review, recent changes have been made to promote greater interaction with industry to diffuse and commercialise DSTO research.

Nevertheless, it still remains true that the DSTO's prime focus remains with serving the ADO.

The nature of the relationship throws considerable onus on the ADO to ensure that it is getting good value for money from DSTO and that it cannot do better, taking its security and strategic concerns into account, from contracting scientific work to outside organisations, either directly or through the DSTO itself.

Adequacy

Although the Commission has not made a detailed evaluation of each PSRA, there is no evidence that the performance evaluation and measurement processes used by those bodies are not adequate. Indeed, considerable improvement has been made in recent years, particularly through bringing reporting into an output/outcomes framework. Some arrangements — for example, those of the CSIRO — are particularly notable for their appropriateness and comprehensiveness. And further improvement can be expected as programs and institutions develop their performance evaluation frameworks and their ability to specify and measure relevant key performance indicators, particularly in relation to the rationales and objectives for public support.

Another safeguard is the requirement under the Triennium Funding Agreements for 2004-07 for the Australian Institute of Marine Science, the Australian Nuclear Science and Technology Organisation and the CSIRO to undertake a continuous process for assessment of research performance consistent with the objectives of the RQF process (sub. 87, p. 30).

Higher education institutions and programs (including the ARC and the NHMRC)

Science and innovation activity, including R&D activity, in higher education institutions is often part of a broader functional responsibility which includes undergraduate and postgraduate teaching. Given this learning focus, as well as the basic research focus of much of their activity, defining expected outcomes in other than very general terms becomes difficult, even allowing for the relatively recent focus on increasing commercialisation (chapter 6). For this reason, much of the past and current performance evaluation of higher education institutions relies on output measures, rather than on the assessment of outcomes.

Each higher education institution has its own internal procedures for allocating funds to research, including block funding, for monitoring research in progress and for assessing outputs and outcomes. These arrangements are reported by the institutions to DEST in Research and Research Training Management Reports. The latest publicly available are 2003. But as far as the Commission is aware, there is currently no published comprehensive retrospective evaluation of the quality and impact of higher education research, nor of that funded specifically from block grants (see chapter 11).

Funding institutions such as the ARC and the NHMRC have their own performance measurement frameworks. As an illustration, that of the NHMRC is briefly summarised in box 7.4. The NHMRC indicated that it is still developing its methodology, but that it has:

> … made considerable efforts to demonstrate practically the benefits of health and medical research. The NHMRC has directed significant resources towards developing and implementing its Performance Measurement Framework and developing protocols to evaluate the impact and the benefits of the Australian Government's investment in health and medical research. (sub. 80, p. 12)

Box 7.4 **The NHMRC's performance measurement arrangements**

Performance measurement arrangements for the NHMRC ultimately stem from its strategic plan (NHMRC 2003). This defines seven 'strategic objectives' for the 2003-06 period, each with one associated 'outcome'. In the terminology generally used in this chapter, these objectives and outcomes, however, appear to relate variously to inputs, outputs and outcomes.

A number of 'strategies' are associated with each 'outcome' and, in turn, a non-exhaustive list of performance 'measures' are listed in the strategic plan. These also relate variously to inputs, outputs and outcomes.

The formal performance measurement framework (NHMRC 2004a) takes each strategic plan 'outcome' and defines a number of performance measures called 'indicators' arranged under subheadings. Each measure has an associated target although many of these are described as 'new' with targets 'to be benchmarked and reported'. The NHMRC has described this framework as including 'a balance of inputs, processes, outputs and outcomes' (NHMRC 2004a).

Included in the indicators and associated targets are some measures of efficiency as well as effectiveness measures. However, many indicators and targets are expressed as simple input and output measures.

According to the NHMRC, a 'key initiative' has been the establishment of its Evaluation and Outcomes Working Committee to steer peer review of final project reports and to 'evaluate and disseminate the outcomes arising from NHMRC funded research' (sub. 80, p. 13).

Similarly, the ARC is making considerable effort to demonstrate the net benefits to the community from ARC-funded research (see sub. 73 from page 34), although it commented that:

> Conceptual and practical difficulties plague any attempt to measure research impact in any aggregated way, and are exacerbated in the case of research undertaken by or for government agencies, whose focus tends to be on research with diffuse benefit streams and/or longer time horizons than that of the private sector. (sub. 73, p. 20)

Adequacy

A major perceived current deficiency in performance evaluation and measurement is the lack of comprehensive retrospective information about the quality and impact of higher education research.

Part of the rationale for the development of the RQF is to address this issue, particularly in regard to block funding. However, as discussed in chapter 11, the Commission suggests that it is still too early to make a final decision about implementation of the RQF and suggests that a number of other approaches be investigated — including limited trials directly aimed at seeking indicator information about the current quality and impact of block funded research.

In regard to competitive funding, both the ARC and the NHMRC are enhancing their efforts to promote research with good quality and impact and to measure the outcomes of research they fund. While, at this stage, some performance measures appear 'soft' and/or unquantified, both organisations are constantly refining and improving their performance evaluation methodology.

Business and similar programs

Tax concessions for BERD

As discussed in chapter 3, economic theory suggests that businesses are likely to underinvest in R&D. It is argued that public support would induce more R&D from business, providing beneficial spillovers for the community and thus increasing net social returns.

However, this theoretical argument leaves two central points to establish in practice. That is, to what extent does public support, in the forms in which it is provided, actually engender additional BERD; and how much public support should be provided (beyond a certain point it could be expected that additional public support would also come at a net cost). Both these questions necessitate performance measurement and evaluation.

Although individual businesses will want to monitor and assess the benefits and costs of their R&D expenditure, from a public policy point of view what is of most relevance is the degree of success of the overall program in engendering net benefits for the community.

The Industry Research and Development Board provides annual registration data, together with some information on eligible R&D expenditure and its nature, and information about its administrative processes. In regard to up-to-date performance evaluation of the merits of the concession program, the Commission notes that the CIE conducted a review for the Department of Industry, Tourism and Resources in 2003 of ‘the effectiveness, appropriateness and efficiency of the 125 per cent R&D Tax Concession’ (DITR web site). However, although the Commission has now obtained a copy, the report has not been widely publicised. Its results are described in chapter 9 — but its findings do not appear to have been fed back into program redesign. Further, there is no publicly available evaluation of the performance of the (relatively recently introduced) 175 per cent element of assistance or the R&D tax offset.

Agriculture R&D

Government-industry funding arrangements for rural R&D have been in place for more than 50 years. In broad summary, under current arrangements a number of industry based rural research and development corporations and companies (collectively known as RRDCs) act as funding agencies in channelling research to major agencies such as CSIRO, state departments of agriculture and other research centres. Available funds arise from two main sources: levies on producers; and the Australian Government (chapter 9). But support to primary industries and producers for R&D is not limited to the government’s matching contribution, however, as other federal and state/territory government monies find their way in through research agencies such as the CSIRO, higher education institutions, CRCs and state departments of agriculture.

As with other programs and institutions, performance evaluation can take place at several levels. Individual RRDCs monitor their own performance as well as that of the projects they support — an example relating to the Grape and Wine R&D Corporation is given in box 7.5. (Box 9.4 gives some detail about RRDC priority setting, management and evaluation criteria.)

Box 7.5 Performance measurement — Grape and Wine R&D Corporation

The Corporation's Annual Operational Plan includes information about its overall objectives and its R&D development strategies and priorities. It also includes more detailed information for its programs and sub programs relating to objectives, outcomes, strategies and performance information. It lists expected program outcomes, associated relevant outputs and 'measures of success'.

Source: Grape and Wine R&D Corporation 2005.

As well, RRDCs have published information about many 'successful' projects which illustrate worthwhile benefits for producers and, in some cases, for the community more broadly (see, for example, the submission from the Council of Rural Research and Development Corporation Chairs — sub. 96). Success, of course, depends on more than just the 'wisdom' of an RRDC in selecting projects to fund — it also reflects the abilities of the funded agency, be it the CSIRO, a CRC or whatever, in undertaking the actual work.

With programs of this nature, it is important that evaluation of their broad rationales as well as the justification for the levels of public support provided should be undertaken from time to time. However, no such broad level independent evaluations appear to have been undertaken in recent years.

A submission from the Australian Centre for International Agricultural Research (ACIAR) noted that it has 'a long standing program of quantitative evaluation of the impact of its activities' (sub. 81, p. 25), and that it is continuing to develop its evaluation methodologies.

CRC program

In effect, the CRC program is a funding arrangement directed at encouraging public sector agencies and private interests to work cooperatively together to 'match the technology push provided by [Australia's] strong research base with the demand pull of industry and other research users' (Howard Partners 2003, p. i).

Australian Government funding for 2005-06 was about $208 million. This is expected to have made up about 30 per cent of total CRC funds available in that year, with the rest contributed by other partners including business, universities, the CSIRO and State and Territory Governments.

As with the above programs, performance evaluation of the CRC program can proceed at a number of levels: the program funding level; the level of each individual CRC; and that for individual projects sponsored by a particular CRC.

The latest program evaluation was published in July 2003. Howard Partners commented that:

> The arguments for public involvement in industrial research are well rehearsed and it is not proposed to restate them in this Evaluation. … The CRC Programme also addresses a market failure, particularly in environmental research, but also in agricultural research … (Howard Partners 2003, p. i)

A 2005 report by the Allen Consulting Group for the Cooperative Research Centres Association assessed the 'economic impacts' of the program. Its key finding was that:

> … over the 1992 to 2010 period the Australian economy's overall performance has been considerably enhanced when compared to the performance that would have occurred in the absence of the Commonwealth Government investment in the round one to seven CRCs that was provided between 1992 and 2005. (Allen 2005, p. vi)

One particular interesting aspect of this study is that it found, on average, a nine-year period from initial expenditure to reaping of benefit — illustrating the difficulty of linking public support for science and innovation in a causal way to outcomes.

Individual CRCs adopt a range of processes for allocating funds to projects, monitoring quality and impacts, and measuring their own effectiveness and efficiency. The emphasis on such activities is likely to have been enhanced with the relatively recent requirement for CRCs to be established as corporate entities, with governance through boards of directors.

Adequacy

Although the Commission has not undertaken a detailed examination of the performance evaluation and measurement undertaken by individual RRDCs and CRCs, there was no evidence presented to suggest there are any inadequacies at that level.

However, these programs and the other business programs, such as the tax concessions for business R&D, have a number of inadequacies in terms of the considerations set out in section 7.3. These relate mainly to a lack of regular, transparent, and independent reviews of the rationales for assisting business in the forms and at the levels provided and of the detailed program arrangements. More specifically, in a number of these programs:

- desired outputs and outcomes are not linked back to the rationales and objectives for public support;
- levels of support are not clearly related to those rationales and/or objectives, nor to science and innovation objectives more generally;
- causality and additionality issues are overlooked or inadequately addressed;
- forms of support may be inconsistent with rationales and objectives;
- there can be inappropriate reliance on selective case studies; and
- comprehensive evaluation is infrequent, and may be lacking in transparency and independence.

And where evaluations have been undertaken, it is not always clear that their findings have been drawn on in program review and redesign.

State/Territory programs

Although this report primarily focuses on federal programs, State and Territory Governments are significant players in science and innovation in Australia. Their involvement ranges across many areas including rural industry, other primary industries, manufacturing and industrial development, health, technology and environmental and social issues.

A traditional area of involvement at this level of government has been in respect of agriculture. Indeed, this remains the case with, for example, the NSW Department of Primary Industries Division of Science and Research employing over 900 staff, managing over 700 projects, with a budget of over $130 million. Similarly, the Victorian Department of Primary Industries has a scientific strength of some 950 staff.

Some States has formalised activity through science and innovation plans or initiatives. For example, Victoria has made a total of $620 million available over the 1999 to 2005 period for strengthening the science and technology infrastructure and support base in the State, and for promoting commercialisation. South Australia, also, has a ‘10 year vision for science, technology and innovation’ (sub. 92, p. 1).

Submissions from State Governments generally recognised the importance of adequate performance evaluation and monitoring. Some examples were provided which illustrated the evaluation methodology used. These examples, however, concentrated on the evaluation of projects, rather than on higher level evaluation of the rationales for public support, and the forms and levels in which it is provided at the state level. The extent to which such evaluations exist, whether they are public and whether they are undertaken independently is not clear to the Commission, at this stage.

Summary

The Commission is not in a position to undertake detailed assessments of the performance evaluation arrangments of individual programs — nor would it be worthwhile attempting to do so in a study of this nature. Nevertheless, it is apparent that there are noticeable inadequacies in performance evaluation in relation to some existing programs and arrangements. Even where existing arrangements are satisfactory, scope remains for further improvement.

In the Commission's view, performance evaluation and reporting arrangements for every relevant science and innovation program should be reviewed against considerations such as those detailed in the previous section. If applied consistently across science and innovation, this should lead to a marked improvement in performance evaluation and reporting overall and thus, ultimately, in the programs themselves and the effectiveness and efficiency of public support.

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Performance evaluation and reporting arrangements have developed significantly in recent years, particularly through the adoption of an outputs/outcomes focus. There are, however, examples of major deficiencies. Arrangements should be reviewed against the following criteria.

- *Outputs and intended outcomes should be defined in relation to the rationales for public support and to the community benefits expected from that support.*
- *Evaluation should be developed in a benefit–cost framework, balancing greater precision against administrative and compliance costs.*
- *Where undertaken, selective case studies of impacts should be placed in a supplementary rather than central evaluation role.*
- *Assessment should be undertaken with adequate frequency — this might vary between different types of measure.*
- *Assessment should be as independent and transparent as reasonably possible.*
- *Feedback mechanisms that promote continuous improvement in terms of funding allocation to programs and to projects should be developed and implemented.*

8 Funding levels, funding mix and coordination issues

Key points

- In theory, public funds should be allocated to science and innovation whenever the net social benefit of marginal spending remains both positive and exceeds the next best alternative use.
- However, in practice, the information requirements to determine the *optimal* scale and mix of public funding for science and innovation are too demanding.
  – These are matters of political judgment, informed by the available evidence.
- International comparisons and examination of a range of domestic socio-economic indicators do not support a contention that the overall quantum or mix of public funds allocated to science and innovation is inappropriate for Australia's needs and aspirations.
  – Any science and innovation spending targets for Australia should be expressed in relation to those needs and aspirations, rather than in relation to overseas levels. International benchmarking should only serve an informative, not prescriptive, role.
  – There are dangers if the trend towards publicly funding applied problem solving and commercialisation, at the expense of basic and strategic science and innovation, goes too far.
- The existing policy and budgetary processes of government provide a reasonably satisfactory mechanism through which information flows and advice can be integrated to facilitate decision making.
  – These processes generally support an incremental approach to change — with a reliance on diversity and devolution.
  – Program evaluation and feedback are critically important. They are in need of improvement (as discussed in chapter 7).
- There is no need to markedly strengthen existing coordination mechanisms, or create new ones, in relation to the high level institutional arrangements for funding of science and innovation programs.
- The disadvantages of greater specification and quantification of National Research Priorities would outweigh the advantages.

As discussed elsewhere in the report, there are sound rationales for public support for science and innovation. But determining how much governments should spend, and where, are not easy issues. If too little is spent, Australia misses out on beneficial economic, social and environmental outcomes, and fails to contribute its share as an international citizen. If, on the other hand, too much is spent, funds are used that could be better devoted to such needs as health, education, defence, contributed to international goals, or simply not collected from taxpayers. Similarly, misallocation of funding within science and innovation would reduce the net benefits of public support.

In theory, the decision rule to guide public spending on science and innovation is straightforward — public funds should be allocated whenever the net social benefit from each additional dollar of public spending on science and innovation is both positive and exceeds the benefit from the next best alternative use. Theoretically, the optimal expenditure on science and innovation can thus only be determined by summing the components — rather than determined in aggregate up front.

This theoretical answer is virtually impossible to apply in practice, however. Not only would it require detailed knowledge about the benefits and costs of all possible spending options on science and innovation, but also knowledge about the benefits and costs of all other possible areas of public spending.

In practice, policy decisions have to be, and are continually being, made about the level of public resources allocated to science and innovation for each component and thus in total. Such judgments are, of course, supported by Australia's existing political, bureaucratic, institutional and regulatory structures. They can be informed by international comparisons and by a range of socio-economic indicators influenced by science and innovation expenditure.

8.1 Is Australia spending enough?

International comparisons

Adverse comparisons with spending levels in other countries were made by several participants. Many participants called for greater domestic spending on science and innovation in general, or on R&D in particular, while some participants proposed specific target levels. For instance, the Australian Vice-Chancellors' Committee and the Business, Industry, and Higher Education Collaborative Council (BIHECC) proposed that Australia should aim to spend on R&D the equivalent of 2 per cent of GDP by 2010 and 3 per cent by 2020. According to BIHECC:

> This would keep Australia apace with global competitors such as China, which has set a target of increasing research and development to 2.5 per cent of GDP by 2020, and the EU and Canada which have recently committed to spending to 3 per cent of GDP by 2010 to compete with similar levels in Sweden, the United States and Japan. (sub. 55, p. 17)

Several participants saw merit in judging Australia's performance relative to that of other countries not only in terms of spending levels, but also against such aspects as quality, impact, research focus, funding allocation systems, and human capital formation. For example, the Walter and Eliza Hall Institute of Medical Research commented that:

> International benchmarking is vital to enhancing competitiveness in research outcomes since knowledge generation and associated translation and commercialisation are international activities. (sub. 31, p. 7)

But others warned about the inherent difficulty of international comparison. Innovative Research Universities Australia commented that:

> Due to Australia's unique mix of economic, demographic, geographic, historic, and other factors it is almost impossible to identify a reliable comparator nation to benchmark research and development performance against. (sub. 54, p. 4)

Similarly, the CSIRO stated that:

> Benchmarking against other countries does not always provide a useful indicator, given the differences that inevitably exist between countries and the importance of local factors and capabilities. (sub. 50, p. 96)

And Macquarie University considered that:

> … international benchmarking is difficult … as there is a wide diversity in the way publicly funded institutions contribute to different countries' economies. (sub. 47, p. 3)

In the Commission's view, international comparisons can have merit, if interpreted carefully. Although they cannot directly provide an answer to the question of 'how much' to spend, major disparities in public or business R&D spending levels relative to GDP between Australia and other developed countries would warrant further detailed examination. International comparisons and benchmarking can also assist by providing information about such things as the relative quality and impact of Australian research and its focus. In this way, impetus can be provided for the improvement and development of science and innovation in Australia, and of programs and institutions.

However, in making international comparisons, it is vital to distinguish between the actual achievements of other countries and any targets they may have set, in terms of such matters as spending levels and of public support. As noted in appendix C, almost all other OECD countries have employed targets for international benchmarking and goal setting for science and innovation policy in recent years. But, as that appendix also notes, those targets often exceed actual achievements. The following analysis considers their actual achievements.

The key indicators of comment from participants were Australia's GERD and BERD to GDP ratios relative to OECD countries. Indeed, despite strong real increases in R&D spending over the past two decades (discussed in chapter 1), Australia's R&D intensity, at 1.64 per cent of GDP in 2002, remains well below the OECD average. Overall, on this measure, Australia ranked 18th out of 30 OECD countries — 0.6 percentage points below the OECD average of 2.2 per cent.

Australia's performance against this measure reflects much lower business financed R&D intensity, which, at just under 1 per cent (relative to GDP) was 0.7 percentage points below the OECD average in 2002.

This was counteracted to some extent by Australia's above average government-financed R&D spending which was 0.69 per cent of GDP compared with an OECD average of 0.66 per cent in 2002.

Although one interpretation of these international data is that Australia is underperforming in terms of R&D spending, in particular on business R&D spending, this cannot be supported on detailed examination.

- First, the OECD averages are skewed heavily by a few key players — when spending by the United States and Japan are excluded, for example, the OECD average for the remaining countries drops sharply to just 1.76 per cent for 2002, just above the figure of 1.64 per cent for Australia (appendix C).
- Second, differences between countries, particularly in industry structure, are important when comparing business R&D expenditure. These are also examined in appendix C. It is concluded that, when differences in country size, industry structure, firm size and wage rates are taken into account, Australia's business R&D expenditure is broadly in line with that of other OECD countries.

A second issue concerns the proportion of business R&D which is funded by government. Some participants claimed that Australia is below the OECD average in this regard. However, this indicator does not provide a complete picture of intercountry differences in support for BERD as it excludes assistance via tax concessions. For example, over the five years to 2003-04, Australia provided more than twice as much assistance to BERD via the tax concession than in direct assistance (as measured by the OECD).

It is difficult to pinpoint exactly how Australia measures up with other countries in terms of the level of support for BERD via tax measures. The OECD confirms that such comparisons are difficult as detailed data on tax expenditures from public budgetary accounts are available only for a few countries (OECD 2006b). Nevertheless, a comparison of the relative inducement effects of R&D tax measures across countries suggests that Australia's public support for BERD is around the mid point for the OECD (Warda 2006; appendix C).

In summary, based on the international evidence, Australia's business R&D performance relative to other countries appears to be broadly in line with the level that would be expected when differences in country size, industry and firm structure and wage rates are taken into account. And in terms of public R&D spending, the investment of Australian governments compares favourably internationally.

Irrespective of these conclusions, it is the Commission's view that the achievements of other countries on the one hand, and their particular targets on the other, can never provide a definitive answer to the question of how much Australia should devote to science and innovation (or R&D) in total, or from public support in particular. They should not be applied prescriptively in Australia. In particular, overseas targets are fundamentally aspirational in character and best viewed as policy tools to assist in generating and maintaining the will to achieve desirable goals in the context of each country's science and innovation systems. Similarly, any policy action in Australia resulting from international comparison needs to be carefully assessed in the light of Australia's own aspirations, its science and innovation needs, and the Australian institutional and regulatory environment.

Nevertheless, when put in that context, targets can play a useful role for Australia. For example, by locking in future expenditure levels in a number of program areas, Backing Australia's Ability has set a number of targets to be achieved over the years ahead. Targets can be particularly useful in providing focus and certainty where programs run over a number of years.

Socio-economic indicators

Expenditure on science and innovation, including on R&D, can have a wide range of economic, social and environmental outcomes. Thus, examination of relevant socio-economic indicators can provide a broad feel for the appropriateness of expenditure levels (and mix).

In this regard, macro indicators such as multifactor productivity growth, the world competitiveness index, and business innovation propensities, show that Australian businesses are performing well with their current R&D investments compared to other countries (see appendix C and chapter 2).

Indeed, Australia has also consistently performed strongly in international comparisons of non-economic indicators. For example, Australia was ranked third by the United Nations Human Development Index in 2005 — a composite indicator that includes life expectancy, adult literacy, and enrolment ratios for primary, secondary and tertiary education (UN 2005). Moreover, the 2005 Environmental Sustainability Index (Yale Center for Environmental Law and Policy 2005) placed Australia 13th in the world (of 146 countries) and eighth in the OECD.

Clearly, while Australia will rank differently depending on the methodology employed, the key point from a policy perspective is that Australia performs strongly relative to other developed countries across a wide range of socio-economic indicators. To the extent that public support for science and innovation influences these outcomes, confirmation is provided for the broad appropriateness of its level (and mix).

8.2 Is the spending mix appropriate?

Governments do not fund science and innovation for its intrinsic worth as a whole, but rather for the benefits from achieving a range of specific outcomes linked to the rationales and objectives discussed in chapter 3. Thus, a mix of spending is necessary. But as noted above, there is no practical rule about how to allocate public support to achieve the optimum mix.

The matter is complicated by the many dimensions that mix can take, including by:

- functional objective — basic (pure and strategic), applied, experimental development;
- socio-economic objective — such as health, environment, defence, and industry;
- funding agency;
- funding recipient; and
- type of funding — such as block versus competitive.

Issues relating to many of these dimensions are discussed throughout the report, while the following sections of this chapter discuss matters dealing with the decision making environment, coordination and the National Research Priorities (NRPs). The rest of this section concentrates on the balance of funding by functional objective — examples of participants' views are given in box 8.1 (also see box 11.5).

Box 8.1 Participants' views on the mix of public support

It is important to strike the correct balance between pure, strategic research and applied research driven by contemporary community and market needs. This will always remain a role for government. (Western Australian Department of Industry and Resources, sub. 82, p. 11)

[Recent work] emphasises the uncertainty that surrounds future states of the world and the value of possessing options for responding to those uncertainties. It focuses on the need to protect as well as generate wealth, and on the value of having the capacity to do both. In the ARC's view, this constitutes an important additional objective for the science and innovation system. (Australian Research Council, sub. 73, p. 14)

… [there is] lack of appreciation of the pluralistic nature of the outcomes of [the CSIRO's] investment and thus the value proposition for maintaining or growing the investment. Australia's commitment to publicly funded science is based on, at best, a poorly constructed view of what the investment is for, and at worst, a short term, ideological and narrow view of the role of science in modern societies. (Graeme Pearman, sub. 86, p. 2)

… we should move to introduce the concept of 'preparedness' to complement the more familiar concepts of science and innovation — resulting in a policy framework that focuses on science, innovation and preparedness (SIP) policy. (Mark Matthews, in sub. 83, p. vi)

The system has to encompass all varieties of research: short term and long term; high risk and low risk; curiosity driven, investigator led research and experimental development; research in different fields and across different sectors. Achieving the right balance is not easy but a complete system that includes all varieties of research provides the best means of retaining and developing the capability that maintains preparedness. In an uncertain world, this ability to keep open Australia's options for action and to create new options has a value beyond the direct impact of the research itself. (CSIRO, sub. 50, pp. 37–8)

A significant proportion of publicly supported R&D is concerned with improved levels of preparedness and contingency options for handling unwanted and unexpected events … While 'preparedness' is an outcome that the general community has come to expect from public R&D it does not currently feature with comparable weight in considerations about how public funded research benefits society. (Group of Eight, sub. 68, pp. 7–8)

… there is still a tendency in the sector to undervalue the potential social and environmental impacts of public R&D funding, particularly with rigid outcome based funding models. (CSIRO Staff Association, sub. 78, p. 23)

Several participants considered that the balance of public support had shifted inappropriately towards applied science and innovation at the expense of basic and strategic science and innovation. Certainly, there does appear to have been some such shift, as evidenced by the recent emphasis on commercialisation (chapter 6), the greater focus of CRCs on business needs (chapter 9), the increasing external funding of PSRAs such as the CSIRO (chapter 10) and the reducing proportion of block funding for higher education institutions (chapter 11).

While there is no absolute standard against which to judge the appropriateness of this shifting balance, it is clear that, when assessed against the rationales for public support for science and innovation, there are dangers if the trend goes too far. These include:

- providing public support for expenditure that should be privately funded;
- focusing on short term impacts at the expense of valuable medium and longer term outcomes;
- losing research capacity across a number of disciplines, including the ability to absorb R&D undertaken in other countries;
- losing strategic capacity and preparedness to shift focus and emphasis if events dictate; and
- downgrading the fundamental importance of basic research and knowledge generation.

The key policy question is one of fine tuning Australia's existing funding arrangements rather than making substantial changes to funding levels or allocation.

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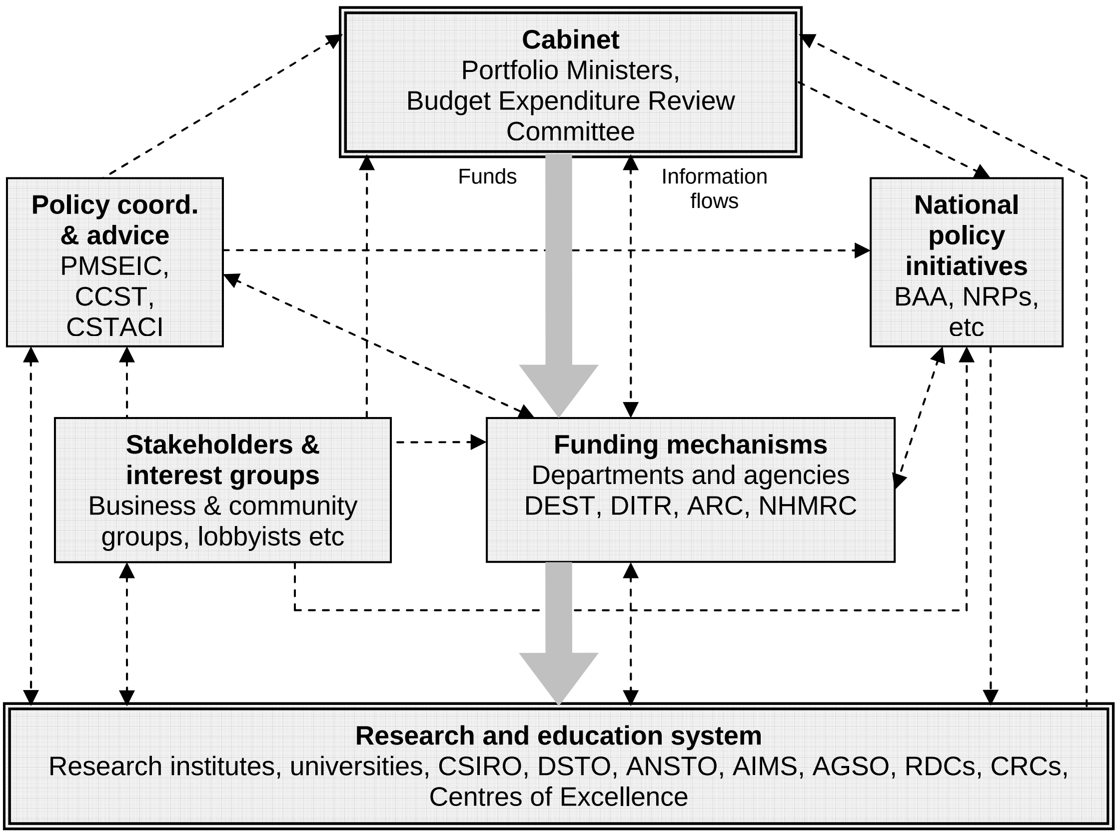
There is no evidence that the overall quantum or mix of public support for science and innovation in Australia is currently inappropriate for Australia's needs and aspirations. However, there are concerns if the trend towards publicly funding applied science and innovation, at the expense of basic and strategic science and innovation, goes too far.

8.3 Advantages and disadvantages of existing funding arrangements

While the ultimate decisions about the appropriate tradeoffs between various objectives are political ones, the existing budgetary and non-budgetary bureaucratic processes provide a framework that supplies and organises the information on which these decisions are based.

In effect, science and innovation spending has to compete for funds with all other areas of public spending and thus is subject to the same justification and substantiation processes for ongoing programs and for new policy proposals. The process draws on a wide array of information from a diverse range of stakeholders including government departments, R&D performers, funding bodies, facilitators and regulators (figure 8.1). Research stakeholders, such as universities and publicly funded research agencies, have well organised processes that enable them to engage effectively with departments and Ministers on policy and funding debates. In addition, the funding outcomes are influenced by key science and innovation players such as industry lobby groups as well as information and advisory bodies such as the Office of the Chief Scientist, the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) and the Coordination Committee on Science and Technology (CCST).

Figure 8.1 **Science and innovation public funding and information flows at the federal level**



Within Government, proposals also receive scrutiny from key central departments such as PM&C, Treasury, Finance and from such bodies as the Expenditure Review Committee of Cabinet. While these processes provide a reasonably satisfactory mechanism through which information flows and advice can be integrated to facilitate decision making by the Government, this does not mean that they cannot be improved. The next section examines the advantages and disadvantages of two key features of the current arrangements, before the remainder of the chapter goes on to consider coordination issues and the role of the NRPs.

Key features: incremental change; diversity and devolution

There are two key characteristics of Australia's approach to allocating funding for science and innovation:

- *incremental change* — change is generally made gradually, with an emphasis on adaptation based on learning from experience; and
- *diversity and devolution* — there is a number of funding bodies, spending bodies, funding instruments, and priorities and, in some programs, an emphasis on devolved decision making.

As discussed below, these aspects have both positives and negatives — which need to be explicitly recognised when developing science and innovation programs and deciding funding levels.

Incremental change

Australia's science and innovation funding allocation mechanisms accord a reasonably strong weight to past practice and generally rely on incremental change to improve outcomes. In this respect, they are similar to many other processes of government and program funding. But even so, there can be quite large changes made from one year to the next. In relation to business programs, for example, public support declined by some $300 million from 1995-96 to the following year. And there have been some significant short lived programs such as the one-year $200 million funding of the NHMRC for medical support infrastructure in 2005-06. As well, over time, even relatively small annual changes compound, such as with the increased share of funding for higher education research going to the ARC and NHMRC competitive funding streams, away from block funding.

Benefits of incremental approaches

Incremental approaches may be good 'rules-of-thumb' in the presence of uncertainty about the relative benefits of spending, where science and innovation funding can be influenced by 'fashions' whose benefits are not established, and where there are costs of adjustment from shifting program funds from year to year.

First, if returns from programs are uncertain, then a reasonable approach is to have a portfolio of programs, with reasonably stable funding from year to year. Such gradualism allows policy learning via 'intelligent trial and error'. Clearly, this is highly dependent on the quality of the evaluation and feedback mechanisms.

Second, gradualism also provides protection for science and innovation funding agencies from changes in government policy and in fashionable fields of research. The OECD (2003a, p. 8), for example, notes the importance of insulating public science and innovation systems from 'rapid shifts in funding or interests' to ensure long-term sustainability.[1]

Third, adjustment costs are reduced and the scope for capability development is enhanced if there is some inertia in funding arrangements. In bureaucracies, it takes time to develop operational procedures, train staff, and collect and assimilate information. These are the fixed costs of developing these program-specific capabilities. Firms and other research agencies face similar difficulties in environments where policy is always changing. It takes time for them to shift resources to the given research area, and to develop efficient compliance and information systems. Firms prefer certainty and often will not respond much to short-lived programs because the costs of adjustment are high.

Costs of incremental approaches

Some commentators attribute the appeal of incrementalism to risk aversion on the part of decision makers, noting that it increases the ability of incumbents to control the agenda, limits the scope of alternatives, shuts out unsympathetic voices, and skews the decision making in favour of vested interests and past practice (Hayes 2002).

Incremental systems can pose problems for science and innovation policy in instances where the appropriate policy response to new information about particular research opportunities and challenges requires substantial changes to funding allocation among institutions and fields of work.

Another concern — not of high relevance in the current Australian context — is that incremental approaches pose particular challenges in a context of declining total funding. For instance, Smith and McGeary (1997) note that in regard to US science and innovation spending, although experience shows incremental budgeting to be preferable to 'comprehensive' budgeting schemes, the virtues of incremental budgeting are far more apparent when budgets are increasing than in a period of 'decremental' budgeting. Problems identified include: the tendency to spread cuts across the board rather than in the areas that are underperforming, deferring infrastructure and other investments to protect staff, increasing cost sharing, and

[1] Sarewitz (2003, p. 3), also notes that the high degree of 'embeddedness' of public science in the US budget process offers 'significant protection against major disturbances in overall funding commitments for R&D activities'.

avoiding risky projects. Experience in OECD countries has also shown that achieving change in science and innovation policies is much easier with new money and when budgets are increasing (OECD 2003a).

Policy implications

There is really no practical alternative to incremental approaches for the vast majority of science and innovation spending. This, however, does not mean that support should be continued for existing policies and programs uncritically. Nor does it suggest that alternative funding arrangements that could better meet the objectives for support should not be considered. Occasional 'foresight' exercises could be valuable in this respect — their outcome could, of course, feed into such things as national research priorities (see below). Bougias and Kulkarni considered that:

> LRP [long range planning] and foresighting are areas that require further attention in Australia. LRP involves identifying the opportunities and challenges we face as a nation in the long term. The process would be systematic and significant in size and scope and involve a coordinated approach across a range of stakeholders including Government, business and the academic community. (sub. 59, p. 25)

An important implication stemming from Australia's reliance on incremental approaches in allocating public funds for science and innovation is the crucial role of program and performance evaluation, including drawing on the lessons of experience. Unless evaluation and feedback systems work effectively, the risks of the negative consequences of incrementalism and merely locking in the status quo are high.

As discussed in chapter 7, there are significant deficiencies in some current program evaluation arrangements. That chapter suggests ways of improving their relevance, quality, independence and transparency, so that evaluation results can be considered as part of funding decisions.

Diversity and devolution

Benefits

In a number of respects, there are advantages to diversity and devolution of decision making.

- *Instruments.* A combination of interventions will generally be needed — (such as tax concessions, public research institutes, ARC grants, block funding for university researchers etc.) — not only because some may better meet particular objectives than others but also because their relative efficacy is somewhat uncertain.

- *Funders.* Selecting the best research is a difficult task and even the most competent assessors inevitably make mistakes. Having more than one potential funder available to a given researcher or research institution reduces the risk of rejecting projects that should have been accepted ('Type II errors'). As the then Chief Scientist noted in his *Review of Science and Technology Arrangements* (Stocker 1997, p. 3), 'overlaps in science and technology effort need to be recognised as a necessary and desirable part of the science and technology system'.
- *A mix of centralised and decentralised decision making.* Centralised decisions can have the advantage of breadth of perspective and broad tradeoffs can be made. But decentralised decision makers may have the advantage of more complete and cheaply acquired information about the merits of the researcher and the local infrastructural and other circumstances of the proposed project.
- *Different levels of government*. While the Australian Government has primary responsibility for science and innovation policy, different levels of government all play important roles in innovation.
- *Research performers.* Size can be very important to the success of some research projects, but others can benefit from being small and focused. It is important that funding arrangements promote the best research and research institutions, regardless of their size (IC 1995).

The recent *Pathways to Technology Innovation* report (House of Representatives Standing Committee on Science and Innovation, June 2006, pp. 55–6) concluded that 'the plurality of programs, while posing some difficulties, is a necessary feature of a comprehensive suite of innovation support to address different innovation needs'.

Diversity can also play an important role in strengthening a country's capability to respond to challenges (and opportunities) as they arise — as discussed above, it is important to maintain an appropriate mix of funding.

Costs and policy implications

The most obvious costs of diversity and devolution is that funds could be wasted on ineffective programs, merely for diversity's sake, rather than better spent elsewhere. This again highlights the importance of effective evaluation processes in ensuring Australia's science and innovation system operates effectively and efficiently.

Another cost relates to the potential risk of gaps, inefficiencies, overlaps and duplication in funding arrangements that a pluralistic system entails. For example, an investigator whose proposal is turned down by one agency might find another one that will provide support. Although this can be advantageous (as noted above), it can also create additional administrative costs, magnify compliance costs and provide gaming and lobbying opportunities. Devolution of decision making can add to problems of setting meaningful national priorities, if agencies make decisions without full regard to the impact on the broader system.

The policy challenge is how to retain the positive features of incrementalism, diversity and devolution while minimising the negative downsides. This is discussed below in the context of coordination.

8.4 Coordination

Some countries have endeavoured to deal with the problems associated with incrementalism and diversity through greater centralisation of funding decisions. Examples include the use of central coordinating bodies (Japan), rationalised/amalgamated science ministries (Denmark), fewer funding councils and one source of R&D funds (Sweden).

However, as discussed above, incrementalism, diversity and devolution bring advantages. Should problems exist in terms of overlaps, duplication, coordination or divergent or inconsistent priorities, another strategy is to address them within the existing institutional context through improving or strengthening coordination and liaison mechanisms.

In Australia, a number of formal and informal coordination arrangements already exist, including the budgetary/policy arrangements described above. Other formal mechanisms include the Prime Minister's Science, Engineering and Innovation Council, the Coordination Committee on Science and Technology and the Office of the Chief Scientist (box 8.2). In addition, there is a mechanism for regular interaction with State and Territory Government bodies involved in innovation policy development (see below).

Less formal mechanisms include ongoing peer-to-peer interactions across agencies, and taskforces. The latter can undertake across-government activities, as occurred for the mapping of Australian science and innovation exercise in 2003.

Box 8.2 **Coordination and advisory mechanisms**

Prime Minister's Science, Engineering and Innovation Council (PMSEIC)

PMSEIC is the Australian Government's principal source of independent advice on issues in science, engineering and innovation and relevant aspects of education and training. The Council meets twice a year to discuss major national issues in science, engineering and technology and their contribution to the economic and social development of Australia. To underpin its advisory role, the Council has resources to examine Australia's science and engineering capabilities and the effectiveness of their organisation and utilisation. The non-ministerial members constitute the Standing Committee of the Council, and oversee and contribute to studies and research aimed at improving understanding of the major science, engineering and innovation issues.

Coordination Committee on Science and Technology (CCST)

The CCST brings together Deputy Secretaries and heads of Australian Government agencies with an interest in science and technology. It facilitates networking, information exchange, strategic thinking and coordination of activities in areas of science and technology, and complements the work of PMSEIC. CCST meetings are primarily to provide an up-to-date and broad information base to feed into well coordinated advice to Government on science and technology matters. There is also scope in CCST for initiating cooperation between departments and agencies on specific science and technology issues, problems or identified opportunities. CCST can examine major cross-portfolio issues and hence assist policy development through an early 'whole of government' discussion of issues. CCST may also address the specific portfolio issues raised by its members.

Office of the Chief Scientist

The Office of the Chief Scientist provides information and advice on policy issues, research and administrative support for the Chief Scientist, PMSEIC and CCST. The Office supports the Chief Scientist in engagement with the research and industry communities, learned societies, and other portfolios and governments, which informs advice to Government on a wide range of scientific and technological issues of importance to Australia.

Coordinating funding allocations to programs

The issue of funding coordination within the Australian Government science and innovation portfolio has long been debated (Stocker 1997). Participants' views differed on such issues. On one side, the Australian Vice-Chancellors' Committee commented favourably on existing mechanisms, advising that many programs 'are free standing and require relatively little government coordination' (sub. 60, p. 38). It considered that:

> The key point is not whether there are too many programs, but rather that there is not enough funding to support the breadth and depth of university research activity. (sub. 60, p. 38)

In contrast, the Western Australian Department of Agriculture and Food commented that:

> To facilitate R&D activity across the private-public good spectrum and the basic to applied continuum the Commonwealth needs to support a coordinated approach to building innovation pipelines from research to commercialisation. (sub. 44, p. 14)

And the Cooperative Research Centre for Spatial Information argued that:

> Australia would be well served if it were to establish a peak body to oversee the investment of public funding of science and innovation. (sub. 32, p. 4)

In particular regard to PMSEIC, the Australian Academy of Technological Sciences and Engineering recommended that:

> … PMSEIC ensure that mechanisms are implemented to achieve the coordinated development of policies and strategies related to innovation. (sub. 27, p. 16)

However, there is no certainty that centralised allocation of funding, or even an increase in high level coordination, would offer a net advantage over current processes. Some of the strengths of a more devolved decision making system, such as allowing those with the best working knowledge of particular science and innovation aspects to make decisions, would also be watered down or lost.

In conclusion, the Commission considers there is no need to markedly strengthen existing mechanisms or create new ones in relation to the high level institutional arrangements for coordination across the funding of programs.

Coordination between programs

A related issue is whether at a program and project level, there may be scope for better coordination. Clearly there is already considerable coordination and consultation — for instance, the ARC and the NHMRC liaise and coordinate on appropriate matters, with each other and with higher education institutions. The Department of Agriculture, Fisheries and Forestry noted that improved collaboration and coordination between the RRDCs is being led by the Council of RDC Chairs (sub. 100, p. 32). And many programs actively aim to leverage additional funding from other funding sources — obviously requiring a degree of coordination. Further, there is evidence that coordination can work well when planning major infrastructure, such as for the Australian synchrotron project.

Nevertheless, it would be surprising if, given the diversity of current arrangements, there were not some coordination problems.

Participants offered only few comments specifically directed at such issues, however. GlaxoSmithKline Australia submitted that:

> … better coordination between … programs [such as CRCs and PIIP/P3] could enable the objectives of increased collaboration and more effective commercialisation to come together. (sub. 38, p. 30)

The Commission notes that Australia's diverse set of programs and funding arrangements are likely to result in costs due to coordination problems. But while it would support efforts to improve coordination, care should be taken to ensure that such efforts do not fundamentally change existing funding arrangements to the detriment of the advantages of diversity and devolution.

Coordination across levels of government

A number of institutional arrangements facilitate discussion and coordination between the various State and Territories and between them and the Australian Government in relation to science and innovation policy and programs.

These include the Commonwealth State and Territory Advisory Council on Innovation (CSTACI), which was established in February 2000. The Council comprises senior representatives of each Commonwealth, State and Territory industry department, as well as each State and Territory innovation council or equivalent. Various Chief Scientists also attend its meetings. According to CSTACI, its role is:

> … to enhance innovative activity across Australia by adopting a targeted and strategic approach to innovation issues to improve the effectiveness, integration and coordination of the National Innovation System. (sub. 98, p. 1)

As well, for example, a 'National Collaborative Research Infrastructure Strategy' is currently under development (box 5.4).

There was no evidence presented which suggested such mechanisms have not served a positive role. Nevertheless, the increased involvement of the various levels of government in science and innovation policy in recent years together with a multiplicity of programs increases the risk of coordination problems. Further, costs can arise when programs focus on competitive industry or state development rather than on the rationales for public support for science and innovation. In regard to such issues, CSTACI commented, however, that:

> While the number of programs available may be criticised as too large and/or confusing, they are a response by Australian and New Zealand governments seeking to address particular market failures. Several states and territories have been through their own review processes over the last year in the innovation research and policy area, with rationalisation and restructuring resulting in some instances. CSTACI does, however, support the view that very large programs may not be appropriate when particular target outcomes are being sought — for example, for a particular sector or size of firm. (sub. 98, p. 3)

In its submission, the Victorian Government noted that it had begun consultations with Victorian and national stakeholders to identify collective and individual actions to progress a 'National Innovation Agenda'. It commented that, from its initial consultations, there:

> … emerged a strong impetus for a coordinated national approach to innovation that more clearly defined the respective roles for Federal and State Governments and addressed linkages across the innovation system. (sub. 84, p. 10)

The New South Wales Government argued that:

> Developing programs in isolation is unlikely to deliver the best results for either the Commonwealth or State Governments to achieve their respective policy objectives. The NSW Government would like to see a greater commitment to consultation with the States at the design stage of funding programs for science and innovation. (sub. 91, p. 11)

And the South Australian Government also expressed some concern:

> The general policy thrust of the Backing Australia's Ability packages has been to improve collaboration at all levels, set national priority areas, accelerate the commercialisation of ideas and invest in people and skills. These goals are commendable; however, the South Australian Government believes that there are continuing impediments and obstacles to these goals. (sub. 92, p. 5)

The Commission supports current initiatives to improve collaboration across jurisdictions although it has not given consideration to what further measures might be appropriate.

8.5 National research priorities

Australia has generally avoided high level direction of the research sector, with a preference for allowing funding organisations, research bodies and individual researchers to exercise considerable autonomy in deciding what research to pursue. And, despite the developments outlined below, it still remains true that there is little formal centralised direction of research effort.

In recent years, though, there have been changes of emphasis — for example, in encouraging efforts towards greater commercialisation (chapter 6). Also, the share of 'competitive' funding has grown somewhat relative to institutional funding, for example in higher education research (chapter 11).

Further, there has been a number of national initiatives aimed at providing greater guidance to funding agencies. For example, the Australian Government's January 2001 statement on innovation, Backing Australia's Ability, flagged the desire for an emphasis on research in areas in which Australia enjoys or wants to build competitive advantage. Subsequently, in January 2002, the Government announced four areas of priority for the ARC's National Competitive Grants Program — nano- and biomaterials, genome/phenome research, complex/intelligent systems, and photon science and technology — and specified an investment target for these areas of at least 33 per cent of funds in the ARC's 2003 funding round.

Then, in December 2002, the Prime Minister announced four National Research Priorities (NRPs) for Commonwealth-funded research (box 8.3):

- an environmentally sustainable Australia;
- promoting and maintaining good health;
- frontier technologies for building and transforming Australian industries; and
- safeguarding Australia.

These priority areas, and associated priority goals, were further developed in 2003.

The NRPs are an attempt at a comprehensive explicit articulation of where national science and innovation effort should be directed. The Government announced that, as a general principle, all Commonwealth research and research funding bodies that can contribute to a national research priority would participate in the national research priorities initiative to the extent that this is consistent with their mandate or mission. The NRPs do not apply to industry R&D programs or to university block grants, however.

The priorities, and priority goals, are not ranked in importance, nor are they quantified, nor is funding earmarked for particular priorities. Further, a cursory examination of the different national priorities adopted across OECD countries indicates Australia's NRPs are pitched at a considerably broader level that in many other countries. Many countries have identified a limited number of priority sectors to receive above-average amounts of new funding because of their anticipated leverage in terms of future economic growth, employment and overall social value. While there are variations, the broad areas receiving the most attention are ICT, biotechnology and nanotechnology (table 8.1).

Box 8.3 National Research Priorities

In 2002, the Government announced four National Research Priorities (NRPs) to focus research in specified areas. These NRPs, and their associated priority goals, revised and enhanced in 2003, are:

1. An environmentally sustainable Australia

- *Water* — Sustainable ways of improving water productivity, using less water in agriculture and other industries, providing increased protection of rivers and groundwater and the re-use of urban and industrial waste waters.
- *Transforming existing industries* — New technologies for resource-based industries to deliver substantial increases in national wealth while minimising environmental impacts on land and sea.
- *Overcoming soil loss and acidity* — Identifying causes and solutions to land degradation using a multidisciplinary approach to restore land surfaces.
- *Reducing and capturing emissions in transport and energy generation* — Alternative transport technologies and clean combustion and efficient new power generation systems and capture and sequestration of carbon dioxide.
- *Sustainable use of Australia's biodiversity* — Managing and protecting Australia's terrestrial and marine biodiversity both for its own value and to develop long term use of ecosystem goods and services ranging from fisheries to ecotourism.
- *Developing deep earth resources* — Smart high-technology exploration methodologies, including imaging and mapping the deep earth and ocean floors, and novel efficient ways of commodity extraction and processing (examples include minerals, oil and gas) while minimising negative ecological and social impacts.
- *Responding to climate change and variability* — Increasing our understanding of the impact of climate change and variability at the regional level across Australia, and addressing the consequences of these factors on the environment and on communities.

2. Promoting and maintaining good health

- *A healthy start to life* — Counteracting the impact of genetic, social and environmental factors which predispose infants and children to ill health and reduce their well being and life potential.

(Continued next page)

Box 8.3 (continued)

- *Ageing well, ageing productively* — Developing better social, medical and population health strategies to improve the mental and physical capacities of ageing people.
- *Strengthening Australia's social and economic fabric* — Understanding and strengthening key elements of Australia's social and economic fabric to help families and individuals live healthy, productive and fulfilling lives.

3. Frontier technologies for building and transforming Australian industries

- *Breakthrough science* — Better understanding of the fundamental processes that will advance knowledge and facilitate the development of technological innovations.
- *Frontier technologies* — Enhanced capacity in frontier technologies to power world-class industries of the future and build on Australia's strengths in research and innovation.
- *Advanced Materials* — Advanced materials for applications in construction, communications, transport, agriculture and medicine.
- *Smart information use* — Improved data management for existing and new business applications and creative applications for digital technologies.
- *Promoting an innovation culture and economy* — Maximising Australia's creative and technological capability by understanding the factors conducive to innovation and its acceptance.

4. Safeguarding Australia

- *Critical infrastructure* — Protecting Australia's critical infrastructure including our financial, energy, communications and transport systems.
- *Understanding our region and our world* — Enhancing Australia's capacity to interpret and engage with its regional and global environment through a greater understanding of languages, societies, politics and cultures.
- *Protecting Australia from invasive pests and diseases* — Counteract the impact of invasive species through the application of new technologies and by integrating approaches across agencies and jurisdictions.
- *Protecting Australia from terrorism and crime* — By promoting a health and diverse research and development system that anticipates threats and supports core competencies in modern and rapid identification techniques.
- *Transformational defence technologies* — Transform military operations for the defence of Australia by providing superior technologies, better information and improved ways of operation.

Source: DEST (2003a).

Table 8.1 **Science and technology priorities in OECD countries**

Country	*Priority fields of science and technology*
Australia	Environmentally sustainable Australia; promoting and maintaining good health; frontier technologies for building and transforming Australian industries; safeguarding Australia.
Austria	Life sciences; ICT; nanosciences and micro technologies; mobility, transport, space and aeronautics; environment, energy and sustainability; social sciences, humanities, and cultural studies.
Czech Republic	Embryonic cell research.
Denmark	Biotechnology; nanotechnology; and ICT.
France	Research for health; development of renewable energy; resource management (water and food); diffusion of knowledge and promotion of scientific culture.
Germany	ICT; microsystems engineering; optical technology; materials research; clean processes and production technologies; biotechnology; nanotechnology.
Hungary	Material science, production engineering and equipment; energy; transport; electronics, measurement and control technology; biotechnology; environmental protection; and ICT and its applications.
Iceland	Environment; ICT; and nanotechnology.
Ireland	Biotechnology; and ICT.
Japan	Life sciences; ICT; environment; and nanotechnology and materials.
Korea	Digital TV and broadcasting; displays; intelligent robots; new-generation automobiles (intelligent car, clean car, etc.); next-generation semiconductors, next-generation mobile communication; intelligent home-networks; digital content and solutions; next-generation batteries; and biomedicine (bio-chips, artificial organs, etc.).
Mexico	ICT; biotechnology; materials; design; and manufacturing processes. In addition, sectoral funds have been established for applied research and technology development in areas such as health, communications, environment, housing, and agriculture.
Netherlands	Life sciences and genomics; nanotechnology; and ICT.
New Zealand	Biotechnology; ICT; and creative industries.
Norway	Marine research; medical and health research; ICT; energy and environment; functional genomics; and new materials (i.e. nanotechnology).
Spain	Chemistry; materials (including nanotechnology); industrial design; quality of life (including biomedicine and biotechnology); space; physics; information society; social sciences and humanities; security.
United Kingdom	Stem cells; sustainable energy; post-genomics and proteomics; e-science; and basic technologies.
United States	Inter-agency priorities include: homeland security; networking and information technology; nanotechnology; priority areas of the physical sciences; biology of complex systems; climate, water and hydrogen.

Source: OECD (2004c).

As part of the implementation process for NRPs, Commonwealth research agencies and funding bodies were asked to submit implementation plans indicating, among other things, the current level of investment in priority areas and projected changes over a two to five year timespan. At first glance, an overview sample of these plans indicates that even though the priorities are very broad in nature, their establishment has had an impact on the directions of research activity. For instance, several agencies have reported increases in alignment of their funding allocation to NRPs.

Nevertheless, their effect should not be overestimated. DEST (2003c) examined the reported alignment between expenditure and the NRPs for six agencies, programs and funding bodies (CSIRO, ARC, DSTO, NHMRC, CRCs and Antarctic Division), accounting for just over three-quarters of all expenditure by those subject to the NRPs for 2002-03. While some of the spending in these agencies reflected more specific priorities set by the Commonwealth and other stakeholders a strong alignment between allocations and the NRPs was already evident at that early stage. As DEST commented, 'the NRPs are intended to be a light touch approach to priority setting' (sub. 87, p. 29).

Leaving aside issues of their coverage, and the processes for their formulation — the Victorian Government, for instance, called for State and Territory involvement (sub. 84, p. 54) — important issues concern whether the NRPs should be specified in greater detail, quantified and/or tightened in effect.

Some participants did not support tightening of the NRPs. For instance, the Australian Vice-Chancellors' Committee considered that 'the NRPs are satisfactory in their current form and would not want to see them more narrowly defined (sub. 60, p. 36). And CHASS commented:

> Recent suggestions that the Government may seek to have the NRPs applied less flexibly raise concerns that this may result in funding for some forms of research, and for some fields, being reduced. (sub. 52, p. 11)

Nevertheless, it went on to argue that the NRPs needed to offer 'a better match between Australian needs and Australian expertise' (sub. 52, p. 14).

And the Western Australian Department of Agriculture and Food said:

> There is a need for objective determination of national R&D priorities linked to areas with prospective high return and strategic importance. (sub. 44, p. iii)

Building greater detail into the NRPs would bring both potential advantages as well as disadvantages. On the advantage side, the Government would be able to more precisely specify the outcomes sought from the spending of public funds based on its judgment of where community benefits are most likely to occur. Moreover, more tightly specified NRPs would mean that guidance to agencies as to what their expected outcomes should be could be strengthened, which, in turn, could make performance evaluation more meaningful.

However, such a prescriptive approach would raise a number of problems. Essentially, it would detract from the advantages of incrementalism, diversity and devolution discussed above. Governments would be making decisions about the details of funding allocation which are possibly best left to expert funding agencies, research institutions and individual researchers. A focus on quantifiable inputs or outcomes could bias funding towards the applied end of the research spectrum at the expense of basic and applied research. And it would add to uncertainty through exposing individual projects and researchers more directly to political direction and research ‘fashions’.

On balance, the Commission does not support any strengthening or tightening of the existing NRPs.

9 Business programs

Key points

- The inherently uncertain nature of science and innovation processes and outcomes poses challenges for programs aimed at supporting these activities. Their primary goals should be to encourage activity that would not take place without public support (additionality) and deliver benefits not appropriated by the R&D performer (spillovers). Designing programs to achieve these goals is not easy.
- Australia's current suite of business programs do not effectively target these objectives and, as a consequence, involve substantial transfers from taxpayers to firms without attendant net benefits. The need to raise taxation revenue to fund these transfers creates efficiency losses for the community.
- Of particular concern is the basic R&D tax concession because it is available to all eligible firms whether or not the R&D would have been performed without support. It also assists R&D with low levels of spillovers such as incremental innovation. The effectiveness of the program could be improved by rebalancing support toward the premium component. That component could itself be improved by moving to a scheme based on changes to a firm's R&D intensity from a fixed base period. Modifications to the beneficial ownership requirements and access to the premium component by start-up firms could also be made.
- In principle, competitive grant programs such as Commercial Ready provide greater scope to target socially valuable R&D projects that would otherwise not proceed. However, the current focus on the commercialisation end of R&D can work against the selection of projects with those characteristics. Introducing repayment or benefit sharing arrangements might provide scope to improve project selection.
- There are strong grounds for public support of RRDCs that provide spillover benefits beyond industry members where R&D would not proceed in the absence of support. But there is only a weak rationale for the present substantial co-funding of some industry-centred RRDCs. However, any changes to current arrangements should be delayed until current economic conditions in the rural sector have improved.
- Although assistance to automotive R&D is generous in comparison to other sectors, this needs to be viewed in light of the transition to a lower tariff environment.
- The complete shift to industry-focused CRCs is inappropriate. In addition, current cost sharing arrangements do not appear to reflect the distribution of benefits from the program, with potentially large subsidies available to business partners. Given high associated compliance costs, consideration should be given to introducing a complementary arrangement to support smaller-scale and short term collaborations between groups of firms either independently or without universities and public sector research agencies.

9.1 Introduction

Science and innovation programs (through which public support is provided to firms, public research agencies and higher education research providers to perform socially valuable research), face particular design challenges because of the uncertainty regarding the outcomes of support and the behaviour of the agents chosen to pursue those outcomes.

Research is an inherently risky endeavour. As such, policy makers (and in many cases the agents themselves) cannot know in advance which projects will deliver the greatest (if any) private and social benefits. Moreover, the agents (firms, scientists and academics) given support by the government to produce and diffuse knowledge have information that could improve policy decisions but which may not be in their own interests to reveal (such as whether a firm would undertake a research project without the aid of a public subsidy).

Accordingly, program designers must use eligibility criteria and incentives as a means of selecting the research performers and projects that will produce the most socially valuable outcomes from any given level of public support.

9.2 Elements of good program design

Where programs have the capacity to improve economic, social and environmental outcomes, the focus of policy and program design should be on getting the maximum benefit for the funding involved. This will be supported by adhering to a range of desirable design principles (see box 9.1). While there will inevitability be tradeoffs between some of these principles, the relative importance of each will depend on the objective being targeted (for example, whether the aim is to increase business R&D or raise the quality and impact of higher education and public sector research).

Targeting and inducement

Effective programs are based on sound rationales and target appropriate objectives rather than particular firms, sectors or activities. The ultimate objective of science and innovation programs must be to encourage a higher level of socially valuable activity than would be undertaken in the absence of public support.

Box 9.1 **Design principles**

- Target the source of the problem (objectives/rationales)
- Inducement (additionality)
- Contestability
- Consistency
- Funding duration
- Avoidance of risks
  - Adverse interactions with other programs
  - Unforseen liabilities for government
  - Strategic behaviour by firms
- Administrative and compliance efficiency
- Accountability and transparency
- Cost effectiveness
- Compliance with international obligations
- Evaluation, monitoring and reporting

Source: Lattimore (1998).

Where support is provided more broadly than this, there will be both an opportunity cost (the resources used could have been applied to more valuable endeavours from the community's point of view) and a distortionary cost associated with the need to raise taxation revenue (the marginal excess burden of taxation). These costs ultimately reduce economic activity and national income. These issues were recognised in some submissions to this study including that from the Australian Research Council:

> The potential for government funding to replace, rather than complement, the efforts of private investors is now widely canvassed. Such substitution, if substantial, could undermine returns to public investment by subsidising research that would otherwise be undertaken by those most likely to capture its benefits (creating little or no 'additional' research) and diverting funds from areas where the public return is likely to be greater. (sub. 73, p. 23)

Although various design tools are available to help meet these goals, they all have problems. For example, while eligibility criteria can restrict support for business R&D activity to that above a base level, there is no guarantee that public support itself induced the expansion. Similarly, incentive mechanisms which aim to ensure that only genuinely new research proposals are put forward to receive support can be problematic in their implementation (see below).

Contestability

Where possible, funding arrangements should provide an incentive structure that maximises the value of science and innovation activity to the community. One important design tool is to make public support open to all potential providers on a competitive basis as this encourages merit-based project selection and efficiency in resource use.

A number of submissions to this research study acknowledged the benefits of contestable funding mechanisms. The Association of Australian Medical Research Institutes (AAMRI), for example, noted that:

> Contestability in the allocation of public support for science and innovation — that is, competition for funding — is of course necessary to ensure that the limited funds available are delivered to the projects most likely to produce the desired outcomes. The only disadvantages are that this increases the time delay between the idea and its initiation and it requires considerable effort on the part of policy makers to get the judging criteria right and on the reviewers to do their job diligently. These are opportunity costs but the alternative of not formally assessing and ranking proposals would make it difficult to justify that the expended funds were used in the best interests of taxpayers. (sub. 41, p. 6)

Competitive funding arrangements are a feature of science and innovation systems in most countries. In Australia, for example, the majority of business support and a significant share of higher education support is provided on this basis. But there are also major elements of Australia's innovation system (such as public sector research agencies) where public funding is not directly contestable except through the budget process. The R&D tax concession is similarly not a contestable program. As discussed below, there may be some reasons for not always relying on contestable funding arrangements, including the need for strategic capability building, infrastructure provision and on the grounds of administrative efficiency. The appropriate balance between contestable and non-contestable funding mechanisms is a key issue.

Contestable funding arrangements can be applied at different levels, from individual projects to research institutions. As noted in the Commission's earlier report on R&D (IC 1995), the choice between contestable and other forms of funding will depend on a range of issues including the:

- ability to evaluate the merits of competing proposals against the objectives of the funding program;
- administrative and compliance costs involved in the application and evaluation of funding proposals; and
- potential for strategic behaviour by stakeholders to obtain preferential treatment.

Importantly, contestable funding arrangements need not be inconsistent with the promotion of cooperation and collaboration between research providers. Perhaps the most visible example in an Australian context is the funding basis for the Cooperative Research Centres (CRC) program. The success of that program in fostering cooperation was cited in a number of submissions to this study. The Department of Agriculture and Food Western Australia (DAFWA) specifically used the CRC initiative as a model against which other programs should be compared. It said:

> Although some funding programs (e.g. Cooperative Research Centre funding) facilitate cooperation between research institutions to deliver focused research outcomes, many other programs promote organizational or regional competition for funds. This competitive approach can improve efficiencies and may stimulate innovative research approaches. (sub. 44, p. ii)

Administrative and compliance efficiency

All programs involve administrative costs for government and compliance costs for participants. While efficient program design should aim to minimise such costs, the extent of the burden imposed needs to be weighed against the requisite level of program effectiveness. Similarly, program evaluation and monitoring improve program outcomes but require additional administrative resources. In a different context, a threshold level of compliance costs can be useful in deterring lower quality project proposals (although it may also deter smaller socially valuable project proposals).

Programs based on centralised decision making can involve higher administration and compliance costs than those where decisions are delegated to the performers of research. Competitive grant schemes, for example, often require detailed information to be provided on individual projects and involve resource-intensive review and assessment processes to select the most meritorious proposal. Similarly, the distribution of block funding within public sector research agencies and higher education institutions can also involve internal resource intensive decision-making processes. An example is provided by CSIRO’s approach to project selection (see chapter 10).

As a final point, coordinating and rationalising programs and delivery agencies is an important means of avoiding duplication and minimising administrative and compliance costs. A number of submissions pointed to coordination problems associated with the multiplicity of programs and delivery networks in Australia’s science and innovation policy space. Engineers Australia, in particular, highlighted the issue and proffered an example of the consequences:

> … because control of programs and funds is decentralised within and between Commonwealth and State and Territory government and research organisations, and because there are inadequate coordination mechanisms, government expenditure on R&D is still fragmented, complicated and often unaccountable.
>
> …
>
> One of the consequences of the lack of coordination is that there may be insufficient funds to take advantage of major opportunities or address major challenges. (sub. 65, pp. 13–14)

Coordination issues are also covered in chapter 8.

Transparency and simplicity

Transparent and simple programs minimise compliance and administrative costs, provide for greater accountability and are more readily amenable to evaluation and refinement. Straightforward and well-specified criteria for providing support reduce the level of administrative discretion, the uncertainty faced by participants regarding eligibility and also the incentive to inappropriately reorient activities in order to qualify for support. Moreover, simple and broadly-based rules can reduce the absorption of resources devoted to wasteful lobbying and litigation.

That said, there can be valid arguments for allowing greater administrative discretion in decisions regarding funding support. This is because the extent of social benefits and/or the responsiveness to financial support will vary from one research proposal and provider to another. While accurate information regarding the net social benefits of public support (whether in university-based basic research or private sector R&D) can be difficult, if not impossible to obtain, proxies do exist. Examples include academic merit or excellence in a higher education context and the risk profile (perhaps related to project size), potential breadth of utilisation and scope for appropriability of a new product or process invention.

This serves to highlight the inherent tradeoffs involved in program design. For example, in a business program context, while discretionary grant programs involve higher administration and compliance costs than the entitlement based R&D tax concession, they also offer potentially greater scope to target projects with high social benefits because competing project proposals are thoroughly scrutinised and ranked on the basis of merit.

Funding duration

Program duration needs to be aligned with the objectives that underlie public support. Where a program is intended to change culture regarding the value of undertaking a particular activity or provide a demonstration of better practices, the program should have a fixed life with the objective that the better practices will continue once public support has ceased (Lattimore et al. 1998).

While the characteristics of science and innovation activity mean that under-provision is a permanent feature of the market for knowledge and ongoing public support will be warranted, there are examples of Australian programs introduced specifically to change attitudes to innovation (including collaboration) but which appear to have achieved a degree of permanency. Examples range across the business, higher education and public research agency spectrum and are discussed in the following sections.

Avoidance of risks

Interactions among programs

Public support for science and innovation in Australia is spread across a multiplicity of different programs that aim to meet a number of (sometimes conflicting) objectives. Some of these programs can overlap, compensate for, complement or adversely affect each other. Effective program design needs to take account of these interactions. Where support is provided for different activities and in different sectors it is important that the combined level of support is consistent, as far as practicable, with the net social benefits associated with the research undertaken.

In this context, the potential for (and impact of) 'double-dipping' needs to be closely scrutinised. For example, although 'clawback' arrangements are in place to prevent this in specific circumstances, current arrangements do provide scope for subsidised sectoral research bodies to participate in collaborative arrangements which are partly publicly funded and, under certain conditions, also access the R&D taxation concession. This has the potential to significantly increase the subsidy rate provided to certain types of research and lead to a less effective allocation of overall public support.[1]

1 The complexity associated with some aspects of Australia's science and innovation funding arrangements means that care should be exercised in judging what constitutes double-dipping. In the higher education sector, for example, block-funding is partly determined by an institution's success in securing ARC grants. But project overheads (such as infrastructure) are not covered by ARC grants and therefore require supplementary funding from other sources.

Avoiding excessive financial risks

Excessive risks to government revenue should be minimised, preferably through a formal risk-management strategy that efficiently limits sizeable risks (including legal or taxation liabilities). While the simplest approach involves placing a cap on potential liabilities (a feature of most but not all science and innovation program funding in Australia) this involves an implicit and arbitrary judgement about the net social benefits available to support provided above and below the cap.

This issue is especially relevant where program funding is provided via the taxation system as revenue foregone (such as in the case of the R&D tax concession) and where the complexity of that system makes it difficult to accurately estimate in advance a program's actual cost to revenue. In this context, there is some uncertainty regarding the impact of the dividend imputation system on the value of concessions associated with, for example, accelerated depreciation of plant and equipment and R&D expenditures (see the next section). For the same reasons, the robustness of any program (in terms of the constancy of the benefits provided and the program's cost) needs to be re-assessed in line with changes to other policies and the economic environment.

Strategic behaviour

The higher the proportionate level of support provided to a research project the greater the chance of encouraging an unwanted behavioural response because the financial consequences of failure are reduced. In turn, this could lead to potentially poor project management and project selection as well as a desire to find loopholes that allow non-R&D activity to pose as genuine R&D (as occurred in the case of core technology, feedstock and interest deductions in the R&D tax concession during the 1990s). Accordingly, programs should aim to build on market incentives wherever possible.

For certain types of activity (for example, applied research) an involvement by commercial stakeholders (either on a collaborative or contractual basis) can reduce the potential for inappropriate behaviour by directing research to areas more likely to have practical applications. And in most areas (notably in funding arrangements for higher education and public sector research agencies), contestability can provide an effective discipline on researchers as it raises the potential for funding to be reallocated to higher quality and more efficient providers in case of poor performance.

Evaluation, monitoring and reporting

As discussed in chapter 7, proper evaluation of research programs and research proposals is critical to transparency, accountability, achievement of program objectives and policy learning. Program evaluations should be conducted on both an ex ante and ex post basis — the former in order to assess and rank the potential social returns from the provision of support and the latter to facilitate improvements to program design.

The cornerstone of evaluating programs themselves should be through formal cost-benefit analysis (where possible) to assess the net social benefits expected and those delivered. Initiation or continuation of a program should be dependent on the results of that analysis. Science and innovation activity is inherently risky and uncertain with the specific outcomes from research difficult to specify in advance and also measure in hindsight (especially at the basic research end). But this is not a reason to dispense with systematic and consistent analysis.

Public reporting of the results of program evaluations should be a mandatory requirement as it increases transparency, reinforces disciplines on those designing and managing programs to act in the community's best interests and can also provide useful information to potential program participants. As noted below, some program administrators have serially failed to release the results of program evaluations in a timely manner. This raises questions regarding their findings. The level of detail in reports could be linked to the amount of public support provided. Core requirements should include program objectives, selection criteria, and evidence of the net impacts of the program or project.

Finally, many decisions about program delivery will be quite difficult in practice. This highlights the importance of administrative innovation and learning, as the initial program design or other features may need to be modified in the light of experience. It also reinforces the need for effective program evaluation to provide information about program performance.

Assessment of current arrangements

The following sections provide a sketch of the main elements of Australian Government support for science and innovation in Australia. Their purpose is to highlight the key program design strengths and weaknesses in current science and innovation arrangements and to offer some insights into potential improvements. While they draw on the above material, that material is not used as a checklist against which to assess every feature of those arrangements.

Four broad funding approaches are used by governments to support science and innovation systems — intellectual property regimes may be considered another element (with funding provided by the users of the resulting knowledge) but these are discussed elsewhere in this report:

- direct fiscal incentives to firms to subsidise the cost of R&D;
- hybrid arrangements involving public-private partnerships aimed at encouraging collaboration and the utilisation of research outputs (such as the CRC program);
- sponsorship of research activity in higher education institutions; and
- intramural provision of research activity (with both public and private benefits) in public sector research agencies.

These approaches can be viewed as complementary in the sense that they target different objectives and this highlights the need for diversity in policy design. That said, none of these mechanisms is a perfect solution to the underlying problems they seek to address as they each create incentives which are, to varying degrees, incompatible with ideal community outcomes. Nor are they costless to implement. Accordingly, the most appropriate form of policy intervention will depend on the nature of the activity and the market incentives for its supply. This also implies that, in certain cases, the most effective response may be to do nothing as there is a net cost associated with intervening. An important (though difficult) policy question is the appropriate funding mix. This issue is discussed in chapter 8.

9.3 Business sector support

Direct support for business sector science and innovation activity by the Australian Government was around $1.2 billion in 2004-05 (or 22 per cent of total federal funding for science and innovation). That support is delivered through a range of programs distinguished according to: whether they are sector-specific or generally available; the stage of business development for which they are intended; and whether the funds are allocated on a competitive or entitlement basis (sub. 93, p. 5).

The main programs are: the R&D Tax Concession (which accounts for about 50 per cent of total business support); Rural Research and Development Corporations; grant funding under the Commercial Ready Program (which replaced R&D Start and several other smaller programs); and the Automotive Competitiveness and Investment Scheme (see table 9.1). A number of smaller programs (many of which target small and medium sized enterprises) make up the remainder. The level of support provided by these arrangements — defined in this chapter as the level of the Australian Government's contribution for every $100 of business spending on R&D — varies considerably across programs (see table 9.1).

Table 9.1 **Government contribution to major business support programs in 2004-05**

Program	*Government contribution for every $100 of business spending*	*Program cost*
	Dollars	$ million
R&D Taxation Concession [a]		
Basic 125 per cent	7.5	490
Premium 175 per cent	22.5	90
Rural Research & Development Corporations [b]	76.8	214
Commercial Ready	100.0	152
Automotive Competitiveness and Investment Scheme (R&D component)	45.0	128
Cooperative Research Centres [c]	125.0	195

[a] The differential tax treatment of certain R&D capital expenditures (which can be expensed immediately) compared to the depreciation of capital items over time may be considered an additional form of assistance. [b] Based on average industry contribution across industry-focused RRDCs (see table 9.4). [c] Maximum potential support based on average industry contribution to CRC program since 1991. Ignores additional support provided by the R&D taxation concession and other programs where relevant.

Sources: Budget Papers 2005-06; IR&D Board Annual Report 2004-05 and PC estimates.

R&D tax concession

Key features

The R&D Tax Concession Scheme was introduced in 1985 (originally at a uniform rate of 150 per cent) as a temporary measure to '… encourage Australian industry to undertake increased levels of systematic R&D' (IR&D Board 2005). Program objectives have been variously modified since that time (in line with trends in general policy thinking) with the current stated goals being much wider than the original motivation and now include improving competitiveness and export-orientation.

The scheme is broadly-based, provides for decentralised decision-making on the type of activity undertaken (subject to eligibility criteria) and is open-ended in that it is not subject to sunset provisions or a funding cap. Since its introduction, it has been reviewed and refined on several occasions — primarily to deal with unforeseen problems in its operation. It currently involves the following three components:

- a basic 125% R&D Tax Concession — allowing all companies incorporated in Australia and undertaking eligible R&D activities to claim a deduction of 125% of R&D expenditure.
- an incremental 175% Premium R&D Tax Concession — introduced in June 2001 to provide a higher level deduction for eligible expenditure on labour[2] and for that part of a company's claim that is greater than its average R&D expenditure over the previous three years.
- an R&D tax offset — to assist small companies, especially those in tax loss, by providing an immediate benefit from the basic and incremental components by allowing benefits to be 'cashed out'. The offset is available to companies with an annual group turnover up to $5 million subject to an R&D expenditure threshold of less than $1 million.

The definition of eligible R&D is based, in principle, on the widely-recognised OECD (2003) *Frascati Manual* classification (covering all types of activity from basic research to experimental development). It requires systematic, investigative and experimental activity that involves innovation or high levels of technical risk conducted for the purpose of acquiring new knowledge (whether or not with a specific practical application) or creating new or improved materials, products, devices, processes or services. To ensure there is a scientific or technological basis to eligible expenditure, a range of activities are excluded. Among these are the making of cosmetic modifications to products, processes or production methods (this is relevant to the discussion later regarding ACIS).

In practice, however, much of the R&D undertaken in Australia involves product-based incremental change with benefits more likely to be specific to the individual firm conducting the research. As such, this type of activity will involve lower levels of spillover benefits (the widely accepted rationale for government support) compared with truly novel and technically risky research and that with broader potential utilisation.

The submission by the DITR acknowledged this feature in the following way:

> Most Australian industry innovation is incremental — ie it does not involve the introduction of radical new products, processes or changes that may create a new industry, but poses improvements to existing products or systems. It generally does not involve a new to the world technology, service, process or organisational change, but more commonly encompasses 'new to the business' or 'new to the industry' innovation. (sub. 93, p. 34)

2 In 2004-05, around 43 per cent of business expenditure on R&D was accounted for by labour. Other current expenditure accounted for a further 50 per cent and capital items about 6 per cent (ABS 2006b).

The submission from Biota Holdings Limited (in making a case for extending the concession to larger tax loss companies) similarly highlighted the current nature of activities supported by the program:

> As such, the [lack of] application of the R&D concession to truly innovative companies is actually counter to the spirit of innovation, where high risk takers are penalised and those engaged in low level, low risk innovation are the prime beneficiaries of one of Australia's primary [support] mechanisms for research and development. (sub. 94, p. 4)

While tightening eligibility criteria to target higher spillover activity would increase the net social benefits from the program, the Commission concedes that the specific nature of any such change would necessarily involve a considerable degree of subjectivity. For example, access could be restricted on the basis of firm size and R&D intensity as smaller firms with a greater R&D focus are more likely to perform genuinely new and more widely utilised research. But the choice of what is an appropriate activity threshold would be highly arbitrary and involve perverse incentives as firms would effectively be penalised for growth beyond the threshold.[3]

At a 30 per cent company tax rate, the level of the Australian Government's contribution for every $100 of business R&D varies between $7.50 for the basic concession and $22.50 for the incremental component. While this is in the mid-range of support provided by other OECD countries (see appendix C), a number of participants called for an increase in the subsidy rate (see below). Importantly, payments to Cooperative Research Centres (CRCs) for the purpose of eligible R&D may also be eligible for the R&D Tax Concession. This means that for research projects conducted within those collaborative structures, the overall subsidy rate to business can be considerably higher than that provided by the tax concession alone.

There were around 5500 companies registered for the program at 30 June 2006 with total eligible expenditure of just over $7.7 billion in 2004-05. Firms eligible for the premium tax concession (including the tax offset) reported R&D expenditure of about $3.7 billion in that year (although the majority of this activity would attract the lower concession rate because it is not additional R&D).

Key design issue — inducement

As noted above, public programs should aim to have the highest possible inducement rate. However, the Commission considers that the basic tax concession is likely to have a relatively low inducement rate because it provides an across-the-board subsidy to eligible expenditure regardless of whether the R&D would have

3 By way of example, there is currently evidence that some firms are restricting investment in R&D and turnover in order to qualify for the R&D tax offset (DITR 2005).

been undertaken anyway. In that case, large annual transfers are being provided to firms which generate economic costs as distortionary taxes are levied to make up for the revenue forgone under the scheme. Accordingly, the net social benefits from the program are likely to be lower than they would have been had the program been better targeted.

The importance of inducement was acknowledged in the submission by the program designer — the Department of Industry, Tourism and Resources (DITR) — as was (by omission) the failure of the basic concession to meet this criteria:

> Most DITR programs are designed to induce additionality — that is, to induce an outcome or behaviour that would not otherwise have occurred, or would have occurred more slowly, if government support had not been forthcoming. Competitive entry programs like Commercial Ready do this through the assessment process while the 175% R&D Tax Concession and [the Pharmaceuticals Partnerships Program] only subsidise activity above a historical base. A focus on additionality helps to ensure that the support provided by Government is economically efficient. (sub. 93, p. 11)

With this issue being widely understood, several evaluations of the scheme have concluded that it still delivers a net social benefit to the Australian community. For example, the Bureau of Industry Economics (1993) found that the earlier 150 per cent tax concession provided a net social benefit of $56 million per annum even though up to 90 per cent of the supported R&D would have occurred anyway. Importantly, that study found that the tax concession had a much higher inducement rate for small firms (with less than 20 employees) compared to larger firms (this is relevant to the discussion below).

A more recent cost-benefit analysis found the net social benefit from the 125 per cent tax concession was around $52 million per annum despite the scheme raising R&D by 10 per cent at most (Lattimore 1997). That study also found that the estimated net social benefit would have nearly doubled if unnecessary transfers to firms had been avoided. Similarly, the most recent analysis (CIE 2003b) concluded that a likely benefit-cost ratio associated with the scheme was around 1:1 with around 70 per cent of the budget cost of the program ($280 million in 2003-04) invested in marginal R&D projects and 30 per cent simply a (non socially beneficial) transfer between the government and firms. As noted by the CIE, the results of its analysis rest crucially on the estimate of spillover benefits for which there is little hard evidence. On the basis of the range of inducement and spillovers rates preferred in that study, the Commission notes it is quite plausible that the scheme involves a significant net social cost and that the risk of such an outcome would be considerably reduced if the inducement was higher (see table 9.2).[4]

4 The Commission notes that the CIE evaluation estimated the inducement rate associated with the program was between 50 and 90 per cent (with a best estimate of 69 per cent) While this is much

Table 9.2 **Benefit-cost analysis of the 125 per cent R&D tax concession**
$ million

Benefits	
Transfer from government to companies [a]	22.4 – 112.0
Private benefit from induced R&D [b]	112.0 – 201.6
Spillover and flow-on benefits from induced R&D [c]	42.0 – 327.6
Total benefit	***176.4 – 641.2***
Costs	
Budget cost of scheme	280
Efficiency cost	85
Administrative cost	10
Compliance cost	35
Total cost	***410***
Net benefit	**-233.6 to +231.2**

Note: Benefit calculations are based on an estimated inducement rate between 0.5 and 0.9 and assumed spillover rate between 0.3 and 1.3. No account is made of clawback of the tax concession through the dividend imputation system which would reduce (increase) the net social loss (benefit) from the program.

[a] This is the budget cost of the scheme * (1 – inducement rate) * (1 – leakage to foreign firms). [b] This is the budget cost of the scheme * inducement rate * (1 – leakage to foreign firms). [c] This is the budget cost of the scheme * inducement rate * spillover rate.

Source: Based on the methodology used in CIE (2003b).

Several participants to this study implied, either directly or indirectly, that the ability of the basic concession to induce new activity had been compromised by restrictions on its accessibility (primarily the beneficial ownership requirements for intellectual property and the activity thresholds applying to the tax offset) and a reduction in the value of the concession due to a lowering of the corporate tax rate and the concession rate (from 150 per cent to 125 per cent). Beneficial ownership requirements effectively prevent subsidiaries of foreign owned companies from access to the tax concession. The submission by GlaxoSmithKline outlined the nature of the restriction in the following way:

> Under the Income Tax Assessment Act and the IR&D Act the concession is limited to those entities that hold the intellectual property associated with the R&D domestically. This effectively prevents subsidiaries of multi-national entities, for which head office requires intellectual property to be held centrally, from accessing the benefit and means that a significant proportion of the R&D carried out by members of the pharmaceutical industry is without any significant public support by way of tax incentives. (sub. 38, p. 27)

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higher than the findings from the earlier studies, it simply reflects the use of a different definition of inducement. The earlier studies defined the inducement rate as the increase in R&D as a share of total R&D eligible for the concession. The CIE defines inducement as the increase in R&D as a share of foregone tax revenue (a much smaller base). Based on the alternative definition, the CIE finding is equivalent to an inducement rate of between 4.5 and 8.1 per cent.

The apparent rationale for restricting access has been a desire by Government to avoid transferring revenue to foreigners without delivering a corresponding benefit to Australia.[5] For their part, foreign firms have previously argued that lack of access to the concession makes Australia a less attractive location to conduct R&D than other countries. However, in the Commission's view the modest subsidy provided by the concession is unlikely to play a key role in influencing location decisions especially in comparison to other features of Australia's innovation environment. As AusBiotech highlighted in it submission:

> Australia has an innovative and cost-effective research base. Compared to ten countries in Europe, North America and Asia as of January 2006, Australia was ranked the second most cost-effective location to conduct biotechnology research over the past ten years, behind Singapore. Austrade sees Australia's high ranking due partly to a strong supply of highly-qualified scientists, with more graduates in the fields of science and technology relative to other fields than in other developed countries. (sub. 95, p. 4)

Nevertheless, the concession is obviously of some value to foreign firms as it could be applied to the R&D activity they already conduct in Australia (that is, activity that was not induced by the concession). In considering whether to relax the restriction, however, the relevant criteria that should be applied is whether the net social benefits (spillovers) to the Australian community from foreign access outweigh the associated leakage and financing costs. Empirical evidence suggests that this is not the case. For example, one recent Australian study concluded that the net social return to Australia from providing the tax concession to foreign-owned firms was highly negative largely because of the social cost of the transfer payments (Lattimore 1997).

In addition, the Commission's recent evaluation of Pharmaceutical Industry Investment Program (PC 2003a) noted a range of risks involved in making a broad change to beneficial ownership requirements and also that the advantages of quarantining such a change to the pharmaceutical industry were outweighed by the disadvantages. It went on to suggest:

> … the problems associated with accessing the Tax Concession and the other identified rationales for intervention provide a prima facie case for some other form of direct industry assistance, oriented to R&D. (PC 2003a)

And, as noted in the submission by Medicines Australia (sub. 99, p. 23), the implementation of the Pharmaceuticals Partnerships Program (succeeding the earlier program and which now provides a 50 per cent public subsidy for increases

5 DITR (sub. 93, p. 21) noted that there is no beneficial ownership restriction under the Pharmaceutical Partnerships Program because the support provided by that program '… is based on the rationale that spillovers are derived from conducting R&D activity, rather than owning the IP, which is why [it] has an emphasis on partnering and requires all R&D to take place in Australia.'

in eligible R&D) could in part be described as the Government's response to that recommendation.

On the basis of this evidence, there does not appear to be a strong case for relaxing the beneficial ownership requirements applying to the 125 per cent tax concession. However, given that the extent of transfers is likely be lower for an incremental program (due to higher expected inducement) it may be worth considering allowing access to the premium component of the tax concession scheme (see below).

In a different context, Biota Holdings noted the detrimental impact of excluding larger firms that were in a tax loss position from access to the concession or the tax offset because they needed access to capital. It said:

> … many innovative companies can not access the benefits of the R&D tax concession when they most need it (during the capital intensive development phase) and gain access to the benefits of the concession when they least need it (often after they have commercialised the innovation and are profitable). This scenario may account for the increasing number of companies who are unable to fund the ongoing research needed to produce innovative results and goes some way to explaining why so many companies are unable to take innovation through to commercialisation. (sub. 94, pp. 3–4)

According to DITR (sub. 93, p. 16), the basis for explicitly targeting small firms with the tax offset is that capital is a critical issue for these firms if they are to sustain their research programs. As noted in chapter 3, there is some evidence that capital constraints may be more significant for small firms and start-ups than for larger firms. Accordingly, the Commission does not see a general case for expanding access to the offset on the grounds of the need to access capital.

However, it does concede that the asymmetric treatment of tax losses will significantly reduce the value of R&D support for firms such as Biota with long lead-times in product development (and may extinguish it if there is a change of ownership). Again, in considering whether to amend the eligibility criteria, the Commission reiterates that the purpose of public support should not be to subsidise activity that would have occurred anyway. This is much less likely to be an issue under an incremental scheme.

Participants also raised concerns regarding the erosion in the value of the concession over time. The submission by Engineers Australia, for example, stated:

> The R&D tax concession has been extremely successful, and Engineers Australia supports its continuation. Where successfully applied by companies, it has the added advantage of providing government with taxes after the initial development period, which can, in many cases, adequately cover the initial outlay. However, business has been deterred from investing in R&D by frequent changes to incentives, and by the reduction in their value. (sub. 88, p. 6)

The Victorian Innovation Economy Advisory Board went further by asserting a causal link between the reduction in the concession rate and subsequent trends in Australia's business R&D:

> … since 1996, when the 150 per cent tax concession was reduced to 125 per cent … this had an immediate and negative impact on business R&D. (sub. 89, attachment p. 2)

While the timing of the reduction in the concession rate certainly coincided with a decline in Australia's BERD to GDP ratio, there were a number of other policy changes around that time which were far more important influences. In particular, the syndicated R&D program (which accounted for more than 30 per cent of claims under the tax concession in 1994-95) was terminated as a result of concerns regarding abuse of the scheme and the definition of eligible R&D was tightened to exclude a range of overheads, consumables (such as feedstock) and interest items from being claimed. Against that background, the rise in the BERD to GDP ratio in more recent years is even more significant.

The incremental scheme

In principle, the premium component of the tax concession scheme offers much greater potential to encourage additional R&D and increase the net social benefits from the program. This point was highlighted by the program designer:

> The 175 per cent Premium Tax Concession promotes higher additionality by offering the higher rate only to firms that increase their average investment in R&D. (sub. 93, p. 16)

Importantly, while incremental schemes have the capacity to reduce non-beneficial transfer payments significantly, they are unlikely to eliminate them entirely as firms will still accept support even if the increase in R&D is not stimulated by the subsidy. However, it is very difficult to design policies that do not subsidise some R&D that would have occurred anyway (see below). In the absence of information about the behaviour of firms accessing the incremental component of the tax concession both prior to and following its introduction, it is difficult to accurately estimate the extent of inducement and the net social benefit from that component.[6]

That said, for a given level of assistance to marginal R&D, it is reasonable to assume that an incremental scheme will require much less revenue and has the potential to generate much higher rates of social return. In turn, this can allow for a higher rate of incentive to be provided (which could also increase progressively the

6 The Commission sought to assess the extent to which the R&D behaviour of firms registered for the incremental component of the tax concession had changed since its introduction but it was not granted access to the relevant data. This highlights a need for greater clarity by Government in defining the roles and responsibilities of program administrators.

greater the increase in activity from a base period) or for the revenue to be redirected to alternative business R&D or other innovation programs (see below).

The actual social return will depend critically on the specific features of the incremental scheme with the challenge to design a program that delivers the biggest net benefit for the amount of revenue forgone. As discussed below, while there is a range of alternatives available it is likely that a scheme with a fixed activity base will have a higher return than a rolling base especially if the fixed base is appropriately indexed. As an illustrative example, a recent empirical study in the United Kingdom used the historical R&D experiences of a sample of UK firms to estimate the cost to revenue and associated net benefit of four different R&D support scheme designs (see table 9.3). It found that the effectiveness of a sales-indexed fixed activity base was more than three times greater than a rolling activity base — a design similar to that currently used in Australia (Bloom et al. 2001).

The design of the incremental scheme

As mentioned, the extent of inducement from incremental schemes depends on their design characteristics. In this respect, the definition of the activity base against which future R&D expenditures are compared can have a significant impact on the behaviour of R&D performers. As noted in an earlier Industry Commission report (IC 1998), there are a range of potential dimensions to determining the base including: whether it moves over time or is fixed; the length of the base period; activity measure used; whether the benchmark is an individual firm or industry; and whether the base is adjusted for differences between firms.

The Industry Commission argued that adopting a rolling base (such as that which is now used in Australia's incremental scheme) could lead to perverse incentives for R&D performers if R&D does not follow a smooth growth path. For example, its operation would mean that the more a firm spends in one year, the lower the opportunity to access the scheme in future years. In addition, a rolling base may also encourage some firms to deliberately increase the variability of their R&D expenditure.[7] In addition, it is simply not possible for a firm to continually increase its R&D activity in perpetuity — a requirement for ongoing support under a rolling base.

7 The Commission acknowledges that the current arrangements include a moderating facility where there has been significant prior-year downswings in R&D expenditure.

Table 9.3 **Impact of different R&D scheme designs**

	Volume credit (no base)	*Three year rolling average base*	*Inflation-indexed fixed base*	*Sales-indexed fixed base*
A: Induced R&D [a]	£684.0m	£113.0m	£497.0m	£427.0m
B: Revenue Cost [b]	£820.8m	£126.0m	£199.2m	£145.2m
C: Ratio of A to B	0.83	0.90	2.48	2.94

[a] Estimates based on a long run own price elasticity of R&D demand of -1.0. [b] Headline tax credit rate is 20 per cent.

Source: Bloom et al. (2001).

For these reasons, the Industry Commission suggested that the use of a fixed base would be the preferred route for Australia. It also endorsed the use of R&D to sales as the relevant activity measure (the approach used in the United States) as it provides a more effective means of targeting changes in real R&D activity than a general inflation measure.[8] The desirability of this approach was also raised by the Victorian Innovation Economy Advisory Board:

> It would also be useful to consider a differential tax concession on the basis of R&D intensity, eg as a proportion of sales revenue. The objective would be to encourage more Australian companies to increase their R&D activity to a scale comparable with leading international companies. If budget neutrality was required, it could be achieved through careful management of the various levels of the concession. Notwithstanding this, we would prefer to see an increase in the overall level of incentive being made available. (sub. 89, attachment p. 4)

Another issue involves the treatment of start-up firms — traditionally an important source of innovative activity — which have no base year defined by their past experiences. Under current arrangements, companies require a three-year history of registering for, and claiming the concession (AusIndustry 2006b). This effectively excludes start-up firms from access to the 175 per cent concession and the premium tax offset (the latter providing a potentially significant benefit for what are characteristically loss-making and liquidity-constrained high technology firms). The lack of incentive for these firms was highlighted by the Victorian Innovation Economy Advisory Board:

> The R&D tax concession is, of course, not a universal solution. It does not, for example, provide an incentive for those companies that are R&D intensive but not paying tax, such as high technology start ups. (sub. 89, p. 4)

Under a revised arrangement based on the ratio of R&D to sales, this issue could be addressed by setting an appropriate reference number against which to compare

8 This conclusion is supported by Bloom et al. (2001) although they note that one problem with this activity measure is that the base will expand or contract in line with total sales, which may be more volatile than R&D expenditure.

current R&D to sales ratios for start-up firms (again the approach adopted in the US) with those firms falling below the benchmark able to claim full deductibility if they were profitable or the tax offset if they were in a position of tax loss.

In conclusion, the net payoff from the concession could be substantially improved by rebalancing the tax concession away from the generally available 125 per cent component towards the 175 per cent incremental component of the program. This could be achieved, for example, by maintaining the basic concession for smaller firms, whose R&D is more responsive to the subsidy, but otherwise using the 175 per cent incremental component as the principal vehicle for stimulating business R&D. Alternatively, the scheme ultimately could be shifted completely to the 175 per cent component, if threshold issues about firm size were considered to provide adverse incentives for growth of smaller R&D-intensive enterprises.

Complementary arrangements

Rebalancing the scheme toward the incremental component has the potential to significantly reduce the revenue forgone under current arrangements. This would provide scope to generally increase the concession rate for the premium component or perhaps introduce a tiered system with progressively higher subsidy rates depending on the extent of the increase in a firm's R&D activity.

Alternatively, part of the budgetary savings could be used to pilot and (depending on the outcome of an evaluation) establish a program which provides a financial incentive for firms to form R&D networks undertaking collaborative research projects in groups or in conjunction with universities and public sector research agencies. The appropriate design of such a program has the potential to both increase inducement and target research projects with high spillover benefits. As discussed below in the context of the CRC program, there are a number of different options for establishing flexible collaborative arrangements.

DRAFT FINDING 9.1

The R&D tax concession could be improved by:

- *shifting the orientation of the concession towards its 175 per cent incremental component;*
- *relaxing the beneficial ownership requirement and the expenditure and turnover thresholds for the tax offset for the incremental scheme alone;*
- *changing the base on which the incremental subsidy is paid to a firm's ratio of R&D to sales at a given, fixed date; and*
- *allowing access to the incremental scheme to start-up firms.*

At a more general level, other options to raise inducement levels include moving to a greater reliance on competitive grants as they may provide a more effective means of targeting socially valuable activity that firms may be reluctant to undertake. However, as discussed below, inappropriate design features can compromise project selection and heavy information requirements make these approaches costly to administer. Other alternatives include stock-option grants or contingency-based repayable loans to encourage firms to undertake genuinely new projects (see box 9.2). While they are not perfect methods of inducing socially valuable innovation they do offer insights on ways to improve on current arrangements.

Competitive grants programs

Key features

Fiscal incentives for business sector R&D in Australia have included a suite of programs providing merit-based competitive grants to individual firms since 1986. A major motivation for these programs (at least until the current arrangement was introduced) has been to complement the R&D tax concession by supporting smaller firms unable to access benefits from the more generally available scheme (such as where a firm is in a tax loss situation). While the programs have also served a range of other evolving objectives, the criteria used to assess project eligibility have remained relatively constant (see below).

A set of five different grant schemes was originally introduced at the same time as the R&D tax concession with the relative merit of project applications assessed on the basis of economic, technical and commercial criteria. Largely because of industry concerns that the number of schemes was causing unnecessary complexity, they were amalgamated into a single scheme — Competitive Grants for Research and Development — in 1994 with a single set of eligibility and merit criteria. Under the new scheme, the maximum grant available was a uniform 50 per cent of the total eligible project cost with no minimum level of expenditure.

Box 9.2 **Incentive compatible R&D schemes**

There are a number of approaches available to reduce the motivation for firms to accept payments for R&D that they would have been prepared to fund in the absence of an incentive. Incentive compatible mechanisms aim to achieve this by penalising firms seeking unwarranted support. A requirement for the disclosure of the intellectual property from a research project is one such mechanism. Another involves a stock option grant.

Stock option grants

With a stock option grant, the government purchases a share in a company established to undertake and commercialise a technology. After a specified time, the government has the option of selling its share and profiting (if the project was successful) from the sale. A private firm that has a commercially attractive R&D proposition will be reluctant to dilute its interest in that project by agreeing to such an arrangement as it would lead to a net less of income. Royalties and repayable grants impose similar disciplines on firms to present truly additional projects.

A firm that would not have proceeded, on the other hand, may be willing to allow such equity participation. However, as noted by the BIE (1993) there are a number of practical difficulties in the application of stock option grants including the fact that share values can be influenced by factors other than the success or failure of R&D projects. Perhaps for these reasons, the Commission is unaware of any international example of the use of stock option grants. As such it illustrates a conceptually appealing yet practically flawed policy instrument.

Incentive subsidies

Another option involves providing a subsidy that is proportional to the social returns from a project. In this context, the subsidy increases as the expected social benefit rises to provide firms with an incentive to choose the most socially beneficial projects. In principle, this approach can also be shown to discourage the acceptance of mere transfer payments and encourage firms to diffuse the results of their research — effectively compensating them for lowering the private value of an invention but raising the social value.

Folster (1991) argues that while a perfect incentive policy is impossible to devise due to uncertainty about the private and social benefits of a project, there are near substitutes. He advocates that firms be required to repay a share of profits from successful projects that are at least equal to the level of subsidy they receive (a form of repayable loan). As with stock option grants, a rational firm would never apply for such a scheme if it intended to proceed in the absence of support. In contrast, unsuccessful projects would not be required to repay the subsidy. This feature is important because it provides an incentive for firms to conduct projects with expected private and social benefits but which they view as being too risky to undertake.

Sources: Folster (1991), BIE (1993), Lattimore (1997).

A new measure focusing on larger commercially oriented R&D projects in smaller firms was introduced in 1996 — the R&D START program. Funding was offered in the form of both grants and loans on a competitive basis. Grants of up to 50 per cent of project costs were available for smaller companies (annual turnover less than $50 million) and up to 20 per cent for larger companies. Importantly, repayable loans were also provided for 'high-quality' projects which increased the maximum subsidy rate to 56 per cent of total project costs for both small and large firms. As discussed later, repayable schemes increase the likelihood of inducing new activity because a firm that would proceed without support has no financial incentive to apply.[9] According to the IR&D Board (2005), the key eligibility criteria for START were that projects had to have clearly identified commercial potential and that applicants had to demonstrate the projects could not proceed 'satisfactorily' without support.

Program funding of just over $1 billion was allocated to START and other programs sharing similar objectives through to 2006 (Allen Consulting Group 2000). The program (along with two smaller programs) was incorporated into the latest business innovation policy measure — the Commercial Ready Program — which again focuses on commercialising R&D outcomes. Introduced in 2004, the stated objectives of Commercial Ready include:

- increasing the level of R&D, early-stage commercialisation and proof-of-concept activities of small and medium sized Australian enterprises; and
- generating national benefits, such as through higher productivity, supporting collaboration and developing Australia's skills base (IR&D Board 2005).

The program will provide up to $200 million annually over seven years and is expected to assist around 1700 small and medium-sized enterprises (the annual turnover threshold was recently increased from $50 million to $100 million) over that period. Around 50 per cent of program funds will support R&D activities with 30 per cent for early stage commercialisation and 20 per cent for proof-of-concept activities (sub. 93, p. 5).

Funding is provided in the form of competitive grants with successful applicants receiving up to 50 per cent of project costs. A grant ceiling of $5 million applies. Importantly, the repayable loan component of the START program has not been carried over to Commercial Ready. Applications are assessed on five merit-based criteria each of which receive equal weighting (see box 9.3). Given the relatively recent introduction of the program, the discussion below draws on the experience of its predecessors in order to assess the likely impact of the current program.

9 However, repayable schemes do not encourage projects with low private but high social returns.

Key design issues — inducement, adverse selection

As noted earlier with respect to the R&D tax concession, public support for business R&D should not simply act to transfer public funds to firms that would have undertaken a project in the absence of an incentive. The importance of this feature is also explicitly acknowledged in the objectives and eligibility criteria of the Commercial Ready program and its predecessors.

In principle, selective assistance of the type funded by competitive grant programs should provide greater scope to target R&D projects which would otherwise not proceed (including those with high social returns) because they allow for detailed scrutiny of individual proposals. This is how other innovation funding programs, notably those administered by the ARC and NHMRC, also operate. In practice, however, asymmetric information regarding an applicant's motivation for seeking support makes effective program design critical. It also means that administration and compliance costs are likely to be much higher than entitlement-based programs such as the R&D tax concession.[10]

In assessing the effectiveness of earlier grant programs (including R&D START) in encouraging new activity, it is important to recognise that eligibility for the various schemes required only that grant support be necessary for a project to proceed *satisfactorily*, and that this is a considerably lower hurdle than requiring assistance be provided only to projects that would not proceed in the absence of funding. The apparent rationale underlying this weaker criteria is that: where speed to market ('first mover advantage') is critical to an innovation's commercial success, the grant would allow the project to be completed earlier (IR&D Board 2005). Notably, the eligibility criteria for the current Commercial Ready Program maintains the reference to satisfactory project progression (see box 9.3).

A number of empirical studies have attempted to assess the proportion of subsequent projects that were likely to have been induced by earlier schemes. Survey results from the three main grant programs which preceded START (the Discretionary Grants Scheme, Generic Technology Grants Scheme and the National Procurement Development Program) showed that up to 50 per cent of the projects would have proceeded without support, although they would have taken longer to complete. A fourth program (the National Companies Teaching Scheme), was independently assessed with the main finding that two-thirds of the projects supported would have proceeded without public funding (IC 1995).

10 According to Allen Consulting Group (2000), the administrative cost of the R&D START program was three times higher than the R&D Tax Concession.

Box 9.3 **Merit criteria for Commercial Ready program funding**

Management Capability

- An appropriate level of expertise in:
– commercialisation management
– project management
– business management, including in human resources and financial management
- a core business which is directly relevant to the project
- demonstrated company stability and/or growth over the last two years
- a business plan which includes and supports the proposed project.

Commercial potential

- solid track record in commercialisation and marketing of innovative products
- well articulated and sound commercialisation strategy
- realistic appraisal of the commercial potential for the project outcomes, including the product
- understanding the route to market for the project, such as trade barriers, manufacturing and timeframe to commercial exploitation
- understanding of the competitive situation the project outcomes will face:
– the extent of competitive advantage from the project's commercial outcomes such as on cost, IP position and strengths and weaknesses compared to competing products
– the frequency with which new products or services enter the market.

Technical strength

- The technical capacity to undertake the project, including:
– adequate infrastructure, facilities and equipment to meet project requirements
– good understanding of technical product development, testing and production start-up
– appropriately skilled technical staff and/or sub-contractors
- well articulated project plan, eg methodologies and milestones linked to a feasible timeframe
- strong track record in the project field
- appropriate level of innovation
- appropriate level of technical risk, demonstrated by uncertainty over results.

National benefits

- how the project will improve national productivity and contribute to economic growth
- how the project will result in social, community *and/or* environmental benefits
- that significant spill-over benefits will accrue to Australia through conduct of the project and/or commercialisation of its results including:
– diffusion of knowledge and skills
– diffusion of new products, processes or services, and/or
– increased collaboration between businesses and/or businesses and research institutions.

Need for funding

- the project budget is realistic
- *Commercial Ready* funding is required for the project to progress satisfactorily, for one or more of the following reasons:
– insufficient resources to fund the entire project
– longer time frame for project delivery would erode competitive advantage
– the technical risk of the project mitigates against it proceeding, and/or
– project benefits that may justify government investment cannot be adequately captured.

Source: AusIndustry (2005).

More recently, a survey of START grant recipients found that while more than 60 per cent of firms suggested their project would have been undertaken without public funding the majority of those firms indicated that the absence of support would have resulted in a project that was slower, less well resourced and with reduced outcomes (IR&D Board 2005). In commenting on this result the program administrator said:

> The need to get high quality innovative products to market quickly is critical to the competitiveness and growth of Australian industry. As such the R&D Start grant has a clear and positive impact, even on projects which would have proceeded in the absence of grant funding. (IR&D Board Annual Report 2005, p. 51)

While the Commission acknowledges the importance of 'first mover' advantage in determining commercial viability it is highly sceptical that this should form a basis for providing public support. Leaving the case for supporting commercialisation objectives aside for the moment, it questions why a rational firm would undertake a project (without public support) if it considered its innovation would not reach its market quickly enough to ensure commercial viability. This suggests that much of the grant funding under START simply represents an unnecessary transfer to firms.

Although the IR&D Board has used these results to support the effectiveness of the grant programs it administers, the Commission is concerned about the prominence of commercial outcomes in project selection. In this context, the Board describes its overall mission is:

> To increase the economic return from successful technology-based enterprises in Australia by supporting their performance and commercialisation of research and technical development. (IR&D Board Annual Report 2005, p. 1)

Accordingly, the merit criteria of grant programs are tailored to increase the likelihood of selecting projects that have the greatest potential for commercial success. In Commercial Ready, for example, emphasis has been given to indicators such as the applicant's track record in commercialisation, expertise in commercialisation management and the commercial environment faced by the innovation (see box 9.3).

While the Commission recognises the general shift toward commercialisation objectives across innovation policies both in Australia and overseas, it views the case for public support in this area as having much less force than activities which involve benefits not readily amenable to capture by the innovator. In addition, using commercial success as a major objective for an R&D support scheme can adversely impact on the behaviour of the program administrator. As Folster (1991) noted:

> The likelihood of a project succeeding commercially depends on two things. First, the administrators' skill in choosing winners and helping to shape a project so that it succeeds. Second, the inherent riskiness of the project. The less risky a project is, however, the greater the chance that the firm would have conducted it anyway and the

> less effective the government subsidy in stimulating innovation. The administrator therefore has an incentive to pick non-risky projects that the firm would have researched anyway in order to show its acumen for spotting winners. (p. 36)

To highlight his point, the author drew on the results of an early Australian study which showed that R&D grants were given to exactly the same kinds of projects that firms conduct without the aid of public support.

Repayable grants

As touched on above, one way to address this issue, at least in principle, is to require firms to repay at least the value of the grant in the event of commercial success. The supplementary loan feature of the START program included such an instrument but it was discontinued under Commercial Ready. Repayable schemes have been widely used overseas, and in countries such as Japan, Germany, Israel and Sweden they are major forms of R&D support.

In Israel, for example, repayment takes the form of royalty payments from successful project revenue up to a maximum value equal to the grant plus interest (Lach 2002). The royalty proceeds are then used to fund future R&D projects with around a third of the administering agency's budget coming from that source in 1999 (up from 10 per cent in 1990). In addition, the program is entitlement-based in that all eligible proposals are approved with no requirement for competitive ranking In that sense, it operates in a similar manner to Australia's tax concession.

Encouragingly, the value of these types of incentive mechanism have been recognised in other parts of Australia's innovation system. CSIRO, for example, is developing a competitive repayable funding program — *Australian Growth Partnerships* — to transfer technology to SMEs and provide technical assistance. In CSIRO's words:

> If the SME were to be successful in commercialising the technology, it would repay the funds received from the program. If participation did not result in successful (profitable) commercial outcomes, no repayment would be necessary. (sub. 50. p. 86)

A disadvantage of these schemes, however, is that they do nothing specific to encourage projects with high social (as opposed to private) returns.[11] Establishing a set of eligibility criteria for grant funding that focuses on projects with potentially high social returns (that would not be conducted in the absence of support) is not an

[11] Some other problems include relatively high administrative costs, the inability to quarantine income streams from individual projects within larger companies and the potential for avoidance of repayment.

easy task.[12] While proxy indicators such as the level of technical risk, the number of potential beneficiaries and the scope for the innovator to capture the benefits of a new invention may provide some guidance they will require a considerable degree of subjective judgment. That said, repayable grants can still be used to screen projects with private benefits that would proceed in the absence of public support. As noted above, this is currently not a feature of the Commercial Ready Program.

Providing selective assistance

Another design issue involves the underlying rationale for providing selective assistance to small and medium-sized enterprises in the first place. Historically, grant programs in Australia have been used as a complement to the R&D tax concession because new or small technology-intensive firms may often be in a position of tax-loss in their early years (thus rendering the R&D tax concession ineffective). However, the redesign of the tax concession scheme in 2001 included the introduction of a tax offset which allows the cashing-out of the concession for firms without sufficient taxable income. Of course, the subsidy rate for the concession is considerably lower than the 50 per cent subsidy (up to the threshold) provided under the Commercial Ready program.

At a more general level, there is an in principle question of why large firms should be excluded from access to grant funding. The main rationale for targeting small and medium sized firms appears to be based on their perceived inability to access finance. While the Commission accepts there is evidence that capital constraints may be more significant for small firms than for larger firms, it also notes that in an environment of limited budgetary resources, projects with the highest social returns should receive funding priority. Excluding large firms from access to grant funding potentially limits the scope to maximise the social benefits from these types of program.[13,14] However, this may also require a substantial increase in overall program funding given differences in the scale of research activity by larger firms.

12 Folster (1991) has suggested that a subsidy scheme can be designed so that a firm only applies when a socially valuable project would not otherwise proceed. The author notes that the exact size of the subsidy is determined after project completion and in line with the estimated ex post social benefits. He also shows that the efficiency of this scheme does not depend on accurate measurement of those benefits.

13 The exclusion of locally based subsidiaries of multi-national enterprises may also be questioned on these grounds.

14 The threshold issue has also recently been considered by the House of Representatives Standing Committee on Science and Innovation (HRSCSI 2006) which recommended that consideration be given to raising the threshold as part of a review by DITR of the effectiveness of the program.

Not surprisingly, broader access to grant funding was raised by larger firms and their representative associations. Science Industry Australia (which represents scientific product manufacture and marketing interests), for example, said:

> The $50 million turnover criterion for programs such as Commercial Ready is unrealistic. … The effect of this limit is that the relatively few larger Australian science industry companies that compete in world markets and contribute to Australia's economic and social welfare are denied access to many government support measures. … R&D and other innovation activities are an on-going high risk process for all science industry enterprises, and a higher more realistic turnover ceiling should be established in the range of $100m to $150m. (sub. 22, p. 11)

As noted above, the turnover threshold has recently been increased to $100 million.

Other programs

A range of other business programs administered by the IR&D Board also focus on the commercialisation of research conducted by SMEs. They include the Innovation Investment Fund, a competitive program committing $200 million in public support over five years to early-stage venture capital. A maximum subsidy rate of 50 per cent is provided with private sector fund managers responsible for selecting and managing early-stage investments. The Commercialising Emerging Technologies Program aims to assist *very* early stage development for firms that lack knowledge about market opportunities and intellectual property issues through funding for business advisory services. Competitive allocation of $100 million in program funds (over seven years) provides up to an 80 per cent subsidy on eligible expenditure.

The Industry Cooperative Innovation Program involves $25 million in competitive grants providing up to 50 per cent matched funding on cooperative innovation projects which can demonstrate spillover benefits (sub. 93, p. 25). In a different context, the Pre-Seed Fund was introduced to raise the commercialisation of research within higher education, CRC and public research agencies by establishing four venture capital funds with around $70 million in program funding. The subsidy rate is up to 75 per cent with a repayment of all public funding required upon divestment of successful commercialisations.

As a collective comment, the rate of support provided by these programs (at up to $300 for every $100 contributed by industry) is very high. This increases the chance of encouraging an unwanted behavioural response from the selected fund managers and firms because it reduces the consequences of failure. In turn, this could lead to potentially poor project management and project selection. In addition, a greater reliance on repayment and benefit-sharing mechanisms (such as that used in the Pre-Seed program) would provide more effective incentives in these areas.

DRAFT FINDING 9.2

In principle, competitive grant programs such as Commercial Ready provide greater scope to target socially valuable R&D projects that would otherwise not proceed. However, this can be compromised by the current focus on commercialisation objectives.

Rural Research and Development Corporations

Key features

Rural Research and Development Corporations (RRDCs) were first established in 1989 under the *Primary Industries and Energy Research and Development Act*. As a group, they plan, fund (primarily from compulsory industry levies and public support) and manage much of the agricultural R&D conducted in Australia (CIE 2003c). There are currently 15 RRDCs (statutory and industry-owned) with all but two of these established to operate within specific industries (see table 9.4). In many instances, primary producers contribute to, and benefit from, more than one RRDC (sub. 96, p. v).

The rationale for this industry-specific arrangement is based on the characteristics of many primary industries with a large number of producers, each accounting for a relatively small share of relatively undifferentiated industry output. This makes it difficult for producers to capture sufficient benefit from R&D they might conduct individually in order for them to proceed. Accordingly, even though the collective benefits may justify the investment, there may be under-provision of rural research.

An effective means of addressing this potential problem is to conduct rural R&D cooperatively with funding sourced from producers in proportion to the benefits received. But in cases where there are a large number of producers, compulsory levy arrangements may be required in order to avoid free-riding by some on the R&D funded by others. Furthermore, the existence of benefits which extend beyond the primary industries themselves, but which are captured by the broader community (such as improved transport, storage and food safety and environmental benefits), are argued to justify the provision of some public support.

In practice, the Australian Government generally provides a matching contribution to R&D managed by the RRDCs usually up to a ceiling of 0.5 per cent of the industry’s gross value added. In some cases, for example fisheries, horticulture and meat and livestock, the government also matches some industry funds raised for R&D under other arrangements (CIE 2003c). Elsewhere, in research areas with strong public good features such as land, water and vegetation management (conducted through Land and Water Australia) there is no direct requirement for industry to contribute. Importantly, producers in some RRDCs contribute beyond the level which attracts matching support. Collectively, these differences mean that the level of public support varies considerably across rural industries (see table 9.4).

However, the actual subsidy to rural research is considerably higher when combined with the explicit and implicit support provided by those groups that actually perform the R&D for the RRDCs. These include the research arms of State Departments of Agriculture, the CSIRO, universities, CRCs (with 16 operating in the agricultural sector in 2005-06), industry owned research institutions (including those formed from the statutory RRDCs), ABARE and a range of other groups including industry associations.

Evidence presented by the Department of Agriculture, Fisheries and Forestry shows that including some of these additional funding sources increases the potential subsidy rate significantly depending on how the benefits are distributed. It said:

> Total investment in agricultural R&D in 2002–03 was approximately $1.2 billion, having increased by approximately 20 per cent in real terms since 1996–97. States and territories provide the greatest proportion of funds (43 per cent in 2002–03) but this has proportionally declined since 1996–97 (53 per cent). Commonwealth contributions (including higher education) have remained relatively constant (approximately 40 per cent) and business investment has increased in this period (from 8 per cent to 17 per cent). (sub. 100, p. 3)

Research planning in both statutory and industry owned RRDCs involves the preparation of five-year strategic R&D plans in consultation with user groups and annual operational plans designed to focus research activity on endorsed objectives. The RRDCs are responsible for funding and monitoring research and facilitating the dissemination, adoption and commercialisation of research results (sub. 96, p. 3). In addition, the RRDCs collaborate with each other in order to facilitate coordination and adoption of research. Priority setting, monitoring and evaluation processes share similarities with recent approaches used by the CSIRO and generally involve:

- determining broad R&D priorities;
- program planning;
- ex-ante project evaluation and planning;
- project investment;
- performance monitoring and management; and
- ex-post project evaluation.

A more detailed description of these processes is presented in box 9.4.

Table 9.4 **Industry and Australian Government contributions to total RRDC expenditures in 2004-05**

RRDC	*Industry contribution*	*Australian Government contribution*	*R&D [a] expenditure*	*Government contribution per $100 of industry spending*
	$ million	$ million	$ million	Dollars
Statutory RRDCs				
Cotton	4.58	4.32	12.62	94.3
Fisheries	11.20	16.90	29.06	150.1
Forest and Wood Products	3.77	2.97	8.20	78.8
Grains	64.19	35.74	119.53	55.7
Grape and Wine	9.68	8.10	16.89	83.7
Land and Water Australia	-	12.50	26.27	- [b]
Rural Industries	2.68	14.65	21.09	- [b]
Sugar	5.13	4.56	8.66	88.9
Industry owned corporations				
Australian Egg Corporation	0.75	0.76	1.71	101.3
Australian Pork Limited	3.80	4.22	7.67	111.1
Australian Wool Innovation	42.84	13.51	78.49	17.2
Dairy Australia	14.53	14.53	36.11	31.5
Horticulture Australia Limited	31.63	32.91	66.92	104.0
Meat and Livestock Australia	39.04	39.04	78.08	100.0
Total	233.82	204.71	511.30	76.8 [c]

[a] Includes other sources of income such as royalties, interest, voluntary contributions and co-investments with public sector agencies and other RRDCs. In addition, contributions in one year may not be expended in the same year. [b] These are predominantly public good RRDCs. [c] Excludes the predominantly public good RRDCs.

Source: Data drawn from Sub. 96 and Commission estimates.

Key design issues – targeting, consistency

Collective industry research models can provide an effective means of internalising the externalities associated with R&D without the need for public support when those externalities are specific to a particular group. In situations where there is a small number of producers this can (and does) occur on a voluntary basis. But in industries with many firms which are also geographically dispersed, compulsory levies are often necessary to avoid the problem of ‘free riders’.

Australia’s rural research corporations are one model of industry-based collectives. In this case, producers vote on whether there should be a levy (and, if so, its size), have a say in governance arrangements for the corporations and in establishing research priorities. Funding issues aside, this serves to align the interests of the producers with both the level and type of research undertaken.

Alternative models to fund R&D also exist. In Australia, for example, a number of manufacturing research associations perform similar functions to those of their rural counterparts — albeit without public support. In the mining sector, privately funded collaborative research bodies (such as AMIRA), providing services to firms located in a number of different countries, have also been established. Such arrangements are also common in other countries. The United States has a system of agricultural research funding based (solely) on industry levies as well as research associations in the electricity and gas industries. In the United Kingdom, there are several research associations (originally established with public support) which function on a self-financed basis.

Given these alternatives, a major issue in considering the design of Australia's rural research arrangements is to determine the right balance between industry levies and public subsidies. As the Industry Commission noted in its earlier report on R&D (IC 1995), levies act to beneficially influence the behaviour of producers and consumers by:

- encouraging producers to focus on how their own contributions are used to finance research projects;
- reducing incentives for wasteful lobbying to attract public funding; and
- providing incentives for consumers to make more efficient choices (as the total cost of research is incorporated into the cost of products).

But once an industry has formed a binding arrangement among members to contribute to jointly beneficial R&D, the risks associated with underinvestment are significantly reduced. The usual rationale for government funding would now rest on whether there were spillovers outside the industry.

In the case of RRDCs undertaking significant public good research, such as the environmental research sponsored by Land and Water Australia, strong grounds for large public subsidies remain. However, for industry-centred RRDCs this is less certain. Currently, the actual funding formula provides contribution rates per dollar of industry R&D that are between three and ten times that for eligible R&D in the manufacturing, mining and services sectors (see table 9.1). This would imply either:

- much greater prospects for additionality; or
- significantly higher spillover rates than other industries.

The first seems unlikely to the extent that joint R&D arrangements have been successfully formalised to allow the internalisation of spillovers.

Box 9.4 **RRDC priority setting, management and evaluation criteria**

According to the Council of Rural Research and Development Corporation Chairs (CRRDCC), typical features of priority setting processes across industry-specific RRDCs involves a bottom-up approach with beneficiaries, end-users and co-investors determining priorities for relevant jurisdictions, industries and enterprises. Funding proposals are assessed and ranked by advisory bodies and considered by each RRDC Board. Program planning is undertaken in consultation with governments, industry, other stakeholders and research providers to focus strategic direction and avoid duplication. Ex-ante project evaluation is judged against both attractiveness and feasibility criteria. *Attractiveness criteria include:*

- Is the application relevant to the RRDC's R&D programs?
- Is the need and planned outcomes well-defined and relevant to R&D priorities?
- Is the application a priority of the potential beneficiaries?
- Does the application demonstrate user and beneficiary support and a commitment to utilise the outputs?
- Does the application describe the scope and pathway by which the nation will capture the benefits of the research?
- Is the applicant, potential beneficiary or other entity making an appropriate financial contribution to the project?
- Will the planned outcomes, if achieved, provide a high benefit-cost ratio of a sound return on investment for money?
- Is there an appropriate level of collaboration between researchers and between researchers, industry managers and industry interests?
- Is the application innovative? Does it add value to previous R&D?

Feasibility criteria include:

- Are the planned outputs well described and is the strategy for extending the outputs sufficient to achieve the planned outcomes?
- Are the objectives clearly specified and consistent with planned project outputs?
- Are the methods well described and consistent with the project's stated objectives?
- Does the applicant have the capacity and commitment to produce planned outputs?
- Are the principal investigator and other researchers to be engaged on the project competent? Have they performed well in the past?
- Is there a strategy for managing data arising from the project so that it will be easily accessible to others in the future?

R&D management operates through a number of mechanisms including through:

- project management systems which integrate technical, financial and administrative data and monitor the status of projects when key project milestones are not met.
- technical evaluations by external advisers reporting on milestone achievement.
- audits of financial and risk management, compliance with agreed project conditions.
- a range of external information sources to monitor projects between reporting periods including workshops, management advisory committees, advisory bodies and other parties involved in research. This may prompt intervention when projects are not meeting their reporting schedule or other agreed performance indicators.

Source: Sub. 96.

The second is then the pivotal issue. It is clear that there are still mechanisms for spillovers from industry-centred RRDCs. For example, a new grain that reduces pesticide use not only lowers costs and improves productivity, but also reduces pesticide residues in water systems, with environmental benefits. However, the overall evidence does not point to spillover rates for R&D by industry-centred RRDCs that are clearly out of line with the rates estimated for other industries. The general consensus is that many of the (substantial) benefits from R&D by these RRDCs could be captured by their members. The Western Australian Department of Agriculture and Food, for example, noted that:

> It is possible that almost half the value of agricultural output in Australia in 2003 can be attributed to new technology generated by domestic R&D since 1953. At a real rate of interest of 4%, the compound value of the stream of benefits from domestic research from 1953 to 2003 is $878 billion (in 2004 $s). It is likely that Australian producers, processors and consumers have retained about 80 per cent of all benefits generated by this national agricultural R&D. (sub. 44, p. i)

The submission by the CRRDCC cited econometric evidence showing somewhat higher social rates of return (although that evidence was related to basic research) but also noted the results were likely to overestimate the actual return.

> Salter and Martin (2001) in their review of the economic benefits of publicly funded basic research present known estimates of the rate of return to publicly funded R&D in the area of agriculture. The estimates generally range from 30 to 50 per cent, however the author notes that these results should be used with caution as they tended to focus on relatively successful government R&D programs and generally do not take into account the investment in complementary assets needed to bring the technology to market. Consequently, the resulting return on investment may underestimate the true costs of technological development. (sub. 96, p. 14)

On the basis of average social rates of return derived in previous studies, that submission estimated that the net social benefit from the research activity of the RRDCs was around 30 per cent per annum. This is not higher than estimates more generally found for R&D (chapter 4). In that instance, the large disparities between high subsidy rates for some industry-centred RRDCs and those applying for other industries may not be justified on economic grounds.

On balance, while the Commission sees a strong case for continuing compulsory levy arrangements it considers that on the basis of available evidence, the level of social benefits associated with rural R&D does not justify the extent of public support collectively provided to the sector. However, in considering changes to these arrangements, the Commission is aware of the severe financial situation that many rural producers face over the short to medium term as a result of persistent drought conditions. In this context, a reduced government contribution in the short term would probably not be made up through increased levies, putting at risk R&D

that is important for the future sustainability of the sector. This suggests that the present arrangements should remain in place until the effects of the current severe climatic conditions have receded.

DRAFT FINDING 9.3

There are strong grounds for significant public co-funding of RRDCs that provide spillover benefits beyond industry members where that research would not proceed in the absence of support. But there is a weak rationale for the present substantial co-funding of some industry-centred RRDCs. Any changes to current support arrangements should be delayed until current economic conditions in the rural sector have improved.

Automotive Competitiveness and Investment Scheme

Key features

The Automotive Competitiveness and Investment Scheme (ACIS) was established to provide transitional assistance and encourage competition and innovation in the Australian automotive industry during the move to a lower tariff environment (AusIndustry 2006a). The first stage of the scheme operated from 1 January 2001 to 31 December 2005 and delivered a similar quantum of support to the assistance arrangements that preceded it but in a manner which was considered consistent with Australia's obligations to World Trade Organisation (WTO) subsidy agreements.

The scheme provided eligible participants with tradeable import duty credits based variously on their production, R&D and investment activities. As such, assistance took the form of forgone tariff revenue with the duty credits used to offset customs duty obligations on vehicles and components. Under the scheme, only automotive component and tooling producers and service providers were able to earn duty credits on the basis of their R&D expenditure. The earning rate was set at 45 per cent of eligible investment in R&D and was capped at 5 per cent of the participant's previous year's sales (to comply with WTO subsidy guidelines).

Importantly, the definition of eligible automotive R&D was much wider than eligible expenditure under the R&D tax concession. In particular, it included the 're-engineering and modification of existing products and processes' (Minchin 2000). These activities are explicitly excluded from access to the R&D tax concession as they are not considered to be sufficiently innovative or to involve a high level of technical risk. In practice, the bulk of automotive R&D activity claimed under the ACIS was for just these types of activity.

As the Commission noted in its recent review of automotive assistance (PC 2002a), this could include, for example, the production of variants of a vehicle based on the same platform and research into making work stations more productive. It also noted that while these activities may have applications to other industries (the spillover argument), it was also possible that firms would appropriate enough of the benefits from this type of development work to proceed without the need for public support.

Following that review, the Australian Government announced that the ACIS would be extended through to 31 December 2015. Support for R&D under the new scheme mirrors the arrangements described above with the exception that motor vehicle producers now also earn duty credits (at a rate of 45 per cent) for eligible R&D. For this group, however, a competitive merit-based scheme has been introduced with stricter requirements on eligible activity including technical risk and level of social benefits (such as environmental amenity). In combination with the funding allocation for vehicle producers (a maximum of $150 million), total R&D funding support under ACIS is estimated to double in the two years to 2006-07. By that time it will be equivalent to around 40 per cent of the funding provided to Australian industry in total under the R&D tax concession.

Key design issues — targeting, inducement, consistency

Australia's automotive manufacturing industry accounts for less than 0.5 per cent of total economy production and employment. In comparison, the level of assistance provided to automotive R&D accounts for 13 per cent of total business sector innovation support (and will rise to 20 per cent in 2006-07). However, the extent of resource misallocation (if any) resulting from this favourable treatment will depend on the level of R&D induced by the subsidy.

As mentioned above, the type of automotive 'R&D' activity which has been supported by public funding — modification of existing products, processes and production systems — is likely to have been undertaken without public support as the majority of benefits from this kind of development work are captured by either individual automotive firms or the wider automotive industry.

However, definitive conclusions regarding the extent of inducement are difficult to draw. Complications are also presented in attempting to separate the impacts of the R&D subsidy from other elements of the ACIS package (such as the significant production subsidy provided to the vehicle producers) and the more competitive business environment as tariff protection declined.

A survey conducted on behalf of the automotive industry associations in 2002 suggested that had ACIS not been implemented, R&D expenditure by component producers would be around 40 per cent lower over the period 2002 to 2005 (PC 2002a). However, these results need to be treated with caution as the magnitude of the impact is considerably greater than R&D projections provided by the component sector to the program administrator around the time the scheme was introduced.

A comparison of pre- and post-ACIS R&D expenditure (including by vehicle producers) does reveal strong growth in R&D spending. In the three years preceding the scheme's availability, annual growth in R&D averaged just 2 per cent while in the three years after its introduction annual growth averaged around 30 per cent (ABS 2005c). However, this trend was also reflected in the experience of the manufacturing sector as a whole with comparative figures of -1 per cent and 17 per cent respectively, and thus ACIS may not have been the catalyst for higher automotive R&D. Further, the transfer from taxpayers to firms had an associated economic cost equivalent to $25 million in 2004-05 (assuming a marginal excess burden of taxation of 20 per cent).

The Commission does acknowledge, however, that the support provided by R&D and other incentives need to be weighed against the economic benefits to Australia associated with the transition to a lower automotive tariff environment.

9.4 Public-private partnerships

Public-private partnerships have become increasingly popular features of innovation systems in a number of countries over the last two decades. While they have taken a variety of different forms they share the same underlying goal — to reap broader benefits from investment in public research. As such, these structures are explicitly viewed as more effective means of addressing perceived gaps in innovation systems than other policy instruments. By bringing together researchers and research users from markedly different backgrounds to pursue genuinely challenging projects these types of arrangement have the potential to deliver outcomes with high spillover benefits which would not otherwise be pursued. But cultural differences in terms of the respective aims and approaches of the different partners also means that the transaction costs of these relationships can potentially be very high.

In Australia, a suite of partnership initiatives have been implemented since the mid-1980s — some more 'successful' than others. The main programs currently operating are the ARC Linkage Grants (see chapter 11) and the Cooperative Research Centres (CRC) program. The latter stands out in terms of: the size of the financial commitment by the Australian Government (around $2.7 billion since the program's inception); the long-term and open-ended nature of that commitment; and a requirement for all core participants to commit to the collaborative venture for a substantial length of time.

Since its introduction, the CRC program has developed into an emblematic feature of Australia's innovation system. It has also been heralded internationally as a pioneering example of collaborative research arrangements — variants of which have been adopted in a number of other OECD countries. As discussed below, while the program incorporates a number of desirable program features, the Commission considers there are important areas where the program's effectiveness could be significantly improved. The most pressing issues involve the shift in focus of its stated objectives and the respective contributions of the main beneficiaries of the program.

Cooperative Research Centres (CRC) Program

Introduced in 1990, the CRC program focuses on the perceived need to improve the economic, social and environmental benefits from Australia's extensive public research effort. The program calls for (on a biennial basis) and supports applications to establish partnership arrangements that bring together researchers and research users. Research groups in the same or complementary fields from universities and public research agencies are linked with users (typically but not exclusively private firms) that can apply research outcomes through commercialisation or other forms of adoption (a relevant distinction for CRCs focused on 'public good' research).

All fields of physical and life sciences are eligible and there is considerable flexibility in the range of participants and organisational structures of the Centres. Public funding support is provided for a fixed seven year term (although existing CRCs may re-apply for funding of genuinely new research proposals) after which it is anticipated that the collaboration will become self-financing. Nine completed selection rounds have established 158 CRCs (100 new CRCs and 58 new from existing CRCs) since 1991. In 2005-06, some 72 CRCs operated across six sectors: manufacturing technology; mining and energy; agriculture; information and communications technology; environment; and medical science (see annex box 9.1). Following the 2006 selection round, 54 CRCs will have operational status.

The considerable diversity in organisational structure and research focus among CRCs disguises three distinct models of application and use of research outcomes (Howard partners 2003). The nature of these models has implications for optimal financing arrangements. The CRCs can be classified as follows:

- CRCs that operate primarily as national benefit centres (which historically have accounted for around 20 per cent of total program resources) — with a strong focus on public good research in areas including resource sustainability, maintenance of biodiversity, environmental health and national disaster research.
- CRCs involved in industrial research (60 per cent of total program resources to date) with a strong focus on collective industry outcomes concentrating on mature, commodity-based industries with research aimed at raising productivity, product quality and international competitiveness.
- CRCs that focus on commercial benefits through expanding and creating new businesses based on the transfer or sale of intellectual property and reflected in new products or services (20 per cent of total program resources to date).

Funding contributions (cash or in-kind) vary across participants with the share of benefits from each CRC (including ownership of intellectual property and income from royalties) notionally determined on the basis of respective resource commitments. The only exception is the Australian Government — it does not participate in the benefit sharing arrangement. Yet over the life of the program, two thirds of all resources have been provided (either directly or indirectly) from Commonwealth sources (see tables 9.5 and 9.6).[15]

The relatively minor contribution by research users (around 20 per cent in 2004-05) means the effective subsidy to this group can potentially be very high compared with support provided by other science and innovation programs. In addition, CRCs are not restricted from access to other innovation support measures (such as the R&D tax concession) to which they may be eligible and some participants (such as automotive firms and a number of RRDCs) also receive substantial assistance under other programs (see earlier).

Notably, the user-contribution to CRCs in Australia is also at the lower end of international experience with funding arrangements for public-private partnership programs. For example, in many countries including the United States, Norway, Sweden, Finland and France, industry users are required to contribute at least 50 per cent of total program funding (OECD 2005c).[16]

15 Interestingly, direct Commonwealth funding accounted for more than 60 per cent of total cash resources devoted to CRCs over this period. In-kind payments dominate the contributions from other CRC participants and this raises issues regarding valuation methodologies (particularly the treatment of overheads). It may also have implications for CRC governance arrangements.

16 There are also a number of examples where no industry contribution is required such as in Japan or where it is very low, for example, Belgium.

Table 9.5 **CRC program contributions — 1990-91 to 2001-02**
Per cent

Funding source	*Share of total CRC resources*	*Share of own resources in-kind*
CRC Program	25	0
Universities	22	92
CSIRO	14	98
Industry	17	59
State Government	8	82
Other Commonwealth	5	78
Other participants	7	74
Other funding	2	14
Total	100	60

Source: Howard Partners 2003.

Table 9.6 **CRC program contributions — 2004-05**
Per cent

Funding source	*Share of total CRC resources*	*Share of own resources in-kind*
CRC Program	20.2	0
Other Australian government	14.0	na
Universities	28.9	na
State Government	12.2	na
Industry and industry associations	20.7	65.1
Other [a]	4.0	na
Total	100.0	66.7

[a] Includes local government, research institute/organisations, uncategorised, other.

na not available

Source: Sub. 87.

Along with the general shift toward supporting industrial imperatives and the commercialisation stage of the innovation process (both here and abroad) the stated objectives of the CRC program have changed over time. The guidelines for the most recent CRC selection round describe the main objective as being: 'to enhance Australia's industrial, commercial and economic growth through the development of sustained, user-driven, cooperative public-private research centres that achieve high levels of outcomes in adoption and commercialisation' (Nelson 2006).

This is a significant departure from the previously stated objectives which were evenly balanced across four areas: research excellence; effective collaboration; creation of new educational opportunities for graduate researchers; and the translation of research outputs into economic, social and environmental benefits to Australia. In effect, the recent change means that proposals which focus on outcomes in social and environmental research have been disadvantaged by the policy shift. Currently, 25 of the 72 operational CRCs are involved in these two areas (see annex box 9.1 at the end of this chapter). This was confirmed by DEST:

> With the revised focus of the CRC programme the commercial and economic outcomes which can be attributed to the programme should remain high. Nevertheless some concerns have been raised that with the refocussing of the programme long term strategic collaborative proposals that will not generate economic growth are unable to attract funding. While these proposals may be in the national interest, such as reducing health care costs leading to more healthy Australians, reducing loss through the mitigation of risks or result in a healthier environment, they are unlikely to be competitive [for CRC funding]. (sub. 87, p. 70)

CRC proposals are currently selected on a competitive basis against the following four broad selection criteria (the detailed criteria are presented in box 9.5):

- outcomes will contribute substantially to Australia's industrial, commercial and economic growth;
- path to adoption (commercialisation/utilisation) will deliver identified outcomes;
- collaboration has the capability to achieve the intended results; and
- funding sought will generate a return and represents good value for the taxpayer.

Research programs to be conducted by a proposed Centre and an initial set of projects to be pursued under each research program form the basis of the formal proposal for funding support. Program development and priority setting for individual projects is a collaborative effort between the CRC participants (ie. a bottoms-up approach) with only general guidance (in the form of alignment to the National Research Priorities) dictated by the program eligibility criteria (box 9.5).

Proposals are assessed in a two-stage process (a recent modification designed to ease the compliance burden) by two external technical expert advisory panels (one for physical sciences and one for life sciences); national and international referees (who can comment on scientific value, likely value of research outcomes and the quality of collaborative arrangements), and the CRC Committee (which manages the program and decides successful applicants and whose membership is drawn from industry, research providers and Australian Government agencies involved in research or research funding).

Governance arrangements are based on a corporatist model with chief executive officers responsible for the daily management of each CRC. They report to a Board of Directors (with an independent chairman) which, in turn, is responsible for the overall direction of each Centre. Importantly, the Board of Directors must have majority representation by research users (such as private firms or RRDCs). This requirement has only recently been introduced and reflected a concern that the program 'had been too focused on research with an insufficient emphasis upon meeting industry and other end-user needs through attention to adoption and application of research results' (Howard Partners 2003, p. iii).

However, some participants questioned the impact of this change noting there may be consequences for the extent of inducement associated with the CRC program. The Invasive Animals Cooperative Research Centre, for example, said:

> Too much power in the hands of end-users can lead to short-term research that probably would have been done anyway. (sub. 57, p. 5)

In addition, until the 2006 CRC selection round, applicants were not required (although it was strongly encouraged) to establish the CRC as an incorporated entity and the majority (around 75 per cent) did not choose this pathway. All new CRCs must now be incorporated. This change was expected to reduce internal negotiation and transaction costs and provide greater certainty regarding the legal status of the entity compared to the individual participants.

Once established, progress against contractual obligations to the Commonwealth is mainly monitored through detailed annual reporting requirements which contain a range of information relating to each CRC's progress toward meeting its objectives (DEST 2006e). The qualitative information contained in the annual report is also complemented by financial and other quantitative data required in a Management Data Questionnaire (MDQ). According to DEST:

> The information provided in the Annual Report and data provided in the MDQ will be analysed and used to monitor the performance of individual CRCs over the funding period. … Where there are issues of concern, the [CRC] Committee may direct that a review or audit be undertaken of the relevant CRC. DEST may also independently initiate a review or audit of the relevant CRC. (DEST 2006e)

In addition, the Commission understands that a performance review of CRC research activity is conducted after three years (originally two) of operation by a panel of mainly international experts in the particular field of research conducted by each CRC.

As discussed below, the Commission considers that despite these requirements, the incentives facing both the program administrator and CRC participants may be such that individual research projects with limited scope to produce worthwhile benefits are allowed to continue beyond the point justified by a prudent approach to project risk management. It proposes a possible mechanism which could provide improved incentives for participants to cease project funding in those instances.

Box 9.5 CRC selection criteria for 2006 round — full business case

Selection criteria 1 — Outcomes

- Scale (quantity and value) of the outcomes' contribution to Australia's industrial, commercial and economic growth including, but not limited to:
  – additional economic activity either nationally or for a region(s) within Australia
  – improved competitiveness or productivity of business, eg. through improvements in product and service quality, cost savings, reductions in inputs or increased outputs
  – new and improved goods and services and technologies
  – creation of new jobs
  – increased exports or development of import replacements
  – creating new or assisting emerging industries
  – improved capability (including education and skills development) in firms/industry sectors to identify, adopt and adapt technologies.
- Robustness of the estimation of the scale of the outcomes.
- Extent of the contribution of outcomes to relevant NRP Goals. Applications which can demonstrate a substantial contribution will be ranked more highly than those that demonstrate little or no contribution.

Selection criteria 2 — Path to adoption

- Robustness of the assessment of market or other end-use opportunities.
- Quality of planning and resourcing (including use of external expertise) for commercialisation and/or utilisation (including technology transfer) strategies and communication activities.
- Adequacy of the intellectual property management arrangements.
- Strength of commitments by end-users (including through international collaborations).
- Strategies to engage additional end-users during the life of the CRC.
- Strategies to reinvest some of the returns from commercialisation of IP in CRC's activities.
- Approach for engaging small to medium sized enterprises (SME) end-users in the CRC.

Selection criteria 3 — Collaboration

Research

- Innovativeness and achievability of the research.
- Coherence of research programme including balance between the longer- and shorter-term projects.
- Strength and integration of international linkages.
- Time commitment and quality of the key individual researchers.

Adoption

- Quality of staff and industry participants involved in the commercialisation/utilisation of CRC outputs.

Governance

- Effectiveness of the collaborative arrangements and the structure and effectiveness of management and governance arrangements. Applicants are expected to become incorporated entities unless a compelling case can be made for alternative structures.

Education and Training (Skills development)

- Extent and quality of end-user focus in education and training, including industry PhD supervision.

Benefits of Collaboration

- Strategies to maintain the benefits of a CRC collaboration and for the closure or continuation of the CRC after Commonwealth funding has ended.

For 'new from existing' applicants track record including assessment of the economic impact of outcomes; key commercialisation or utilisation outcomes; key achievements of research and education programs; effectiveness of the collaboration (including in maintaining or enhancing participant involvement and contributions); and effectiveness of governance and management arrangements.

Selection criteria 4 — Return

- Return on the investment through increases in Australia's industrial, commercial and economic growth, including the value of the proposed outcomes relative to the costs.
- Appropriateness of the budget and the resource allocations.
- Any strategies for obtaining additional contributions over the funding period.

Source: Nelson (2006).

Key design issues — targeting

The recently announced shift in focus of the CRC program to industrial, commercial and economic objectives assumes that the community benefits associated with research activity in this area (which depends on the extent of inducement and the level of spillovers) are considerably higher than that in social and environmental research. However, as discussed in chapter 4, there are compelling reasons for public support in these latter areas including: the significant impacts from social and environmental research activity (including economic); its role as an input to public policy; and increasing Australia's preparedness to deal with a wide range of environmental and social concerns.

In addition, as previously stated in this chapter, the emphasis on supporting the commercialisation stage of industrial research as opposed to the earlier R&D stage is much less defensible from an economic efficiency perspective. Such a focus can also adversely bias the behaviour of selection committees toward collaborations that pursue less risky project outcomes involving lower levels of spillover benefits — precisely the type of research that a firm or industry collective would undertake anyway. And it can also interfere with the wider adoption or utilisation of research results, especially important in areas where the research is generic to a large number of potential beneficiaries (such as in agriculture). In this context, the submission by the Department of Agriculture Fisheries and Forestry noted:

> The current emphasis on commercialisation as a key mode of innovation delivery can also reduce the freedom to operate of R&D providers through their need to seek formal IP rights such as patents, copyright and plant breeders' rights. This can ultimately reduce the rate of adoption of IP-dependent R&D products. (sub. 100, p. 20)

Accordingly, the Commission considers that the original objectives of the CRC program provide a much more appropriate focus for public support. Those objectives did not discriminate between CRC research programs in economic, social or environmental fields and emphasised the broad translation of research results rather than those with a greater chance of being captured by the innovator.

At a more detailed level, a number of the CRC selection criteria outlined in box 9.5 — including the creation of new jobs, increased exports, expansion of import replacement activities or assisting emerging industries — are not valid objectives for government policy aimed at influencing science and innovation activity. The most appropriate policy action involves promoting competition and maintaining a stable and conducive macroeconomic policy environment (see the Commission's report on National Competition Policy).

Inducement

Given that the CRC structure aims to overcome the challenges with collaborative ventures involving research partners from diverse professional cultures; the significant associated administrative and compliance costs confronting prospective participants; and the level of public support, it would be surprising if the CRC program did not induce considerable additional research activity (including through the enhancement of existing projects). The most recent evaluation of the program surveyed both researchers and user groups to gauge the extent of additionality and found evidence in support of this expectation. From the research user perspective, around 50 per cent of respondents noted a high or very high program impact on stimulating new research projects and accelerating or improving existing research projects (see table 9.7).

These results were reinforced by the researcher cohort with around 75 per cent of CRC managers (primarily university partners) indicating a high or very high program impact in these areas (Howard Partners 2003). In addition, 80 per cent of this group also indicated a very high impact on the introduction of new or improved products and processes, although for research users only around half of this proportion agreed with that assessment.

Additionality issues were also canvassed in two recent evaluations of the economic impact of the CRC program. The key finding of the first study, by Allen Consulting (2005), was that the delivered (as opposed to prospective) benefits from the program cumulatively increased economywide output by 60 cents for every dollar of direct public funding. The study noted that the benefits put forward by the CRCs to be included in the modelling must have been unlikely to have occurred in the absence of the CRC ‘in the timeframe under consideration’. More recently, Insight Economics (2006) estimated an economic impact almost twice as great as the earlier study with a cumulative increase in economywide output of $1.16 for every dollar invested in the CRC program. The main reason for the much higher magnitude of benefits compared to the earlier study was due to the identification and quantification of a number of additional delivered benefits. Both evaluations are discussed in greater detail in appendix I.

Table 9.7 **CRC participant views on research outcomes**

Per cent of respondents

	Research users		*Research managers*	
Outcome	*High or very high impact*	*Moderate to low impact*	*High or very high impact*	*Moderate to low impact*
Accelerating or improving existing research projects	48	36	74	20
Stimulating new research projects	48	44	78	18
Contributing to the development of IP	24	60	62	32
Introduction of new/improved products, processes	44	36	80	12
Improving business/industry profitability	28	52	54	36
Improving public programme or policy performance	Na	na	40	36

Source: Howard Partners 2003.

However, the implications of these empirical findings needs to be viewed in light of recent amendments to the program. As noted above, the lower level of satisfaction with outcomes by research users has led to specific changes in CRC governance arrangements including the requirement for majority user-group representation on CRC Boards (to be implemented through the 2006 CRC selection round) and a complete shift in focus to commercial objectives. For reasons outlined earlier, these changes increase the risk of providing support to projects with low potential spillovers and those that would be undertaken in the absence of public subsidies.

In a different context, recent OECD evaluations of partnership programs have noted that additionality has an important behavioural dimension. This refers to the desire to create long-lasting linkages between researchers and research users to ensure persistent beneficial effects (OECD 2005c). The CRC selection criteria specifically reflect this aspiration in calling for strategies to maintain the benefits of the CRC once Commonwealth funding has ceased. This was expected to result from either the generation of sufficient revenue from licensing or other commercial activities (contracting) as a substitute for program funding, formation of 'start-up' companies based on the intellectual property generated by the CRC or an injection of resources from commercial partners to allow a continuation of the cooperative venture.

In practice, however, there is very little evidence supporting the attainment of this objective. Over the life of the program, revenue streams generated via licensing and royalty arrangements have been quite modest, examples of company 'spin-offs' are rare and examples of CRCs continuing operation successfully beyond the funding period are even rarer. In fact, most CRCs have sought repeat funding support for at least a second seven year duration (to pursue new research proposals) with some about to enter a third phase.

Funding arrangements

The actual subsidy provided by the CRC program to firms and other research users (such as the RRDCs) depends on the share of benefits appropriated by those groups. With the exception of the public good CRCs, these benefits have typically been assessed in terms of the value of intellectual property rights (the share of which is based on the respective resource commitment of each partner) and the establishment of ‘spin-off’ companies created by the CRC venture. As noted above, revenue from these sources has been very modest over the life of the program.

But there are other avenues for delivering program benefits. Indeed, as noted by the recent review of the impact of the CRC program:

> Most benefits from the CRC Programme have come from industry application of research rather than through narrowly defined ‘commercialisation’ events such as spin-off company formation and licensing of IP. (Allen Consulting 2005, p. 40)

The CRC Association was more specific in its submission to this study noting that:

> Measured benefits from the Programme have primarily been delivered through the application of research by industry to reduce costs and increase productivity and through the sale of new products (by existing or new companies) that are based on CRC research. (sub. 11, p. 15)

The University of New England (sub. 17, pp. 12–14) presented quantitative evidence on the beneficiaries of CRC research. It noted that based on modelling results, 75 per cent of the expected benefits from the Australian Sheep Industry CRC which commenced in 2002 would accrue to Australian sheep producers because they could directly access the new technologies. Similarly, of the expected benefits from an investment in the Invasive Plants CRC (which is currently in the advanced stage for CRC program funding consideration), around 60 per cent would accrue to the beef and grains industries.

This evidence lends support to the Commission’s view that many of the benefits are in fact captured by firm and industry partners and that, accordingly, the subsidy rate to user-groups is much higher than that provided under most other innovation programs. It raises the question of what an optimal cost-sharing ratio should be and whether financing arrangements could be used to improve the selection of genuinely new projects. In principle, the achievement of an optimal cost-sharing ratio should help to:

- ensure selection of the most suitable user-group partners (given they know more about the expected return and risk profile of individual projects);
- secure the desired amount and quality of R&D at least cost to the taxpayer; and
- avoid opportunistic behaviour by university, public sector or user-group partners (such as the risk of choosing inappropriate projects or a bias in research focus).

In practice, determining optimal cost sharing ratios face a number of number of informational dilemmas. That said, as a general rule they should aim to provide differential funding support dependent on the nature of the research undertaken and the extent of expected social benefits from that research. This is not the basis of current CRC funding arrangements (see table 9.8). Those research areas which, prima facie, would appear to involve relatively higher levels of social benefits (such as environmental and medical research) have in the past received lower proportional public support than areas where the benefits of research are likely to accrue to individual firms or industries (such as in the rural and manufacturing sectors).[17]

As a general rule, alongside a return to the original objectives of the program across economic, social and environmental research, a better match between funding levels and the specific mission of different CRCs would involve:

- a higher share of public funding in areas where the social benefits are likely to be the greatest — the national benefit CRCs;
- a lower level of support in the industrial research CRCs which focus on pre-competitive research (innovation in industrial processes and business practices). The concentrated nature of benefits from this activity suggests that levy systems would be more effective means of dealing with the potential for under-provision of research effort (see the earlier discussion on RRDCs); and
- an even lower level of funding for Centres aimed primarily at commercialising research outcomes such as the business development CRCs.

There may also be a case (particularly for the business development CRCs) for introducing repayment mechanisms for successful projects in the form of a share in the royalty stream of successful projects (to target genuinely new projects). Given the distinct legal status of the CRCs (especially under the new incorporation requirement) and the finite number of research projects likely to be commercially viable, the royalty stream alternative would appear less problematic in its application compared to entities with multiple revenue streams (an issue raised in the earlier discussion on avenues to improve business programs).

17 Note that significant public support for environmental and medical research is provided through other means such as the CSIRO and grant funding by the ARC and NHMRC.

Table 9.8 **Australian Government contribution to CRCs by sector**

CRC sector	*Total program funding*	*Share of total CRC resources*	*Round 9 funding*	*Share of total CRC resources*
	$ million	Per cent	$million	Per cent
Manufacturing	398.7	27.4	103.9	35.0
Information and communication technology	285.5	21.6	0.0	-
Mining and energy	358.9	22.2	20.0	26.0
Agriculture and rural based manufacturing	615.3	28.3	129.4	26.0
Environment	620.7	23.4	99.9	30.0
Medical science and technology	379.7	21.1	47.9	36.0
Total	2648.8	24.0	401.1	30.0

Source: Sub. 11.

Performance management

Despite the requirements on CRC participants to report against the achievement of research milestones on an annual basis, there is a risk that ‘marginal’ projects may continue even when beneficial outcomes are unlikely because of inappropriate program incentives.[18] This is especially significant given the duration of the funding agreements and because CRC participants have more information regarding likely research outcomes than the program administrator and an understandable interest in maintaining funding continuity. In addition, although the program administrator has the power to intervene in a CRC’s activities, it may be reluctant to do so because it will highlight a failure in the approval processes used to select successful participants.[19]

Given the substantial amounts of funding involved, it may be worth trialling an approach to improve the flexibility of CRCs to manage their project portfolio through offering incentives to CRC partners to terminate projects (or the CRC) early if they consider research objectives are unlikely to be met. This could take the form of payment of part or all the contribution by the Australian Government to the CRC as either compensation for resources devoted by the participants to a project (or CRC) that is terminated early or to conduct collaborative research in another area (with appropriate safeguards to avoid abuse).

18 While program participants can request variations in their contractual obligations, the Commission understands this has primarily been used to deal with the exit and entry of CRC partners once they have been established.

19 The Commission understands that previous interventions have been relatively rare and that they do not appear to have been on the basis of failure to meet research objectives.

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The CRC program could be improved in several ways:

- *the original objectives of the program — the translation of research outputs into economic, social and environmental benefits — should be reinstated. This is likely to produce better outcomes than focusing public support on the commercialisation of industrial research alone; and*
- *the share of public funding should be aligned to the level of social benefits provided by each CRC, thereby reducing some of the large rates of subsidy to business collaborators.*

More flexible arrangements

While not reflected in many written submissions to this study, several concerns were raised about the CRC program during discussions with participants (despite or in some cases because of the recent governance changes). In particular, some within the university sector were concerned about the shift in research focus toward commercial objectives and the methodology used by the program administrator to value the overhead component of in-kind contributions. Equally, some business groups commented they were losing confidence in the ability of the program to deliver outcomes of value to them. AusBiotech, for example, said:

> The large number of academic contributors and sometimes complex governance arrangements in CRCs means that the pace of activity is slower than industry would like. (sub. 95, p. 30)

Criticisms about excessive and burdensome compliance and administration costs were widespread.[20] Graeme Pearman (a former CSIRO division head and member of the executive with experience in CRC operations) commented in this regard:

> My rough estimate is that these inefficiencies (proposal planning, start-up costs and termination costs), probably account for effective cost of at least one year's of resources (approximately 14% of the investment over a seven year life of a CRC) (sub. 86, p. 18)

20 The survey conducted as part of the recent CRC program evaluation revealed that the share of resources devoted to administration by all CRCs averaged around 8.5 per cent of total program funds between 1998-99 and 2001-02. Combined with the compliance costs associated with the detailed and lengthy CRC application process (which can take up to 12 months to complete), reporting requirements and the program administration costs borne by the program administrator, the level of resources consumed in these areas appears to be very high in comparison with other competitive funding programs such as ARC and NMHRC grant funding.

That submission also detailed a range of other problems with the CRC model and asked whether a better approach deserved consideration:

> Significant unhappiness exists over the limitations of this CRC approach, yet in a climate of budgetary constraints, the benefactors are reluctant to too openly discuss the real shortcomings. These include vagueness about the balance between knowledge generation and knowledge application, the neglect of public-good activities and the incredibly inefficient way of expending money through relatively small institutional arrangements with enormous overheads. This is compounded by the lack of continuity that does not reflect the real timescales of knowledge generation or application research, the real costs associated with CRCs driven by costly start-up and close-down, a ridiculous level of internal review and governance and related demands of overheads on research staff. Serious questions should be asked about whether some of these targeted areas of research and application could not have been better approached through investment in existing research organisations (albeit with contractual expectations regarding corporation) or through an alternative model of funding. (sub. 86, p. 7)

Against that background, the Commission believes there is considerable scope to improve the effectiveness of the CRC model by introducing more flexibility into the types of arrangement that are supported by the program. Currently, the system is geared toward large-scale, longer-term research programs, which are more suited to big research users, with relatively cumbersome avenues for CRC partners to enter and exit the venture and a heavy compliance burden. The substantial financial and in-kind commitments required of CRC participants also effectively excludes a range of potential beneficiaries from participation and this may well act to reduce the potential for inducement from the program.

In a general sense, giving consideration to complementing the CRC program by also supporting smaller-scale, shorter-term collaborative research proposals would also fill a gap that currently exists in Australia's innovation space. But the benefits to be had from such a move could be counterbalanced by the high fixed costs associated with the existing application, approval and governance processes. The Commission recognises that there is a range of challenges involved in the design of a less costly and more flexible program — not least of which is the need to guard against the inappropriate use of taxpayer's funds.

In that context, there is a number of different approaches available to introducing a more flexible collaborative mechanism, each of which will involve particular trade-offs between the desirable design criteria outlined at the beginning of this chapter (see below). Regardless of the approach chosen, in order to maximise the level of inducement from a new complementary program the eligibility criteria would appropriately restrict access to multi-firm collaborative proposals either undertaking research within the group of firms or in conjunction with universities and public sector research agencies. Another advantage of restricting access on this basis is that spillover benefits are likely to be higher because the research will be aimed at applications that are generic to multiple potential beneficiaries. The promotion of these aims could also be enhanced by progressively linking the level of public support to the number of firms involved in the collaboration.

Of course, the program would not compel universities and public sector research agencies to participate in specific collaborations but opting to do so would provide them access to a supplementary source of income in much the same way that current contracting and consulting arrangements operate.

There is a variety of different mechanisms available to deliver more flexible collaborative support, some of which could be likened to voucher-style entitlements. The potential mechanisms include:

- an entitlement-based program such as a tax concession (or credit) where all proposals which meet the eligibility criteria receive support but with ex post safeguards in place to guard against abuse (in the same way that the ATO polices the present tax concession scheme). This approach has the advantages of funding continuity and allowing decentralised decision-making on the type of research to be undertaken but its open-ended nature will increase the potential revenue cost of the program.
- a grant program for collaborative research proposals where support is made available at regular intervals throughout the year and allocated on a 'first-come-first-served' basis (subject to eligibility). This would also allow for decentralised decision-making, places a cap on the cost to revenue and allows for considerable flexibility in the timing of research.
- applications are invited and assessed on an individual basis to determine whether they have sufficient merit to receive a grant. Proposals could either be disallowed at this initial stage if they did not meet the merit or other eligibility criteria or at a later date (with a requirement to repay the grant) if applicants failed to meet their obligations. This would involve lower administrative costs than the current CRC process but also increases the potential revenue cost.
- a competitive program is introduced with proposals ranked against each other and grants awarded to the best proposals. This is similar to the current CRC assessment process and, accordingly, would raise similar concerns in relation to administrative and compliance costs.

In considering the merits of a complementary program and the choice of delivery mechanism, the Commission is mindful of potential application problems and the scope for abuse. Accordingly, it has not come to definite view on whether a more flexible arrangement of this kind should be introduced. Importantly, it would be very prudent to conduct a pilot program and independently evaluate the outcomes of that pilot before broader introduction was contemplated.

The development of other forms of intermediation between business and research organisations is raised in chapter 6.

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A complement to the CRC program with broader collaboration goals could be developed which supports smaller, shorter and more flexible collaborative arrangements between groups of firms either independently or in conjunction with universities and public sector research agencies.

Annex box 9.1 **Current CRCs (based on 2004 selection round)**

Manufacturing Technology
- CRC for Advanced Composite Structures
- CRC for Bioproducts
- CRC for CAST Metals Manufacturing (CAST)
- CRC for Construction Innovation
- CRC for Functional Communication Surfaces
- CRC for Wood Innovations
- CRC for Intelligent Manufacturing Systems and Technologies
- CRC for MicroTechnology
- CRC for Polymers
- CRC for Railway Engineering and Technologies
- CRC for Welded Structures

Information and Communication Technology
- Australian Photonics CRC
- Australian Telecommunications CRC
- CRC for Enterprise Distributed Systems Technology
- CRC for Satellite Systems
- CRC for Sensor Signal and Information Processing
- CRC for Smart Internet Technology
- CRC for Spatial Information
- CRC for Technology Enabled Capital Markets
- Australasian CRC for Interaction Design
- CRC for Integrated Engineering Asset Management

Mining and Energy
- Parker CRC for Integrated Hydrometallurgy Solutions
- CRC for Clean Power from Lignite
- CRC for Coal in Sustainable Development
- CRC for Landscape Environments and Mineral Exploration
- Predictive Mineral Discovery CRC
- CRC for Sustainable Resource Processing
- CRC for Greenhouse Gas Technologies
- CRC for Mining

Medical Science and Technology
- CRC for Aboriginal Health
- CRC for Asthma
- CRC for Chronic Inflammatory Diseases
- CRC for Cochlear Implant and Hearing Aid Innovation
- CRC for Diagnostics
- The Vision CRC
- CRC for Vaccine Technology
- CRC for Oral Health Science

Agriculture and Rural Based Manufacturing
- Cotton Catchment Communities CRC
- Australian Sheep Industry CRC
- CRC for Beef Genetic Technologies
- CRC for Innovative Dairy Products
- Molecular Plant Breeding CRC
- Aquafin CRC
- CRC for Forestry
- CRC for Sustainable Rice Production
- CRC for Tropical Plant Protection
- CRC for Value Added Wheat
- CRC for Viticulture
- Australian Biosecurity CRC for Emerging Infectious Disease
- Australian Poultry CRC
- Grain Foods CRC
- CRC for Sugar Industry Innovation through Biotechnology
- CRC for an Internationally Competitive Pork Industry

Environment
- CRC for Australian Weed Management
- Invasive Animals CRC
- CRC for Catchment Hydrology
- CRC for Coastal Zone, Estuary and Waterway Management
- CRC for Water Quality and Treatment
- CRC for The Great Barrier Reef World Heritage Area
- CRC for Greenhouse Accounting
- CRC for Plant-based Management of Dryland Salinity
- Sustainable Tourism CRC
- CRC for Tropical Rainforest Ecology and Management
- CRC for Tropical Savannas Management
- Environmental Biotechnology CRC
- eWater CRC
- Desert Knowledge CRC
- Bushfire CRC
- CRC for Irrigation Futures
- CRC for The Antarctic Climate & Ecosystems
- CRC for Landscape Environments and Mineral Exploration

Source: DEST website.

10 Public sector research agencies

Key points

- The objective of public sector research agencies is to perform socially beneficial strategic and applied scientific research that would not, or could not, be conducted by other research providers and, where appropriate, widely diffuse the results from that research.
- Australia devotes a relatively high proportion of its total science and innovation budget to public sector research agencies compared with other countries. It also has a multiplicity of such agencies, although CSIRO and the DSTO dominate the funding allocated to these bodies.
- Recent changes to CSIRO's research investment processes have improved its research focus and provide a framework for ensuring that the organisation does not perform research that the private sector would otherwise undertake. Given the scale of CSIRO activity and the dominance of small and medium sized firms in Australia's industrial structure, it is also unlikely that CSIRO crowds-out private sector research effort.
- Block appropriation funding for CSIRO needs to be sufficient to enable the organisation to make appropriate strategic investment decisions and to maintain its research capability in a range of areas. The share of CSIRO's revenue from that source has declined considerably over the last few years. The real level of block funding should not be reduced.
- Aspects of CSIRO's approach to priority setting and performance management may have wider applicability to other parts of Australia's innovation system (for example, other Federal and State public sector research agencies and the CRC program). The aim of adopting such an approach would be to reduce the risk of unnecessary duplication of research effort and increase accountability across that system.
- The effectiveness of research conducted by the DSTO depends critically on the procurement practices and research directions set by its principal customer, the Australian Defence Organisation. An option to facilitate greater contestability might be to review the potential for providing a component of research funding directly to the users of DSTO research allowing them, if they wish, to allocate funds to external providers.

10.1 Introduction

Public sector research agencies (PSRAs) are a central feature of national innovation systems in many countries. Public funding of these bodies is based on the objective of ensuring that research that has direct significance to national issues is undertaken. This particularly relates to strategic and applied scientific research that would not, or could not, be conducted by other providers (for example, due to the inability to design suitable incentive mechanisms for effective private sector provision). Other rationales for direct sponsorship of research in public sector institutions include the ability to diffuse widely and cost-effectively research results or, in some cases, to constrain dissemination of results in areas where research tasks are focused on sensitive issues — such as in defence and national security.

There is no clear-cut delineation, however, between the respective research roles of public research agencies, private firms, higher education or hybrid arrangements involving public-private partnerships. The most appropriate institutional setting for the conduct of research may also change over time (for example, as research capability develops in different parts of the innovation system). That said, there is a set of core issues to be considered in determining the appropriateness of conducting research in publicly funded agencies. These include:

- the potential to perform research that firms have sufficient incentive to undertake;
- the ability to identify research projects with a high net social return (which places a critical importance on effective priority setting processes);
- the scope and desirability of broader or restricted diffusion of research results; and
- the desirability of public sector provision compared with contracting-out (which has implications for the nature of funding arrangements including the balance between block and competitive funding).

Compared with most other countries, Australia devotes a relatively high proportion of its total science and innovation budget to PSRA research, with these agencies accounting for around 25 per cent of total public support in 2004-05. The two main organisations — the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Defence Science and Technology Organisation (DSTO) accounted for 70 per cent of total public sector research agency funding (see table 10.1).

Table 10.1 **Australian Government funding for Public Sector Research Agencies (PSRA)[a], 2005–06 (estimated actual)**

Agency	*Appropriation funding*	*Share of total PSRA funding*
	$ million	Per cent
Commonwealth Scientific and Industrial Research Organisation	593.9	44.2
Defence Science and Technology Organisation	349.1	26.0
Australian Nuclear Science and Technology Organisation	138.1	10.3
Geoscience Australia	107.4	8.0
Antarctic Division	94.6	7.0
Australian Institute of Marine Science	23.1	1.7
Bureau of Meteorology Research Centre	11.7	0.9
Environmental Research Institute of the Supervising Scientist	7.5	0.6
Australian Animal Health Laboratory	6.9	0.5
Great Barrier Reef Marine Park Authority	6.1	0.5
Anglo-Australian Telescope	4.6	0.3
Total	1 343.0	100.0

Note: [a] Not all funding is dedicated to research activities and can include significant allocations for capital and other expenditure items. For example, only around one third of the Australian Nuclear Science and Technology Organisation’s budget allocation is for research functions.

Source: Australian Government 2006d.

Importantly, portfolio responsibility for public sector research providers is spread across a large number of different federal and state/territory departments. This raises issues regarding effective coordination and the scope for duplication of research effort (see below). In this regard, the submission by the Department of Agriculture, Fisheries and Forestry (DAFF) mentioned that a major impediment to better coordinating R&D effort across research providers was the differences in their respective operating systems:

> The cost and management effort of implementing collaborative approaches can be a significant impediment to better coordinating R&D. R&D providers operate under widely diverse conditions and in very different sectors and the reporting, evaluation and project management systems they have developed for their own purposes and to provide accountability to their stakeholders can impede efforts to develop more common systems and approaches. (sub. 100, p. 27)

Commonwealth Scientific and Industrial Research Organisation

As an introductory comment, the Commission is mindful that CSIRO has been the subject of a multiplicity of reviews throughout its recent history. Current priority setting, performance management and evaluation processes reflect its reaction to those investigations, to government policy responses and to other changes to the external environment. The revised processes (and the organisation's current view of its role) have been in place for a relatively short period of time and will require a 'settling-in' period before firm conclusions can be drawn regarding their impact. The scale of the change to the way CSIRO operates was recognised by some participants to this study with the Business, Industry and Higher Education Collaborative Council, for example, saying:

> CSIRO has undergone a massive change program over the last four years which is only now delivering results. CSIRO initiatives such as the new Science Investment Process, which is specifically designed to avoid a mismatch between the research environment and market, and the Flagship program, which is aimed at supporting engagement and collaboration, have resulted in major cultural change and an organisation with greater collaborative capacity. The impact of these changes have not yet been fully realised, and sufficient time needs to be allowed to fully establish their impact on developing and supporting ongoing partnerships with other research focused institutions, and enhancing knowledge transfer and innovation. (sub. 55, p. 20)

But there has also been considerable recent criticism of the organisation's research investment decisions in other forums. However, there was very little coverage of these issues or of alternative decision-making approaches either in discussions or submissions.

Key Features

CSIRO is Australia's peak scientific research agency. It operates as an independent statutory authority and performs a broad range of functions in accordance with the *Science and Industry Research Act 1949* (amended in 1998). Its primary tasks include conducting research to: assist Australian industry; further the interests of the Australian community; and encourage or facilitate the application or utilisation of scientific research results. It also performs a number of subsidiary roles such as the training of research workers and the interpretation and dissemination of scientific and technical information.

In contrast to the curiosity-driven nature of university research, CSIRO's role is mission-based. In line with its mandate, the bulk of its research activity is at the applied and strategic end of the research spectrum. It devotes very few resources to experimental development (the domain of the business sector) or to pure basic research — a major focus of activity in higher education institutions — (see table 10.2).[1]

1 In 2004-05, CSIRO devoted around 47 per cent of its research expenditure to applied research, 38 per cent to strategic basic research, 9.5 per cent to experimental development and 5.5 per cent to pure basic research (CSIRO sub. 50, p. 38).

Table 10.2 **CSIRO's expenditure and revenue, 2005–06**[a]

Expenditure	*$ million*	*Share of total*
Core roles		
Advancing frontiers of science[b]	91	9.2
Creating new or significantly transforming industries	147	14.9
Solving major national challenges	129	13.0
Delivering incremental innovation for existing industries	157	16.0
Science-based solutions for the community	60	6.1
Satellite roles[c]	128	13.0
Other		
Research support services	242	24.5
Enterprise strategy and governance	33	3.3
Total expenditure	985	100.0
Revenue	*$ million*	*Share of total*
Appropriation	593.9	62.7
Co-investment	210.1	22.2
Services and consulting	61.9	6.5
Intellectual property	37.1	3.9
Other[d]	43.8	4.6
Total revenue	946.8	100.0

[a] Expenditure figures relate to budgeted outcomes at the beginning of the period while revenue figures relate to actual outcomes at the end of the period. [b] According to CSIRO this element is directed at improving capabilities in other areas of CSIRO's research rather than being purely curiosity driven research. [c] Satellite roles include providing technical services, supporting post-graduate and post-doctoral development, outreach and education, managing national collections, managing national facilities and scientific publishing services. [d] Includes revenue from asset sales and interest.

Source: CSIRO 2005b, 2006 and sub. 50.

The organisation also has a very wide charter with research projects spread across a range of activities including advanced materials, ecosystem management, mineral exploration and processing, plant and animal sciences, climate science and water management, information and communication technology and astronomy (sub. 50, p. 10). The organisation's scale (it has 6500 employees and 17 research divisions located across 57 sites throughout Australian and overseas) also provides considerable scope for multidisciplinary research to be conducted 'in-house'.

CSIRO emphasised certain beneficial aspects of this capability in its submission:

> Achieving [solutions to complex problems] usually involve multiple stakeholders, multiple, intricate social interactions, and the bringing together of a wide range of technical skills and expertise from a range of disciplines. The transactions costs in trying to implement this approach across many different organisations, each with its own culture, process, procedures and objectives can be considerable. In many cases CSIRO can achieve this from within its own resources. (sub. 50, p. 54)

In a broader context, the Commission also notes that combined with other features of CSIRO's operating environment, this capability is likely to involve lower transaction costs compared with either competitive grant funding arrangements or the contracting-out of research activity by a central purchasing agency (see below). Public support is provided via a single block grant under a triennial funding agreement as well as through dedicated resources for the recently introduced Flagships program (see box 10.1).[2] Total public funding accounted for 63 per cent of CSIRO's budget in 2005-06. Significantly, nominal growth in the organisation's public appropriation has been very modest over the last decade, leading to claims that the agency is under-resourced.[3] This issue is discussed below. Under its funding agreement, CSIRO is required to meet and report on an extensive range of outcome-based performance criteria over the life of the funding cycle (annex box 10.1 at the end of this chapter). As discussed later, some participants (for example, the submission from the CSIRO staff association, sub. 78, pp. 12–13) were critical of the administrative burden associated with these reporting requirements claiming that they were diverting resources away from research functions.

This funding is supplemented by external consulting, co-investment (with a range of public and private sector research user groups) and contract revenue. Although a formal external revenue target (set at 30 per cent of CSIRO's budget) aimed at increasing collaboration and engagement with research users[4] was removed in 2002 due to a range of associated problems[5], the share of funding from this source has actually increased since that time. In effect, if CSIRO is to maintain its pre-2002 gross funding budget, it must still meet an implicit external revenue target. Thus far, income from royalties and intellectual property (IP) rights accounts for a relatively minor share of total revenue (around 2 per cent in 2004-05).

2 This differs from the dual funding arrangement in higher education research which involves both block funding for institutions (on the basis of allowing greater flexibility to set their own priorities) and competitive grant funding for teams and individual researchers (to encourage excellence through merit criteria).

3 Between 1997-98 and 2004-05, CSIRO's public appropriation increased at a nominal rate of just 3.4 per cent annually. CSIRO's share of Australian Government support for science and innovation declined from 12.6 per cent to 10.6 per cent over the same period.

4 The increasing trend toward collaborative research is highlighted by CSIRO being the largest single participant in the CRC Program. It is involved in around 50 of the 72 CRCs currently operating.

5 According to the review of the external revenue target (Batterman 2002), these included encouraging short-termism at the expense of longer term planning, focusing effort to areas more likely to provide a financial return, limiting collaborations with SMEs, restricting optimal performance in CRCs and creating difficulties in building the value of intellectual property.

Box 10.1 **CSIRO's National Research Flagships**

According to CSIRO, the recently introduced Flagship programs represent some of the largest directed research efforts ever undertaken in Australia and the largest ever redirection of CSIRO funding. They involve partnerships with other research providers and the users of research outputs including leading scientists, research institutions, firms, government agencies and selected international partners. Their aim is to help shape the future of an industry or sector in Australia or address a major national challenge by identifying opportunities that require a research solution. Total Flagship funding (including external and in-kind) is projected to be $240.4 million in 2006-07.

The programs are based on: tackling Australia's biggest national challenges; delivering high impact, high quality science in pursuit of those challenges; delivering effective outcomes by working with partners; achieving long-term goals by a combination of short, mid and long-term science outputs; introducing a new way of doing science (multidisciplinary, multi-agency, transformational science to make a difference); investing significant resources from CSIRO and its Flagship partners; and delivering high standards of accountability through rigorous governance controls.

CSIRO currently manages six individual flagships (there is also a Flagship Collaboration Fund), each with an explicit goal.

- Energy Transformed
  – To halve greenhouse gas emissions and double the efficiency of the nation's new energy generation, supply and end use, and to position Australia for a future hydrogen economy.
- Food Futures
  – To transform international competitiveness and add $3 billion annually to the Australian agrifood sector by the application of frontier technologies to high-potential industries.
- Light Metals
  – To lead a global revolution in light metals, doubling export income and generating significant new industries for Australia by the 2020s while reducing environmental impact.
- Preventative Health
  – To improve the health and wellbeing of Australians and save $2 billion in annual direct health costs by 2020 through prevention and early detection of chronic diseases.
- Water for a Healthy Country
  – To achieve a tenfold increase in the economic, social and environmental benefits from water by 2025.
- Wealth from Oceans
  – To position Australia by 2020 as an international benchmark in the delivery of economic, social and environmental wealth based on leadership in understanding ocean systems and processes.

Source: Sub. 50 and CSIRO 2006.

As a statutory body, the CSIRO Board decides how its public funding appropriation is directed to specific research areas (though there is very general guidance provided by the National Research Priorities).[6] In determining that research agenda, the agency has developed what many consider to be a rigorous, flexible and robust priority setting framework which has generated interest from other parts of Australia's research community (including some universities and science program administrators). As discussed later, CSIRO considers its framework is more widely applicable to other parts of Australia's innovation system (sub. 50, p. 18).

Priority setting (known as the Science Investment Process) is based on an assessment of CSIRO's capabilities (scientific strengths) and an analysis of the potential impacts of different areas of research (that is, it asks which areas would deliver the greatest benefits to Australia — see box 10.2). Broad consultation with stakeholder interests is also a feature of the process. This allows research activity in other parts of the innovation system, both domestically and abroad, to be specifically considered in determining project funding. This is relevant, inter alia, to addressing issues regarding additionality and CSIRO research crowding-out activity by other research providers (see below).

A feature of the operational management of CSIRO research (the Performance Management Framework) is that regular monitoring of progress against science outcomes and path-to-market milestones allows for a redirection of resources should progress fail to meet specified targets (at so-called stage gates). CSIRO noted that an example of its ability to shift resources in response to changes in the internal and external environment is reflected in a recent decision to replace an intelligent transport research stream with a transport fuels stream in response to escalating global oil prices. Another example was the 'fast-failing' of 14 research projects in the Light Metals Flagship for not meeting technical, economic or partnering performance criteria (sub. 50, p. 84).[7]

Another element of CSIRO's research management framework, the Science Assessment Process, has similarities to the proposed Research Quality Framework (RQF), which is discussed in chapters 7 and 11.

6 Research priorities for externally generated revenue are influenced by industry and collaborative partners.

7 CSIRO noted in discussions that the scale of the organisation's research portfolio allowed the affected research scientists in these situations to be diverted to other projects in their existing disciplines, thus allowing the organisation to maintain research capability in these areas. This was contrasted with the operation of alternative organisational models such New Zealand's Crown Research Institutes (CRIs) which were involved in a much smaller number of research projects and hence risked losing capability should a project be terminated. The CRIs are discussed below.

Box 10.2 The selection and management of CSIRO research

According to CSIRO, the allocation of research funding is based on the principles of science excellence, relevance and impact. The organisation uses a variety of methods to promote these goals including what it terms the organisation's Science Investment Process (SIP), Performance Management Framework and Science Assessment Process. Formal stakeholder engagement (such as Sector Advisory Councils and Flagship Advisory Committees) allow user groups to participate in developing CSIRO's overall research strategy and the priority setting process in order to align its activities with the needs and capacities of user groups and to improve the utilisation of CSIRO's research results.

Science excellence encompasses research quality and the extent to which research achieves its intended outcome (its fitness for purpose). The two main tools used to assess research quality are: peer review of science quality and its importance to users (used in the science assessment process described below); and citation performance relative to other national and international research institutions. Fitness for purpose is measured via customer value surveys and indicators of repeat business.

The **Science Investment Process** (recently introduced) is forward looking and aims to ensure the relevance and impact of CSIRO science. It represents a systematic approach to managing the research portfolio and is based on an extensive range of indicators across 18 different socio-economic areas. These indicators are used to determine *research relevance* (with broad investment criteria based around value from R&D; whether CSIRO should be engaged and its role; and the relevance of R&D) and *research impact* (with broad investment criteria based around the likelihood of adoption; R&D productivity/potential and CSIRO research competitiveness). In turn, they help to prioritise decisions regarding resource allocations. A listing of the indicators used to assess research relevance and impact is presented in annex box 10.2 at the end of this chapter.

The **Performance Management Framework** is both forward and backward looking and aims to manage research to achieve impact and underpin accountability within CSIRO and with stakeholders. It involves tri-annual reporting of: strategy implementation; program performance; science highlights; outcomes (adoption and use of outputs) and organisational health. Performance monitoring and reporting is conducted against a detailed set of indicators in order to maximise the return on investment. The framework allows individual projects to be stopped or accelerated depending on changes to external conditions (such as the development of competing technologies or changes in community attitudes) and provides for the reallocation of resources to projects offering greater potential.

The **Science Assessment Process** is backward looking and periodically evaluates the work conducted within, and by, each division. It draws on peer review through expert external committees (predominantly comprising international experts and including end-user representatives) to review the quality, relevance, capability development and impact of each division.

Source: Sub. 50.

At a broader level, the application of this approach to research governance is also reflected in expenditure shifts of up to 10 per cent across core research roles such as occurred between 2005-06 and 2006-07 (CSIRO 2006). This flexibility contrasts with the operation of other parts of Australia's innovation system (notably ARC and NHMRC grants and the CRC program) where ongoing research management is largely a matter for the individual researcher or team and funding continuity is guaranteed for the life of the research project with much less rigorous monitoring of whether research objectives are being met. This issue is discussed further below.

Research priorities are guided by sectoral advisory committees spanning seven broad socio-economic areas: 1) agribusiness; 2) energy and transport; 3) environment and natural resource management; 4) health; 5) information, communication and services; 6) manufacturing; and 7) minerals resources. In addition there is an external advisory committee for each National Research Flagship (see box 10.1). The committees provide stakeholder input (from industry, government, higher education institutions and community groups) about strategic research needs and the utilisation of research results and assist in the evaluation of performance against planned outcomes. The organisation also draws on the expertise of eminent international scientists in determining research priorities and evaluating the outcomes of CSIRO's research activity.

10.2 Are CSIRO's processes effective in targeting the right research projects?

As noted above, a core rationale for sponsoring research within public agencies is to meet socially valuable research needs that would not, or could not, be effectively performed by other providers. In principle, this type of research primarily involves strategic and applied work with strong (though not necessarily exclusive) public good characteristics in areas such as managing the environment, improving the quality of life and, more generally, providing input to government policy setting processes. Private firms would not participate in these areas if they could not capture sufficient benefits (even in the presence of government subsidies) while university researchers (whose incentive structure is based on furthering the frontiers of knowledge and academic reputation) would abstain because such pursuits may lack sufficient originality.

As shown in table 10.2, CSIRO's research spending in areas that appear, prima facie, to reflect relatively strong public good outcomes across social, environmental and economic spheres (advancing the frontiers of science, solving major national challenges and science-based solutions for the community) accounted for just over 50 per cent of research activity in 2005-06. While the rationale for public provision in these areas is relatively clear cut the justification for CSIRO's involvement in industrial research (creating new or significantly transforming industries and delivering incremental innovation for existing industries) is less so because these activities are likely to involve both private benefits and public good elements.

The submission by Graeme Pearman, a former CSIRO division head and member of its executive committee, effectively questioned whether the organisation's current emphasis on performing industrial research was appropriate:

> With respect to CSIRO's current focus on capturing scientific knowledge for economic benefit it is argued that this is a huge, potentially dangerous experimentation with a national and publicly supported asset that is being undertaken on what are basically ideological grounds, in a vacuum, devoid of open debate concerning the overall benefit of this approach for Australia. (sub. 86, p. 6)

This highlights the importance of putting in place rigorous priority setting processes in avoiding committing appropriation revenue to areas where the beneficiaries are likely to have sufficient incentives to perform and/or fund the research themselves (the additionality issue). A prominent historical example is CSIRO's involvement in agricultural R&D where the organisation's strong record of achievement in that field has delivered significant financial benefits to primary producers, sometimes without a requirement for the beneficiaries to contribute proportionally to the cost of research or for CSIRO to share in the income streams that resulted (see chapter 4).[8,]

The Commission considers that CSIRO's ongoing involvement in its core research area of delivering incremental innovation to existing industries poses the greatest potential risk of encroaching on activity that private firms would otherwise undertake because that research is likely to involve considerably lower levels of technical and commercial risk than other industrial research. As CSIRO itself noted in the context of generating interest from potential users:

> … it is easier to attract external funding for incremental improvement work than for research aimed at major transformations of industry, which is much riskier and long term. Yet CSIRO's major responsibilities fall into the major transformation area. (sub. 50, p. 64)

Importantly, the wording of the CSIRO Act does not provide specific guidance on the type of industrial research activity that CSIRO should undertake — only that it carry out scientific research to assist Australian industry. It is therefore up to CSIRO itself to determine the most appropriate use of its public funding. Of course,

8 CSIRO's research activity in the mining and elements of the manufacturing sector has similar potential. The Commission recognises the organisation's recent efforts to move resources away from these areas in the face of criticism from the groups benefiting from past investment decisions.

this does not mean that CSIRO should be precluded from performing contract research (on a full cost-recovery basis) for industry as the associated interaction with research users achieves a number of outcomes including that: it can provide a valuable 'relevance check' for research, it has the potential to trigger public good research grounded in practical problems and it can also lead to more effective utilisation of CSIRO's research infrastructure.

As discussed below, the Commission considers that the recently introduced priority-setting processes provide a framework for systematic and robust evaluation of research areas that warrant investment of CSIRO appropriation revenue. An element of that framework asks whether CSIRO should be engaged in specific research and the respective role the organisation should play (see annex box 10.2).

However, questions remain about the nature of its involvement in certain areas. In particular, a forthcoming review of the impact of recent CSIRO research noted that the R&D program in light metals and cotton research had a strong commercial emphasis and that a key factor underpinning CSIRO involvement 'is its legislative requirement to carry out scientific research to assist Australian industry and the extensive light metals [and cotton R&D] capability already held by the organisation.' (ACIL Tasman 2006e, pp. 5-6)

As noted in chapter 4, even where a small number of large firms are the potential beneficiaries (such as in the light metals industry), there may be a case for CSIRO involvement in the early stages of a research project on the grounds that the project is so technically risky that it would not otherwise proceed. However, that involvement would need to be re-assessed as the project evolved and the prospects for full private funding increased. In the case of cotton research, on the other hand, the Commission sees a much weaker argument based on additionality (see chapter 9).

That said, the submission by CSIRO emphasised the organisation's position is that it 'does not fund research that the private sector is likely to support itself' (sub. 50, p. 64) and that a decreasing proportion of its appropriation revenue was directed to the incremental innovation for existing industries role (the area it also viewed as having the greatest potential to encroach on work private firms would fund).[9]

In seeking to give effect to this goal, CSIRO also commented it had moved toward a co-investment approach where the benefits from the application of research were

9 While incremental research activity represented the largest single core role in 2005-06 (see table 10.2), the relative importance of that component has declined drastically in 2006-07. At a disaggregated level, resources allocated to incremental innovation decreased by 5.8 per cent in the Agribusiness Group in 2006-07, 3.0 per cent in the Information, Manufacturing and Minerals Group and 6.7 per cent in the Sustainable Energy and Environment Group (CSIRO 2006).

shared by collaborative partners. This is, in essence, a form of incentive subsidy in that it acts to dissuade firms from seeking support for research they would have conducted anyway (see chapter 9). CSIRO noted:

> If the private sector view is that the research has a high level of certainty and will produce significant benefits, it is less likely to agree to co-investment proposals, preferring to pay the full costs of the research upfront and retain for itself all of the expected returns. The greater the level of uncertainty and risk, the more likely firms will be to agree to share the costs, risks and benefits. (sub. 50, p. 64)

Evidence of the adoption of this approach is provided by the increasing share of CSIRO’s total revenue from co-investment activity (see table 10.3).

On balance, however, the Commission considers that there may still be some value in reinforcing CSIRO’s stated aim by appropriately amending the wording of its *Act* to target high spillover research that would not otherwise take place and explicitly incorporating a more specific set of ex-ante evaluation criteria to improve CSIRO’s current processes (see below).

In a similar context, the organisation highlighted its planned *Australian Growth Partnerships* model which would provide competitive funds to SMEs who have a track record of commercialisation success but who are unwilling to accept the full risk associated with a particular new project. Its aim will be to transfer CSIRO technology and provide the technical assistance needed for successful commercialisation. In that event, CSIRO would require repayment of the funding it provides. One participant, AusBiotech (the representative association for Australia’s biotechnology sector) supported this type of arrangement on the grounds that it would improve the accessibility of CSIRO research although it also noted potential risks:

> CSIRO is currently exploring some schemes, such as the Australian Growth Partnership model which could result in deferred payment for contract research in exchange for a share of the IP generated. This would make CSIRO services more accessible particularly for SMEs.
>
> Until this model gains approval, CSIRO has been trialling a similar scheme, using the resources of the Division of Molecular and Health Technologies. The approach is to offer scientific resources on the basis of flexible business models, using a risk-adjusted mixture of up-front payment, IP sharing, royalties, milestone payments and equity options, depending on what suits particular SMEs and their investors. There is however a risk for CSIRO that in deferring some or all of its returns, these returns may not materialise. (sub. 95, p. 29)

Table 10.3 **CSIRO's co-investment, consulting and services and IP revenue, 2002-03 to 2006-07**

	2002-03	*2003-04*	*2004-05*	*2005-06*	*2006-07* [a]
Co-investment	179.8	194.0	209.4	218.1	235.6
Services and consulting	83.7	78.7	60.9	61.9	65.0
IP revenue	13.8	22.0	20.4	37.1	37.2
Total [b]	275.4	296.2	280.9	309.1	337.8

[a] Figures in this column are CSIRO budget estimates and include work-in-progress and deferred revenue adjustments and for this reason are not strictly comparable to previous years. [b] Except for 2006-07, total revenue includes work-in-progress and deferred revenue adjustments but individual components do not.

Source: Sub. 50 and CSIRO 2006.

As discussed in chapter 9, the Commission strongly endorses the use of instruments which dissuade firms from unnecessarily seeking financial assistance. However, it considers that the use of a royalty sharing arrangement would be far more effective in achieving this aim compared with a requirement of just repaying the funding support received by the firm. In this context, the Commission considers the flexible funding and royalty approach adopted in the trial scheme cited by AusBiotech as a more preferable funding mechanism.

Finally, in reviewing potential improvements to CSIRO's investment processes, the Commission judges that incorporating an explicit set of quantitative and qualitative criteria to assess the case for, and extent of, CSIRO involvement in research where public and private benefits co-exist would be valuable. In this regard, the investment criteria used by the Victorian Department of Primary Industries for agricultural research, development and extension (RD&E) is instructive. The main principles (some of which are already reflected in CSIRO's investment process) used in that process involve an assessment of:

- *Role of Government*: A market failure test is used to help determine the role of government in future RD&E investment and the beneficiaries and funders test is applied to help determine who benefits and therefore who should be funding the work;
- *Alignment with strategic direction and investment priorities*: Scanning the environment (external and internal) to identify the key drivers and emerging issues that might inform setting strategic direction as well as annual investment priorities. Project proposals need to align with the strategic direction and priorities to be considered for funding.
- *Equity in funding:* Investors should make a quantum of investment proportionate to the benefit of the output to that investor using the market failure test. Some projects should be fully funded by industry, some fully funded by government, and others a mix of both government and industry.
- *Impact of investment and value for money:* The success of government investment in RD&E through DPI will be underpinned by demonstrated achievements in relation to

> economic impacts for the agri-food sector and benefits to the natural resource base and regional communities. (sub. 84, p. 34)

Crowding-out

A closely related issue to the inducement question is whether public sector research 'crowds-out' or substitutes for activity that might otherwise have been conducted by the private sector (an issue more widely discussed in appendix M). This may occur where, for example, in the face of supply constraints in the market for scientists and engineers, public sector demand acts to raise salaries and make research uneconomic for private firms. In that respect, CSIRO noted it was unlikely that its industrial research activity (specifically its core role of creating new or significantly transforming existing industries) substitutes for business funded R&D due to the scale of research effort in that area.

It argued that the absence of large corporate laboratories in Australia (in contrast to countries like the United States) meant that major research efforts aimed at developing breakthrough technologies would simply not be undertaken here. As an indicator it presented comparative data on the distribution of research effort by firm size in four countries showing a much higher proportion of research conducted by small firms in Australia (see table 10.4). It also noted that this feature of Australia's research landscape also precluded most private firms from managing risk across a broad portfolio of projects.

The Commission notes empirical evidence both from Australia and internationally lends a degree of support to this contention. For example, a recent Commission study into the relationship between R&D and productivity (Shanks and Zheng 2006) found a strong positive relationship between government and business sector R&D (a 1 per cent increase in public R&D raised business R&D by 1.9 per cent over the long run). For the OECD as a whole, on the other hand, there was evidence of modest crowding-out, though this appears to be isolated to countries with large public sector defence R&D (appendix M).

Table 10.4 **Research effort by firm size, 1999 — selected countries**
Per cent

	Firm employment size			
Country	*Less than 100*	*100-499*	*500-999*	*Greater than 1000*
Australia	29.2	20.7	12.3	37.8
Canada	16.8	15.8	10.1	57.4
United States	10.4	8.3	3.8	77.5
Korea	4.1	8.8	8.2	78.9

Source: Sub. 50.

Similarly, in a recent review of international studies sponsored by the Department of Employment, Science and Training, Dowrick (2003) noted that while crowding out of private sector research was a common finding for the United States (where more than 50 per cent of industrial R&D is conducted in very large firms with more than 10 000 employees), the majority of studies for other countries found a degree of complementarity between public and private sector research activity. In other words, public R&D raised private sector productivity.

Accordingly, the Commission does not consider that crowding-out is a major issue.

10.3 Are CSIRO's funding arrangements appropriate?

As noted above, the bulk of CSIRO's research budget is provided through a block appropriation grant. Block funding offers significant advantages for mission-based research agencies like CSIRO as it achieves a number of objectives: it provides greater flexibility to make strategic decisions about research direction; it creates opportunities to respond to emerging priorities; it allows the organisation to plan and build multi-disciplinary research capability; it provides scope to engage in larger scale and longer-term research and finally, it involves a lower administrative and compliance burden compared with competitive funding processes such as grant funding or contracting out. From the community's point of view, these features also deliver potentially valuable contingency or option benefits through the reduction of a range of social (eg. public health) and environmental risks and a preparedness to deal with future uncertainty. In the words of CSIRO:

> … one reason why the government provides a (largely) one line appropriation to CSIRO [is that] this buys capacity rather than projects from CSIRO – it is in effect an insurance policy, supporting a preparedness to deal with possibilities that flow from CSIRO's more directed activities that result from an expert analysis of Australia's needs and challenges conducted in the context of existing and emerging scientific opportunities. (sub. 50, p. 56)

But there are also potential disadvantages associated with block funding including reduced external accountability (at least over the term of the funding cycle and especially given the diffuse and uncertain nature of public good research outcomes); less direct involvement in research investment decisions by stakeholders; and lower incentives to maintain or improve research quality and impact compared with more ‘at risk’ funding sources.

However, the Commission considers that current research investment and research governance processes employed by CSIRO provide a degree of reassurance against these risks. Firstly, the science investment process involves an element of internal contestability as research scientists and research divisions are required to compete for available appropriation funding. Research proposals are assessed and ranked on merit against detailed relevance and impact criteria in the science investment process framework (see annex box 10.3). Broad stakeholder consultation will also help to shape research strategy from a top down perspective.

Secondly, a much greater share of funding now comes from competitive sources with external revenue estimated to account for just under 40 per cent of the organisation’s total budget in 2006-07 (CSIRO 2006). Accordingly, interaction with research users has, by necessity, increased significantly over time (with the strength of these linkages reflected in the responses to CSIRO’s regular customer value survey). Finally, accountability will also be enhanced by: the performance management system that redeploys resources if agreed objectives (science excellence and impact) are not met; and outcome-based performance reporting requirements under the triennium funding agreement.

Importantly, the breadth of that engagement includes research applications in areas with strong public good characteristics. In particular, direct government grant and contract funding (with research outputs used to address policy responsibilities in areas such as environmental management) accounts for the largest share of external revenue (see table 10.5). The submission from CSIRO highlighted the mechanism through which that funding influences the direction of its research effort:

> … a grant is one means through which external public bodies can draw on CSIRO’s appropriation funding and affect its overall research strategy. Because grants originate from public sector organisations, involve public funding and generally aim to produce public good outcomes in the public interest, the necessary subsidy of grant-supported work from appropriation funding does not result in any conflict with CSIRO’s roles and objectives. However, grants do reduce some of the flexibility that CSIRO has to allocate its appropriation funding purely according to its internal assessments. (sub. 50, p. 61)

In effect, this means that the actual share of funding determined on a competitive basis is considerably higher than that indicated by external revenue sources alone.

Table 10.5 **Sources of CSIRO's co-investment, consulting and services revenue, 2005–06**

Source	*Revenue*	*Share of total*
	$ million	per cent
Government	86.7	31.9
Private sector	71.2	26.1
RRDCs	44.3	16.3
CRCs	35.2	12.9
Overseas entities	35.0	12.9
Universities	7.7	2.8
Work in progress and deferred revenue	-8.0	-2.9
Total	272.1	100.0

Source: Sub. 50.

Moreover, this raises a broader question of whether these government bodies could play a more direct role in decisions regarding how CSIRO's appropriation funding is allocated or, alternatively, whether a central purchasing agency could be involved in determining research directions such as occurs in New Zealand (see below). CSIRO argued strongly against a move away from current arrangements highlighting both the advantages of block funding (of which it did not seek an addition) and the consequences of relying too heavily on external bodies in allocation decisions. It said:

> The budget appropriation … provides for a degree of certainty and stability. This facilitates the strategic planning of research and investment in longer term, challenging projects, as well as the maintenance of capability. Appropriation funding supports basic infrastructure, including facilities, equipment and expertise. Just as importantly, it provides an essential base from which it becomes possible to invest resources into the development of long term research projects requiring the assembly of large teams of experts from several disciplines across different organisations. Grant schemes do not support such planning or cover the considerable overheads required to manage such projects. Neither do grant schemes provide the single point accountability within one organisation which is necessary for the effective management of this kind of large scale program. (sub. 50, p. 58).

In considering the issue of funding balance, the Commission notes the operating environment of New Zealand's Crown Research Institutes (CRIs). The CRIs are separated along similar divisional lines to that of the CSIRO and are required to compete against each other, universities, private firms and research associations for public good research funding administered by a centralised research purchasing agency (see box 10.3).[10]

10 In 2004-05, 53 per cent of the available funding was allocated to the CRIs, 23 per cent to higher education institutions and 23 per cent to business.

Box 10.3 New Zealand's Crown Research Institutes

The establishment of Crown Research Institutes (CRIs) in 1992 represented a new approach to public sponsorship of scientific research in New Zealand. Prior to their introduction, public research activity was conducted within portfolio agencies including the Department of Scientific and Industrial Research and the research arms of the Ministry of Agriculture and Fisheries and Ministry of Forestry. The CRIs were established as independent statutory bodies subject to the New Zealand Companies Act (requiring the payment of dividends and corporate tax). They are expected to be commercially viable (with a strong focus on financial performance), compete for public and private sector contracts, exhibit a sense of social responsibility and undertake research for the benefit of New Zealand.

There are currently nine separate institutes aligned to research in the following economic, environmental and social fields: agriculture; horticulture; crops; industrial research; forestry; geological and nuclear science; landcare; water and atmospheric research; environmental science; and social research and development. The CRIs undertake both basic (mainly strategic) and applied research with most effort focussed on the application of research results over the medium to long-term. They are required to produce science and technology of both high quality and relevance to end users including industry and government.

Public funding is primarily provided under the Public Good Science Fund and allocated by the Foundation for Research, Science and Technology (FRST) — established to act as the main public purchasing agent — on a contestable basis. The CRIs compete against universities, private firms, research associations for funding from FRST and other purchasing agents who then contract to the successful bidders for the research. Unlike universities, CRIs receive very little block funding from government, and are instead dependent on FRST funding, private sector contracts or generating commercial revenue. CRIs also receive non-contestable public funding to build and maintain research capability required for the provision of public good science. In 2004-05, 60 per cent of CRI revenue was sourced from government, 20 per cent from private firms and around 8 per cent from 'own funds' (commercial revenue).

Source: New Zealand Ministry of Research, Science and Technology (2003, 2006), OECD (2004a).

In principle, there are a number of potential advantages of centralised purchasing including a lower risk of duplication across the public research sector (including State research bodies) compared with multiple funding models such as that operating in Australia; greater consistency in selection processes across research providers; more responsive priority setting to community expectations (ie targeting projects with high social benefits); and greater transparency and accountability.

But there may also be disadvantages. As discussed in chapter 8 in the context of considering an increased emphasis on National Research Priorities, these include the higher transaction costs involved with collecting and assessing information from competing bidders; a greater risk of purchasing errors compared with decentralised decision-making models; higher administrative and compliance costs for research providers; wasteful lobbying effort; adverse incentive effects from a less certain funding environment (such as gaming); and the potential loss of capacity building and the other advantages of block funding.

In practice, these and a number of other problems have been associated with New Zealand's move to a more centralist approach. While recent evaluations of the research funding arrangements in that country noted strongly beneficial impacts in certain research fields (mainly industrial and environmental research), improved linkages with research users and better performance against financial benchmarks, there were a range of concerns identified by the CRIs and other stakeholders (purchasing agents, policy makers and end-users) about the impact of the contestable funding model (MRST 2003).[11] These included:

- grant funding duration compromising the management of long-term research;
- tensions between public good and commercialisation objectives;
- inappropriate purchasing decisions with respect to the core role of the CRIs;
- reduced ability to maintain core competencies in certain areas;
- encouraging game playing to secure funding (at the expense of other CRIs); making collaboration with universities more difficult; and
- imposing an unnecessary administrative burden in terms of securing funding and a legal burden in dealing with intellectual property issues.

While there were no specific recommendations in relation to funding, the latest evaluation noted that the range of suggested solutions from stakeholders 'were mainly variations on the theme of reducing the amount of funding allocated on a contestable basis.' (MRST 2003).

The Commission recognises that adoption of this model, as a whole, would represent a radical departure from Australia's approach to funding CSIRO and other public sector research agencies. The associated risks of causing abrupt and significant costly disruption to that part of the innovation system need to be taken into account. As discussed in chapter 8, there is also no guarantee that centralised funding allocation would be more effective than Australia's current devolved processes including because important aspects of the present approach (such as allowing those with expert working knowledge of particular science and innovation aspects to make decisions) would be hampered by such a move. Accordingly, the

11 In 2004-05, around 50 per cent of the public research funding pool was allocated to the CRIs (down from 85 per cent in 1998).

Commission considers there is not a strong case for moving to a centralised purchasing model.

The level of appropriation funding

A related issue involves the adequacy of the *level* of CSIRO's public funding. As noted above, appropriation funding has been static in real terms over the last decade and now accounts for a smaller of share of overall Australian Government support for science and innovation (down from 12.6 per cent in 1997-98 to 10.2 per cent in 2006-07). Some participants highlighted the adverse consequences of the increased emphasis on attracting external funds in the face of stagnant appropriation revenue. Graeme Pearman said in this regard:

> The process and other cultural changes have led to early retirements, redundancy of productive and experienced senior staff and most importantly failure to attract young and mid-career scientists from overseas and the loss of mid-career scientists to Europe and North America. (sub. 86, p. 7)

A range of different problems associated with the increased reliance on external funding (and reflective of issues to be considered in contracting-out) are also possible. These include an inappropriate focus on short-term research at the expense of medium- and longer-term outcomes; greater emphasis on the needs of large firms at the expense of SME's (due to higher transaction costs); the resource-intensive nature of managing intellectual property; and the potential for cross-subsidisation of contract research from appropriation funding (though CSIRO's submission asserted that this practice had been eliminated by 2004-05).

Notably, CSIRO did not seek an increase in its public funding allocation although it did mention in discussions with the Commission that it had the capacity to support additional worthwhile research if more funds were available. The submission from CSIRO's staff association (sub. 78, pp. 15-16), on the other hand, claimed that an 'inadequate increase in government funding' was responsible, among other things, for insufficient scientific research capability (including the ability to respond to emerging challenges) and significant problems with staff satisfaction including issues associated with job security.

In consideration, the Commission notes that there has been no hard evidence presented to it on where current capability gaps exist (either within CSIRO or across Australia's public research sector) and also the difficulty in it assessing the organisation's ability to respond to future challenges. It also notes that CSIRO research continues to be considered world class in a number of areas including entomology, plant science and advanced materials. In contrast, the main concerns conveyed to the Commission during discussions with participants related to some duplication of effort across the public research sector (see below).

More broadly, the Commission sees considerable merit in maintaining sufficient block funding so that effective strategic choices can be made by CSIRO. This places a limit on the extent to which the level of appropriation funding can or should be reduced in real terms. As noted above, appropriation funding is already being used to augment competitive funding. This means that more than 40 per cent of the organisation's total funding is subject to competitive influences. Notably, this is around the same proportion as that for higher education institution funding where it could be argued a stronger relative case for competitive funding exists given the nature of the of the research in that environment (see chapter 11).

10.4 Are there any lessons from CSIRO's approach for other parts of Australia's research sector?

CSIRO's current approach to priority setting, performance management and assessment is a distinctive feature of Australia's innovation system. It incorporates both ex-ante and ex-post appraisal processes, combines bottom-up and top-down input to research planning, involves broadly-based consultation with potential users and other stakeholders and actively manages projects against performance benchmarks. It is also relatively transparent in comparison with some other public sector research agencies and the higher education sector (at least in terms of the allocation of block funding by institutions).

In part, the approaches used in different components of the research system reflect differences in purpose and function. For example, the focus of much higher education research is on advancing the stock of scientific knowledge where impacts are difficult to measure. Mission-based research organisations, on the other hand, are outcome focused as they primarily aim to solve applied problems. Despite these differences, some participants considered that divergent research management and governance processes and a lack of clarity regarding organisational roles among various components of Australia's research system were resulting in unnecessary duplication and a lack of accountability and transparency. Against that background, CSIRO noted:

> … a number of the changes CSIRO has made to the way it operates would also generate greater benefits in applied more widely across the [National Innovation System]. (sub. 50, p. 18)

As noted earlier, an important feature of CSIRO's priority setting involves taking account of research activity in other parts of the innovation system. Performed properly, this means that CSIRO can avoid duplicating research conducted by other private and public sector research performers. While competition among research organisations can provide strong incentives to improve quality and efficiency there is also a risk that resources may be inefficiently devoted to solving identical problems. Potentially, this could be avoided be adopting similar priority setting processes in those parts of the system where this is feasible. Another advantage of a more consistent approach to project selection is a greater likelihood of undertaking research that would not otherwise be conducted by the private sector.

The most obvious area of adoption would be in applied public research organisations at both federal and state government level with agricultural research being a specific example where the Commission sees a heightened risk of duplication. Past problems in this area were acknowledged by the Department of Agriculture, Fisheries and Forestry which said in its submission:

> Institutionally, difficulties in prioritising, coordinating and collaborating on R&D between different actors in the agrifood innovation system have previously led to duplication in some areas and gaps in others. There are also concerns about the potential for a decline in research provider skills and capacity. (sub. 100, p. 4)

The Department also noted that specific initiatives in train to improve the effectiveness and efficiency of public investment in this area included a review of rural research and development priorities and implementing a national framework to improve national collaboration. While acknowledging these efforts, the Commission considers that there may still be value in applying CSIRO-type decision processes to agricultural research activity more broadly. This is already a feature of the RRDC model (see chapter 9).

Another area of potential adoption is in the applied research work of the industry-oriented Cooperative Research Centres where ex-ante appraisal of impacts are more readily identifiable (see chapter 9). On the other hand, it would not be well suited to basic research in the higher education sector because impacts are more diffuse and applications can take much longer to be realised.

Similarly, features of the project management system used by CSIRO appear to offer particular advantages compared with the approaches used in other areas. As noted earlier, research management within CSIRO involves ongoing monitoring against set performance criteria across the organisation's research portfolio. This provides considerable flexibility in allowing the redeployment of resources at various stages throughout the life of a project should agreed objectives not be met.

It contrasts with the processes used in grant-funded higher education research where ongoing project management is largely a matter for the investigator. Accordingly, the ability to change research direction is limited to when a project is completed.

That said, the curiosity-driven nature of basic research means that application of an effective forward looking performance management system would be problematic.

However, this appears to be less of an obstacle for CRCs which receive significantly higher levels of public funding (the average was around $20 million for successful partnerships in the latest selection round) than the typical grant awarded to a university researcher. These application-focused entities also operate for much longer time periods (of up to seven years) without, in practice, the same degree of scrutiny regarding the achievement of project objectives as occurs in CSIRO (see chapter 9). It is in this area that the Commission sees a useful role for adopting elements of CSIRO's performance management system. As discussed in chapter 9, while CRCs are subject to detailed annual reporting requirements and a comprehensive technical review after 3 years of operation, there may be a case for providing financial incentives to encourage CRCs to change research direction if it becomes apparent that research objectives are not being, or will not be, met.

The Commission acknowledges that CSIRO's approach is resource intensive and that, inevitably, there is a trade-off between improved accountability and administrative burden. It also notes that the compliance and administrative costs faced by CRC applicants (whether successful or not) are already significant. In this context, there was some criticism of the onerous nature of CSIRO's performance management system. The organisation's staff association claimed that the associated increase in administrative expenses had, in the context of an essentially flat appropriation budget, meant there was less scientific capability for the organisation's research agenda. It went further in saying:

> We believe CSIRO may have gone too far in introducing project management bureaucracies following the findings of the Auditor General's Report (No 51, 2002). This has resulted in increased reporting requirements on researchers in both appropriation and externally-funded projects. … There is little analysis to suggest greater productivity and efficiency with the recent adoption of project management bureaucracy, and even less clarity that the organisation is more accountable because of it. More accountability is not always better accountability. (sub. 78, pp. 11–12)

Nevertheless, the Commission sees merit in exploring mechanisms to improve the operation of CRCs and other research bodies given the substantial amounts of public funding involved (see chapter 9).

DRAFT FINDING 10.1

The Commission considers that the current real level of public appropriation funding for CSIRO should not be reduced. Aspects of its approach to priority setting and performance management may have wider applicability to other parts of Australia's innovation system.

10.5 Defence Science and Technology Organisation

The Defence Science and Technology Organisation (DSTO) is the principal science and technology advisor to the Australian Defence Organisation. As such, its mission-based research effort is far more concentrated than that of the CSIRO and focuses on the short and long term 'application of science and technology to the defence of Australia and its national interests' (Trenberth 2004). Its activities also support national security goals through an involvement in counter-terrorism and defence against chemical and biological threats. Specific functions supporting DSTO goals include:

- investigating future technologies for defence applications;
- ensuring efficient acquisition and use of defence equipment;
- developing new defence capabilities; and
- enhancing existing capabilities by increasing performance and safety, and reducing the cost of ownership. (DSTO 2006).

Public funding for DSTO research is provided though a single block grant from the Department of Defence budget allocation which is supplemented by external revenue derived primarily from other defence groups and government bodies with a very minor contribution from licensing income and revenue from contract research services. With regard to intellectual property, the organisation has noted that its philosophy is not to earn revenue but to provide its IP to industry to enhance defence capabilities (DSTO 2006, p. 8).[12]

Increasing DSTO's engagement with industry has been identified as an important government policy objective (Hill 2003). According to a recent organisational review, while the DSTO does have extensive industry linkages — including through technology and skill transfer; collaboration with CRC and university partners; and international expertise and technology links — this was an area that offered scope for significant improvement (Trenberth 2004). It also raises the issue of the most appropriate balance between in-house, co-investment and contracted research.

The majority of DSTO's research is conducted internally through three laboratories — military platforms, systems technologies and information sciences — which are assisted by a science policy unit whose role includes planning research and development activity. In delivering its research outputs, the organisation employs around 2300 scientists, engineers and support personnel. External expenditure is mainly directed at technical support and manufacturing services with a very minor

12 The Commission has been unable to establish the magnitude of the technology transfer involved.

share devoted to research partnerships with universities and CRCs (around $3.6 million spread across seven universities and ten CRCs in 2002-03).[13]

DSTO's research agenda is directed almost exclusively by its principal defence clients (the three services, joint commanders, intelligence agencies, the Defence Materiel Organisation and strategic policy and information groups). Around 90 per cent of its budget is committed to projects agreed to by its funding agency. This purchaser-provider arrangement is, accordingly, considerably more formal than the funding model employed for the CSIRO. It also implies that any flaws in the decision-making processes of DSTO's principals will affect the quality, nature and magnitude of its research effort. The Commission notes that those processes, including issues associated with defence procurement, are outside the scope of this study.

The framework that determines DSTO's R&D activity is based on assessing short-term and emerging defence priorities (articulated in the *Defence Capability Plan 2001–2010*). More than half of the DSTO's research activity is directed at the long-term needs of its clients with the remainder spread equally between short and medium-term research. The research agenda is based on a rolling three-year work program and is mapped to specific defence outcomes. Research committees comprising both scientific and military personnel (from each defence area) determine the scientific direction of research with the following broad objectives:

- identifying those areas where DSTO resources can be applied effectively;
- determining task priorities to assist DSTO manage resources;
- ensuring that tasks are managed efficiently; and
- promoting goodwill and understanding (Trenberth 2004).

10.6 Are DSTO's funding arrangements appropriate?

Notably, the funding arrangements for the DSTO are subject to considerably less competitive influence than CSIRO or other parts of Australia's research system. While the organisation contends that its research program is supported by engagement with external agencies, it devotes a relatively minor share of its overall financial resources to such arrangements. These interactions include:

- collaboration with other Australian research agencies, universities, a number of Centres of Expertise, CRCs and industry to broaden Defence's science and technology (S&T) base;

13 There are also in-kind contributions which, in the case of the CRCs, amounted to $1.8 million in 2002-03.

- collaboration with international defence S&T agencies, particularly in the US and UK, which is also an important component of the wider government to government military alliances; and
- partnerships with Australian industry to transition Defence's research into military capability and to contribute to national wealth (DSTO 2004a).

External expenditure accounted for just 9 per cent of the total budget in 2002-03. Although this represents a doubling over the last decade it remains very low by international standards.[14] For example, three quarters of the United Kingdom's defence research budget is spent externally. Similarly, the scientific research arm of the US Air Force contracts around 70 per cent of its budget to external providers. In a more extreme example, the US Defence Advanced Research Projects Agency commits its entire research funding allocation to industry, universities and other research bodies. And Canada's military research laboratory (Defence Research and Development Canada — Suffield) spends around half its research budget externally (Trenberth 2004).

Arguments cautioning against the use of international experiences to benchmark the level of defence research contracting in Australia have previously been put by the DSTO (IC 1995). They highlighted a number of differences between Australia and other countries which made such comparisons problematic. In particular, they noted that:

- Australia's strategic circumstances and industrial structure differs from that in other countries;
- Australia is primarily an importer of defence equipment rather than a designer, developer and manufacturer of that equipment (as are the United States and United Kingdom);
- The size of Australia's defence science budget makes it difficult to contract-out a meaningful amount of research to universities, industry and other research providers and still maintain an intramural defence technology knowledge and hence an impartial advisory capacity to government.

In addition, the recent review of DSTO's external engagement noted that the modest external spending reflected a need to maintain a complete set of skills to service its clients internally; its desire to ensure those skills were not eroded by external spending; and the limited ability of Australian industry to undertake the majority of the type of R&D that DSTO conducts. The review also highlighted the complicating security issue, given the classified nature of much defence-related research. That

14 This doubling in external funding was in fact a stated objective of the DSTO at the time of the Commission's 1995 R&D inquiry.

said, it found there was a case for increasing the proportion of research funded externally (although it did not nominate a target).

The Commission considers that while it may not be appropriate to aim for a similar share of contract research as that in other countries, the value of contestability in providing a discipline on efficiency in resource use and fostering creativity in the development of ideas suggests that more emphasis should be placed on this avenue of defence research provision. That said, it acknowledges that contracting-out will involve higher transaction costs because information about potential providers, assessment of bids, determination of prices and monitoring quality is more resource-intensive than in-house provision.

It also notes that Australian industry is more likely to build a competence in delivering research with a specific defence application if given more scope to compete for contract work. In this context, the Commission acknowledges that the science and technology activities of DSTO require a level of technological sophistication which can limit the scope to increase the level of external engagement. The Commission also notes the recommendation of the recent review of DSTO to create a Defence Science Access Network (DSAN) which would assist industry, especially smaller companies, to improve engagement with DSTO's science and technology portfolio (Trenberth 2004). That recommendation is currently being implemented (DSTO 2004b).

Finally, another option to facilitate greater contestability might be for the Australian Defence Organisation to review the potential for providing a component of research funds directly to the users of DSTO research (the three services, joint commanders, intelligence agencies, the Defence Materiel Organisation and strategic policy and information groups) allowing them to allocate these funds to the DSTO or to contract with other external providers.

DRAFT FINDING 10.2

The effectiveness of DSTO research is heavily dependent on the effectiveness of the procurement practices and the research directions set by the Australian Defence Organisation.

Annex box 10.1 **CSIRO performance reporting**

Focussing CSIRO science investment

- Share of CSIRO investment in National Research Priorities
- Assessment of science capability
- Share of CSIRO science budget in Flagships initiative
- Number of Flagship programs operating successfully
- Percentage of Flagship annual performance goals achieved
- Total external revenue for Flagships (including private sector element)
- Major cross – divisional programs operating successfully

Delivering world class science

- Staff Commitment and Engagement
- Number of postgraduate students supervised by CSIRO researchers
- Number of Post-docs with excellent credentials
- External/internal audit findings on project management practice
- Customer Value Survey (CVS) rating on process/people
- Citations of publications (citations per paper — cpp — as measured by ISI)
- Citations of publications (CSIRO's institutional ranking as measure by ISI)
- Citations of patents (as measured by CHI Inc's Patent Impact Index)
- Number of publications (by type)
- Number of publications, excluding client reports, per Research Scientist/Engineer
- Australian positioning on Square Kilometre Array (SKA)
- Initiatives to establish international science facilities

Partnering for community impact

- Partner feedback from collaboration with Unis, CRCs, other agencies
- Partnerships with Unis, CRCs, other agencies focused on clear strategic goals
- Co-location of major new facilities
- Engagement with the federal and state/territory governments
- Partnerships with other agencies to advance Australia's global development contributions
- More focussed and effective international effort (number/value/spread of overseas projects)

Serving as a catalyst for industry innovation

- Number of significant commercial relationships with rural RDCs ($10 m threshold)
- Value of commercial relationships with RDCs
- Customer Value Survey results — RDCs (comparative score)
- Number of significant commercial relationships with states/territories ($10m threshold)
- Value of commercial relationships with commonwealth, state and local governments
- Number of significant large corporate relationships ($2m threshold)
- Value of commercial relationships with large companies
- Customer Value Survey results — large companies (comparative score)
- Number of significant relationships with SME growth stars ($0.1m threshold)
- SME investment in CSIRO projects (Value of SMEs engaged with CSIRO)
- Customer Value Survey results — SMEs

Building one-CSIRO capabilities and commitment

- OH&S injury indicators (Lost Time Incident and Medical Treatment Frequency, Average Time Lost)
- External assessment/benchmarking of relevant processes
- External recognition for CSIRO practices
- OHS positive performance indicators (induction, investigation, training, assessment)
- Management of performance (Insight Survey results)
- Proportion of projects completed on time, on brief and on budget
- Number and proportion of projects discontinued under the fast failure approach (by type)
- Working relationship and Work Organisation and Efficiency
- Inter-divisional collaboration in CSIRO-wide support

Securing a financial foundation for growth

- Intellectual property revenue
- Subsidy in consulting service activity
- External revenue and total expenditure (co-investment; consulting and services; exploitation of IP)
- External revenue by source (market segment)
- Overhead and support costs
- Overhead ratio

Source: CSIRO personal communication.

Annex box 10.2 **Indicators used in CSIRO's Science Investment Process**

Relevance

Value from R&D

The intent is to assess how much value the successful completion, adoption and use of R&D might create, taking into account the full range of potential economic, social and environmental benefits. Assessment does not confine itself to Australia or to CSIRO's traditional research activities. It compares what would happen with successful completion, adoption and use of R&D with what would happen with no additional investment in research. Indicators/ data include:

- Industry Community Area (ICA) size (industry/market size, growth, employment, exports)
- Addressable benefit to Australia
- Trends in distribution of CSIRO investment (appropriation and external funding by ICA)
- Distribution of CSIRO ICA spend compared to Australian public and private R&D spend
- Contribution of ICA to the economy, looking at both GDP and environmental risks
- Key environmental challenges relating to each ICA
- Projected GDP growth and historic OECD change in ICA contribution to GDP
- Contribution of ICA to employment and changes in this measure over recent years
- World trade trend
- Resource use by ICA (water and greenhouse gas emissions)
- Trends in greenhouse gas emissions

Whether CSIRO should be engaged and the role it should play

Even if research has the potential to make a major contribution to the development of the ICA, it is still necessary to consider whether there is a role for CSIRO. Assessment considers:

- CSIRO's mandate
- Whether CSIRO has any specific responsibilities or restrictions relating to the ICA.
- Whether government policies or obligations bear upon level or kind of effort in CSIRO.
- Australia's National Research Priorities
- CSIRO's role compared with that of other members of the national innovation system
- Whether the nature of the users or potential users of CSIRO's research results has any implications for the role of public sector R&D generally and CSIRO's role in particular.

Possible data include:

- Australia's total R&D spend for each ICA
- Ratio of public/private expenditure for each ICA
- R&D spend ratio between CSIRO, other PSRAs, higher education, states/territories
- CSIRO spend relative to economic contribution of ICA (eg, value added and employees)
- CSIRO spend compared to each ICA's contribution to GDP
- Australian challenges and opportunities
- Trends in the balance of trade for each ICA

Relevance of R&D

Assesses relative importance of R&D in creating value for each ICA and whether science and technology are key to the development of the area. Assessment considers relevance of R&D to the problems and opportunities presented by the ICA. Possible indicators/data include:

- An industry sector's own investment in R&D.
- Global business expenditure on R&D (BERD) intensity for major countries for each ICA
- Australian BERD trend for each ICA
- Aust R&D intensity: Total $ spent on R&D per $m of value generated
- Aust R&D intensity: Industry $ spent on R&D (BERD) per $m of value generated
- OECD intensity in Business R&D Expenditures as a % of Industry Value Added
- USA R&D Intensity: R&D Expenditures as a % of Industry sales
- Industry innovation focus: Industry action agendas
- Business innovation

(continued next page)

Annex box 10.2 continued

Impact

Likelihood of adoption

Assesses likelihood research users will adopt successful research, develop it if necessary, and put it to use. Requires analysis of state of 'receptor' system for CSIRO's research. Considers:

- Willingness of partners/receivers (eg. firms, resource agencies) to adopt or use results.
- Ability of likely partners/receivers to convert successful R&D into commercial or other value.
- – Identification of what will be necessary to realise the benefits from successful R&D. (eg. capital investment; distribution networks; marketing skills; changed enterprise processes)
- Identification of what factors would drive adoption of the research results.
- – Whether these driving forces are short-term or long-term?
- – Whether factors (eg community acceptance) are likely to promote or impede uptake.

Possible data include:

- – Proportion of external revenue to total expenditure by CSIRO for each ICA
- – European Industry Innovation: New products (last two years) % of total sales

R&D productivity/potential

Intent is to assess how much technical progress would result from R&D investment. Purpose is to identify: areas of science and technology which are most productive in enabling new applications or advances in applications; number of highly productive areas for an ICA; and breadth and size of impact across the ICA. Assessment evaluates R&D productivity/potential as global measure independent of particular research group or organisation. Takes account of:

- Scope for technical progress (or technically-based improvement in performance).
- – The larger the scope the higher the R&D productivity/potential for the area.
- Likely cost of achieving this progress.
- – The higher the cost, the lower the R&D productivity/potential for the area.
- – Whether technical progress is likely to be quick or slow (as a proxy for cost)
- Technical progress measured in terms of parameters important for use of R&D in the ICA.
- Assessment considers uniformity and rate of technical progress in core areas of science and technology. This is important as if there is a significant mismatch between progress in one area and in those complementary areas needed to deliver value to end-users then overall rate of technical progress will be viewed by the users of research results as relatively low.

Indicators/data include:

- – Global science and technology 'hot spots'
- – CSIRO research competitiveness (now and future networks)
- – CSIRO's ability to make scientific or technical progress in a timely and competitive way

CSIRO research competitiveness

The intent here is to assess CSIRO's ability to make scientific or technical progress in a timely and competitive way. In conducting this assessment, CSIRO takes into account its existing and potential research collaborators. Factors taken into account include:

- Skills and experience needed and how CSIRO's capability compares with elsewhere.
- CSIRO's track record.
- Whether CSIRO can assemble internationally or nationally competitive research teams.
- Whether necessary infrastructure (equipment, other facilities) is or can be put in place.

Measures of CSIRO's research competitiveness include

- – CSIRO citations per paper compared to selected Australian institutions
- – Ranking of CSIRO research in areas in which are ranked in the Global Top 1%
- – CSIRO divisional 'quality' as measured by customer value surveys
- – CSIRO divisional Intellectual Property positions

Source: Sub. 50.

11 Funding of higher education research

Key points

- The rationales for dual streams of funding of higher education research are sound.
  - An appropriate balance of block and competitive funding should be maintained. In particular, as block funding levels should be sufficient to enable meaningful strategic choices to be made at the individual institutional level their share should not be reduced further.
- Differing funding allocation methodologies — for example formula-based approaches and peer review-based approaches — should be evaluated in a benefit–cost framework against relevant criteria.
- There is no clear objective evidence pointing to deficiencies in the quality of research currently funded through block grants. There is, however, evidence that the RQF will bring costs as well as benefits but, at this stage, it is not possible to assess the balance.
  - The Commission would suggest that it is still too early to make a final decision about implementation of the RQF, one way or the other.
- The Commission would suggest that adoption of the RQF should be delayed, pending the following investigation and analysis:
  - continue with limited trials, based on RQF peer review principles, but focused on providing indicators of the quality and impact of research dependent on block funding;
  - examine whether current procedures within institutions are sufficiently rigorous to promote the quality and impact of block funded research;
  - examine what benefits, if any, fine tuning of existing block funding formulae could bring; and
  - examine the merits of externally applied, risk-minimisation, approaches to enhancing the quality and impact of block funded research applied in conjunction with formula-based funding.
- In regard to competitive funding, little, if anything, would be gained through amalgamating the ARC and the NHMRC.

Funding of higher education research accounts for over 40 per cent of total Australian Government financial support for science and innovation. This highlights the importance of such issues as: aligning funding arrangements to different activities such as basic research, applied research, commercialisation, strategic capability building, and risk minimisation; program design, including administrative and gaming issues; and performance evaluation and monitoring.

This chapter focuses on the *allocation* of Australian Government higher education research funding, rather than the total and, in particular, on the roles of block and competitive funding. (As noted below, higher education research receives substantial support from other funding sources as well.) The term *higher education* in this chapter refers to the university sector. It includes higher education course providers, but excludes such entities as separately constituted medical research institutes.

The chapter does not cover all issues of relevance to higher education in a science and innovation context. Some issues, such as those relating to collaboration and to commercialisation, are covered elsewhere in the report. The Commission has also judged that some issues are beyond the scope of this study. In particular, this report does not cover issues relating to the quality of higher education teaching nor related funding issues. Nor does it consider the merits, or otherwise, of changing funding arrangements so as to encourage greater specialisation by particular institutions in teaching or research. And the chapter is not examining the strengths and weaknesses of peer review processes for existing programs.

The Commission is very aware that conclusions on funding issues necessarily involve considerable judgment (chapter 8), and that even small changes in arrangements can have important financial implications for individual institutions. Consequently, the Commission's approach in this chapter has been to explore possible alternatives, and to reach only tentative conclusions at this stage of the study, given the many uncertainties.

11.1 Current funding arrangements

In 2004, higher education research funding totalled some $3.3 billion (table 11.1). This compares with total Australian expenditure on R&D in 2002-03 of some $12.8 billion.

Even though funding from other sources is significant, Australian Government funding accounts for the majority of higher education research funding — nearly 75 per cent in 2004, for instance.

This chapter concentrates on Australian Government block funding ($1079 million in 2004 for the schemes in table 11.1) and Australian Government competitive funding ($697 million in 2004) for (non-teaching related) higher education research. Block funding accounted for about 59 per cent of that combined total in 2004. But there appears to have been a significant decline in the share of block funding in recent years at least, with that share in 2000-01 being about 70 per cent. (This estimate is based on the assumption that the share of NHMRC funding going to higher education institutions would have remained constant over the period at the 2005 level of 72 per cent indicated in NHMRC 2005a.)

Table 11.1 **Higher education research funding 2004**[a]

Includes funding from government and non-government sources

Category	*Funding ($m)*	*Proportion of total (%)*
Imputed share of Australian Government operating grant for teaching-related research (2004-05)	***587***	***18***
Australian Government Research block grants[b]		
Research Training Scheme	540	16
Institutional Grants Scheme	284	9
Research Infrastructure Block	160	5
Australian Postgraduate Awards	89	3
Regional Protection Scheme	6	..
Total	***1 079***	***33***
Research income		
Australian competitive grants[c]	734	22
Other public sector	300	9
Industry and other[d]	459	14
CRC research income[e]	113	4
Total	***1 606***	***49***
Total	**3 272**	**100**

a The latest year for which comprehensive data is available. **b** Excludes the Systemic Infrastructure Initiative and International Postgraduate Research. **c** Includes Australian Government funding of $697 million — ie not all Australian competitive grants are Australian Government funded. **d** Includes other non-government funding including from donations, bequests and foundations as well as international income. **e** Includes Australian Government funding of $74 million.

Source: DEST Higher Education Research Data Collection (from internet) and DEST Science and Innovation in the 2006-07 Budget.

The share of the operating grant shown above is merely an imputed or notional amount, representing the component of that grant estimated to be applied for teaching related research in aggregate. Separate amounts are not indicated for particular institutions in line with their teaching related research activity — individual institutions can spend more or less. Indeed, for that matter, operating grant monies may be spent on non-teaching related research just as block funding for research could, to a degree, be spent on teaching or on teaching related research. Given its nature, this teaching related research funding is not considered further.

‘Performance based’ block funding

Leaving aside some smaller programs, block funding is provided through a number of ‘performance based’ arrangements — the Research Training Scheme (RTS), the Institutional Grants Scheme (IGS), the Research Infrastructure Block Grants scheme (RIBG) and the Australian Postgraduate Awards scheme (APA) — with funding in 2006 totalling almost $1.1 billion. These arrangements are known as ‘performance based’ because allocations to each institution depends on its past ‘performance’ as assessed by various formulae (administered through DEST) — see box 11.1. In effect, institutions ‘compete’ for this block funding, which they are then free to allocate according to their own priorities (but see below).

The objectives of particular arrangements are as follows.

- Research Training Scheme. Its objective is to strengthen Australia’s knowledge base and research capabilities by enhancing the quality and effectiveness of research training environments (DEST 2004c). Funds are allocated to individual higher education providers to support training for students undertaking PhD and Masters Degrees by research (in the form of HECS-exempt scholarships).
- Institutional Grants Scheme. This shares the same underlying aim as the RTS. But, in contrast to that scheme, higher education providers have the discretion to use IGS funding for any activity related to research.
- Research Infrastructure Block Grants Scheme. This is allocated to higher education providers to enhance the development and maintenance of project-based research infrastructure. Institutions have discretion to distribute it as they see fit.
- Australian Postgraduate Awards. Their objective is to assist students of exceptional potential undertaking a higher degree by research with general living costs. Institutions are, in effect, awarded a number of APA places and the associated funding.

Some information about how higher education institutions allocate their block funding is provided in section 11.5.

The methodologies associated with the block grants shown in the box act to allocate funding continuously, rather than discretely — that is, a marginal change in an institution’s ‘score’ would result in a marginal change in its funding. (This contrasts with the proposed RQF methodology, discussed below, which appears discrete in nature.)

Box 11.1 Allocation of performance based block grants: criteria and weightings for 2006

Research Training Scheme (2006 funding of $563 million) A 'performance index' is calculated for each relevant institution on the basis of its higher degree by research (HDR) student completions (weighted 50 per cent), its research income (40 per cent) and its research publications (10 per cent). Research income is the total of Australian competitive grants income, other public sector research income, industry and other research income, and CRC research income. Publications comprise books (weighting of 5), book chapters (1), journal articles (1), and conference papers (1). A 'pre-safety net' grant is then determined on the basis of the formula: (A x 0.5) + (B – (0.75 x A)) + (C x performance index), where A = the institution's 2004 grant indexed to 2006 prices, B = the institution's 2005 grant indexed to 2006 prices, and C = total 2006 RTS pool x 0.25. A safety net applies so that no grant will fall below 95 per cent of the previous year's grant indexed to current prices.

Institutional Grants Scheme ($296 million) A 'performance index' is calculated for each institution on the basis of research income (60 per cent), student load (30 per cent) and publications (10 per cent). Research income and publications are determined as for the RTS above. A pre-safety net amount is then calculated on the basis of available IGS funds and the institution's performance index. No grant will fall below 95 per cent of the previous year's grant indexed to current prices.

Research Infrastructure Block Grants ($200 million) The grant is calculated directly on the basis of each institution's share of Australian competitive grants income over the most recent two years for which data is available.

Australian Postgraduate Awards ($93 million) The grant is based on the number of places allocated to an institution in the current and previous three years. In turn, the number of allocated places is based on research higher degree completions (weighting of 50 per cent), research income (40 per cent) and research publications (10 per cent).

Source: DEST documents (from internet).

Further, the change from one year to the next in the proportionate distribution of funding to individual institutions from each of the schemes in the box can only be small, given reliance on previous years' funding, income and activity in the formulae and the operation of safety nets. Nevertheless, significant change could arise over a number of years. (This also contrasts with the RQF which appears as if it might lock in funding relativities for periods of six years.)

'Competitive' funding

In terms of Australian Government funding, the two main sources of 'competitive' funding are the ARC and the NHMRC, which both allocate funding at the project and sub-institution level. The ARC funds research in all fields except clinical medicine and dentistry, with specific funding for medical research administered by the NHMRC. Funding levels have increased significantly over the past few years (table 11.2), but with considerable variability from year to year.

Table 11.2 **ARC and NHMRC funding**

	ARC[a]		*NHMRC research grants*[b]	
Year	Funding	Annual increase	Funding	Annual increase
	$m	%	$m	%
1997-98			164.3	
1998-99			177.1	7.8
1999-00			173.6	-2.0
2000-01	247.8		183.3	5.6
2001-02	265.8	7.3	243.0	32.6
2002-03	298.3	12.2	209.4	-13.8
2003-04	399.6	34.0	332.4	58.7
2004-05	480.9	20.3	369.4	11.1
2005-06 (estimate)	546.2	13.6	403.5	9.2
2006-07 (budget estimate)	570.3	4.4	437.6	8.5

a Provided under different arrangements prior to establishment of the ARC as a statutory body. **b** Excludes separate programs and infrastructure funding.

Source: DEST (2006f).

ARC

The ARC is an independent statutory agency established under the Australian Research Council Act 2001. Its day-to-day operations are now under the control of the CEO appointed by and reporting to the Minister for Education, Science and Training. The ARC Board was abolished in July 2006 in line with the recommendations of the Uhrig Report to improve governance arrangements. However, according to the ARC — many of the following details are taken from its submission, sub. 73 — the Minister has indicated an intention to appoint an advisory council to provide advice to the CEO.

Main areas of responsibility and role

The ARC administers the National Competitive Grants Program under which funding is made available for research conducted in universities and other eligible organisations across all fields outside of clinical medicine and dentistry. The vast majority of its funding is directed towards research conducted in universities. The main streams of funding are:

- *Discovery* – for investigator initiated research and research fellowships; and

- *Linkage* – which supports collaborative research projects, infrastructure, and fellowships undertaken with partner organisations in the private sector and government. A component of this stream also provides funding for several centres of excellence in research priority areas. Such funding can be valuable in contributing to the utilisation and commercialisation of research outputs.

Ministerial direction

The Minister receives the ARC's recommendations on funding and must approve each proposal before it is funded. In 2003, the ARC targeted over a third of annual funding to four areas of research priority: nano-materials and biomaterials; genome/phenome research; complex intelligent systems; and photon science and technology, following a direction from the Minister (sub. 73, p. 28).

Level of funding

The ARC's estimated program budget for 2006-07 is $551.8 million. Of this, $315.3 million or 57 per cent is for Discovery programs and the remaining $236.5 million is for Linkage programs. The previous year's program budget, 2005-06, was slightly higher, $552 million, and an increase on 2004-05's budget of $481 million. (Note that this information revises that shown in table 11.2.)

For grants commencing in 2005, the average Discovery grant was around $258 000 and the average Linkage grant was around $246 000. Discovery grants and Linkage projects are funded from one to five years (ANAO 2006). In 2005, the ARC's advisory committees recommended a smaller number of proposals for funding to increase the average grant size.

The ARC's operating costs as percentage of its program costs were 2.7 per cent in 2004-05 and 3.1 per cent in the previous year (ANAO 2006). (Of course, to the extent that services are provided to the ARC either gratis or below cost, this figure understates the full administrative cost.) A recent report on the 'costs of scholarly communication' (Houghton et al. 2006) estimated that the total cost of higher education related to peer review of ARC and the NHMRC grant applications was about $22 million per annum.

Success rates

In 2005, there were 3414 applications for Discovery grants and over 1500 applications for Linkage project funding (ANAO 2006 and sub. 73). Fewer than one in four proposals submitted for Discovery projects and just over one in three Linkage projects were successful in 2005.

Up and coming researchers

There are no specific ARC programs for 'up and coming' researchers. However, the ARC states that 'fostering the careers of Australia's best and brightest researchers is one of [its] key objectives' (see ARC website). For example, under Discovery-Projects, the ARC identifies targeted funding for early career researchers applying individually or in teams in which all investigators are early career researchers.

How it works

Both the Discovery and Linkage grants operate on an annual cycle that commences with the announcement of the funding rules for applicant eligibility. This is followed by calls for applications, the assignment of applications to assessors, assessment of applications, meetings of college of experts/selection advisory panels, recommendations made to Minister and concluding with the announcement of the funding rounds by the Minister (ANAO 2006).

Eligibility

The ARC Act sets out that only applications that meet the requirements set out in the approved funding rules are to be recommended to the Minister. For example, Discovery project funding rules for projects commencing in 2006 set out that the researcher cannot hold more than two Discovery project grants, may not be named as a Partner Investigator on more than four Discovery grant projects and must be submitted by an eligible organisation.

In the case of Linkage projects, applications can only be submitted by eligible organisations, which according to the ARC funding rules for Linkage projects are all Australian universities. As partner organisations, the commercial organisations of universities, CRCs, public research agencies, State and Territory Government research agencies or any organisations the ARC considers to be substantially funded for research by the Australian Government are specifically excluded (ARC Funding Rules for Linkage Programs commencing in 2007).

Assessment

Once received by the ARC, Discovery Project applications are provided to two College of Expert members, two Australian readers (assessors) and up to four international readers (international assessors). Australian readers receive a nominal payment of $30 per application and international readers receive no payment for assessing applications. Australian readers completed around 90 per cent of applications sent to them and the response rate of international readers ranged from 20 to 40 per cent (ANAO 2006).

These assessors use the following section criteria for Discovery projects:

- Investigator (40 per cent);
  - track record relative to opportunities; and
  - capacity to undertake the proposed research;
- Project content (60 per cent) made up of:
  - significance and innovation (30 per cent);
  - approach (20 per cent); and
  - national benefit (10 per cent).

The selection criteria for all Linkage projects are:

- Investigator(s)
  - Track record (20 per cent)
- Proposed project content
  - Significance and innovation (25 per cent)
  - Approach and training (20 per cent)
  - National benefit (10 per cent)
  - Commitments from partner organisation (25 per cent).

The assessments of Linkage project proposals are undertaken by members of the college of experts.

Following assessment, recommendations for both Discovery and Linkage grants are submitted to the Minister for approval.

There is an appeal process for administrative matters only. The ratings and comments of assessors are not appealable.

NHMRC

The NHMRC is an independent statutory agency established under the National Health and Medical Research Council Act 1992. In response to the ANAO review of governance structures in 2004 and the Investment Review of Health and Medical

Research in the same year, changes were made to the legislation in June 2006 to alter the governance arrangements. Prior to July 2006, the NHMRC was a statutory body corporate run by the Council. The CEO is now responsible for all the day-to-day operations and is appointed by and reports to the Minister for Health and Ageing. The role of the Council of the NHMRC, which previously was responsible for governance of the NHMRC, is to assist the CEO in implementing the NHMRC's strategic plan and provide independent advice on scientific and technical issues (see sub. 80 and Parliament of Australia Bills Digest NHMRC Amendment Bill 2006).

The bulk of NHMRC funding goes to the higher education sector (72 per cent of funding in 2005, but funding also goes to medical research institutes (25 per cent of funding in 2005), and hospitals and other government and non-government research organisations (3 per cent).

Main areas of responsibility and role

The NHMRC's role is to:

- raise the standard of individual and public health throughout Australia;
- foster the development of consistent health standards between the various States and Territories;
- foster medical research and training and public health research and training throughout Australia ; and
- foster consideration of ethical issues relating to health.

It also has statutory obligations regarding the research surrounding human embryos and the prohibition on human cloning.

It provides funding under three categories — researcher support, infrastructure support and research support.

Researcher support includes:

- *Training Fellowships* to allow researchers to undertake research that is of major importance in its field and of benefit to Australian health.
- *Career Awards* to provide support for experienced researchers to undertake research that is both of major importance in its field and of benefit to Australian health.
- *Career Development Awards* to build health research skills, increase knowledge and encourage the growth of knowledge-based industries in Australia.

- *Scholarships* to support Australian health and medical graduates early in their career.

Infrastructure support includes:

- *Enabling Grants* to provide support for specific facilities and/or activities to enhance the national health and medical research effort.
- *Equipment Grants* and *Infrastructure Grants* to provide funding for specific equipment and overhead infrastructure.

Research Support includes:

- *Project Grants* to enable individual researchers or a group of researchers to undertake a scientific investigation in the biomedical, clinical, public health or health services field.
- *Program Grants* support teams of researchers to pursue broadly based collaborative research activities.
- *Strategic awards* provide a mechanism by which the NHMRC can respond to opportunities for pursuing innovative projects and national and international collaborations research.

The NHMRC has a number of other award schemes for specific health issues, including:

- palliative care;
- potential avian influenza-induced pandemic;
- preventive healthcare and strengthening social and economic fabric; and
- type I diabetes.

Ministerial direction

The legislation sets out that the Minister can provide general direction to the CEO only and the 'Minister is not entitled to recommend the allocation of research funds to a particular person, organisation, State or Territory'. The Minister is also not entitled to direct the NHMRC's treatment of a particular scientific, technical or ethical issue. Any general Ministerial direction to the NHMRC is to be tabled in each house of Parliament within 15 sitting days.

Level of funding

The NHMRC's estimated expenditure for 2006-07 is around $450 million. Estimated expenditure in the previous year, 2005-06, was about $432 million and actual expenditure was around $420 million in 2004-05 (see sub. 80, pp. 8–9). In the 2006 Budget, the Government announced an additional $905 million for health and medical research to be spent over the next four to nine years. This includes $170 million over nine years for a new Australian Health and Medical Research Fellowship scheme (sub. 80, pp. 7–8).

By broad research area, in 2005-06, nearly half (49 per cent) of the NHMRC funding was directed to basic science, 28 per cent to clinical medicine and science and 13 per cent to public health. The remainder was directed to health services research and preventative medicine and science and nearly 5 per cent was not allocated (see sub. 80, p. 7).

Of the grants awarded in 2005 and to commence in 2006, 65 per cent went to research support, 24 per cent for researcher support and 11 per cent for infrastructure support (NHMRC 2005a).

Total administrative expenses incurred by the NHMRC (including review of new proposals and managing existing grants) amounted to 4.5 per cent of total grant administration in 2004-05. As with the ARC, this proportion would understate the true amount to the extent that services are provided to it free or below cost.

Success rates

The 'success' rates for the NHMRC programs vary. The following rates are for 2003.

Researcher support:

- Research Fellowships — 119 applications were received, of which 46 (38 per cent) were successful. By comparison, in 2002, 123 applications were received, of which 24 (19 per cent) were successful.
- Career Development Awards — 148 applications were received, of which 39 (26 per cent) were successful. By comparison, in 2002, 135 applications were received, of which 39 (29 per cent) were successful.
- Training Awards — there were 308 applications for Scholarships, with 159 awarded (51 per cent), and 307 applications for Training Fellowships with 91 awarded (30 per cent). By comparison, in 2002, there were 299 applications for

Scholarships with 154 awarded (51 per cent) and 173 applications for Training Fellowships with 82 awarded (47 per cent).

Research support:

- Project Grants — there were 1798 applications for Project Grant funding, of which 407 (22 per cent) were successful.
- Program Grants — there were 27 applications for Program Grant funding, of which 11 (40 per cent) were successful (NHMRC website).

Are up and coming researches provided for?

The NHMRC provides Career Development Awards specifically for researchers in the early stage of their careers and a range of Post-Graduate Scholarships. In 2005, 50 Career Development Awards were granted worth a total of nearly $22 million and there were 155 Post-Graduate Scholarships awarded worth just over $9 million (NHMRC 2005a).

How it works

The NHMRC funding arrangements have been established on a triennial basis, with the current arrangements in place from 2003 to 2006. The applications for grants for the infrastructure support (enabling grants and infrastructure grants), research support (program and project grants) and researcher support (fellowships, scholarships etc.) are undertaken on an annual basis with the funding made available in the following year.

Eligibility

NHMRC research funding is open to most researchers in Australia. Applicants must apply through an NHMRC Administering Institution. University registration as an Administering Institution is automatic. Most other institutions are able to 'self-certify' that they meet specific criteria required by the NHMRC to be accepted as an Administering Institution.

The criteria largely relate to the administration and acquittance of Australian Government funds, and having documented procedures in place relating to such matters as ethics clearances, the proper conduct of research and being able to provide appropriate infrastructure support (NHMRC website).

Assessment

Each year the NHMRC establishes panels which are responsible for the review and ranking of NHMRC grant applications. The panel members also have the opportunity to provide advice to the NHMRC on emerging research developments.

Panel members are experts of high standing drawn from the Australian and international research community, from public and private health and medical research organisations, higher education and industry.

The assessment process usually takes around 6 months. From submission of the application, the peer review process can be broadly summarised as follows:

- allocation of each application to a Grant Review Panel (GRP) and to appropriate spokespersons within that panel;
- the spokespersons write a report on the application which is provided to all panel members;
- the GRP meet to review and determine a category for each application and then rank each application in comparison with all others allocated to the GRP;
- the primary spokesperson writes a final report on the application which is sent to the applicant;
- the outcomes of the GRP meetings are considered by the NHMRC and a funding recommendation sent to the Minister for Health and Ageing; and
- subsequent to Ministerial approval, applicants are advised of the outcome of their applications.

The current funding schemes will cease after the 2006 application round and the number of existing schemes will be reduced to provide efficiency gains in both peer review and the time researchers are required to devote to preparing applications for different schemes. The initial calls for applications under the new schemes will be conducted in 2007, for funding commencing in 2008. The details of the new schemes are yet to be finalised (NHMRC web site).

11.2 Proposed implementation of a Research Quality Framework

Background

Current arrangements for Australian Government support for higher education research funding stem from 2000. Prior to that, block funding was essentially allocated in one bucket as a separately identified part of the operating grant, using a formula-based approach.

A 2003 review of these arrangements — the Fell review (DEST 2004c) — concentrated on block funding, essentially recommending little change to the arrangements which had been put in place two years or so earlier. It considered that the balance between performance based block funding and competitive funding (ARC/NHMRC) should be retained (rec. 5, DEST 2004c, p. 53) — largely on the basis that universities generally opposed a change and that such block funding was already of a 'competitive nature' (DEST 2004c, p. 53).

As well, that review considered that it was important to enhance the quality of research outputs, and proposed that discussions continue about how 'best to undertake cost-effective research quality assessment' (rec. 6, DEST 2004c, p. 53). These comments were made in the context that such improved assessment mechanisms should be used in regard to 'additional research support funding' (rec. 7, DEST 2004c, p. 53).

An Expert Advisory Group subsequently expressed the view that there are deficiencies in the current formula-based approach to block funding allocation and considered that a method based on peer review would be preferable:

> Currently there is no system-wide and expert-based way to measure the quality and impact of research conducted in universities and PFRAs and its benefits to research and the wider community. For example, the existing distribution of university research block funding is based on inadequate proxy measures of quality, eg numbers of publications, external research income and student completions. Clearly these quantity-based measures do not satisfactorily assess the quality of research undertaken in the university sector. The EAG believes that the only assessment process which will enjoy the confidence and consent of the research community is one based on expert review. (RQF 2005, p. 11)

DEST considered that:

> [the existing] indicators appear comprehensive and have the advantage of being reasonably easy to collect. The major disadvantage … however, is that while they incorporate some element of quality, there are actually quite coarse. There is no way to measure gradations of quality, or to compare actual quality across HEPs and across disciplines. (sub. 87, p. 25)

Stemming from that group's report, work has been proceeding towards developing a Research Quality Framework (RQF) for Australia, to be used in the allocation of (block) funding to universities and public sector research agencies. The overall objective of the RQF, as defined in the final advice to the Government:

> … is to develop a broad assessment mechanism of research quality and impact that will be relevant across the full breadth of research organisations in receipt of public

> funding. The RQF will recognise and reward high quality and high impact research wherever and whenever it occurs. (RQF 2005, p. 11)

In effect, the RQF would be used to assess the aggregate research performance of an institution over a *past* specified period of time in terms of both output *quality* and outcome *impact* — the latter broadly defined as 'the extent to which research is successfully applied … to achieve social, cultural, economic and/or environmental outcomes' (RQF 2005, p. 12). Such assessments would then be used in making decisions about *future* funding allocations to the institution. Box 11.2 provides a brief summary of the main features as proposed by the Expert Advisory Group.

In providing its final advice to the Government in December 2005, the Expert Advisory Group recommended that the RQF be implemented in 2007. It envisaged that, initially, one hundred per cent of IGS funding and a minimum of fifty per cent of RTS funding would be allocated on the basis of the RQF. But the advice recognised that a number of 'threshold questions' need to be resolved including taking the size of an institution into account and allowing for variations in the volume and cost of research.

In response, in the 2006 budget the Government announced $3 million in funding to allow:

> … further development of the model and the next phase of the process. The recently appointed RQF Development Advisory Group will advise the Government on how the RQF model, **if adopted by the Government**, could be most effectively implemented. (Bishop 2006b, emphasis added)

Information from DEST (sub. 87, p. 30) indicates that:

- in accordance with advice from the Development Advisory Group, the Minister has proposed that the RQF will come into operation in 2008, with the next exercise after that to be undertaken in 2014;
- under that timeframe, data gathering and assessment would take place in 2008, with financial consequences to flow from 2009.

Some participants' views

Given its current relevance as a policy issue, it is not surprising that several participants commented on the proposed RQF.

No participant explicitly argued against it, although the Australian Academy of Technological Sciences and Engineering expressed 'doubts about the value of such an approach' (sub. 27, p. 13). The Australian Vice-Chancellors' Committee was non-committal, one way or the other. Many participants offered in-principle support, but raised a number of concerns nevertheless. These centred on the proposed assessment of impacts (box 11.3).

Box 11.2 **Features of the RQF proposed by the Expert Advisory Group**

- Institutions to nominate Research Groupings that can be aggregated to Research Fields, Courses and Disciplines (RFCD) Codes, subject to adherence to RQF Guidelines as developed by the RQFIG [RQF Implementation Group];
- Assessment of both the quality of original research outputs and associated impact, within the assessment period for the RQF;
- An expert review-based assessment process overseen by the RQFIG;
- A Research Grouping to provide an Evidence Portfolio (EP), comprising of:
  - A Context Statement detailing the type, composition and focus of the Research Grouping;
  - The 4 ‘best’ outputs of each of the eligible researchers;
  - The full list of Research Outputs produced in the 6 year production period; and
  - Statements of early impact, verified by qualified end-users of research.
- 12 Expert Assessment Panels to develop their own discipline-specific guidelines (consistent with overarching RQF Guidelines) and assess EPs of nominated Research Groupings;
- Panels able to flexibly expand membership and have access to Specialist Assessor Groups to make assessments, as required, particularly for cross-discipline and/or emerging research areas;
- Panels moderated by an RQF Moderation Panel;
- Independent validation of a statistically-significant sample of panel assessments to ensure RQF ratings are appropriately benchmarked both nationally and internationally, coordinated by the RQF Moderation Panel;
- Assessment of quality and impact to be primarily based on the same ‘best’ four Research Outputs per eligible researcher for each Research Grouping over a six-year period;
- Quality to be assessed against a 5-point scale and impact against a 3-point scale;
- Reporting of RQF ratings of quality and impact by Research Groupings, and discipline areas (including profiles of ratings at either 6, 4 or 2-digit RFCD level) for each institution; and
- Funding distributed to institutions based on quality and impact ratings through an appropriate mechanism.

Source: RQF 2005, pp. 7–8.

Box 11.3 Concerns with the proposed RQF

Assessment of quality and impact

> … the RQF criteria of quality and impact are not the only criteria for assessing research, and in some cases are not the most important. (Deakin University, sub. 15, p, 2)

> … the allocation of a single ranking based on aggregate scores for 'Quality' and 'Impact' … is confusing, as these different measures protect interests which are of varying relative importance for different kinds of research. 'Quality' protects the integrity of the process of investigation and knowledge formulation, recognising that this may have unforeseen consequences significant in time. 'Impact' recognises the need for some kind of return on science investment within a finite time frame. (Australasian Institute of Mining and Metallurgy, sub. 71, p. 6)

Application to the humanities and social science

> … it is the really original and untried approach that has the potential to produce greatest long term benefits, both for individual companies and the nation as a whole, but it is this approach that has the greatest risk. (CSIRO, sub. 50, p. 115)

> … very little macro and micro economic benefit analysis has been performed of the contributions of the humanities and creative arts to national innovation. This … is due to the difficulty of measuring the impact of humanities research in such terms. (Australian Academy of the Humanities, sub. 64, p. 7)

> … citation rates should be used with care for all disciplines and especially for many professional disciplines and those focused particularly upon improving the social and economic fabric of Australian society. (CHASS, sub. 52, pp. 12–13)

Importance of impact assessment

> … [the RQF] will focus on research excellence, which will not catch all the important research outcomes. (Deakin University, sub. 15, p. 2)

> … [the] lack of incentives for private sector engagement with universities … could become more of a problem with the introduction of the RQF, if quality is seen as more important than impact. (Australian Vice-Chancellors' Committee, sub. 60, p. 37)

> If implemented without an impact measure, the RQF will reduce the attractiveness of the CRC program … Full implementation of the RQF may lead Australia to return to its 1980s position of generating a higher than expected volume of knowledge, as measured through historic methods, but having a lower than expected commercialisation output and attendant lack of patents, spin-offs and licensing revenues. (Desert Knowledge Cooperative Research Centre, sub. 29, pp. 7, 8)

> … the system must consider impact separate from, and equal to (for the purposes of funding distribution), measures of academic quality. This Academy is most concerned that the importance of impact has been substantially downgraded in the RQF preferred model. (Australian Academy of Technological Sciences and Engineering, sub. 27, p. 13)

Workload for assessors/quality of assessment

> … RQF assessments will be of limited value. Because of the pressure on assessors they will be drawn to processes that offer a quick result … (Deakin University, sub. 15, p. 1)

(continued next page)

Box 11.3 (continued)

Six year time affects incentives

> Using a 6-year historical survey … as an instrument to determine any proportion of 'infrastructure support or block funding' could inadvertently result in a loss of momentum … (Australian Technology Network, sub. 34, p. 4)

Unintended consequences

> … we are concerned that universities will perceive that they are best able to achieve high RQF ratings and secure funding through separating the teaching and research responsibilities of academic staff. This could result in the creation of teaching only or teaching intensive positions, and undermine universities general research capacity and capability. (National Tertiary Education Union, sub. 62, p. 19)

> The IRU Australia strongly cautions against Australia adopting a [RQF] that results in the same unintended consequences of the British RAE on the viability of … [science departments through] a non-linear funding formula … (Innovative Research Universities Australia, sub. 54, p. 8)

> The concern of the South Australian Government is that any framework developed to assess research quality will create an environment that will reward universities for existing research strength and stifle the ability to create innovation in new and emerging areas of research. (South Australian Government, sub. 92, p. 8)

The UK's RAE

It is relevant to note, in the context of considering the relative merits of alternative funding allocation mechanisms (see below), that the United Kingdom has signalled that it is likely to discontinue its RAE (research assessment exercise) process for assessing block funding based on research quality assessment, which has operated for some 20 years — the reasons are briefly summarised in box 11.4. It is likely to move to formula-based approaches — in effect, back towards the current Australian system. In broad concept, the RAE can be considered a somewhat *less* ambitious undertaking than Australia's proposed RQF, which has been designed to consider impacts explicitly, as well as research quality.

11.3 Rationales for different funding streams

The rationale for Australia's current arrangements was spelled out in the 1999 Knowledge and Innovation policy statement by the Government as follows:

> … a dual system of funding for higher education research [would] both … encourage institutions to be more flexible and responsive in developing a strategic portfolio of research activities and research training programmes, and … secure the benefits to be

derived from the endeavours and achievements of individual researchers and teams. (Kemp 1999, p. 9)

Box 11.4 **Research quality assessment in the United Kingdom**

In the UK, the RAE (research assessment exercise) has been used to inform quality-related (QR) research funding for higher education institutions (HEIs) — that is, block funding to institutions based on assessed quality. The next RAE round is scheduled for 2008. As well, funding derives through the Research Councils on a competitive basis at a program and project level.

The proposed Australian RQF could serve a similar role in relation to block funding as does the RAE. A difference to the RAE is that Australia's proposed RQF would explicitly assess outcomes impacts as well as research quality.

Australia is considering introducing its RQF just as the UK, after 20 years experience with the RAE in its various manifestations, has announced that, after 2008, it is to be largely replaced by a formula-based approach. There is a possibility also that the 2008 RAE might be scrapped, in favour of such an approach.

The cited reasons relate to administrative cost, behavioural impacts on the HEIs, deficiencies in detailed peer review procedures, and inability to properly deal with user-focused research. More particularly, a 2003 review of the RAE highlighted:

- the substantial administrative costs of the system (estimated to cost the higher education institutions at least £45 million in 2008);
- difficulties in assessing the less research intensive institutions;
- gaming by institutions in relation to staff recruitment and determining 'active' research staff and publishing to maximise scores; and
- the silo driven approach which has failed to capture the value of interdisciplinary research.

The UK has foreshadowed a simpler system based on research income as one QR allocation possibility — noting that the correlations between QR income and Research Council income, and between QR income and HEI's research income from other sources, are both very strong. (The UK argues strongly that both streams of higher education research funding should continue — see text.)

Source: Draws from HM Treasury 2006, RAE Review 2003.

Further:

We need to strike an appropriate balance in research funding among national needs, institutional capacities and individual interests. In doing this, the Government is establishing a dual funding system of competitive research grants for individuals and their teams, awarded on merit, and block funding to institutions to give them flexibility to adapt to new opportunities and to set their own priorities. (Kemp 1999, p. 14)

Such dual funding 'should be competitive in nature, as simple as possible to administer, and be readily intelligible to researchers, institutions, students and the wider community' (Kemp 1999, p. 7).

DEST considered that:

> One advantage of the dual support system is that it offers governments a range of levers to influence the direction and performance of publicly-funded research and research training. Importantly, a dual support system also supports diversity and system robustness, by allowing a focus on national priorities linked to economic and social aspirations, or a focus on research excellence, to be balanced with the ability to support and maintain strategic research capabilities over the long-term, or develop emerging research areas, irrespective of the availability of competitive funding. (sub. 87, p. 24)

And the ARC commented that the dual funding model:

> … provides for both competitive funding and block funding, and so provides incentives for excellence in higher education research as well as scope for higher education institutions to develop particular research strengths and specialties. (sub. 73, p. 24)

Using similar rationales, the UK Government has described such a dual funding system in that country as a 'key strength' which has helped to deliver 'the UK's world class standing in research outputs':

> The logic behind the dual support system is that it provides two distinct, but related sources of income for university research. The Research Councils [similar to Australia's ARC arrangement] … are able to take a national strategic view, ensuring excellence through peer review, and balancing directive and responsive support. By contrast, [QR] funding [similar to Australia's block funding] allows universities to take strategic decisions about their research activities; builds capacity to undertake 'blue skies' research and research not supported from other sources; creates flexibility to react quickly to emerging priorities and new fields of enquiry; and provides a base from which to compete for research funding from other sources. (HM Treasury 2006, p. 29)

Indeed, many countries utilise both block funding and competitive funding arrangements for higher education research, although comparisons of their reliance on each stream are difficult to make.

In the Commission's view, such rationales are sound. Both block and competitive funding have a number of advantages. For example, block funding allows institutions to specialise and develop strategic capability, can have lower transactions costs in project funding allocation, allows easier identification of outstanding and developing talent, makes it easier for resources to be pooled across projects and institutions and makes funding readjustment and reallocation more flexible. Competitive funding, on the other hand, can contribute more readily to the achievement of national priorities, and can place greater emphasis on excellence and impact.

Thus, in principle, continuation of dual funding arrangements in Australia would appear appropriate subject to the caveats that:

- both streams remain contestable;
- an appropriate balance of funding is maintained;
- allocative criteria minimise gaming possibilities; and
- additional administrative costs, if any, can be kept to reasonable levels.

In regard to administrative costs, funding allocation mechanisms can range in complexity from the relatively simple and cheap (such as formula-based approaches, or approaches based on tacit knowledge) to the relatively complex and expensive (such as extensive formal peer review). In principle, an *additional* layer of 'complexity' arises in the case of block funding, in that funds first need to be allocated to institutions, before allocation to researchers and research groups can be determined. As discussed below, however, in practice, depending on the methodologies adopted, the total costs of allocating block funding may well be less than those for allocating competitive funding.

11.4 The balance of funding

While there are sound rationales for dual funding, in practice existing block funding appears to carry with it little of the proclaimed flexibility.

First, the internal allocation processes of the higher education institutions appear to direct much of their block funding to the departments which generate competitive funding. As advised by DEST (pers. comm.):

> Based on reports in the 2005 RRTMRs [Research and Research Training Management Reports], the majority of HEPs [higher education providers] follow the broad pattern of reserving a proportion of funds centrally – for infrastructure, capacity building projects, internal competitive schemes, scholarships and awards – and award the remainder to the faculties or departments who 'earned' it. DEST states that its research data collection (which records publications and research income) is not intended for use by HEPs as the basis for their own internal funding allocation. Usually the allocation to faculties/departments is done on the **basis of similar indicators that DEST uses to allocate the block grants**, although at a greater level of disaggregation, and often with greater emphasis on certain indicators over others. (emphasis added)

In this respect, the allocation of total funds to the block funding schemes significantly relies on research income — which is determined primarily on a competitive project basis. Indeed, the allocation of one particular block funding component, the RIBG, is directly proportional to Australian competitive grants income, and its total quantum is set by reference to competitive grants funding (sub. 87, p. 26).

Second, the competitive grants schemes effectively lock up a significant proportion of each university's block funds. ARC grants (in aggregate) totalled only 34 per cent of the cost of relevant sponsored research commencing in 2002, with universities contributing 47 per cent, industry 11 per cent and other sources 8 per cent (ARC 2002). Thus, in effect, over 35 per cent of block funding in that year would have been used to support ARC funding[1]. A further component of block funding would similarly have been used to augment funding from the NHMRC. The Group of Eight commented that:

> Institutions that succeed in winning competitive grants through the ARC, NHMRC and other schemes must find funding from other sources to match or 'leverage' the funding available under the competitive schemes. In 2003-04 this cost supplementation was estimated at $450 million for the whole sector … (sub. 68, p. 10)

Similarly, DEST noted that:

> Much of the block grant funding is actually being used to underpin the important research being undertaken with support from competitive schemes. (sub. 87, p. 26)

While reflecting desirable leverage to some extent, the additional funding required from institutions could also be considered to reflect inadequate funding through the competitive stream and to limit significantly the discretionary nature of block funding.

To the extent that the distribution of block funding within institutions correlates with competitive funding and that institutions must allocate block funds to augment competitive funding, a case could be made to discontinue the relevant block funding components and include those funds in the competitive stream. In turn, this would reduce the rationale for implementing an RQF, at least for higher education institutions.

At the other extreme, of course, it could be argued that competitive funding should support fewer projects more fully, thus limiting its draw on block funding. This would then maximise flexibility at the institutional level and, of course, add to the case for more rigorous block funding allocation arrangements.

Apart possibly from one participant that pointed to added costs associated with multiple funding sources, no participants argued solely in support of block funding

[1] Calculated as (47/34*265)/1012 per cent, with $265 million and $1012 million being ARC and block funding, respectively, for 2001-02.

or competitive funding. Some, however, argued in favour of the importance of block funding and, in some cases, for increases in allocations to it (box 11.5).

Box 11.5 **Views on block vs. competitive funding**

One of the key purposes of RIBG and IGS is to allow HEPs to build capacity in areas of emerging or strategic strength, rather than in those areas that already have a track record of excellence or support from other sources. There are concerns in the sector that leveraging funds may limit capacity-building in this regard. (DEST, sub. 87, p. 27)

… the direct costs of research are (inadequately) funded by research grants but the funding of researchers' salaries (eg through fellowships) and the indirect costs of the research program (eg through research infrastructure block grants) are funded by completely different schemes so that consistent and full funding of research is difficult to achieve. A business would not run its R&D program this way! (Association of Australian Medical Research Institutes, sub. 41, p. 7)

The AVCC welcomed the increase in funding provided in Backing Australia's Ability I and II. However, these reports allocate increases in funding to competitive funding schemes and each assumes an effective university research base and adds additional demands to this base. There has been virtually no increase in direct public investment in universities' core research capacity …(Australian Vice-Chancellors' Committee, sub. 60, p. 9)

The ATN would strongly oppose any model of allocation that would focus research funding narrowly, given the need to build and grow a broad research and innovation base. (Australian Technology Network, sub. 34, p. 8)

The IRU Australia strongly recommends that a major component of public support for science and innovation in Australia recognise the long term nature of basic research by allowing certainty and stability in the allocation of research block grants to research active universities. (Innovative Research Universities Australia, sub. 54, p. 2)

… increase the base level of research funding provided to institutions, recognising that we need to encourage a modest level of curiosity-driven research to allow new ideas to develop to the stage where larger peer review research funding mechanisms can work to provide further support. (Professor James Trevelyan, sub. 3, p. 5)

… the balance between competitive and base-line research support funding needs to be re-examined in order to encourage universities to offer structured career paths for young, dedicated researchers and attempt to make working at Australian public universities in this capacity, an attractive proposition. (National Tertiary Education Union, sub. 62, pp. 27–8)

As discussed above, the Commission accepts the rationale for continuing with dual funding streams higher education research in Australia. Consequently, it considers that an appropriate balance of funding should be maintained. In particular, there is considerable merit in maintaining sufficient block funds so that meaningful strategic choices can be made at an institutional level. In turn, this places limits on the extent to which Australian Government block funding can or should be reduced relative to Australian Government competitive funding, particularly given existing constraints on the allocation of block funding within institutions. The Commission considers that the block funding's share of the total should not be reduced further.

The remaining sections of this chapter discuss funding allocation methodologies in more detail.

11.5 Allocating block funds

Different approaches — for example, formula-based approaches and peer review based approaches — should be evaluated in a benefit–cost framework against relevant criteria. A number of issues are relevant:

- the appropriate degree of linkage between quality and impact assessment and future funding;
- the extent to which future funding should be in effect a reward for past performance (track record) as opposed to expectations of future performance;
- which methods best assess past performance;
- which methods best offer incentives for enhanced future performance;
- which administrative approaches are best; and
- which perform best against criteria such as the following:
  - appropriate 'neutrality' across disciplines;
  - minimisation of administrative and compliance costs;
  - minimisation of opportunities for gaming and manipulation;
  - independence of assessment; and
  - transparency of assessment.

In terms of such criteria, formula-based and peer review approaches have a number of general strengths and weaknesses. Possible advantages of a formula-based system relative to a peer review approach include: objectivity; ease of application at an institutional level; lower administrative and compliance costs; and greater transparency. The apparent relative advantages of peer review include: possibly better assessment of quality and impact (at least at a project level); assessment of 'marginal' rather than 'average' projects; and possible application ex ante and ex post. Some more specific comments are provided below.

The existing formula-based approach

The existing approach to allocating block funding is formula-based and backwards looking but nevertheless provides incentives to continue to improve performance as it draws on proxy indicators of quality and impact, albeit indicators considered inadequate by some. It was reconfirmed just as recently as 2003, with some fine tuning of the formulae, in the context of existing funding levels. Further refinement of formulae could be advantageous, for example to better account for the different potential earning capacities and publication rates of different disciplines and sub-disciplines. Even so, an arguable case can be made that, in the absence of objective information to the contrary, the present system already adequately promotes good quality outputs and worthwhile outcomes from higher education research funded through the block system.

This conclusion would be stronger if it could be demonstrated that the universities themselves have robust and effective methods of allocating and monitoring the use of that block funding within their bounds, or that external oversight currently addresses poor performance. In that case, it could be argued that any 'errors' in initial funding distribution to institutions will matter less. Such assurance could come in one of two forms:

- direct assessment of research quality and, where relevant, impact; and/or
- demonstration of appropriate and effective allocation and monitoring procedures, together with effective procedures to address any identified deficiencies.

Direct information about the quality and impact of research funded through block grants is not available. Indeed, DEST commented [pers. comm.] that in regard to research quality and impact, 'it is not useful or possible to consider the block grants and competitive funding in isolation from each other'. As noted above, a significant proportion of block funding currently goes to support competitive funding. To the extent that this is the case, it could be assumed that the *quality* of block funded research (in particular, research to which block funding contributes) is somewhat correlated with peer reviewed research funded competitively. As noted by the ARC, 'decisions made by the ARC and other competitive grant funding bodies will affect the distribution of funding for research and research training in ways that will tend to reinforce the selection criteria applied by those agencies' (sub. 73, p. 27).

This conclusion, however, does not mean that all block funded research is of satisfactory quality nor that overall improvement might not be made through a reallocation of block funding among institutions.

Some procedural information is available through the RRTMRs, but the detail of the most recent reports is not yet public.

In regard to a procedural approach, a parallel can be drawn with arrangements for monitoring/ensuring higher education teaching quality. Funding for that is of the order of some $3 billion annually — nearly three times the block funding total — and yet external quality assurance derives from a program of auditing by the Australian Universities Quality Agency (AUQA — see box 11.6) of the self-accrediting undertaken by the institutions themselves, rather than from an extensive and detailed program of direct quality and impact assessment.

Box 11.6 **The role of the Australian Universities Quality Agency (AUQA)**

- The AUQA is an independent national agency that promotes, audits, and reports on quality assurance in Australian higher education.
- It has four main objects:
  - Arrange and manage a system of periodic audits — with a current cycle of about five years — of QA arrangements relating to the activities of Australian universities, other self-accrediting institutions (SAIs) and state and territory higher education accreditation bodies.
  - Monitor, review, analyse and provide public reports on QA arrangements in SAIs, and on processes and procedures of state and territory accreditation authorities, and on the impact of those processes on quality of programs.
  - Report on the criteria for the accreditation of new universities and non-university higher education courses.
  - Report on the relative standards of the Australian higher education system and its QA processes, including their international standing.
- The indicative scope of the AUQA’s work includes: organisational leadership and planning; teaching and learning; courses; research and consultancies; internationalisation; staff and staff support; student and academic support; and administrative support, facilities and resources.
- AUQA pays attention to such things as:
  - planning documents, including strategic plans, QAIPs [Quality Assurance and Improvement Plans] and RRTMRs;
  - the rigor and effectiveness of performance monitoring against institutional plans;
  - systematic, internally-initiated reviews, including the rigor and effectiveness of the review mechanisms used;
  - course and program approval and monitoring;
  - research activities and outputs;
  - overseas operations and partnerships, including consideration of quality comparability; and
  - relationships with stakeholders.

Source: AUQA (2004).

The proposed RQF

At this stage, weighing up the possible advantages and disadvantages of replacing existing block funding arrangements with funding approaches based on the proposed RQF is not possible. Many of the details of assessment are still to be finalised and/or publicised — importantly including the relative weighting of quality and impact — and its links into funding remain uncertain.

However, some relevant observations can be made. As a process based on comprehensive peer review, the RQF is likely to be a better indicator of quality than the current formula proxies (although this depends critically on assessment and weighting methodology — for example, the extent to which any metrics used continue deficiencies in the present formulae). It is less easy to be conclusive in regard to impact. This depends on a number of factors including: the weight given to impact; whether it is interpreted widely as community impact rather than more narrowly as academic impact; the time period over which it is assessed; assessment methodology; and the skills of assessors. Under some scenarios, it could be argued that the present proxy based approach — with external research funding for example indicating at least an expectation of worthwhile impact — might be better.

There are particular concerns in a number of areas, including the concerns raised by participants:

- possible negative incentive effects through funding six years ahead on the basis of the previous six years' work;
- fine tuning of methodology ('fixing mistakes') will be possible, in effect, only every 6 years;
- the discontinuous funding scales implicit with the very limited number of steps on the proposed quality and impact rating scales;
- the proposed 'quotas' on quality ratings (although, depending on funding relativities, the issue may be more semantic than real); and
- the possible high administrative and compliance costs, although incurred only every six years.

Conclusion

The arguments for discontinuing the existing formula-based approach to the allocation of block funding in favour of an approach based on the proposed RQF cannot be fully tested at this stage.

- Although formula-based approaches to funding do have deficiencies, there is no clear objective evidence pointing to deficiencies in the quality of research currently funded through block grants.
- However, there is evidence that the RQF will bring costs as well as benefits. But the full range of benefits and costs cannot be assessed until there are detailed criteria for quality and impact assessment, methodology for weighting and aggregation, and associated funding formulae. (Implementation aspects are currently being studied by the RQF Development Advisory Group.)

In this circumstance, the Commission would suggest that it is still too early to make a final decision about implementation of the RQF, one way or the other.

DRAFT FINDING 11.1

Consideration should be given to delaying the adoption of the RQF further, while undertaking the following investigations and analyses:

- *continue with limited trials based on RQF peer-review principles, but focus them on providing indicators of the quality and impact of research dependent on block funding;*
- *systematically examine whether current procedures within institutions are sufficiently rigorous to promote quality and impact of block-funded research;*
- *examine what fine tuning of existing formulae, if any, might be advantageous in promoting incentives for continuing enhancement of quality and impact of research funded through block funding; and*
- *examine the merits of externally applied, risk-minimisation approaches to enhancing the quality and impact of block-funded research (applied in conjunction with formula-based funding).*

Under the last approach an external auditor, for example, might identify areas of deficiency in institutions, which would then be encouraged to lift their game over the period ahead. Failure to do so would result in significant funding penalties. Institutions operating satisfactorily would be subject to less frequent assessment than those with problems. Such a process would appear to have strong advantages over the proposed RQF in terms of both incentive effects and administrative costs.

This process would be somewhat like that currently used by the existing AUQA in relation to auditing the quality of teaching. (As box 11.6 notes, the AUQA already has some role in relation to research.) But it could extend beyond a paper based assessment of procedural documentation, to processes of selective peer review, for example.

In making this suggestion, the Commission is not making any inference that the AUQA would be an appropriate body to undertake such a role, nor any judgment about the quality of teaching in higher education institutions, nor the processes used by those institutions themselves and the AUQA in monitoring and enhancing teaching quality. Nevertheless, prima facie, if a risk management auditing approach to ensuring $3 billion annually of teaching expenditure is satisfactory (at least in principle, if not necessarily in practice), then serious investigation should be given as to why it would not be satisfactory in regard to $1.1 billion annually of research block funding.

Such an investigative process should deliver information about: quality of research currently funded through block grants; administrative, compliance and efficiency costs likely to be associated with full implementation of the RQF or a similar methodology; whether existing formulae can be improved; and the merits of alternative risk based auditing approaches. A more fully informed decision about the RQF could then be made.

11.6 Allocating competitive funds

Some participants considered there are a number of deficiencies in existing peer review arrangements (box 11.7). As noted in the introduction, however, the Commission is not examining the strengths and weaknesses of peer review processes for existing programs.

Leaving aside the issue of whether existing arrangements can be improved, there is no feasible alternative to expert review or peer review methodology for allocating competitive funds to projects and at the sub-institutional level. Thus, the central issue in allocating Australian Government competitive funding hinges on how many separate programs to establish and, in particular, the advantages and disadvantages of continuing with both the ARC and the NHMRC.

Almost all arguments *against* amalgamation of these two agencies can be readily refuted:

- the two current separate sources of funding — DEST and Health and Ageing — could be easily pooled:
- even if assessment of medical research proposals, or basic vs. applied research, requires different procedures (for example, in regard to ethics issues), there is no convincing reason why this could not be successfully undertaken under the ultimate jurisdiction of the one agency;

Box 11.7 **Comments on ARC and NHMRC assessment processes**

Anyone with experience of, for example, assessment processes of the Australian Research Council since work on the RQF began will know that judgements will be strongly influenced by the source of funding for the work including whether there was significant funding through schemes on the Australian Competitive Grants Register. (Deakin University, sub. 15, p. 2)

… concern with the apparent current move to non-external peer review by the National Health and Medical Research Council (NHMRC). Without external influence as part of the review process, peer review runs the danger of being dominated by conservatism — backing the established investigator, rather than the emerging and less well known investigator, and threatening the growth of innovation … (Australian Technology Network, sub. 34, p. 9)

When funding is limited, the efforts to use it 'effectively' multiply. Typically this sees the development of a peer review system dominated by senior experts. Such approaches tend towards decisions favouring high quality but conservative research. The decision processes of the Australian Research Council illustrate this approach well. (Deakin University, sub. 15, pp. 2–3)

[it has been contended that] under the ARC system one has to apply for funding on the basis of research that has already been completed. Only then does one have the publication record and detailed arguments to explain why the research was necessary in the first place and to establish the required track record needed to win a grant. (Professor James Trevelyan, sub. 3, p. 4)

- the higher workload of a combined agency is no argument against combination, given the delegated committee based approaches to assessment used by both agencies currently;
- similarly, there is no clear argument why a combined agency would not be as competent to distribute funds beyond the higher education sector, as the NHMRC is at present;
- the medical educative and other functions of the NHMRC could easily be split off, say to Health and Ageing itself; and
- if there were concern that a combined agency would downplay medical research, the Minister could issue directions (as is already done in relation to the ARC).

But what, if anything, are the deficiencies with the present arrangements?

- There may be some small saving in administrative overheads if the two agencies are combined.
- Similarly, to the extent that a small number of applicants currently apply for funding from both the ARC and the NHMRC, there might be some compliance savings from combination.

- Potentially, the most serious deficiency is the inability under present arrangements to trade off the merits of medical and non-medical research projects, at the margin. To the extent that it is not constrained by ministerial direction, the ARC currently has that ability in relation to tradeoffs across the non-medical disciplines. However, any gain in this regard from combination would be limited by the possibility that funding for medical research would be quarantined, even in a combined arrangement.

The Commission has concluded that, in the absence of clear evidence of significant deficiencies in present arrangements, there would be little, if any, gain from combining the ARC and the NHMRC.

APPENDIXES

A Participation

A.1 Informal discussions

Alcatel Australia

Australian Academy of Science

Australian Centre for International Agricultural Research

Australian Chamber of Commerce and Industry

Australian Graduate School of Management Innovation Policy Panel

Australian Institute for Commercialisation

Australian Institute of Nuclear Science and Engineering

Australian Nuclear Science and Technology Organisation

Australian Research Council

Australian Society for Medical Research

Australian Technology Network of Universities

Australian Vice-Chancellors’ Committee

Australian Wine Research Institute

Baker Heart Research Institute

Barlow, Dr Thomas

Brisbane Technology Park

Business Council of Australia

Commonwealth Serum Laboratories

Commonwealth State and Territory Advisory Council on Innovation

Cooperative Research Centres Association

CSIRO

Dairy Australia

Defence Science and Technology Organisation

Department of Education, Science and Training

Department of Industry, Tourism and Resources

Federation of Australian Science and Technology Societies

GlaxoSmithKline Australia

Grape and Wine Research and Development Corporation

Group of Eight
Innovative Research Universities Australia
Insight Economics
IP Australia
Melbourne Institute of Applied Economic and Social Research
National Health and Medical Research Council
National Tertiary Education Union
New South Wales Government
New Zealand High Commission
Orica
Pilat, Dirk (OECD)
Rural Research and Development Corporations
South Australian Government
South Australian Research and Development Institute
Uniquest
University of South Australia
Victorian Government

A.2 List of submissions

Participant	*Submission number*
ARC Centre for Excellence for Creative Industries	20
Association of Australian Medical Research Institutes	41
AusBiotech	95
Australasian CRC for Interaction Design	69
Australasian Institute of Mining and Metallurgy	71
Australia Council for the Arts	75
Australian Academy of Science	24
Australian Academy of Technological Sciences and Engineering	27
Australian Academy of the Humanities	64
Australian Biosecurity Cooperative Research Centre for Emerging Infectious Disease	37
Australian Business Foundation	72

Participant	*Submission number*
Australian Centre for International Agricultural Research	81
Australian Electrical and Electronic Manufacturers' Association	51
Australian Institute for Commercialisation	4, 6, 28
Australian Institute of Marine Science	61
Australian Marine Sciences Association	35
Australian Research Council	73
Australian Society for Medical Research	36
Australian Technology Network	34
Australian Vice-Chancellors' Committee	60
Baker Heart Research Institute	40
Biota Holdings	94
Bougias, Mr George and Dr Anand Kulkarni	59
Business Council of Australia	58
Business Outlook and Evaluation	90
Business, Industry, and Higher Education Collaboration Council	55
CAMBIA	42
Commonwealth State and Territory Advisory Council on Innovation	98
Community and Public Sector Union	39
Cooperative Research Centres Association	11
Cotton Catchment Communities CRC	74
Council for the Humanities, Arts and Social Sciences (CHASS)	52
Council of Rural Research and Development Corporation Chairs	96
CRC for Beef Genetic Technologies, CAST CRC, CRC for Innovative Dairy Products, CRC for Forestry, CRC Mining, CRC for the Australian Poultry Industries, the Australian Sheep Industry CRC, Vision CRC	85
CRC for Spatial Information	32
CSIRO	50
CSIRO Staff Association	78
Cutler, Dr Terry	43
Deakin University	15
Department of Agriculture, Fisheries and Forestry	100

Participant	*Submission number*
Department of Agriculture and Food (Western Australia)	44
Department of Communications, Information Technology and the Arts	101
Department of Economic Development (Tasmania)	97
Department of Education, Science and Training	87
Department of Health and Ageing	105
Department of Industry and Resources (Western Australia)	82
Department of Industry, Tourism and Resources	93
Department of Premier and Cabinet (Tasmania)	103
Desert Knowledge Cooperative Research Centre	29
Engineers Australia	65, 88
Federation of Australian Scientific and Technological Societies	83
Fitzgerald, Prof. Brian	21
Gans, Prof. Joshua S	10
GlaxoSmithKline Australia	38
Gourley, Mr Colin	1
Graeme Pearman Consulting	86
Griffith University	7
Group of Eight	68, 104
Industry Research and Development Board	77
Innovation Economy Advisory Board	89
Innovative Research Universities Australia	54
Institute of Public Affairs	30, 76
Invasive Animals CRC	57
Jensen, Dr Paul, Dr Alfons Palankaraya and Dr Elizabeth Webster	9
Lawson, Dr Charles	5
Livingstone, Ms Catherine	56
Lyons, Prof. Lawrie	8
Macquarie University	47
Medicines Australia	99
Meridian Connections	26
National Committee for Mathematical Sciences	25
National Health and Medical Research Council	80

Participant	*Submission number*
National Tertiary Education Union	62
New South Wales Board of Vocational Education and Training	67
New South Wales Government	91
Northern Territory Government, the Northern Territory Research and Innovation Board and Charles Darwin University	23
Office of the Privacy Commissioner	63
Potts, Dr Jason	18, 19
Queensland Nanotechnology Alliance	48
Research Australia	33, 102
Research International	13
Rio Tinto	46
Roach Industries	12
Rooney, Dr David and Dr Tom Mandeville	2
Schibeci, Associate Prof. Renato and Dr Jeffrey Harwood	66
Science Industry Australia	22
Society for Knowledge Economics	53
South Australian Government	92
Standards Australia	70
State Government of Victoria	84
TGR BioSciences	16
Trevelyan, Prof. James	3
University of Canberra	45
University of New England	17
University of Sydney	79
Volterra Pacific	49
Walter and Eliza Hall Institute of Medical Research	31
Winemakers Federation of Australia	14

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B Major Australian Government support

DEST publishes detailed data annually on major Australian Government support for science and innovation through the budget and other appropriations. The estimates given are the cost to taxpayers, which can be different from the amounts of eligible expenditure recorded for specific programs from other data sources. For example, the budget papers record the subsidy equivalent value of the R&D Tax Concession, not the total amount of business spending eligible for the concession. For the 125 per cent component of the Tax Concession, the government contribution equivalent is approximately the additional deduction rate allowed times the corporate tax rate (0.25* 0.30) or only 7.5 per cent of eligible spending. In some instances, such as the R&D Tax Offset, the budget papers do not provide an estimate of the cost to taxpayers.

The Commission has used the DEST data to re-classify the policy measures into four categories, and these are shown in the tables below. Only measures that involve some funding after 2003-04 are included (whereas the original DEST tables include many lapsed programs that record successive zero values for these years). The data for 2005-06 are the estimated actual, while those for 2006-07 are budget estimates.

Table B.1 **Support for industry performed R&D**

Programs that are active for some period after 2003-04

Measure	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
R&D Tax Concession	580.0	615.0	650.0
Commercial Ready Programme[a]	152.1	152.5	199.0
Food Innovation Grants National Food Industry Strategy	10.8	15.4	13.1
Automotive Competitiveness and Investment Scheme	128.0	194.0	238.0
Shipbuilding Innovation Scheme	2.1	0.0	0.0
Motor Vehicle Producer R&D Scheme	0.0	6.6	9.0
R&D Start Loans Programme	10.4	8.0	0.0
Pharmaceutical Partnerships Programme	4.2	10.2	31.6
Total	**887.6**	**1001.7**	**1140.7**

[a] Commercial Ready provides some finance for commercialisation of already developed ideas, but principally acts as a support mechanism for R&D for commercially promising products in small and medium enterprises.

Source: DEST 2006, *The Australian Government's 2006-07 Science and Innovation Budget tables*, Canberra.

Table B.2 **Australian Government business commercialisation and diffusion programs**

Programs that are active for some period after 2003-04[a]

Measures	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
New Industries Development Programme	3.5	2.6	2.3
Building Information Technology Strengths (BITS) – Incubators	12.6	10.6	7.5
BITS – Advanced Networks Programme	8.0	7.0	5.0
Renewable Energy Commercialisation Programme	2.7	3.1	0.7
Renewable Energy Equity Fund	3.2	1.5	1.1
Greenhouse Gas Abatement Programme	12.9	15.7	21.6
Low-Emissions Technology and Abatement	2.5	7.0	9.4
Low-Emissions Technology Demonstration Fund	1.7	2.1	52.0
Commercialising Emerging Technologies (COMET)	7.9	8.4	10.3
Innovation Investment Fund	19.6	16.5	18.4
Industry Co-operative Innovation Programme	0.0	2.2	4.7
Innovation Access Programme – Industry (IAccP)	2.3	0.0	0.0
Pooled Development Funds	7.0	7.0	7.0
National Measurement Institute	8.0	8.0	8.0
Total	**91.9**	**91.7**	**148.0**

[a] Included are measures used to diffuse technologies, best practice or information to business, as well as financing measures for commercialisation.

Source: DEST 2006, *The Australian Government's 2006-07 Science and Innovation Budget tables*, Canberra.

Table B.3 **Other industry-centred R&D programs not typically undertaken in industry**

2004-05 to 2006-07

Measures	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
CSIRO	577.1	593.9	607.2
Pre-Seed Fund	6.7	13.4	12.0
Australian Animal Health Laboratory	6.8	6.9	7.0
Geoscience Australia	100.9	107.4	113.0
Wool Research	13.7	16.2	16.2
Meat Research	35.6	36.3	36.3
Fishing Industry Research	31.7	32.8	28.0
Grains	35.1	35.1	36.0
Horticulture Research	30.0	32.9	32.9
Land & Water Research	12.5	12.5	12.8
Rural Industries R&D Corporation	17.3	17.1	20.0
Other Rural Research	37.7	37.8	39.2
Centres of Excellence National Food Industry Strategy	3.4	2.4	2.3
Centres of Excellence Biosecurity Risk Analysis & Research	0.4	1.7	1.7
ICT Centre of Excellence	17.2	23.5	24.0
Information Technology Online (ITOL)	1.9	2.3	1.3
Australia Council Synapse Program	0.0	0.3	0.3
Cooperative Research Centres Grants	194.6	208.2	189.4
Advanced Electricity Storage Technologies	0.4	3.8	5.9
Wind Forecasting Capability	1.2	5.2	4.8
Biotechnology Centre of Excellence	5.8	7.1	6.5
Small Scale Mammalian Cell Production Facility	0.0	0.0	2.5
Total	**1130.0**	**1196.8**	**1199.3**

Source: DEST 2006, *The Australian Government's 2006-07 Science and Innovation Budget tables*, Canberra.

Table B.4 **Non-industry centred R&D programs**

2004-05 to 2006-07

Measures	*2004-05*	*2005-06*	*2006-07*
	$m	$m	$m
Anti-doping Research Program (ADRP)	0.6	1.1	2.9
Major National Research Facilities	42.3	42.3	0.0
National Collaborative Research Infrastructure Strategy	0.0	13.2	98.2
International Science Linkages	9.3	10.2	9.6
Research Evaluation and Grants for Learned Academies	2.2	2.0	2.0
Capital Works for John Curtin School of Medical Research	0.0	50.0	0.0
Australian Biological Resources Study	3.0	3.0	3.0
Climate Change Science Programme	6.7	6.9	8.6
Emissions Measurement and Analysis	7.4	8.8	8.8
Marine Research	1.8	2.1	1.8
Commonwealth Environment Research Facilities	0.0	4.8	22.1
Bilateral Climate Change Partnerships Programme	0.2	0.1	0.8
NHMRC Research Grants	369.4	403.5	437.6
Capital Works for Medical Institutes	4.1	2.0	0.0
Health Sciences Australian Longitudinal Study on Women's Health	1.1	1.4	1.4
Health & Medical Research Overhead infrastructure Support	10.1	27.0	28.0
Medical Research Infrastructure Projects	0.0	215.0	0.0
Research Support for Counter Terrorism	1.0	2.0	2.1
Payments to Austroads/ARRB Transport Research Ltd.	1.9	2.4	2.4
Australian Research Council	480.9	546.2	570.3
Performance Based Block Funding	1178.0	1234.7	1214.3
Estimate of Other Research and Research Training Support Sourced from the Commonwealth	587.0	447.7	447.7
Defence Science and Technology Organisation	314.4	349.1	340.7
Australian Nuclear Science & Technology Organisation	167.5	138.1	129.7
Australian Institute of Marine Science	22.5	23.1	23.6
Anglo-Australian Telescope	4.1	4.6	4.7
Antarctic Division	86.5	94.6	99.7
Bureau of Meteorology Research Centre (BMRC)	11.0	11.7	12.0
Environmental Research Institute of the Supervising Scientist	7.8	7.5	7.9
Great Barrier Reef Marine Park Authority	6.0	6.1	6.1
National Oceans Office	2.1	0.0	0.0
Total	**3328.9**	**3661.2**	**3486.0**

Source: DEST 2006, *The Australian Government's 2006-07 Science and Innovation Budget tables*, Canberra.

C International comparisons and R&D targets

This appendix provides analysis and data to support the discussion and conclusions set out in chapter 8 in regard to:

- the appropriate role of R&D spending targets for Australia; and
- the appropriate interpretation of differences between Australia's R&D intensities and those of other OECD countries.

The nature and levels of R&D targets adopted for a range of OECD countries as well as their underlying rationales are examined first followed by an assessment of whether they are likely to be achieved. Australia's performance relative to actual, and targeted R&D, levels for other countries is then examined, and country-specific differences are also explored. The key issues of the impact of differences in industry structure on R&D intensity across OECD countries and changes in industry structure over time are considered in some detail. Other factors affecting international comparisons of R&D spending such as firm size, wage rates and public support for BERD are also canvassed.

C.1 OECD R&D targets

Almost all OECD countries have employed targets for science and innovation policy in recent years. Total R&D spending is the indicator generally targeted, as opposed to broader measures of innovation, largely because it is more readily quantifiable as detailed R&D statistics have been available in many OECD countries for over four decades (OECD 2004b). The ratio of gross expenditure on research and development (GERD) to GDP is the most common R&D intensity measure for both domestic targeting and international comparisons. This provides a simple means of comparing R&D spending across different sized countries.[1]

[1] Caution should be exercised in interpreting this ratio, as R&D spending and GDP are not directly comparable measures. The former is a gross expenditure measure while the latter is a measure of value-added. Hence, R&D/GDP does not constitute the proportion of GDP devoted to R&D. R&D intensity can also be calculated as the *net* addition to R&D stock as a percentage of GDP. This measure will differ from GERD/GDP ratios unless the depreciation rate used in the

Although total national R&D intensity is the primary focus for the majority of countries, the targets are generally split into public and private components.

An examination of R&D targets adopted across 30 OECD countries in recent years indicates that around three-quarters of all targets fall within a range of 1.5–3 per cent of GDP (table C.1). On average, OECD countries set targets just under one percentage point higher than their R&D intensities current at the time the targets were announced — which translates into an increase in R&D intensity of 50-100 per cent for most countries. The most common target level chosen is 3 per cent, reflecting the overall European Union R&D intensity target of 3 per cent of GDP by 2010 agreed by the European Council as part of its 'Lisbon strategy' for economic revival and announced in Barcelona in 2002 (European Union 2002).

In setting the target, the European Council acknowledged that different levels of spending on science and innovation were appropriate for member countries and rejected a 'one size fits all' approach. Instead, each member country was expected to determine how best to contribute to the overall target. Latest individual member country targets reported at the Brussels European Council in March 2006 indicate that:

- Austria, Belgium, Denmark, Germany, France, Luxembourg, Norway and the Netherlands are each aiming to meet the 3 per cent target;
- Sweden and Finland, which are already above the 3 per cent level — and were at the time the Barcelona target was announced — are aiming for 4 per cent by 2010;
- Greece, Portugal, Spain, Italy, Ireland and the United Kingdom have clearly aimed lower than the Barcelona target, aiming for targets in the range of 1.5–2.5 per cent; and
- a number of the new member states[2] have set even lower percentage targets (0.75–1.5 per cent), although in terms of total increase, their targets often required doubling or trebling their current investments (table C.1).

Among the non-EU OECD countries, Canada has specified an ordinal, or ranking-based, target rather than a precise figure. Canada is aiming to achieve an R&D intensity level within the top five in the OECD by 2010. Based on current levels this would amount to around 2.9 per cent of GDP. However, the precise level Canada

perpetual inventory method (PIM) calculations underlying the R&D stock is zero. As this method is generally not used for target setting or for international comparisons it is not employed here.

[2] On 1st May 2004 ten additional states joined the EU — Cyprus, the Czech Republic, Hungary, Poland, Slovenia, Slovak Republic, Estonia, Lithuania, Latvia, and Malta.

will need to achieve to meet this target is unclear as it depends on changes in R&D intensities in other countries.

Table C.1 **R&D targets and expenditures, selected OECD countries**[a]
GERD/GDP, per cent

Country/region	*R&D intensity in 2004*	*Target*	*Target date and characteristics*
Austria	2.26	3.00	2010
Belgium	1.93	3.00	2010
Canada	1.96	Top 5 OECD	2010
Cyprus	0.37	1.00	2010
Czech Republic	1.28	2.06	Target of 1% public R&D with estimated 1.06% of private expenditure in 2010
Denmark	2.61	3.00	Target of 1% public R&D in 2010
Estonia	0.91	1.90	2010
Finland	3.51	4.00	2010
France	2.16	3.00	2010
Germany	2.49	3.00	2010
Greece	0.58	1.50	2010
Hungary	0.89	1.80	Increased participation of private sector by 2010
Ireland	1.20	2.50	2013
Italy	1.14	2.50	2010
Korea	2.63	Double spending	2007
Latvia	0.42	1.50	2010
Lithuania	0.76	2.00	2010
Luxembourg	1.78	3.00	2010
Malta	0.27	0.75	2010
Netherlands	1.77	3.00	2010
New Zealand	1.16	..	Target of OECD average (0.68%) for public R&D — no year specified
Norway	1.75	3.00	Target of 1% public and 2% private R&D by 2010
Poland	0.58	1.65	2008
Portugal	0.78	1.80	Target of 1% public R&D and tripling of private R&D by 2010
Slovenia	1.61	3.00	2010
Slovakia	0.53	1.80	2010
Spain	1.07	2.00	2010
Sweden	3.74	4.00	Target of 1% public R&D and unchanged private R&D by 2010
Turkey	0.66	2.00	Target of 1% public R&D and 1% private R&D by 2010
United Kingdom	1.79	2.50	2014

a Values for Italy, Korea, Luxembourg, Norway and Portugal refer to 2003. Value for Turkey refers to 2002.

Data sources: Council of the European Union 2006, Eurostat 2006 (accessed June 2006), OECD 2004c, New Zealand Ministry of Research, Science & Technology Budget Speech (May 2006).

While New Zealand has not targeted total R&D intensity, the New Zealand Minister for Research, Science and Technology recently announced the Government's aim of achieving OECD average public R&D spending levels (0.68 per cent of GDP), although he also stated that additional public spending is contingent on further policy consideration and overall budgetary constraints (New Zealand Ministry of Research Science and Technology (MORST) 2006). This represents a softening of its previous public spending target of 0.8 per cent of GDP identified in its 2000-01 budget (Hodgson 2000).

It is interesting to note that apart from Australia, the only other OECD countries that do not employ empirical R&D targets are the two largest R&D performers, the United States and Japan.[3] Despite ongoing domestic debates about the appropriate level of government commitment to science and innovation in the United States, spending targets do not appear to have played an important part of its national science and innovation policies.[4]

Rationales and choice of targets

Stated rationales for choosing to target R&D were fairly consistent across countries. Invariably, the adoption of R&D targets begins with a recognition of the importance of innovation for productivity growth and economic prosperity. A strong link is then drawn between R&D spending and innovation and productivity growth.[5] The EU, for example justified the overall desirability of increasing R&D intensity on the basis of the positive link between R&D spending and multifactor productivity growth (EU 2002). A key study cited in the EU Barcelona announcement based on panel data for 16 OECD countries over the period 1980–1998 found that a 1 per cent increase in business and public R&D generates 0.13 per cent and 0.17 per cent rises in national productivity respectively (Guellec and Van Pottelsberghe 2001). Guellec and Van Pottelsberghe, however, urged caution in drawing policy conclusions, noting that their work was undertaken at a very aggregated level and that any policy lessons should be confirmed by more detailed country level studies. This study was also cited in support of the Canadian and United Kingdom target announcements (HM Treasury 2004, Government of Canada 2001).

3 Although the Japanese *Basic Law on Science and Technology* (1995) mandates that the government prepare a science and technology plan every five years which outlines planned public R&D investments over the medium term (JETRO 2005).

4 For a discussion of science and innovation policy in the United States see National Science Foundation (2006).

5 See for example, EU (2002); HM Treasury (2004); Government of Canada (2001).

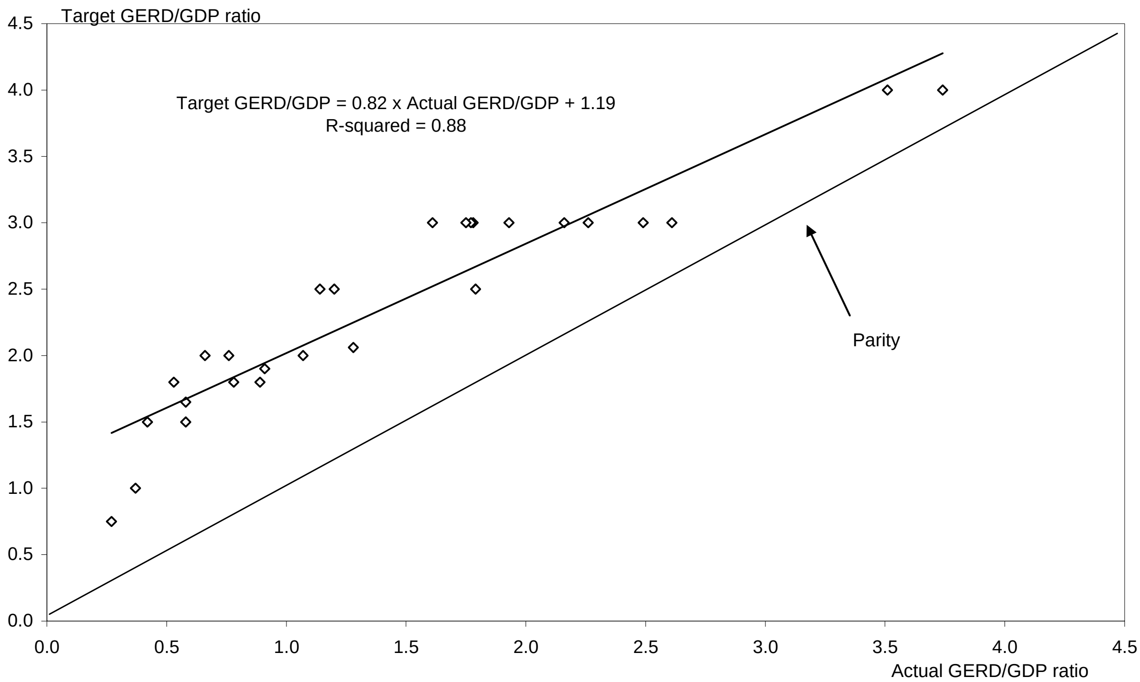
Another factor frequently cited in support of R&D targeting is the need to 'keep up' with 'leading' R&D performing countries or at least to match OECD averages (which are largely driven by the performance of a few key players in any case). Indeed, the desire to maintain or improve relative rankings, rather than empirical analysis, appears to be a key factor in setting the actual level of the target. For example, in announcing the Barcelona target, the European Council noted (EU 2002, p. 5):

> At present, less than 2 per cent of Europe's wealth (GDP) is devoted to research, which compares badly with 2.5 per cent in the USA and more than 3 per cent in Japan … The European Council therefore agrees that overall spending on R&D and innovation in the Union should be increased with the aim of approaching 3 per cent of GDP by 2010.

Clearly, the choice of the target at 3 per cent, as opposed to say, 2.9 per cent or 3.1 per cent, was not empirically based. This was the case across the OECD, with most countries selecting round number targets between 0.5 and 1.5 percentage points higher than their actual R&D spending levels (figure C.1).[6]

Figure C.1 **OECD targets compared with actual R&D intensities**

Per cent, 2004 or nearest available year



Data source: Table C.1.

[6] The average difference between actual and targeted R&D intensity across the OECD was 0.94 percentage points. However, the percentage point difference between actual and targeted R&D intensity declines slightly with increases in actual R&D intensity (ie the slope of the line of best fit was less than one).

The way the EU target was articulated, 'approaching 3 per cent', reflects the fact that the precise level of R&D intensity is not the focus. What is important is raising R&D. For example, when the EU target was announced, both Finland and Sweden were already spending substantially more than 3 per cent of GDP on R&D. However, the target was clearly never intended to suggest they put in place policies to limit their national R&D spending to 3 per cent of GDP. In this sense, the targets are asymmetric in character, reflecting a view that higher national R&D is always a positive sign.

The European Commissioner for Science and Research, Janez Potocnik, recently emphasised the dual role of R&D intensity as both a policy goal as well as an indicator of national success (2006, p. 2):

> When we talk about the 3 per cent goal, we have to be aware it is not just a goal, it is also an indicator of whether we are doing things in the right way. … Increasing investment in R&D will not in itself guarantee success — it is also a question of how we invest. But if we don't invest, we are guaranteed to fail.

Hence, R&D targets employed across OECD countries are more appropriately viewed as fundamentally aspirational policy instruments, rather than empirically based economic assessments of the optimal level of resources each country should be devoting to R&D.

Are the targets likely to be achieved?

The relatively recent commitment to targets by most countries coupled with the lack of up-to-date R&D statistics means that care must be taken in assessing whether specific countries are on track to achieve their targets. Nevertheless, it is possible to gain a sense of whether existing R&D targets taken as are group are likely to be achieved.

In most cases, business was accorded the lion's share of the task of achieving the R&D targets. Hence, several commentators have examined these questions by examining factors such as industry structure, firm size and investment intentions and the availability of skilled personnel.

The European Commission announced that two-thirds of the additional growth required to achieve the Barcelona target should come from the private sector. Given the starting shares, this represents a 1 per cent public R&D spending target and a 2 per cent BERD spending target. In response, the European Round Table of Industrialists, an association of leaders from 42 companies that represent around 13 per cent of total European R&D spending, expressed doubts about whether the target was realistic. They also noted that an internal survey of their member companies revealed that few had expectations of substantially increasing their R&D investments in the coming years and concluded that 'unless there is a dramatic reappraisal of Europe's approach to R&D and its framework conditions for business, the gap between the Barcelona target and the real world will not be bridged by 2010' (ERT 2002).

Other commentators have also expressed doubts about the feasibility of the EU as a whole achieving its 3 per cent target as well as whether a number of individual EU countries are likely to achieve their targets. Sheehan and Wyckoff (2003), for example, examined the economic and policy implications of the Barcelona target. They found that given the labour intensive nature of most R&D, a key constraint would be the supply of suitably skilled researchers, estimating that meeting the target would require the addition of 500 000 to 600 000 workers by 2010. They also highlighted the substantial social and economic challenges associated with achieving the target.

Arundel and Hollanders (2005) studied detailed industry structure data for a selection of 13 EU countries which combined account for around 95 per cent of EU R&D. They concluded that the 2 per cent BERD intensity goal is unrealistic and unachievable by 2010, or indeed, by 2015, noting that meeting the target would require 'massive and economically painful' changes in the structural distribution of sectors within Europe.

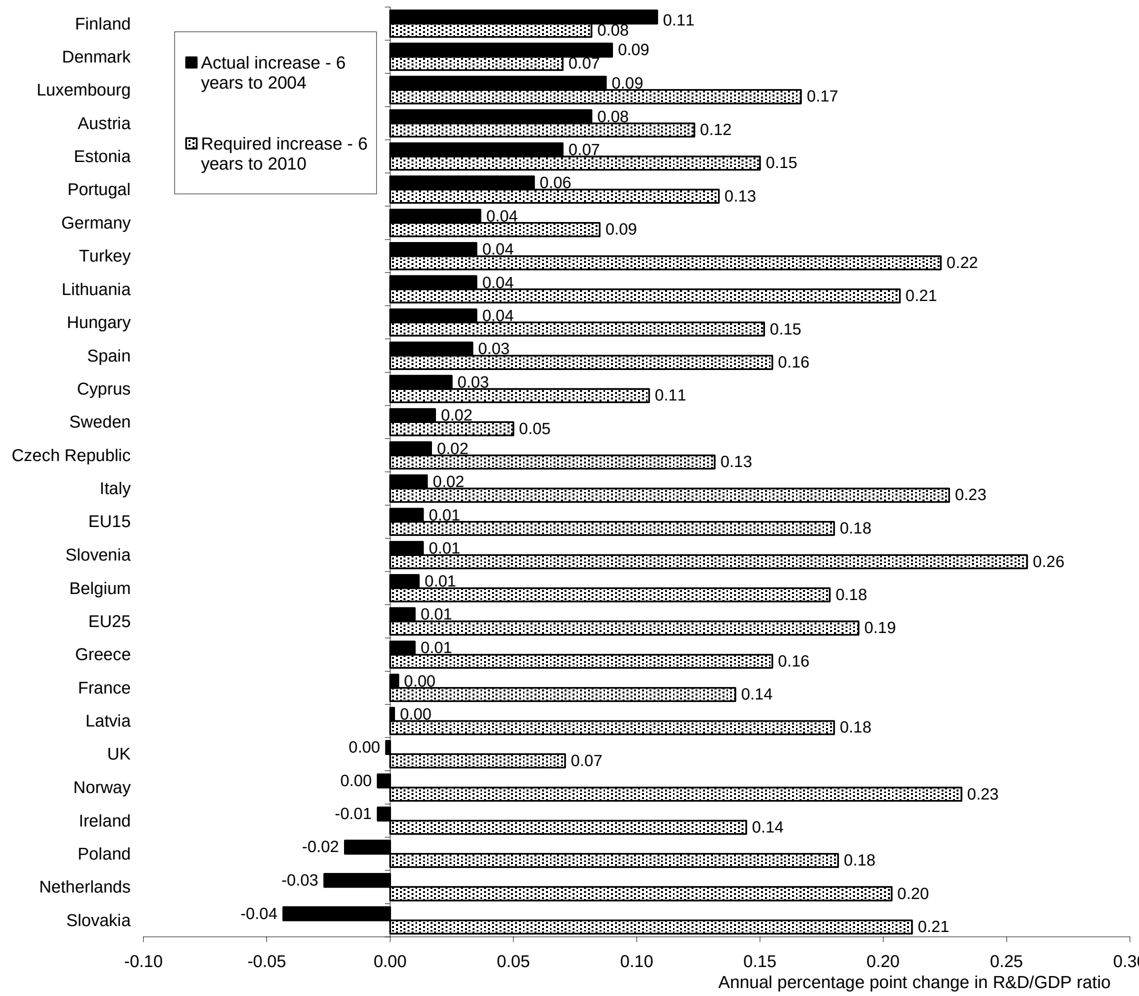
Indeed, latest Eurostat R&D data suggest that the EU as a whole is *not* on track to meet the target. In fact, the overall EU25 R&D intensity has actually declined since the Barcelona target was announced, falling from 1.90% of GDP in 2002 to 1.86% in 2004 (provisional). Even when the 10 EU member countries that joined in 2004 are excluded, R&D spending for the original EU15 is not on track to reach 3 per cent by 2010. EU15 R&D declined from 1.95 per cent of GDP in 2002 to 1.92 per cent of GDP in 2004.[7]

An examination of changes required to meet individual country R&D intensity targets across the OECD between 2004 (latest available data) and 2010 compared with the actual changes achieved in the previous six years illustrates how ambitious most countries' targets are (figure C.2). While explicit R&D targets for each country had not been articulated at the start of the period (1998), the importance of R&D has been widely recognised across OECD countries for many years. For most countries, the required boost in R&D intensity in the six years to 2010 is substantially larger than the increases achieved over the past six years. Overall, only

[7] These data are close but not identical to the OECD R&D data employed elsewhere in this appendix and are used as they contain a more complete set of estimates for 2004.

two countries, Finland and Denmark, achieved growth in R&D intensities commensurate with the increases required to meet their 2010 targets.

Figure C.2 **Actual and required annual changes to R&D intensities across OECD countries, 1998 to 2010[a]**



a Required increases for countries with targets other than 2010 (United Kingdom and Ireland) are on a pro rata basis.

Data source: Eurostat Science and Technology Database 2006, http://epp.eurostat.ec.europa.eu, (accessed October 2006).

C.2 How does Australia compare?

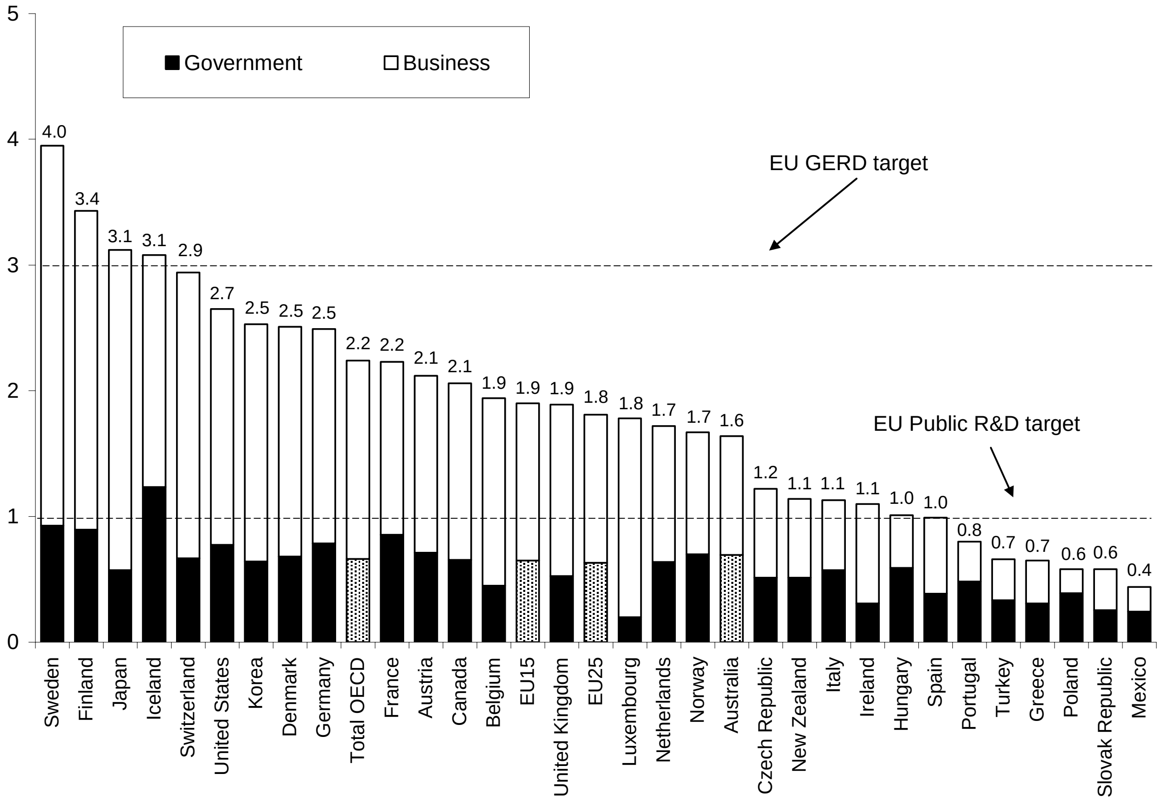
A number of participants to this study noted that Australia R&D intensity was low by international standards (see for example, subs. 31, 41, 51, 54, 59, 87 and 89). Despite strong real increases in R&D spending over the past two decades (discussed in chapter 1), Australia's R&D intensity, at 1.64 per cent in 2002, remains well below the OECD average. Overall, on this measure Australia ranked 18th out of 30

OECD countries — 0.6 percentage points below the OECD average of 2.2 per cent and just over half the Barcelona target (figure C.3).

Australia's performance against this measure reflects much lower business-financed R&D intensity, which, at just under 1 per cent (relative to GDP) was 0.7 percentage points below the OECD average and less than half the EU business R&D target. This was counteracted to some extent by Australia's above average government-financed R&D spending which was 0.69 compared with an OECD average of 0.66 per cent.

Figure C.3 **Government and business-financed[a] GERD to GDP ratios across the OECD, 2002**

Per cent



[a] Also includes other non-government sources of R&D funding. Data for Greece, Luxembourg, New Zealand and Sweden are for 2003 and Switzerland is for 2004.

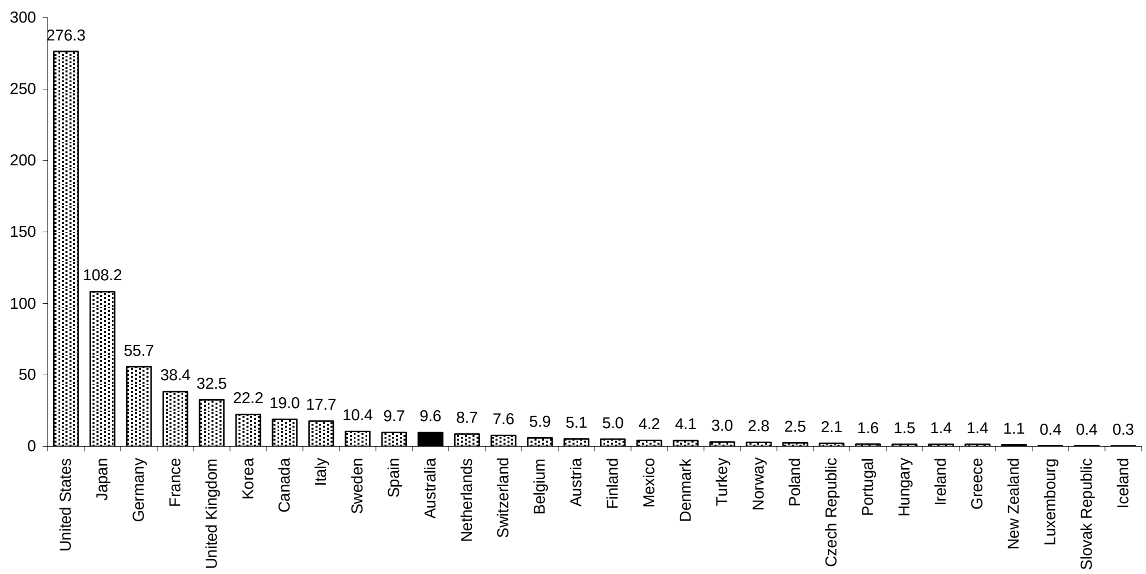
Data source: OECD Research and Development Statistics Database (accessed June 2006).

A fair degree of diversity is evident in R&D intensities across the OECD. For example, Sweden (4.0 per cent), the highest ranking country, achieved an R&D intensity ten times greater than Mexico (0.4 per cent), the lowest ranking country (figure C.3). This variation reflects substantial differences in both private and public investment levels across countries.[8] However, business R&D intensities registered around 50 per cent more variability than public R&D intensities.[9] This, coupled with their larger size, has meant that variations in business R&D spending across countries are the major driver of differences in national R&D intensities.

One interpretation of these international data is that Australia is underperforming in terms of total R&D spending, and in particular, business R&D expenditure. However caution needs to be exercised in interpreting these results. The OECD averages are heavily skewed by a few key players, with the two largest performers, the United States and Japan, accounting for almost 60 per cent of OECD R&D in 2002 (figure C.4). The sheer size of their spending combined with their high R&D intensities drives up the OECD averages considerably. For example, when these two countries are excluded, the average OECD R&D intensity for the remaining 28 OECD countries drops sharply — from 2.24 per cent to 1.76 per cent, just above Australia's R&D intensity in 2002.

Figure C.4 **Gross expenditure on R&D across OECD countries, 2002**

$US billion PPP



Data source: OECD Main Science and Technology Indicators Database (accessed 1 May 2006).

[8] It is interesting to note that there is also substantial variation in R&D intensities *within* countries. For example, in the US, the six states with the highest levels of R&D expenditures — California, Michigan, New York, New Jersey, Massachusetts, and Illinois — accounted for one-half of the entire national effort in 2000 (National Science Foundation 2002).

[9] Business and public R&D intensity levels across OECD countries registered coefficients of variation of 0.64 and 0.39 respectively.

Setting aside absolute differences in economy size, differences *within* countries, particularly in areas such as industry and firm structure, can affect national R&D spending (and intensities). These are examined below.

C.3 The role of industry structure

Normalised indicators, such as R&D/GDP ratios, are useful for international comparisons because they both account for size differences between countries and obviate the need for exchange rates. However, even normalised indicators are not always directly comparable from one country to another. Simple R&D intensities only control for GDP differences, not for structural differences between countries or other factors that can explain R&D variation (National Science Foundation 2006).

It has been observed that countries with higher concentrations of particular manufacturing industries (including computers, communications equipment, pharmaceuticals and transportation equipment), generally have higher R&D intensities than countries whose industrial structures are weighted more heavily toward industries such as mining, agriculture and services (Sheehan and Wyckoff 2003). Recent analysis by Davis and Tunny (2005) of R&D intensities of Australia's industries relative to those in key R&D performing countries such as the United States and Japan, for example, found that industry structure was an important contributing factor to Australia's low BERD intensity.[10]

This issue was raised in a number of submissions (see for example, subs. 22, 23, 56 and 60). However, there was some disagreement about the magnitude of the impact of structural factors, and hence, their importance relative to other drivers of R&D intensity. Citing analysis from OECD (2006b), the Australian Institute for Commercialisation, for example, claimed that the 'structural differences' explanation of intercountry differences in R&D intensity 'has recently been disproved' (sub. 28, p. 5).

This is an important question and warrants further examination. As noted above, differences in BERD are the major driver of intercountry differences in total R&D/GDP ratios. Hence the following discussion focuses on *business* R&D expenditure in OECD countries.

[10] BERD intensity is generally measured as the ratio of BERD to business value added rather than GDP — which also includes non-business value added (OECD 2006a).

Adjusting for structure

National R&D intensity is a function of the intensity with which R&D in undertaken in each industry; and the share of national value added contributed by each industry:

$$R_A = \sum_{j=1}^{31} S_{jA} R_{jA} \qquad \{1\}$$

where R_A is the BERD/VA ratio for Australia; j represents each industry in the business sector (there are 31 industries in total see box C.1 and table C.2); S_j is the share of industry j in total business sector value added; and R_j is the R&D intensity for industry j in Australia.

One means of examining the role played by intercountry differences in industry structure is to apply a uniform OECD average industry structure to all countries and recalculate the overall business sector R&D intensity for each country:

$$R_{A1} = \sum_{j=1}^{31} S_{jO} R_{jA} \qquad \{2\}$$

where R_{A1} is the BERD/VA ratio that would occur if Australia were given the OECD average industry structure and S_{jO} is the OECD average share of industry j in total OECD business sector value added.

The results from this approach indicate that industry structure plays an important role in BERD intensity for Australia. Overall, Australia's BERD increased from 1.2 to 1.9 per cent of value added in 2002 when the OECD structure was employed (figure C.5).

This increase reflected a mix of effects at the industry level. Australia's large mining industry contribution to BERD falls by three-quarters under the OECD structure. However, this was outweighed by strong increases in BERD across a range of manufacturing industries (including electronics, communication equipment, transportation, chemicals and pharmaceuticals and transport equipment).

Not only does Australia's manufacturing sector contribute a smaller share of value added than most OECD countries, but more importantly, the specific manufacturing industries that Australia specialises in generally exhibit low R&D/value added ratios. Overall, Australia's manufacturing industry has half the share of high technology activities as the OECD average (sub 67, p. 6).

Box C.1 **About the data**

The analysis undertaken above was based on two key datasets. Value added data for OECD countries were obtained from the *Groningen Growth and Development Centre, 60-Industry Database* (http://www.ggdc.net/ October 2005) updated from O'Mahony and van Ark (2003). This is a comprehensive dataset based on the *OECD STAN Industrial Database* and supplemented with data published by individual countries' statistical agencies. BERD estimates are drawn from the *OECD Analytical Business Enterprise Research and Development (ANBERD) Database* (accessed July 2006).

The level of analysis undertaken was governed by the availability of data across all countries, industries and years. In some instances BERD data were not available for each industry in all countries and years. To resolve this it was necessary to aggregate the number of industries (from 60 to 33) — which resolved the overwhelming majority of data issues (table C.2).

Data on two industry groups, Agriculture, forestry and fishing and Public administration, community and personal services were not used in the shift-share analysis — in the case of the former, because BERD data are not collected for agriculture, and for the latter because it is not part of the business sector. In Australia's case, the omission of Agriculture, forestry and fishing slightly understates the structural component of differences between Australia's BERD intensity and the OECD average.

If data were missing for particular years within a given country, interpolation was used by applying the R&D intensity of adjoining years to the value added figures for the required year. If there were no data upon which to base an interpolation for a particular industry in a given country, then average R&D intensities for the remaining countries were applied to the value-added data to impute an R&D value. This technique was employed for some smaller industries that did not impact greatly on R&D totals. As noted above, for large industries this method was not used. Instead, the industries were aggregated up to a level where published data were available. The adjustments undertaken to BERD data to complete the dataset typically resulted in changes of 1–2 per cent in total BERD in any given year for countries for which this was required. The resulting estimates of aggregate BERD/VA ratios for the individual countries examined were close, but not identical, to those published in the OECD Main Science and Technology Indicators database (www.sourceoecd.org).

Unless otherwise specified, analysis for all countries was based on the years 1987 to 2002. All estimates are based on current price data converted into United States dollars using GDP USPPPs — the measure used by the OECD for all currency conversions of R&D expenditure data (OECD 2006c).

Adjusting for industry structure also results in strong increases in intensities for Norway and the Netherlands. Moreover, those countries with particularly high aggregate R&D intensities tend to gravitated more towards the OECD mean if adjustment is made for their idiosyncratic industry structure. Sweden, Finland and Korea recorded falls in their BERD intensity of around 30–40 per cent when their structure was adjusted to the OECD average. In contrast, the two largest economies, the United States and Japan, did not record large changes (the former decreased by less than 0.1 percentage point while the latter increased by 0.4 percentage points) — an unsurprising result given that the industry structure of these two countries has a major impact on the industry structure for the OECD as a whole.

Table C.2 **Industry breakdown (and ISIC Revision 3 concordance)**

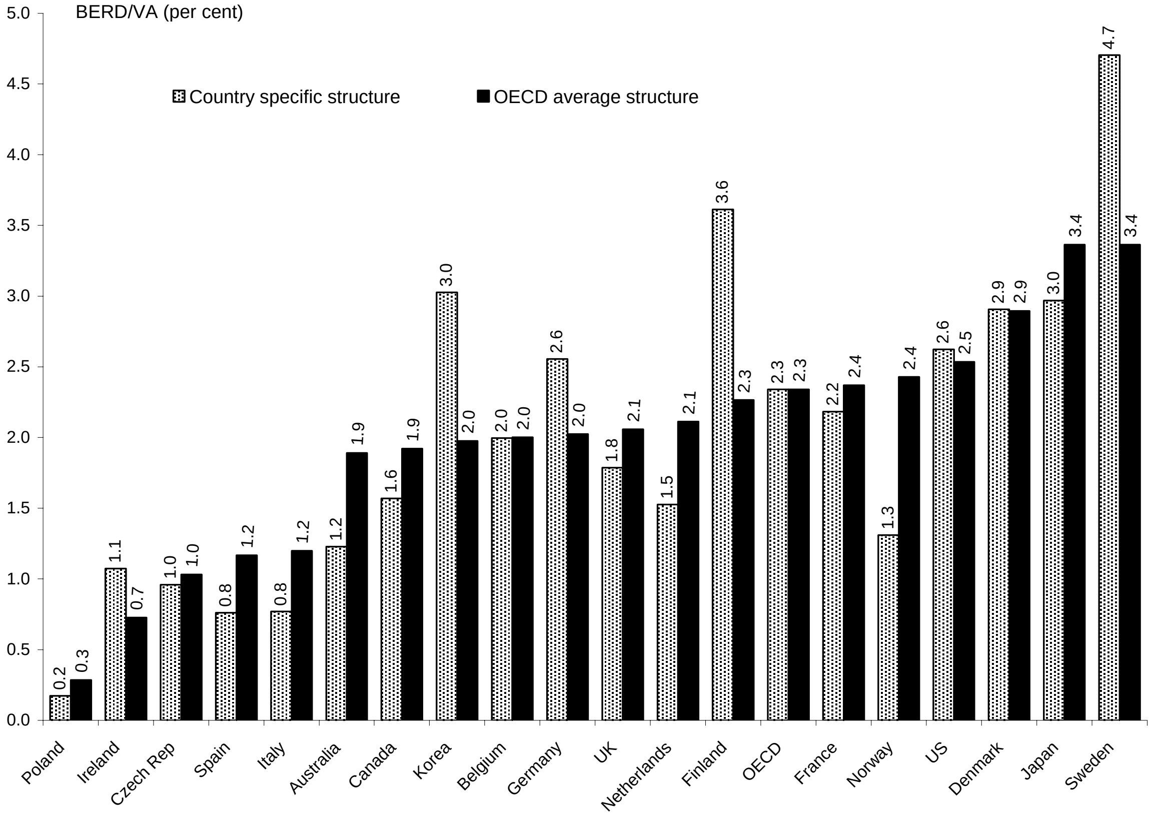
1	Mining and quarrying (10–14)	18	Other transport equipment (351)
2	Food, drink & tobacco (15–16)	19	Aircraft and spacecraft (353)
3	Textiles, textile prod, leather & footwear (17–19)	20	Railroad equip and transport equip nec (352+359)
4	Wood, wood and cork prods (20)	21	Furniture, misc manufacturing/recycling (36–37)
5	Pulp, paper, printing/publishing (21–22)	22	Electricity, gas and water supply (40–41)
6	Coke, refined petroleum prod & nuclear fuel (23)	23	Construction (45)
7	Chemicals and chemical prods (24)	24	Wholesale and retail trade; repairs (50–52)
8	Rubber and plastic prod (25)	25	Hotels and restaurants (55)
9	Non-metallic mineral products (26)	26	Transport and storage (60–63)
10	Basic metals (27)	27	Post and telecommunications (64)
11	Fabricated metal products (28)	28	Financial intermediation (65–67)
12	Mechanical engineering (29)	29	Computer and related activities (72)
13	Office, accounting and computing equip (30)	30	Research and development (73)
14	Electrical machinery & apparatus, nec (31)	31	Real estate and other business (70, 74)
15	Electronics and communication equip (32)	32	Agriculture, forestry and fishing (1, 2, 5)
16	Medical, precision/optical instruments (33)	33	Public admin, community/personal serv (75–99)
17	Motor vehicles, trailer/semi trailers (34)		

Data source: See box C.1.

Despite the importance of industry structure for some countries, the overall evidence suggests that industry structure is an incomplete explanation for international variations in BERD intensities. Even with standardised industry structures, considerable variations in BERD intensities are evident across countries. And the rankings of the 19 countries examined do not change substantially when structure is adjusted for. Overall, industry structure alone accounted for around one-third of the variation in BERD intensity between countries.[11]

[11] The following relationship was found: $R_i = -0.47 + 1.21R_{ia}$; where R_i is unadjusted BERD intensity of country i; and R_{ia} is structure-adjusted BERD intensity (which removes industry structure as a factor); R-squared = 0.69, n = 18, correlation coefficient = 0.84. Ireland was omitted from the regression as its shift-share estimates are affected by aggregation errors due to the absence of detailed industry data on the chemicals and pharmaceuticals industry.

Figure C.5 **BERD intensities across OECD countries adjusted for variations in industry structure[a], 2002**



a All countries are assumed to have the same industry structure. Estimates are calculated on the basis of R&D intensity per industry with the weights of each industry corresponding to their share of total business-sector value added on average across the 19 OECD countries listed (which combined accounted for over 90 per cent of OECD GDP and business value-added in 2002).

Data source: See box C.1.

The impact of industry aggregation

The observed importance of industry structure for some countries, including Australia, is highly sensitive to the level of industry aggregation employed. Recent analysis by the OECD (2006b) (referred to above), for example, found that Australia's BERD intensity only increases by 0.2 percentage points when adjusted for structural differences. The OECD analysis examined the impact of BERD/VA ratios by the imposition of the G7 structure on each country. Although the G7 structure is not identical to the OECD average structure employed here, the high concentration of OECD R&D in these countries means that differences are not large.

Discussions with the authors of the OECD report have revealed that the major source of the discrepancy between their results and those reported here lies in the level of industry aggregation employed. The OECD analysis was based on an eight industry breakdown of BERD.[12] While this level of analysis is sufficient to demonstrate their main point — that structural differences were not the major driver of differences in BERD intensities across the OECD as a whole — it also meant that a large degree of industry diversity was masked in some countries, including Australia.

To illustrate this, equation {2} was recalculated based on only 5 broad industries — mining, manufacturing, electricity, gas and water, construction and services. The resulting estimates found that a much smaller structural effect was evident for most countries. In the case of Australia, the imposition of the OECD's broad structure only resulted in an increase in BERD intensity of 0.2 percentage points. This was one quarter of the structural effect observed with the more detailed analysis and around the same result found in the OECD analysis.

Problems occur for shift-share analysis when industries with markedly different BERD intensities are grouped together. The more aggregated the data the greater is the extent to which differences are masked. For example, it is well known that Australia's manufacturing sector is highly oriented to industries that add value to agricultural and mineral products. And these sectors have much lower R&D intensities than other areas of manufacturing. Although Australia also has some higher BERD intensity manufacturing industries, the relative proportion of low and high BERD industries are very different to the OECD average.

The forgoing discussion highlights the sensitivity of the forgoing analysis to the level of aggregation employed for Australia — with the observance of larger structural effects when a more detailed industry breakdown is employed.

Adjusting for intensity

As noted above, structural factors were not the sole drivers of variations in BERD/VA ratios across OECD countries. Differences in R&D intensities *within* industries across countries also play a role. In the communications sector, for example, R&D as a share of value added in OECD countries ranges from a low of 4 per cent in Poland to a high of 65 per cent in Sweden. In the transportation sector, corresponding values range from a low of 2.5 per cent in Norway to 24 per cent in Sweden. In the service sector, overall levels of R&D as a share of value added were

[12] The analysis presented here was based on a 31 industry breakdown. Other sources of discrepancy include a different raw dataset (see box C.1) as well as a different choice of years — the OECD used period averages for 1999 to 2002 which would be expected to lessen the impact of year-to-year volatility.

much lower, ranging from 0.1 per cent in Poland to 0.9 in the United States (Sheehan and Wyckoff 2003).

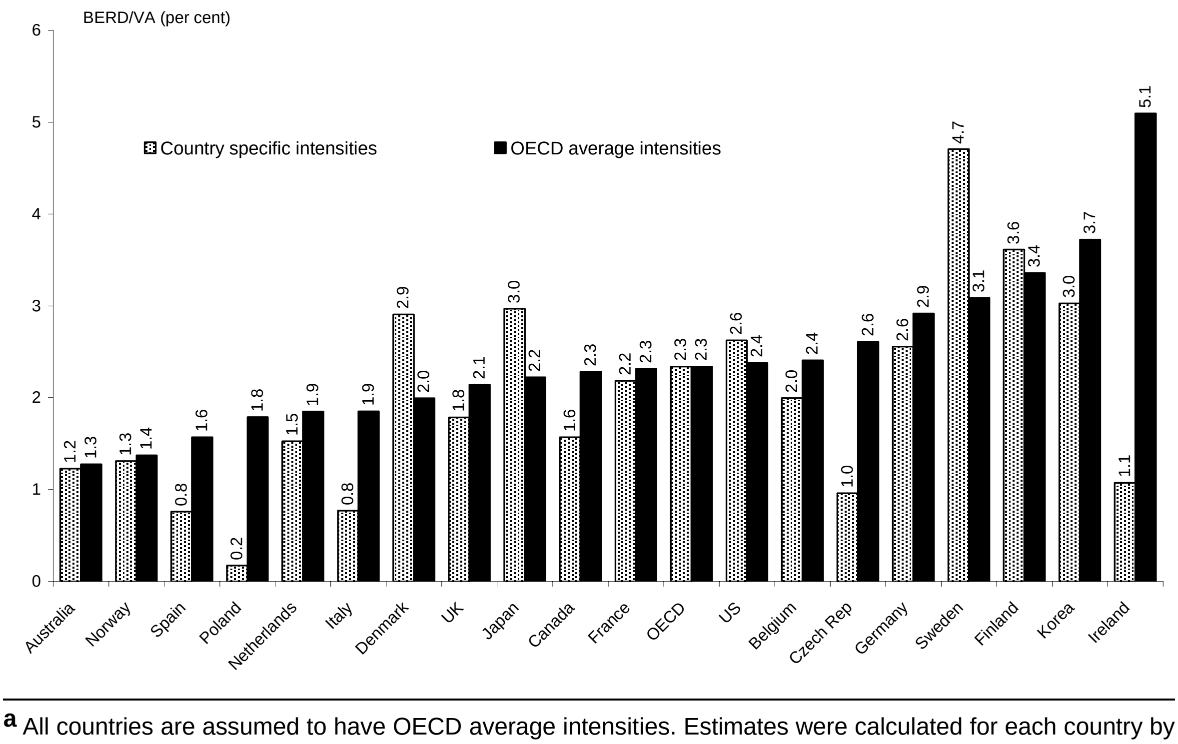
One means of examining the role played by intercountry differences in industry R&D intensities is to apply uniform OECD average BERD/VA ratios for each industry to all countries and recalculate the overall business sector R&D intensity for each country:

$$\mathrm{R}_{\mathrm{A2}} = \sum_{\mathrm{j=1}}^{31} S_{jA} R_{jO} \qquad \{3\}$$

R_{A2} is the BERD/VA ratio that would occur if Australia were given the OECD average industry BERD intensities and R_{jO} is the OECD average BERD intensity for industry j.

As expected, an examination of the resulting ‘intensity-adjusted’ BERD/VA ratios reveals a convergence across OECD countries, with increases in most below average countries (including Australia, Norway, Spain, Poland, Netherlands, the United Kingdom, Czech Republic and Ireland) and decreases in leading R&D countries such as Sweden, Finland, Japan and Denmark, figure C.6).

Figure C.6 **BERD intensities across OECD countries if all countries adopted OECD average industry intensity levels, 2002**



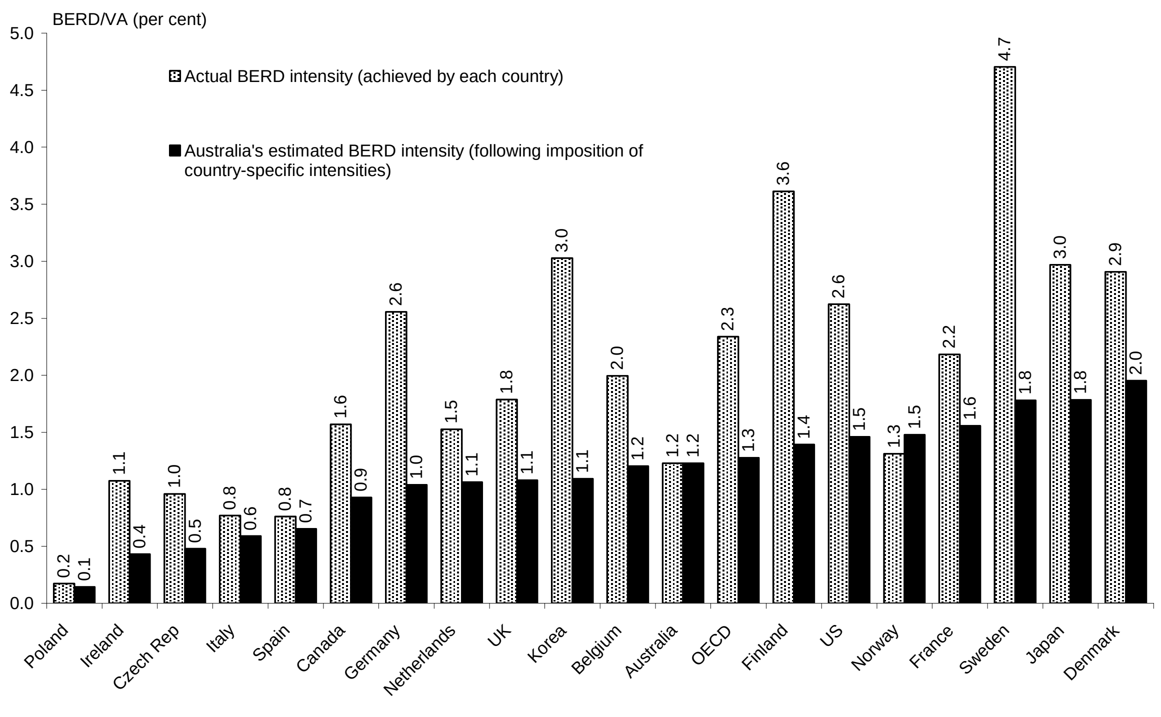
[a] All countries are assumed to have OECD average intensities. Estimates were calculated for each country by multiplying each industry’s observed value added by OECD average BERD intensities.

Data source: See box C.1.

In Australia's case, applying OECD average intensities to Australia results in a minor increase in BERD intensity — of 0.05 percentage points. The fact that Australia's 'intensity-adjusted' BERD ratio (1.3 per cent) was the lowest observed of all countries reinforces the importance of structural differences for Australia highlighted above.

Clearly, it is possible to achieve larger increases for Australia by selectively applying R&D intensities from a subset of countries. For example, applying intensities for countries such as the United States, Japan and Denmark results in more substantial increases in Australia's BERD intensity of 0.3, 0.6 and 0.8 percentage points respectively (figure C.7 — actual country BERD intensities are included for purposes of comparison). While this moves Australia closer to the OECD average, the fundamental point remains that Australia would need to achieve above average 'within industry' R&D intensities to achieve an overall BERD intensity approaching, but still below, the OECD average. Or, put another way, Australia is highly unlikely to achieve the OECD average BERD intensity with its existing industry structure.

Figure C.7 **Australia's BERD intensities if it adopted the industry R&D intensities of each OECD country[a], 2002**



a These results can also be interpreted as the BERD intensities that OECD countries would achieve if they were given Australia's industry structure, while maintaining their own industry intensities. In other words, if the OECD overall were to be given Australia's industry structure, its BERD intensity would drop from 2.3 per cent to 1.3 per cent.

Data source: See box C.1.

This approach was adopted by Davis and Tunny (2005) in assessing the impact of industry structure on Australia's BERD intensity. Although the coverage and aggregation differed for their study, the authors reached similar conclusions to those reported here.

Decomposition

A drawback of the preceding partial analysis in {2} and {3} is that the sum of the total impacts does not equal the total differences between each country's BERD intensity and the OECD average intensity. For example, in Australia's case, adjusting for structure (+0.66 percentage points) and intensity (+0.05 percentage points) only accounts for 0.71 percentage points of the 1.1 percentage point difference between Australia's BERD intensity and the OECD average. The remaining 0.39 percentage points is a 'mix effect' which represents the interaction of structure and intensity effects.

However, it is possible to allocate this mix effect among the structure and intensity effects to allow a full decomposition of the difference between each country's BERD/VA ratios and the OECD average.

The difference in intensity between Australia and the OECD (ΔI_{AO}) is:

$$\Delta I_{\mathrm{AO}} = \sum_{\mathrm{j=1}}^{31} (S_{jA}R_{jA} - S_{jO}R_{jO}) \qquad \{4\}$$

where S_{jA} is the share of industry j in Australia's value added; R_{jA} is the intensity of BERD in industry j in Australia; S_{jO} is the share of industry j in OECD value added; R_{jO} is the intensity of BERD in industry j in the OECD.

There are two (symmetric) representations of ΔI_{AO}:

$$\Delta I_{\mathrm{AO}} = \sum_{\mathrm{j=1}}^{31} (S_{jA}R_{jA} - S_{jO}R_{jO}) = \sum_{\mathrm{j=1}}^{31} (S_{jA}R_{jA} - S_{jO}R_{jO} + (S_{jA}R_{jO} - S_{jA}R_{jO})) = \sum_{\mathrm{j=1}}^{31} (S_{jA}\Delta R_j + R_{jO}\Delta S_j) \qquad \{5\}$$

and that also

$$\Delta I_{\mathrm{AO}} = \sum_{\mathrm{j=1}}^{31} (S_{jA}R_{jA} - S_{jO}R_{jO}) = \sum_{\mathrm{j=1}}^{31} (S_{jA}R_{jA} - S_{jO}R_{jO} + (S_{jO}R_{jA} - S_{jO}R_{jA})) = \sum_{\mathrm{j=1}}^{31} (S_{jO}\Delta R_j + R_{jA}\Delta S_j) \qquad \{6\}$$

where $\Delta R_j = R_{jA} - R_{jO}$ and $\Delta S_j = S_{jA} - S_{jO}$;

which on averaging gives:

$$\Delta I_{AO} = \sum_{j=1}^{31}(\Delta R_j \times \bar{S}_j) + \sum_{j=1}^{31}(\Delta S_j \times \bar{R}_j) \qquad \{7\}$$

where; $\bar{S}_j = (S_{jA} + S_{jO})/2$,

and $\bar{R}_j = (R_{jA} + R_{jO})/2$; and

$$\sum_{j=1}^{31}(\Delta R_j \times \bar{S}_j) = \text{difference due to intensities} \qquad \{8\}$$

$$\sum_{j=1}^{31}(\Delta S_j \times \bar{R}_j) = \text{difference due to structure} \qquad \{9\}$$

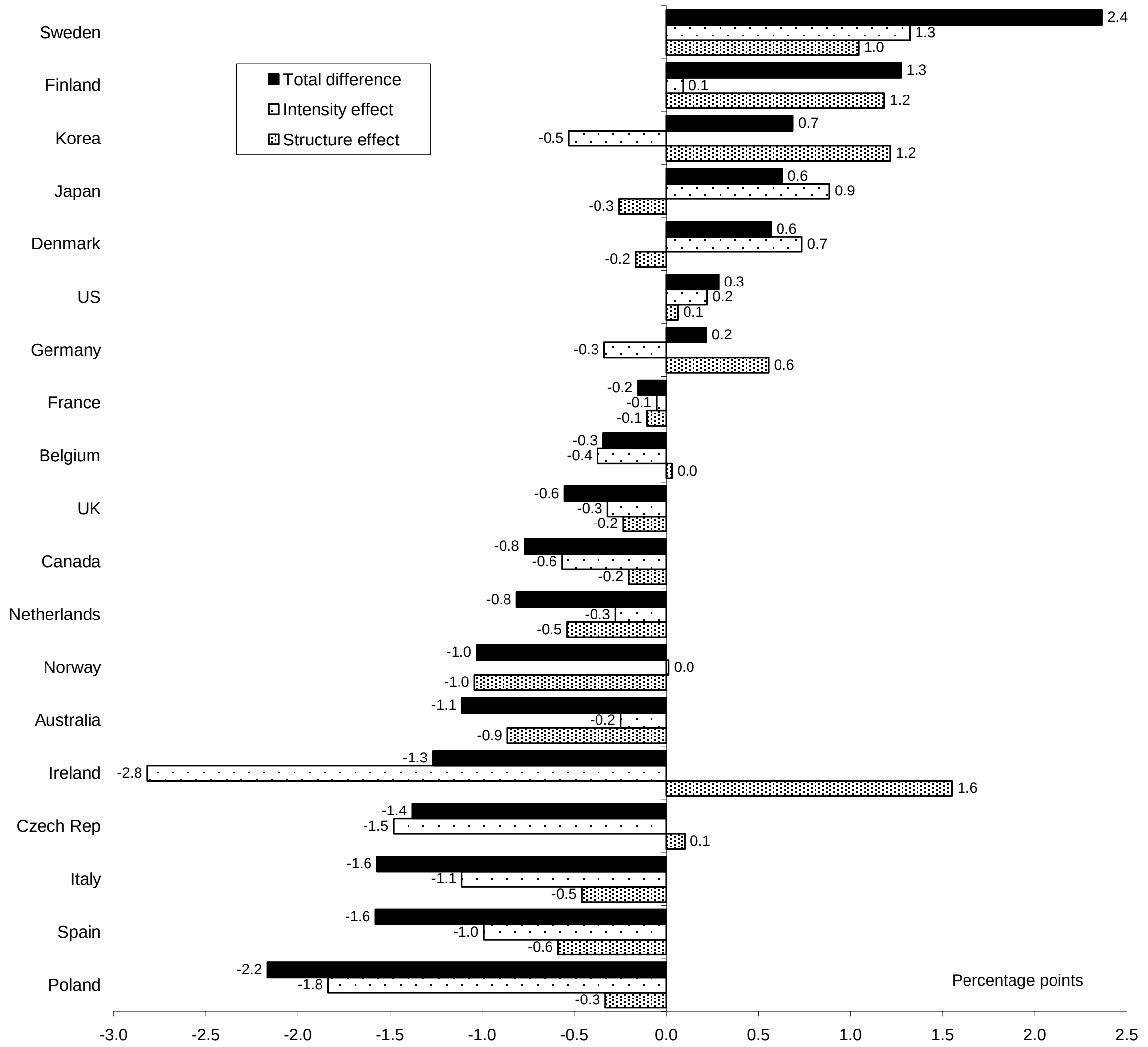
Applying this approach[13] we see that the gap of 1.1 percentage points between Australia's BERD intensity and the OECD's BERD intensity reflects 0.9 percentage points (or 77 per cent) due to structural differences and 0.2 (or 23 per cent) due to differences in intensities within industries (figure C.8).

As noted earlier, this is not the norm for OECD countries, with structural effects outweighing intensity effects in only seven countries — whereas intensity effects were the major contributor to divergence in overall BERD/VA ratios from the OECD average for the remaining twelve countries.

However, for Australia, the decomposition results re-emphasise the importance of industry structure as the key driver of differences between the Australia's BERD intensity and the OECD average. In terms of intercountry rankings, when structure is adjusted for, Australia's BERD intensity ranking increases from 14th to 9th of the 19 countries for which comparable data are available.

[13] For a more detailed explanation of the 'linear interpolation' method — which provides the underlying analytical motivation for deriving the partial effects as the average of the multiple representations of ΔI_{AO} — see PC 2005b (Technical Paper 6).

Figure C.8 **Decomposition of differences in country BERD/value-added ratios from OECD average, 2002**



Data source: See box C.1.

Structural change

In addition to providing useful information about existing BERD intensities within countries, industry structure provides an insight into the capacity for a country to increase its overall BERD intensity. Sheehan and Wyckoff (2003, pp. 22–3), for example, consider that:

> High-technology sectors offer considerably more opportunity than other industry sectors for improving R&D as a share of value added, and high levels of overall R&D intensity are unlikely to be achieved without them.

Industry structures are not fixed — the industrial composition of countries is constantly changing (PC 1998 and 2003b). In turn, this could be expected to influence R&D intensities over time.

A number of participants noted the importance of structural change in the context of BERD intensity. The AVCC, for example, contended that:

> Australia cannot and should not rely on our current industry structure to maintain future living standards … [The] interaction between sectoral BERD intensity and sectoral strength is a 'chicken and egg' issue. (sub. 60, p. 3)

A standard approach for measuring rates of structural change (PC 2003b) is to derive structural change indexes to facilitate comparisons, both between countries, and over time. Structural change (SC) is defined as:

$$SC_{\mathrm{t}} = 100 \times \sum_{\mathrm{j}=1}^{31} \frac{1}{2} \left| S_{jt} - S_{jt-1} \right| \qquad \{10\}$$

where S_{it} is the value added share of industry j at time t. The resulting index is bounded between zero and one hundred, with a higher number representing more structural change.

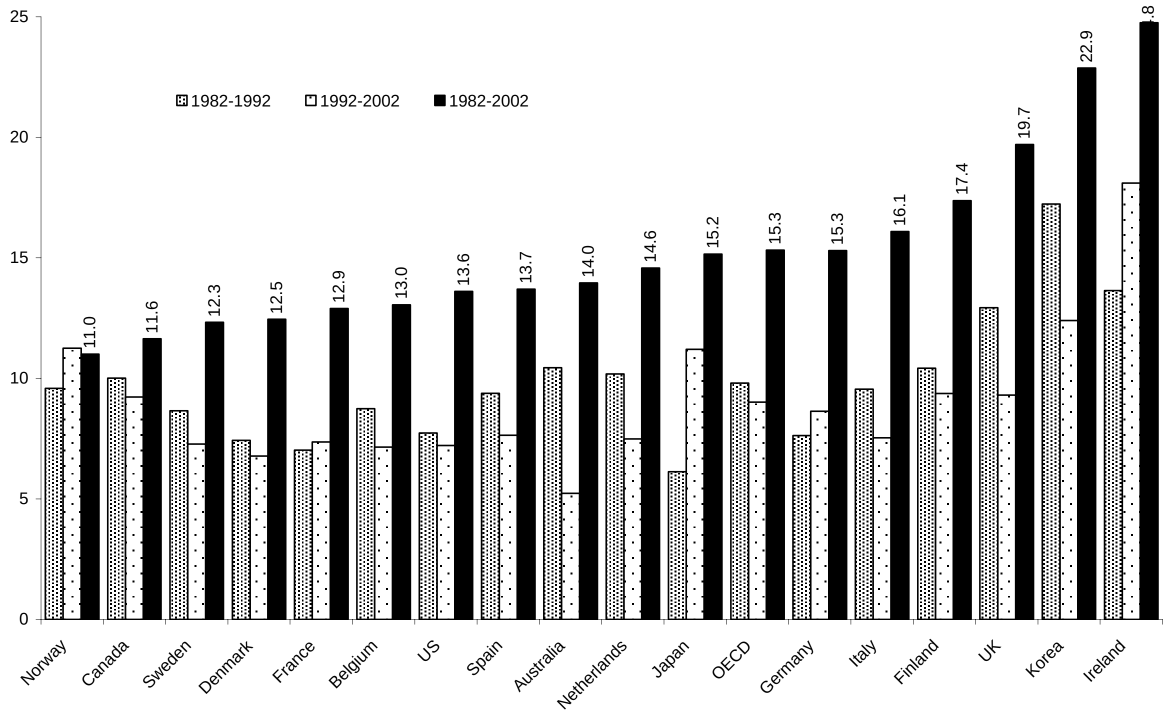
Estimates of structural change for the past two decades indicate that there have been considerable variations in the degree of change across countries and over time — ranging from a low of 11 per cent in Norway to a high of 25 per cent in Ireland (figure C.9).

Between 1982 and 2002, Australia registered an SCI value of 14 per cent, or 0.7 per cent a year. This means that in 2002, 14 per cent of total Australian non-farm business value added would have to be moved into different industries in order to re-establish the industry value added shares prevailing in 1982. Australia's rate of structural change was just under the average for the OECD countries studied (15.4 per cent) over the period, however its rate of change from 1992 to 2002 was the slowest of the OECD countries examined. Rates of structural change were generally slightly higher in the 1980s relative to the 1990s for most countries, although there were some exceptions, including Japan, Ireland and Germany. Australia, along with the United Kingdom, Korea and the Netherlands, registered considerably stronger rates of structural change in the 1980s relative to the rates recorded in the 1990s.

Although SCIs indicate that ongoing structural change is the norm in all OECD countries over the past decades, including Australia, they do not reveal the *direction* of structural change and how it impacts on aggregate BERD intensity.

Figure C.9 **Indexes of structural change, 1982 to 2002**[a]

Value added, current price shares, per cent



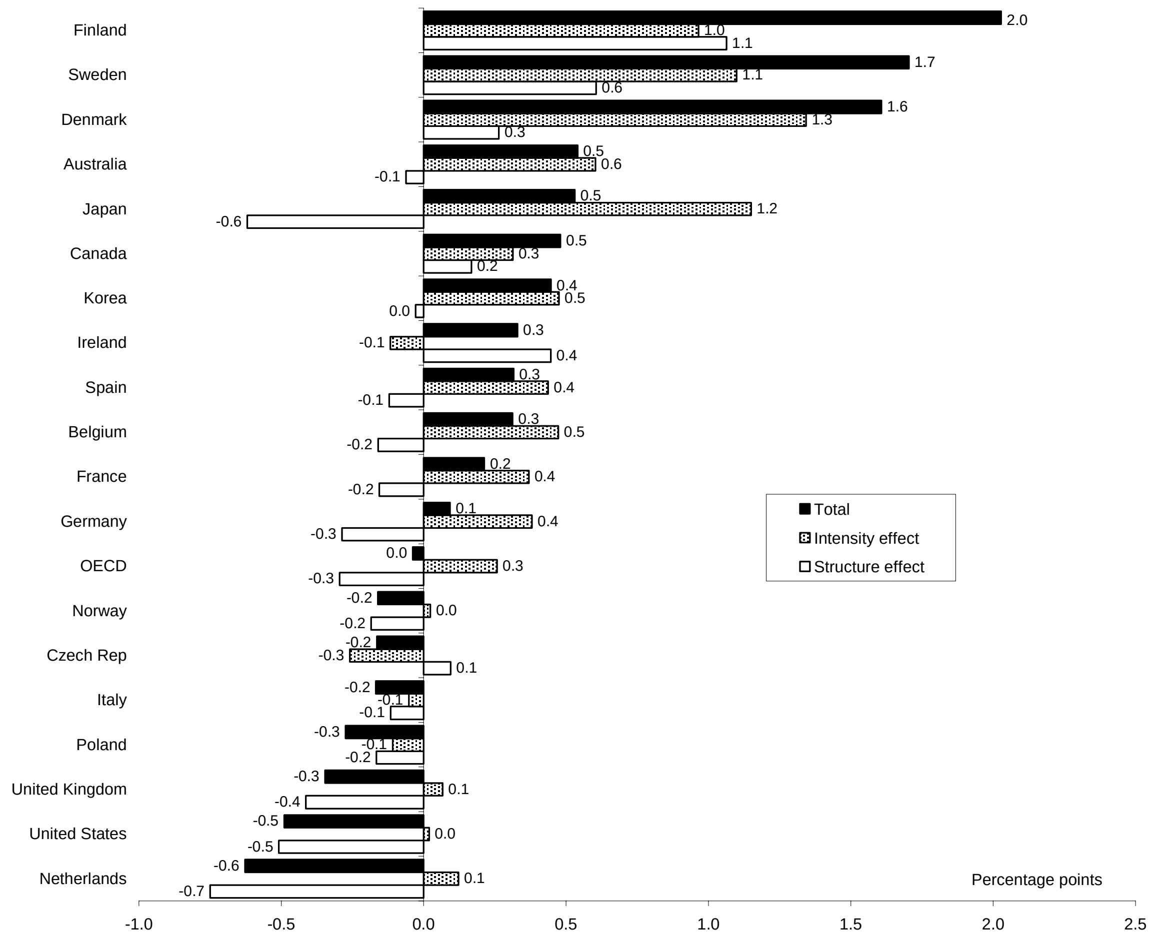
a Subtotals for each decade do not sum to the total for the period due to changes, including reversals, in the direction of structural change across decades. SCIs are highly sensitive to the level of industry aggregation employed, with a lower level of aggregation resulting in the observance of more structural change (PC 2003b).

Data source: See box C.1.

To determine whether the structural change has contributed to increases in BERD/VA ratios it is possible to employ the same methodology outlined in {4} – {9} to decompose the change in BERD intensity over time within each country into a structure effect and an intensity effect (figure C.10).

The results for Australia indicate that, overall, structural factors have had a minor impact on BERD intensity in Australia over the past decade and a half. In fact, the direction of structural change has been slightly away from high R&D industries — with declines in the value added shares of high R&D industries exerting a drag of around 0.1 percentage points on the total increase in observed BERD intensity between 1987 and 2002. Put another way, in the absence of structural change Australia's BERD intensity would have increased by 0.6 percentage points (compared with an actual increase of 0.5 percentage points).

Figure C.10 **Decomposition of differences in BERD/value-added ratios between 1987 and 2002**



[a] Data for Germany, Italy and the OECD (total) cover the period 1991 to 2002. As the results for Korea cover the period from 1995, Czech Republic from 1993 and Poland from 1994, these countries were omitted from the OECD total BERD/VA ratio — which remained flat over the period. This contrasts with the OECD MSTI Database 2006 estimates for the OECD overall of a slight (0.09 percentage points) increase in the BERD/VA ratio between 1991 and 2002. This difference largely reflects the smaller range of countries employed in the analysis presented here. Individual country estimates of total changes in BERD/VA ratios are close, but not identical, to OECD MSTI estimates.

Data source: See box C.1.

Most other OECD countries experienced a similar 'structural drag', although, on average, the structural shifts away from high R&D industries were larger than those experienced in Australia (-0.3 percentage points on average across the OECD). Overall, structural effects reduced BERD intensities in 13 of the 19 countries examined. Although structural effects also made positive contributions to the growth in BERD intensity in six countries, the only countries in which structural effects outweighed intensity effects as drivers of *increases* in BERD intensity were Finland and Ireland.

In contrast, intensity effects exerted a positive effect on BERD intensities in all countries except the Czech Republic, Poland, Italy and Ireland. The generally weak or negative contribution of changes in industry structure to BERD intensity observed here are not surprising. Service industries have historically recorded low R&D intensities on average, in part due to the way R&D data are reported. And structural shifts away from manufacturing industries towards services industries have been observed across most high income countries (PC 2003b).

Hence, these results indicate that over the past decade and a half increases in BERD/VA ratios, and hence R&D/GDP ratios, have generally been driven by increases in individual industry BERD intensities rather than through structural change.

C.4 Firm size

Australia's industrial structure is also characterised by a preponderance of small firms and relatively few multinational corporations headquartered here. The Department of Industry, Tourism and Resources (sub. 93) noted, for example, that Australia is home to only two of the top 1000 global corporate R&D spenders (CSL and Aristocrat Leisure).[14]

While both small and large firms play an important role in innovative performance, their relative importance for business R&D varies. For example, in their submission, Jense et al. stated:

> [T]he relationship between firm size and innovation is well-researched in the economics literature. Schumpeter (1934), for example, argued that large firms are more innovative since they have the retained earnings with which to re-invest in risky innovative activities. There may also be an advantage to being large if there are economies of scale in R&D production and the innovative process more broadly. (sub. 9, p. 12)

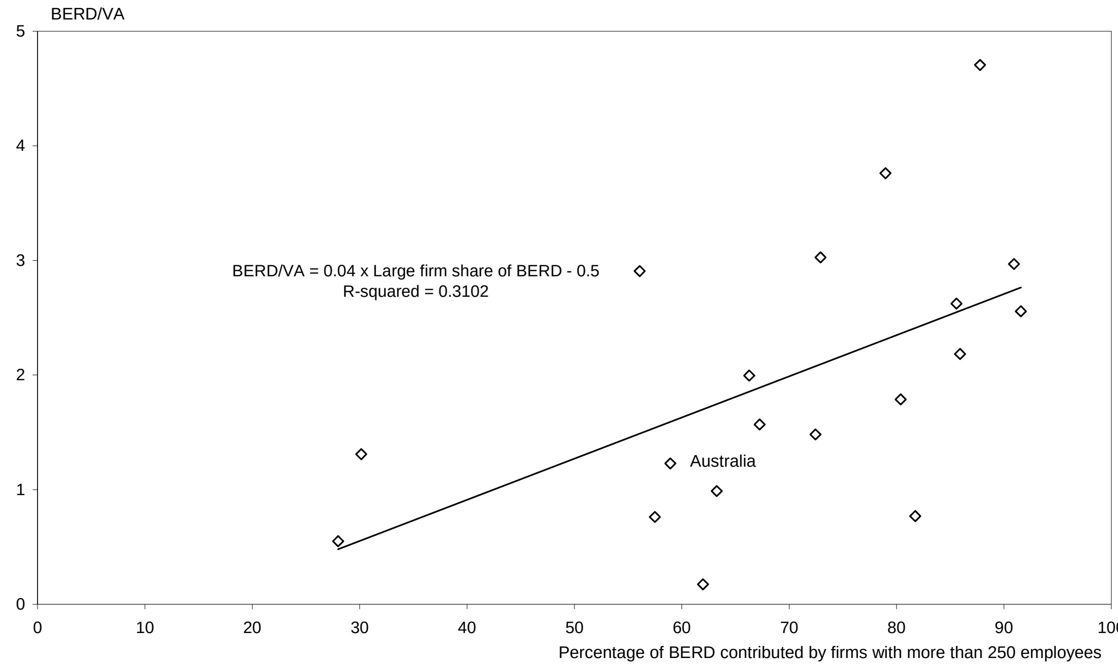
In OECD countries, the share of R&D performed by small and medium-sized enterprises (SMEs) (defined here as firms with fewer than 250 employees) is generally greater in smaller economies than in larger ones.

Firms with fewer than 250 employees account for a large share of business R&D in New Zealand (72 per cent), Norway (70 per cent), Ireland and Greece (49 per cent), the Slovak Republic (46 per cent) and Australia (42 per cent). In the larger EU

[14] While Australia's industry structure is one of the major reasons for this, Australia's geographic isolation is also likely to play a role. This issue is not examined here. However, an overview of recent studies that examine R&D and the role of foreign exposure and trade intensity is included in Tunny (2006).

countries, their share is less than one-fifth, and in the United States it is less than 15 per cent. Japan has one of the lowest shares among OECD countries, with only 9 per cent. Moreover, firms with fewer than 50 employees account for a significant share of business R&D (over one-fifth) in Norway, New Zealand, Ireland, Denmark and Australia. When these data are compared with BERD intensities a positive relationship is evident (figure C.11).

Figure C.11 **Share of BERD performed by firms with over 250 employees compared with BERD/VA ratios across OECD countries, 2002**



Data source: See box C.1.

Although there are insufficient data to incorporate firm size into the decompositions presented earlier, it is clear that these factors are both important (and interrelated) influences on national BERD intensity. Combined, firm size and industry structure accounted for almost 60 per cent of the variation in BERD intensities across OECD countries.[15]

[15] The following relationship was found $R_i = -1.08 + 1.24R_{ia} + 0.53L_{ia}$; where R_i is BERD intensity of country i; R_{ia} is adjusted BERD intensity; L_{ia} is the large business share of BERD; R-squared = 0.58, n = 17, F-stat = 9.8. Industry structure and firm size were found to be positively correlated (correlation coefficient = 0.33), an unsurprising result given the generally higher incidence of small firms in the service sector.

C.5 Researcher wages

The conventional image of R&D involves expensive scientific equipment such as supercomputers, linear accelerators, satellites or wind tunnels. However, the biggest part of R&D expenditures is actually wages paid to researchers. As labour costs comprise around half of R&D costs in OECD countries on average, differences in wage rates across countries can have an impact on measured R&D spending and R&D intensities.

Dougherty et al. (2003), for example, found substantial differences (up to one-third) were evident in labour costs for scientists, researchers and support staff for a selection of the major R&D performing OECD countries. They note these differences are not specifically taken into account in official OECD R&D statistics. When these differences were accounted for, a convergence in R&D spending levels (and R&D intensities) across countries was evident, with most countries making ground on the United States due to its relatively higher wage rates for researchers.[16]

Although the study did not include Australia, an examination of Australia's labour costs for scientists suggests that Australia's R&D spending may be understated relative to the United States at least — which, as noted earlier, accounted for around 42 per cent of OECD R&D in 2002. For example, broad estimates from the Association of Professional Engineers, Scientists and Managers, Australia (APESMA) on salaries for graduate and experienced engineers, professionals and scientists for 2005 suggest a wage gap of between 30–60 per cent for Australian graduates and 10–25 per cent for experienced professionals relative to their United States counterparts (figure C.12).

However, although Australia's lower wages differences will affect dollar value comparisons of R&D between countries, this does not necessarily mean that R&D intensities will be affected. The key factor here is the wages of scientists and research staff in Australia relative to the average wage in Australia. If this ratio differs between countries then R&D intensities will not provide an accurate indication of each country's relative commitment to R&D.[17] As detailed data on this measure are not readily available across countries, this issue is not examined

[16] Dougherty et al. (2003) for example, found that average R&D labour price levels per unit of R&D labour relative to the United States for manufacturing industries were lower in France (86 per cent); Germany (93 per cent); Japan (97 per cent), Netherlands (79 per cent) and the UK (63 per cent) in 1997.

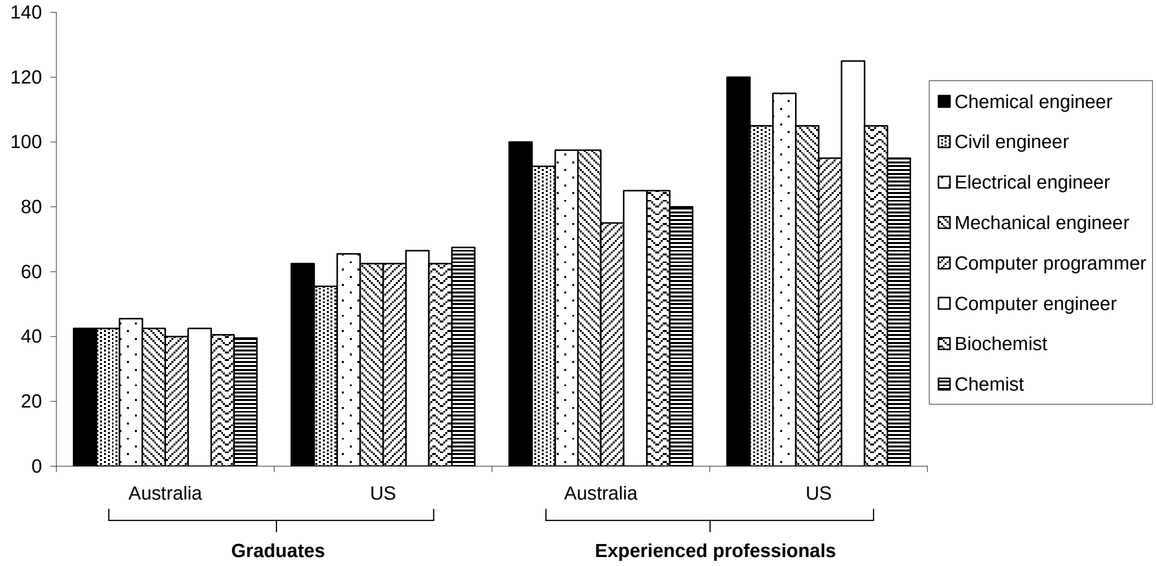
[17] PPPs used by the OECD to convert all R&D spending to a common currency will pick up differences in economy-wide average wages across countries, but do not capture R&D-specific costs (including researcher wages).

here. Time and data constraints permitting, the Commission will examine this issue further in the final report.

Another indicator of a country's commitment to R&D is full-time-equivalent researchers per thousand workers. Australia's figure, of 7.8 in 2002, was above the OECD average (6.9) and eighth in the OECD overall — a jump of nine places relative to the R&D intensity ranking based on expenditure (figure C.13). Australia registered the equal second largest jump in ranking after New Zealand (16 places) (Norway also increased nine places). The largest falls in ranking were registered by Switzerland and Korea (down 11 and 8 places respectively). These differences notwithstanding, there was generally a strong positive correlation between rankings based on R&D intensity and researcher intensity across the OECD.[18]

Figure C.12 **Comparison of median Australian and United States salaries for research professionals, 2005**

$A 000 current prices



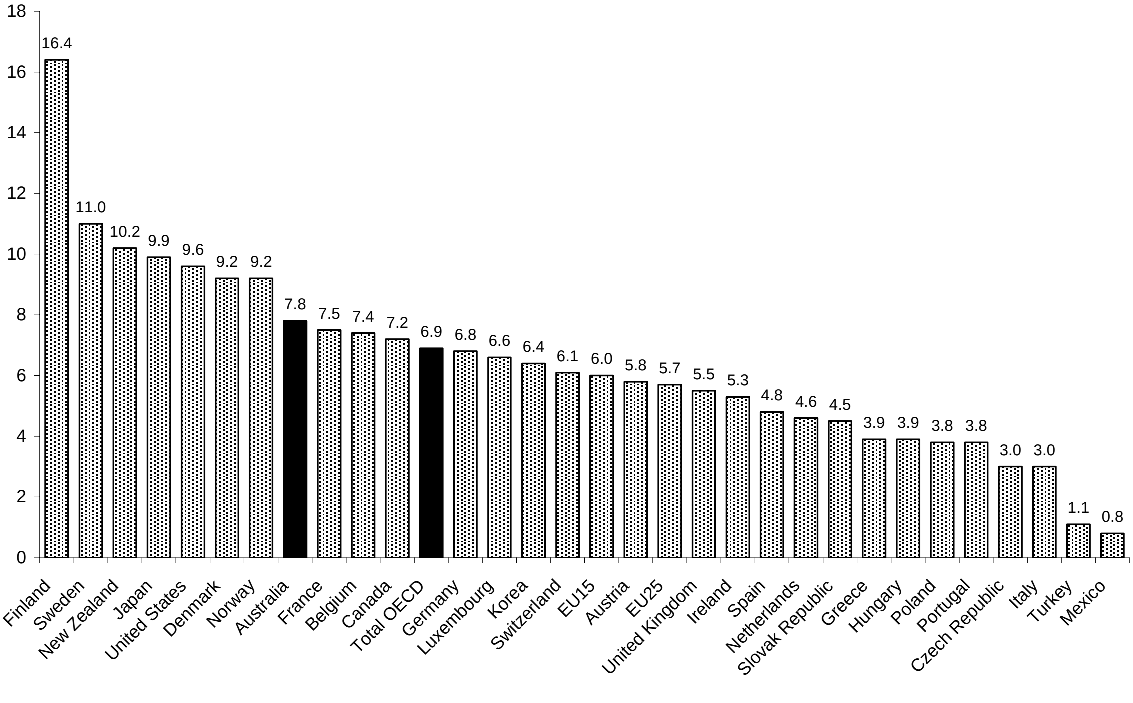
Data source: APESMA 2005, http://www.apesma.asn.au/newsviews/professional_network/2005/dec_jan_05_06/salaries_here_there.asp (accessed June 2006).

Australia's changed position in terms of researcher intensity may reflect, at least it part, lower wages relative to the OECD average. However, the labour-intensive character of much of the R&D undertaken in Australia relative to larger countries is likely to be the major factor. Given Australia's higher concentration in research fields such as health and the environment it would be expected that researchers in

18 R&D intensities and full-time equivalent researchers per thousand workers registered a correlation coefficient of 0.77 for the 29 OECD countries for which consistent data were available. Iceland is excluded due to lack of data on researchers.

Australia would not, on average, require as much capital expenditure as countries with, for example, strong aerospace, defence or nuclear research programs. Barlow (2006) notes that Australia is one of the few countries with substantial weighting in its research output towards the life sciences. Of all Australian scientific publications between 1996 and 2000, thirty per cent were in the medical and health sciences, twenty per cent were in biological sciences, and ten per cent were in agricultural, veterinary and environmental sciences.

Figure C.13 **Total researchers per thousand workers across OECD countries, 2002**



Data source: OECD Main Science and Technology Indicators Database (accessed June 2006).

C.6 Public support

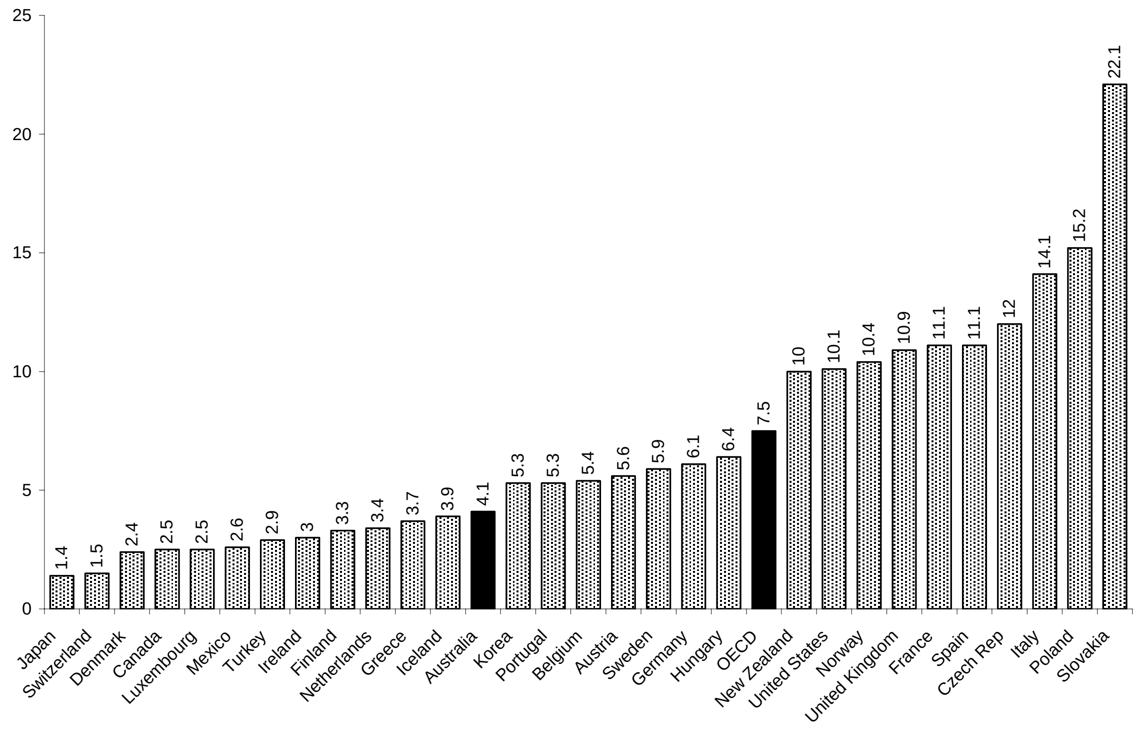
Participants have also noted that a direct comparison of the proportion of Government funded BERD indicates that Australia is also below the OECD average. For example, the AVCC claimed that under-funding of BERD by government has contributed to the structural differences in Australia that contribute to low R&D intensity:

> Many of Australia's industry sectors are small because of Australia's historic lack of support for innovation. (sub 60, p. 3)

Latest OECD data on government financed BERD indicate that public financed BERD, in Australia was 4.1 per cent of total BERD in 2003. This was well below the OECD average of 7.5 per cent (figure C.14), which largely reflected higher public spending on BERD by the United States, the United Kingdom and France. Although the data do not provide a precise breakdown, some of this spending is likely to reflect higher defence spending in these countries. Defence budget R&D as a percentage of total government budget appropriations or outlays for R&D (GBAORD) in 2003 for the United States (55.7 per cent), the United Kingdom (31.8 per cent) and France (24.2 per cent) were considerably higher than Australia (5.6 per cent).[19]

Figure C.14 **Percentage of BERD financed by government**

2003 (or latest available year)



Data source: OECD MSTI Database 2006.

That said, regardless of the type of BERD expenditure funded by government, this indicator does not provide a complete picture of intercountry differences in support for BERD as it **excludes assistance via tax concessions**. For example, in the five

19 The National Science Foundation (2006) notes that although defence-related R&D does result in spillovers that produce social benefits, non-defence R&D is more directly oriented toward national scientific progress, standard-of-living improvements, economic competitiveness, and commercialisation of research results.

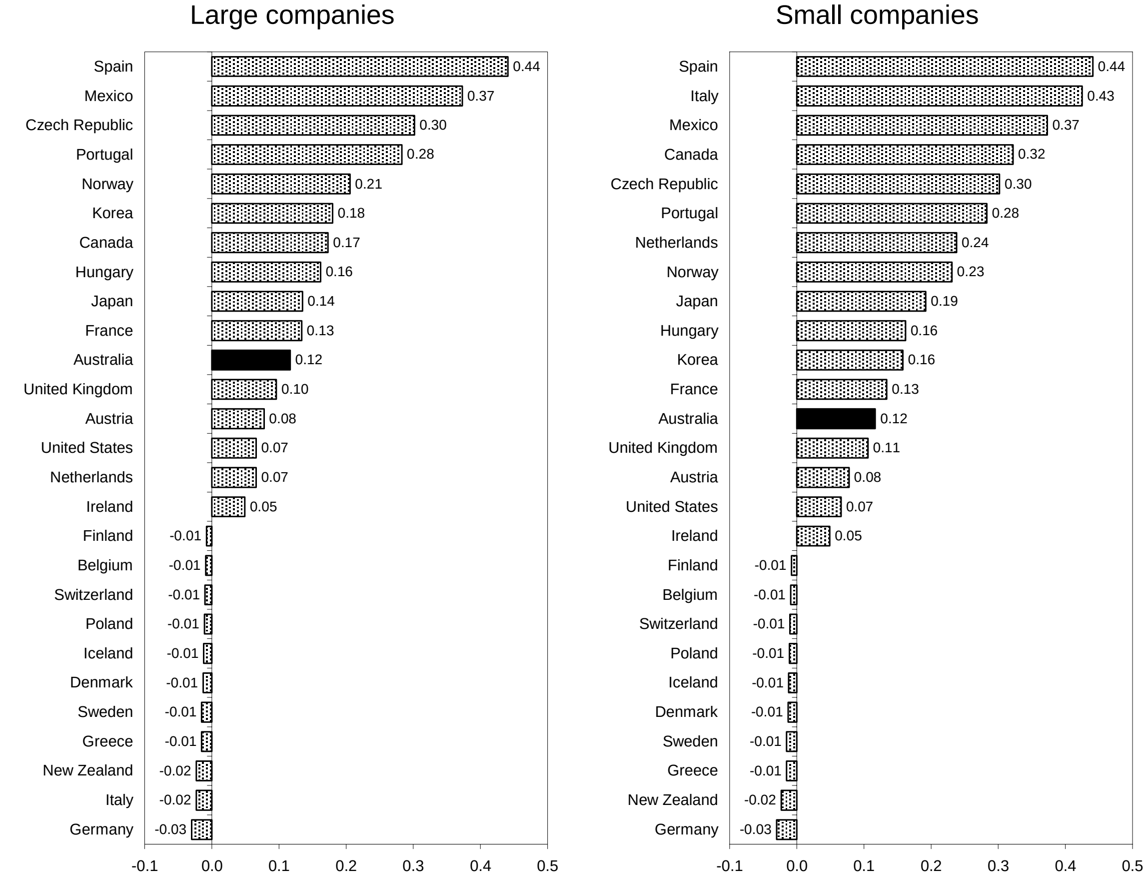
years to 2003-04, Australia provided more than twice as much assistance to BERD via the R&D tax concession than in direct assistance (as measured by the OECD).

Ideally, tax revenue foregone should be added to the OECD figures on government financed BERD prior to working out the share of business value added for each country to gain a more reliable indicator of public support for BERD. It is difficult to pinpoint exactly how Australia measures up with other countries in terms of the level of support for BERD via tax measures. The OECD notes that such comparisons are difficult as detailed data on tax expenditures from public budgetary accounts are available for only a few countries (OECD 2006b).

Warda (2006) employs B-indexes to compare the relative inducement effects across countries (box C.2). According to this measure, Australia's ranks around the mid-point for the OECD (figure C.15).

Figure C.15 **R&D tax subsidies across OECD countries based on B-indexes**[a]

2003 (or latest available year)



a Data presented here are the amount of tax subsidy, which is equal to 1 minus the B-index — with a larger number representing a greater inducement effect.

Data source: Warda 2006.

Box C.2 B-indexes — an explanation

The amount of tax subsidy to R&D is calculated as 1 minus the B-index. The B-index is defined as the present value of before-tax income necessary to cover the initial cost of R&D investment and to pay corporate income tax, so that it becomes profitable to perform research activities. This means that the calculation includes the consideration of depreciation allowances, tax credits and other allowances on R&D assets.

Algebraically, the B-index is equal to the after-tax cost of an expenditure of $1 on R&D divided by one minus the corporate income tax rate. The after-tax cost is the net cost of investing in R&D, taking into account all the available tax incentives.

$$\text{B-Index} = \frac{(1-A)}{(1-\tau)}$$

where A = the net present discounted value of depreciation allowances, tax credits and special allowances on R&D assets; and τ = the statutory corporate income tax rate (CITR). In a country with full write-off of current R&D expenditure and no R&D tax incentive scheme, A = τ, and consequently B = 1. The more favourable a country's tax treatment of R&D, the lower its B-index.

B-indexes are calculated under the assumption that the 'representative firm' is taxable, so that it may enjoy the full benefit of the tax allowance or credit. For incremental tax credits, calculation of the B-index implicitly assumes that R&D investment is fully eligible for the credit and does not exceed the ceiling if there is one. Some detailed features of R&D tax schemes (for example, refunding, carryback and carryforward of unused tax credit or flowthrough mechanisms) are therefore not taken into account.

The effective impact of the R&D tax allowance or credit on the after-tax cost of R&D is influenced by the level of the CITR. An increase in the CITR reduces the B-index only in those countries with the most generous R&D tax treatment. If tax credits are taxable (as in Canada and the United States), the effect of the CITR on the B-index depends only on the level of the depreciation allowance. If the latter is over 100 per cent for the total R&D expenditure, an increase in the CITR will reduce the B-index. For countries with less generous R&D tax treatment, the B-index is positively related to the CITR.

Sources: OECD 2004b; Shanks and Zheng 2006.

However, B-indexes are not designed to measure how incentives translate into total dollars of public money spent on BERD. The quantum of tax revenue foregone through uniform tax concession arrangements (the main source of support for BERD in Australia) is also likely to be higher than through incremental schemes. Although the Commission has not undertaken detailed calculations of this issue, the Office of Technology Assessment (1995, p. 54) has suggested that if the United States were to adopt a scheme something akin to Australia, the tax credit rate would have to be around 2 per cent to be revenue neutral, instead of the current 20 per cent tax credit rate. This implies that Australia's support for BERD via the tax concession is higher, at least relative to countries with incremental schemes, than is implied by a comparison of rates alone. However, without a comprehensive dataset it is difficult to make strong conclusions on this matter.[20] Subject to time and data constraints, the Commission will examine this question further in its final report.

C.7 Other measures of innovativeness

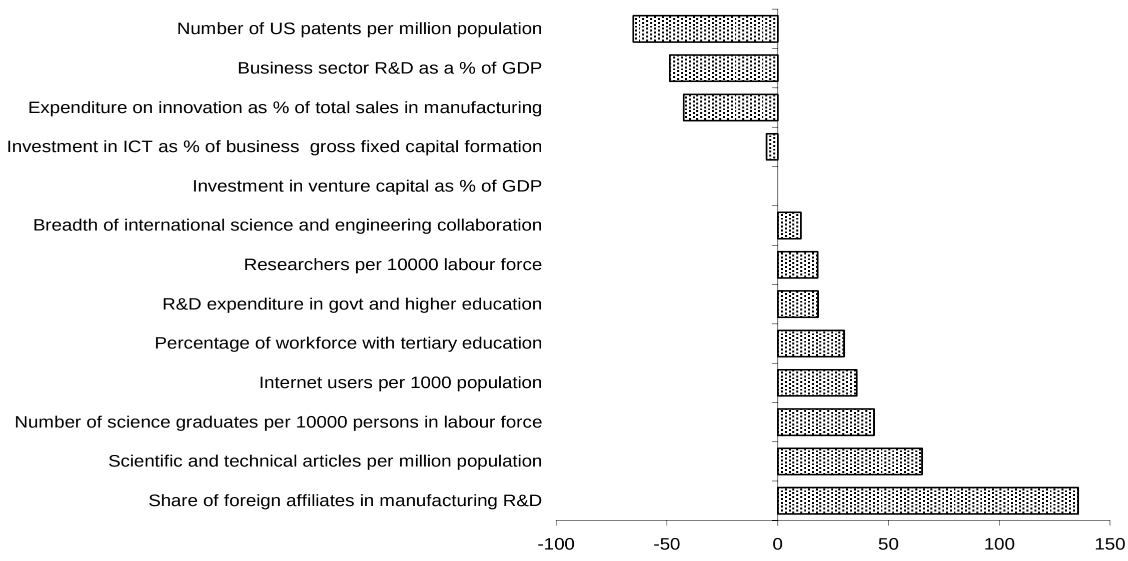
One limitation of focusing on R&D intensity measures is that R&D expenditure is an input to the innovation process rather than an output or outcome. It says nothing about the effectiveness and efficiency with which R&D funds are being, or might be, used. As the OECD noted recently (OECD 2006b, p. 59):

> [L]ooking at the amount of resources devoted to R&D is not sufficient to assess a country's innovation outcome. The main reason is that, as for all types of investment, it is not only how much that is spent that matters but also how efficiently resources are used.

Australia's performance relative to OECD averages for a broader range of innovation-related indicators based on the Australian Innovation Scorecard (DEST 2004a) does not suggest that Australia is performing poorly (figure C.16).

Figure C.16 **Australia's innovation performance compared with the OECD average, 2004[a]**

Per cent difference



[a] Or nearest available year.

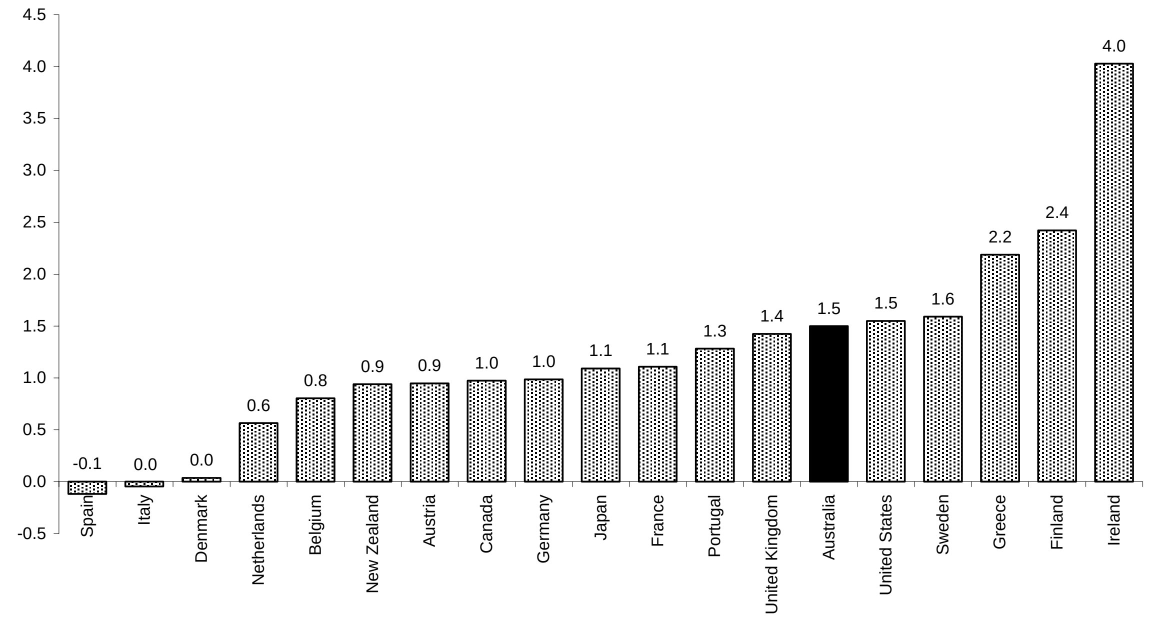
Data source: DEST 2004a.

[20] For a discussion of the difficulties in finding reliable comparisons of fiscal incentives for R&D across countries see HM Treasury (2005).

While Australia was below average on some indicators such as business R&D, United States patents and innovation/sales ratios, it registered above average performances across a range of other indicators including scientific and technical articles, science graduates in the labour force, internet usage, tertiary education and public R&D.

Estimates of multifactor productivity (MFP) growth also provide some insight into a country's relative 'innovativeness'. However, caution should be exercised in making detailed inferences about relative country performances based on comparisons of MFP growth rates without a consideration of differences in business cycles across countries. Relative country rankings can change markedly depending on the time period chosen. That said, period average MFP growth rates can provide at the very least a broad indication of a country's relative position. On this basis, latest OECD estimates indicate that of the 19 countries for which data are available, Australia recorded the sixth highest annual average rate of MFP growth in the decade to 2005 (figure C.17).

Figure C.17 **Annual average MFP growth across OECD countries, 1995 to 2005[a]**



[a] Or latest available year. Data for Australia, Japan and Spain are to 2004; Austria, Denmark, Finland, Greece, Ireland, Italy, Netherlands, Portugal, Sweden and United Kingdom are to 2003; and New Zealand is to 2002. The OECD notes that these estimates are based on harmonised price indices for ICT capital goods to improve international comparability. Data are not adjusted for cyclical factors.

Data source: OECD Productivity Database October 2006.

C.8 Conclusion

On the basis of the evidence presented above, Australia's business R&D performance is broadly in line with that of other OECD countries when differences in country size, industry structure, firm size and wage rates are taken into account. Similarly, in terms of public R&D spending, international evidence does not suggest that Australian governments are underinvesting in R&D. Moreover, based on the way targets are used internationally, it is clear that they are fundamentally aspirational in character rather than prescriptive, and best viewed as policy tools to assist in generating political will to achieve an already identified goal. Some of these issues are examined further in chapter 8.

D Absorption costs

In many instances, firms or individuals must make some investments in 'absorptive capacity' to gain the benefits of others' knowledge creation. As elaborated below, the nature of absorption strategies and the context in which they take place affect whether spillovers justify public support (with the alternative cases illustrated in figure D.1).

Case 1: Absorption of external knowledge is based on R&D that produces its own spillovers

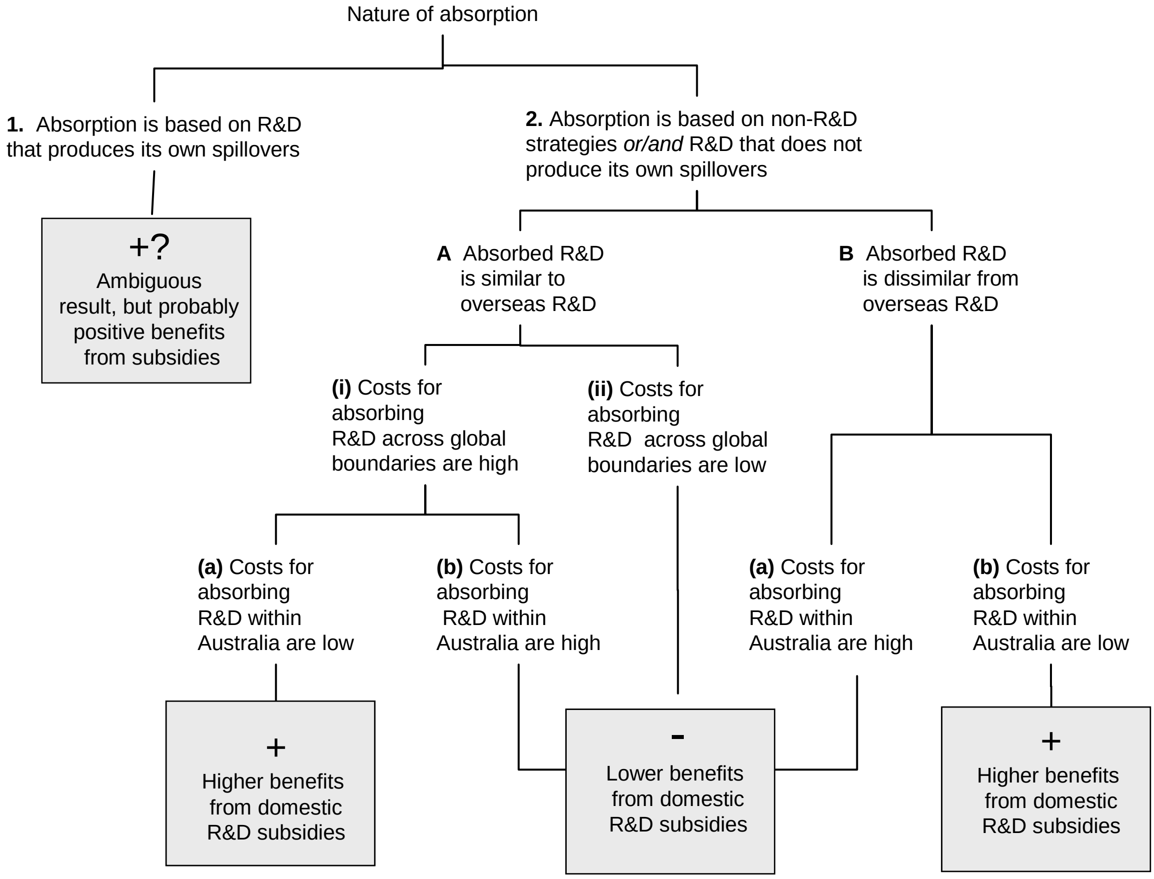
The dominant view of absorption accentuates investments in R&D as the strategy for learning from external knowledge. It is now commonly argued that a firm or agency may need to be close to the research frontier to understand and use spillovers:

> A nation needs the capability to understand the knowledge produced by others and that understanding can only be developed through performing research (Salter and Martin 2001).

There is a wide literature that confirms the importance of such capabilities within firms, such as Cohen and Levinthal (1989), Blomström and Kokko (1998), Wakelin (1998) and Girma (2005) for firms; Griffith, Redding and Van Reenen (2004) in a 13 country macro-panel data study; and Henderson (1998) in a case study of the pharmaceutical industry. Leahy and Neary (2006) provide a useful summary of the literature.[1]

[1] While most of the discussion of R&D as an absorptive strategy is centred on firms, it also applies to universities and public sector agencies. The R&D activities of universities and public research agencies are often the *quid pro quo* for privileged access to international research infrastructure and linkages with the elite academic and research programs.

Figure D.1 **When are subsidies to elicit spillovers from domestic firms warranted?**



This suggests that countries that contribute little to the global stock of frontier knowledge, like Australia, cannot free-ride on the world science and innovation system. Consequently, the possession of a domestic capability in science and innovation is important.

However, the need for absorption also affects firms' R&D investment incentives in a way that makes it ambiguous whether public support is required to develop that capability in a business setting. When R&D has an absorptive benefit, it is undertaken for its own sake *and* to increase the capacity for learning from the relevant pool of global knowledge. This has the effect of increasing the incentives for undertaking R&D. The incentive to undertake innovation may also be stimulated if it takes time for rivals to imitate and then improve an originator's innovation.[2]

When firms are engaged in competitive rivalry, each will undertake R&D to absorb each other's ideas, develop new innovations and gain a temporary edge — thus

[2] The simple spillover models assume instantaneous costless diffusion.

pushing the innovative frontier further out in a virtuous cycle. Consequently, while spillovers are still present, the benefits from, and delays associated with, absorption can increase R&D investment instead of depressing it. Geroski (1996) then poses the question of whether public support to counteract the adverse impacts of incomplete appropriability of returns is then warranted.

However, the policy-relevant issue is whether subsidies to R&D might even further increase R&D and social welfare, not the fact that R&D may increase with spillovers when the need for absorptive R&D is taken into account. In circumstances *where rivals' absorptive R&D adds to the useful stock of knowledge and generates further spillovers* (case 1 in figure D.1), Graevenitz (2004) shows that social welfare is still enhanced when R&D subsidies are provided because it stimulates even further the virtuous cycle of innovation. However, this result depends on the nature of the competitive games played between firms and the characteristics of technologies and costs — hence the question mark about the value of subsidies noted under case 1 in figure D.1.[3]

Case 2: Absorption of external knowledge is based on R&D that does not produce its own global spillovers or on non-R&D strategies

Firms absorb external knowledge in many ways — such as seeking external advice; investing in physical and intangible capital (including software, R&D, hiring and training); and tapping business networks. The choices among strategies depend on nature of the knowledge that is being absorbed, and the capabilities and technological objectives of the recipient firm. Case 1 is only a subset of these strategies, providing a reasonable description of the processes of rivalrous R&D in many innovation-intensive oligopolistic industries (Baumol 2002).

Case 2 captures a broader range of strategies:

- R&D may not add to the global pool of knowledge, but be aimed at imitation (for example, generic drugs and, more generally, copies of brand products), or technology catch-up (such as learning how to apply new foreign process technologies to a domestic firm's production line).
- There are many other non-R&D strategies. In a global innovation system, efficient absorbers of others' innovation have incentives to package that knowledge in digestible components as a source of their own advantage, and to market this globally to less capable absorbers (box D.1).

[3] For example, Grünfeld (2003), who characterises absorption differently, gets different results.

Box D.1 Institutions have adapted to diffuse knowledge among firms and other agents without them having to undertake their own R&D

There are a myriad of national and global scientific consulting companies in the physical, engineering and social sciences, whose purpose is to provide frontier specialist technical advice to clients who lack that capacity.

Professional conferences, fairs and exhibitions are commercially organised mechanisms for knowledge exchange. Around one half of innovative Australian firms say that these mechanisms acted as a source of the idea or information used to generate their innovations (ABS 2006a).

Software can incorporate complex knowledge that is invisible to the user, yet enables users to gain the benefits of that complex knowledge. This is typical, for example, with most modern menu-driven econometric and scientific statistical and mathematical packages.

Review articles, textbooks, and other synthesising methods are widely available that aim to explain, interpret and select the most important of recent developments in any scientific field — their *purpose* is spillover maximisation.

Much of human capital accumulation is premised on efficiently distilling past learning and maximising spillovers from the relevant world stock of knowledge. Higher educational institutions are agencies whose specialised task is to organise, rank and efficiently diffuse this knowledge to students. The spillovers are not free, but they are cheap relative to the costs of generating whole bodies of knowledge, such that the huge efforts in physics or mathematics by thousands of people in the last 1000 years are distilled adequately into four years of training. A particularly important economy of this transmission of knowledge is a filtering mechanism that can avoid imparting failed or redundant theories and methods. For example, Ptolemy developed highly complex calculations that gave (often quite useful) astronomical predictions, but were premised on the earth being the centre of the solar system. None of this large body of knowledge now needs to be transmitted to students. There are many instances in the science and innovation system where failures are cheaply and generally absorbed.

The reason why MNCs exist at all is that they have developed efficient methods for transmitting and absorbing useful knowledge across borders (Kogut and Zander, 1993), through ICT and paper-based systems, and routinised person-specific linkages, such as inter-unit visits, international staff mobility, international committees, cross-country teams and training (Piscitello and Rabbiosi 2006). The density of their inter-unit linkages enable multinational companies to locate R&D facilities in countries quite different from ones in which they establish management, design, marketing, production or maintenance functions.

More broadly, international scientific spillovers are diffused more widely and in unexpected ways than would be implied by the usual absorption models. Australia may benefit from spillovers that are embodied in imported goods and services and that are not internalised by the prices of those services. For example, scientific research in the United States may generate knowledge spillovers that lead to new material technologies that are widely diffused among US firms and then exported globally. No individual firm can re-capture the spillover as a rent because they compete with each other. In this case, Australian firms (and consumers) benefit from the new technology — as an embodied spillover — without having to pay for it.

Australia's experiences with the use of information and communication technologies (ICT) provides a good illustration of the capacity for a country to absorb and exploit technologies, without needing to have a significant global presence in the R&D underpinning the technologies. Australian firms have proven to be excellent and innovative *users* of ICT and this has been a major contributor to Australia's recent high multifactor productivity growth (Parham et al. 2001; DCITA 2005; Diewert and Lawrence 2005).

Whether there is a rationale for subsidies to support R&D in these broad circumstances is contingent on several factors, which are illustrated in figure D.1 above. This is a simplified classification. Obviously absorption costs are on a continuum and the features that make up the competitive environment are very much more complex than figure D.1 suggests. Nevertheless, the possible cases may provide some policy guidance.

Foreign knowledge stocks are expensively acquired — Case 2A(i)

This case applies when the costs of absorbing R&D across national boundaries is high (case 2Ai). This might occur when external knowledge is highly complex, less readily observed, dependent on tapping into local customer-supplier networks, or relies on movements of employees carrying tacit knowledge.

Leading domestic firms are then effectively forced to undertake more costly larger-scale R&D to absorb and partly re-create foreign stocks of knowledge. But if other domestic firms can cheaply absorb the knowledge created by these leaders (case 2Aia), then the leaders may have weak incentives to undertake R&D and subsidies are potentially justified. This is the orthodox spillover case in textbooks.

Alternatively, if the costs of absorbing R&D from the leaders are high (case 2Aib), then leaders retain incentives to undertake R&D and the case for subsidies are weak.

Cheap if not free-riding — Case 2A(ii)

This case applies when the R&D in the domestic originator firm is similar to R&D undertaken overseas *and* the costs of absorbing the equivalent foreign R&D is low. In this instance, 'cheap'-riding on foreign knowledge stocks economises on domestic resources and is, in a unilateral sense, the optimal strategy.[4] A small country, like Australia, can *potentially* benefit from science and innovation conducted overseas, without reducing its use in the countries that produced them.[5] There may be a global need for public support of this type of R&D, but not necessarily a country-specific rationale.

There is question about the likelihood of realistically encountering case 2Aii in applications by Australian firms for R&D subsidies, which is the policy issue under scrutiny. Why would such firms apply for R&D subsidies at all if it is cheap to acquire external knowledge from abroad?

In many cases, firms use small-scale R&D efforts as they routinely adapt their businesses to keep up with continually shifting technological frontiers. Using ABS data, chapter 1 showed that most Australian business R&D is not new to the world. In other words, as emphasised in the broader discussion of case 2 above, R&D *itself* can be a relatively cheap form of acquiring and applying foreign knowledge pools. In this case, firms could be expected to apply for R&D subsidies were they available. But the subsidies would have few social benefits because the R&D would most likely have occurred anyway or would be likely to displace non-R&D methods of absorption. Box D.2 provides an illustration.

R&D is Australia-specific (Case 2B)

The situation when the R&D absorbed from a domestic firm is different from R&D undertaken overseas (case 2B) is more simple, because the question of absorption

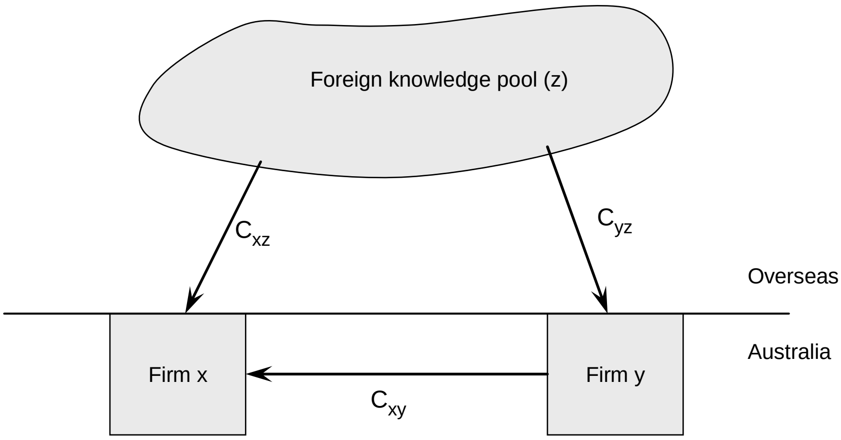
[4] For example, it is sometimes possible to free-ride on the science underpinning foreign regulatory decisions if the regulators can be trusted. A dozen Eastern European countries recognise rulings by the European drug-approval agency, economising on the high costs of approval (*The Economist* 2001, 'How Countries Go High-Tech').

[5] Australian expenditure on innovation and science dwarfed in absolute terms by the expenditure in many other OECD countries, but even single multinational companies spend about the same on R&D as the whole of Australia. For instance, three US corporations, Microsoft, The Ford Motor Company and Pfizer *each* spent about the equivalent of around A$10 billion on research and development in 2003, which was just a little less than Australian GERD and roughly double the Australian Government budget for public support of science and innovation (NSF 2006, p. 4.20). In fact, all of the top 20 global R&D spending corporations spend about the same as, or more than, the Australian Government on R&D.

from abroad does not arise. In this case, there is a symmetry with cases 2Aia and 2Aib, with subsidies again being rationalised on conventional grounds if the costs of absorption are low (case 2Bb)

Box D.2 **An illustration of 'cheap'-riding**

The figure below summarises a simple situation as an illustration of the issues that arise in these circumstances. There is a foreign stock of knowledge (z), which is valuable and can be acquired relatively cheaply by either conducting small-scale R&D (or by using similarly cheap non-R&D methods of absorption). Firm y undertakes R&D to absorb the foreign stock with cost Cyz. Firm x has two choices. It can undertake R&D to absorb from the foreign stock with cost Cxz or from firm y with cost Cxy. All absorption costs — Cyz, Cxz and Cxy — are small under the assumption of cheap absorption costs.



To the extent that R&D subsidies are available, firm y will apply for a subsidy, even though the subsidy is unlikely to have made any difference to its decision to absorb by using R&D. A subsidy to firm y to undertake its R&D cannot produce significant domestic spillovers since, by definition, the beneficiary of those spillovers, firm x, still faces some absorption costs and Cxz-Cxy must be *very* small.

The availability of the subsidy also means that firm x will apply for the subsidy, since this tilts its absorption decision from any other cheaper method of absorption to R&D as the mechanism. So an R&D subsidy will not make a difference to firm x's actual capacity for absorption, just the means chosen to do so.

Consequently, case 2Aii can be expected to elicit applications for R&D subsidies even though those subsidies have nearly zero social welfare benefits.

The insights provided by absorption costs

The argument that Australia could free-ride on global research is not convincing in its extreme form, but neither is the argument that R&D needs to be publicly supported to absorb foreign knowledge flows. So what are the policy implications of this complex story?

The need for strategies to absorb external knowledge complicates assessment of the need for public subsidies of domestic business R&D. There is a stronger rationale for public support of more radical business innovations. These are more likely to elicit virtuous cycles of improvements by rivals (case 1). Such innovations are probably also more likely to be new to the world, yet cheaply disclose to rivals what is possible, if not exactly how to do it (case 2Bb). On the other hand, R&D aimed at imitation, while commercially useful, is more likely to fit into case 2A(ii), without a clear rationale for R&D subsidies.

The significance of absorption further challenges the usefulness of simple international comparisons of R&D intensities. Pure free-riding is not possible, but undoubtedly there are large knowledge transfers across borders and a multitude of strategies to raise these flows. It is more appropriate to identify the capacity of the innovation system to facilitate information flows from abroad and between the parts of the domestic system, than to consider a single measure that represents a given way of achieving this end. Public policy strategies have a role in widening the types of investments that can be successfully used to promote absorption.

E Multifactor productivity

Chapter 4 provides estimates of the returns to multifactor productivity (MFP) of investments in R&D. It is important in that context to understand how MFP is defined, its role in economic growth and the possible connections it has to R&D.

Under certain assumptions, economic growth can be broken down into various components:[1]

$$\Delta \log\left(\frac{MY}{POP}\right)_t = \Delta \log(MFP)_t + (1-\alpha)\Delta \log\left(\frac{MK}{MHOURS}\right)_t + \Delta \log\left(\frac{MHours}{POP}\right)_t$$

where Y is GDP, MY is market sector value added, MFP is market sector multifactor productivity, α is the labour share of total factor income, MK is market sector capital stock, Mhours is annual hours worked in the market sector and POP is the total population.

The three components of growth in market sector output per capita are:

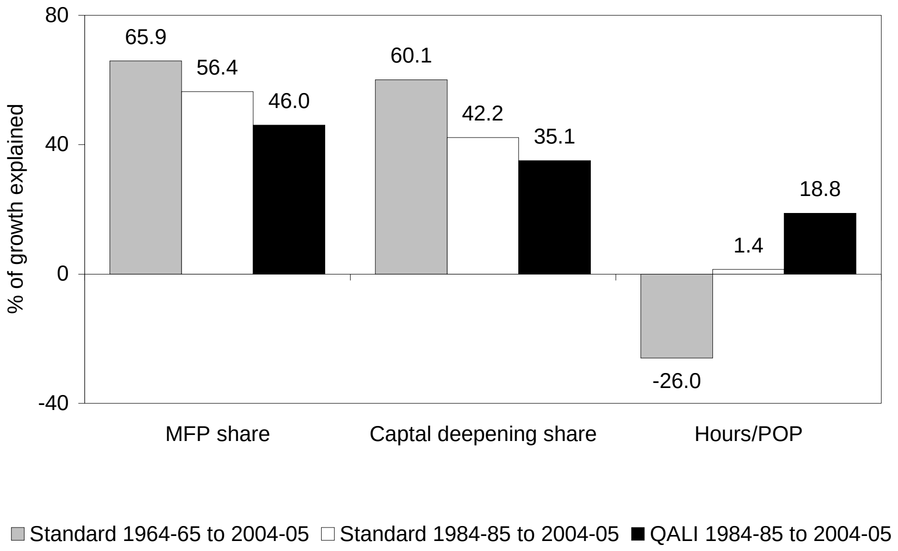
- the annual percentage growth of market sector MFP;
- (1-α) times the annual percentage growth in market sector capital intensity; and
- the annual percentage growth market sector hours per capita.

The ABS only provides MFP estimates for the market sector where output measures are market-based (figure E.1). Actual GDP growth is lower than market sector growth, but this reflects the assumption by the ABS that output growth in some parts of the economy (for example, education services) is equal to the growth of inputs in those sectors (a zero productivity assumption).

This is unlikely to hold in practice. In this case, market sector output growth per capita is probably an adequate proxy for (correctly measured) GDP per capita. Accordingly, the contribution of MFP to market sector growth is probably a good measure of the real underlying contribution of productivity to overall economic growth per capita.

[1] *Source:* IC (1997a) and ABS (2005a,b).

Figure E.1 **Contribution of multifactor productivity to long run prosperity**
Australia, 1964-65 to 2004-05[a]



[a] Growth is measured as market sector output per capita, indexed to 100 in 1964-65. The standard MFP estimates are based on just two inputs: labour and a consolidated measure of capital inputs (calculated by the ABS from weighted average of different types of capital inputs). The QALI measure takes account of quality improvements in labour stemming from improved education of the labour force (QALI=quality adjusted labour index). Because it takes account of another input (education), this reduces MFP. The QALI-adjusted MFP estimates are only available from 1984-85, hence the different time frame for the decomposition. The standard measure of MFP is also calculated for this timeframe as a comparison.

Data source: ABS, *National Accounts, Australia*, Cat. No. 5204.0.

MFP is a catch-all for everything else that affects market output apart from labour and capital. It includes:[2]

- the short-run effects of the business cycle on utilisation of labour and capital. These inputs are often idle during recessions, so measured productivity and output falls during those times;
- the improved quality of labour that results from investments in human capital. The ABS has produced experimental measures of the effects of education on the quality of labour. When these are taken into account when measuring MFP, the effect (over a shorter time frame) is reduced, but is still highly significant at around 45 per cent;
- changes in publicly-provided infrastructure, like roads, that affect the costs of bringing inputs together;

[2] Economic growth is measured in value-added terms, netting out material inputs that are used to produce goods and services. Accordingly, material inputs are not included again as an input into economic growth.

- changes in the mix of capital that might be important for productivity. A series of quantitative studies by DCITA of Australian productivity, backed by rich case study evidence (sub. 101), have indicated an important role of information and communication technologies as a driver of productivity in the 1990s;
- changing rules and regulatory arrangements, which reduce or increase the transactions costs of business (for example, changing trade barriers); and most importantly for the present study; and
- innovation within firms or other entities that produce market goods and services.

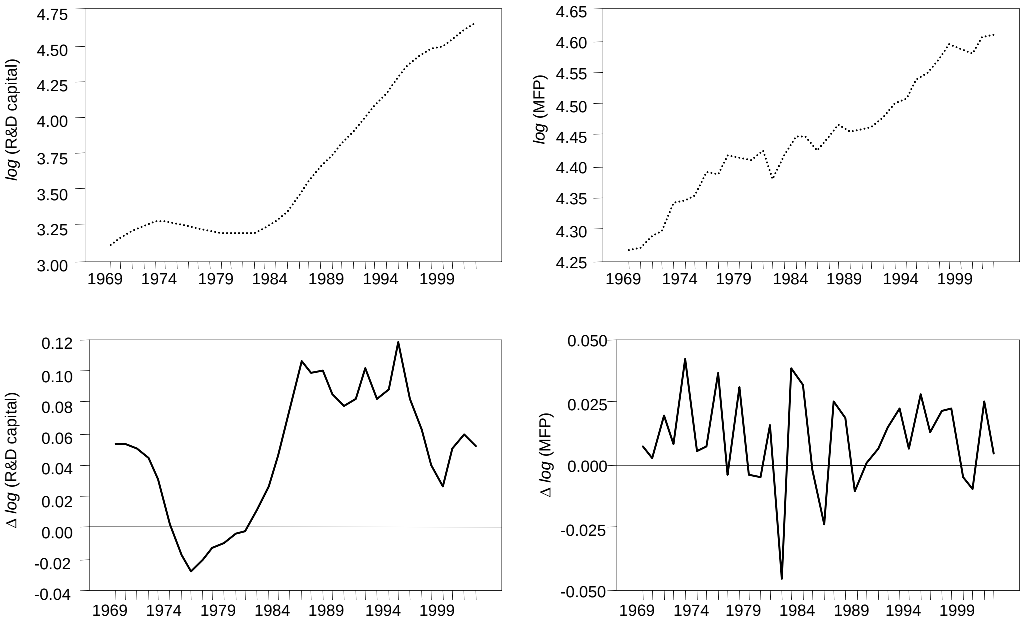
F Static models of multifactor productivity

This appendix sets out some simple static models of MFP that illustrate some of the pitfalls from the spurious regression problem in estimating rates of return. The regressions are based on Australian time series data.

A major issue in econometric estimation of trending series is spurious regression. Many economic variables — including multifactor productivity (MFP) indexes and R&D stocks — exhibit certain forms of growth trends. When the log values of these variables are differenced (amounting to computing the annual growth rates), they typically no longer show such trends. They are like white noise around a flat line (or ‘stationary’). Graphs of log(MFP) and log(domestic capital stocks) are shown in figure A.1 in both their raw form and in this differenced form. The graphs suggest that MFP is difference stationary, but this is less clear for R&D, which might require double differencing — an I(2) variable. When a series can be made stationary through single differencing, they are known as I(1) in their raw form (or integrated of order one)and as I(0) in their differenced form.

When any two I(1) variables are regressed on each other — or an I(1) on an I(2) variable — it is very likely that the relationship will be highly statistically significant and display a high R^2, *even if no relationship exists between the variables* (Granger and Newbold 1974; and Yule 1926). If they are both trending upwards, the sign on the coefficient will be positive. It is apparent that log(MFP) and log(R&D capital) show strong upward trends. Tests suggest that log(MFP) and log(R&D capital) are both at least I(1), with R&D capital possibly I(2) during the period under consideration.

Figure F.1 **Time series behaviour of R&D and multifactor productivity**
Australia 1969-70 to 2002-03



a R&D is business R&D with a depreciation rate of 15 per cent.

Data source: Provided by Shanks and Zheng (2006).

So it can be strongly predicted that a regression of one on the other will show a positive, statistically significant relationship, even if there is no underlying relationship. A regression of these two variables confirms the strong positive relationship:

$$\log(\hat{MFP})_t = 3.83 + 0.171 \log(\text{R \& D capital})_{t-1} \quad \{1\}$$

(77.3) (12.6)

R^2=0.833, Period = 1968-69 to 2002-03 (or N=34)

The figures in parentheses are the t statistics, and the log R&D capital stock is based on business sector R&D estimated with a depreciation rate of 15 per cent. The R&D stock is lagged one period to deal with the possible confounding effect produced by a contemporaneous positive link between the demand for R&D and improvements in national income (an endogeneity bias).[1] Similar positive, highly significant relationships are found between single variable regressions between MFP and the (once lagged) capital stocks based on GOVERD, HERD and foreign R&D expenditures.

[1] Positive shifts in MFP will increase national income.

These estimates imply very large rates of return to R&D. For example, with an elasticity of 0.173, the implied spillover rate of return for business R&D is around 500 per cent.

When two variables are non-stationary, the crux of the test of whether they are really linked to each other is the behaviour of the residuals $\varepsilon_t = \log(\hat{\text{MFP}})_t - \log(\text{MFP})_t$. If they are really linked, then ε will be I(0), even though log(MFP) and log(capital) are non-stationary — this is 'cointegration'. Two cointegrated series can be thought of as linked by elastic. This reflects the fact that in non-stationary processes, shocks to one variable are permanent. So if they are linked, then the permanent shocks in the R&D will affect MFP and the series will remain linked in the long run. But if they are not linked, the cumulative values of permanent shocks to domestic R&D capital will tend to pull the series apart. In this instance then ε will still be non-stationary and as $t \rightarrow \infty$ the variance, $\sigma^2_\varepsilon \rightarrow \infty$.

One symptom of the absence of cointegration is that successive values of ε_t will be highly correlated with each other ('serial correlation'). A routine test for this is the Durbin Watson (DW), which has a value of 2 when there is no first-order serial correlation and less than 2 when consecutive values of ε_t are positively correlated. In the case of {1} above the DW=0.24. A rule of thumb is that when the $DW<R^2$, spurious regression may be present, which certainly suggests that equation {1} is spurious. Further tests of the residuals suggests that they are indeed I(1) and that at least the simple formulation above lacks credibility as an estimate of the spillover rate of return to R&D. It is possible that more complex formulations involving other variables on the right-hand side, or in further transformations of the domestic R&D capital stock, might reveal a cointegrated relationship.

To demonstrate that it is easy to get false correlations of the kind represented by {1}, we ran simulations of regressions of artificially generated log(MFP) on the observed Australian domestic capital stock. In this case, the right-hand side variable is the same as in {1}, but MFP is simulated as a random walk with drift:

$$\log(MFP)_t = 0.01 + \log(MFP)_{t-1} + \varepsilon_t \text{ with } \log(MFP)_0 = \log(100.0) \qquad \{2\}$$

The variance $\sigma^2_\varepsilon \sim N(0,1)$ is re-scaled so as to give a variance for $\Delta\log(\text{MFP})_t$ that is close to the observed $\Delta\log(\text{MFP})_t$.

By design, $\log(\text{MFP})_t$ is not causally linked with $\log(R\&D\ capital)_{t-1}$, so MFP and R&D are not cointegrated. 10,000 simulations were run of regressions of log(MFP) against the lagged domestic R&D capital stock. In 98.6 per cent of the simulations, $\log(\text{R \& D capital})_{t-1}$ had a positive and statistically significant coefficient. The average estimated elasticity was 0.174 with the 90 per cent confidence interval of such elasticities lying between 0.062 and 0.286. All of these translate to apparently large rates of spillover returns (between around 190 and 860 per cent), though they are entirely fictitious. The DW consistently showed signs of the misspecification, averaging 0.29 with a median value 0.22 and being lower than the R^2 in more than 94 per cent of cases (a rule-of-thumb indicator of spurious regression). The lesson of this simulation is that any I(1) variable with characteristics roughly depicted by {2} is nearly guaranteed to give high apparent spillover returns, even when the variables are not linked. The extent of returns can be changed by altering the value of the drift factor in {2}. If it is bigger than 0.01, bigger elasticities will be generated. And changes to the depreciation rate for the calculation of the domestic capital stock can also be used to affect the measured elasticities in a predictable way: Higher depreciation rates give lower measured elasticities.[2]

By the same logic, it can be shown that any non-stationary variable on the RHS will also show high correlations with actual observed MFP in Australia.

There are many regressions involving more complex sets of R&D and other variables in Shanks and Zheng (2006) where the authors observe that the hypothesis that residuals are I(1) cannot be rejected (for example, p. 106). Shanks and Zheng accordingly do not accept such models as adequate. The point to emphasise is that regressions with this property do not count *at all* as evidence about the size of spillover effects. It would be inappropriate, for example, to include such estimates in a meta study of rates of return.

This is why Shanks and Zheng conducted careful tests of their models for stationarity and why the Commission also applies those standards to the extensions used in this study.

2 Rates of return will not be much affected because rates of return are equal to $Y/K*\eta$, where η is the elasticity. K falls as depreciation rates rises. So Y/K is rising as η is falling.

G Semi-parametric estimates of the impact of R&D

G.1 Method

This appendix sets out a semi-parametric method for calculating the impacts of R&D. Its advantage is that it imposes some common-sense priors about the effects of variables other than R&D on multifactor productivity (MFP), which may aid in isolating the possible impacts from R&D. The cumulative impacts of alternative factors cannot exceed MFP growth and any bigger role played by one factor must come at the expense of a smaller role played by another factor. This approach avoids some of the risks entailed by standard econometric analysis, which can result in the unconvincingly high responsiveness of MFP to R&D or other factors.[1]

In natural log form, market sector output can be formulated as:

$$\ln Y_t = \ln A + \varphi \ln L_t + (1-\varphi)\ln K_t + \gamma \ln RO_t + \eta \ln RS_t + \sum_{i=1}^{j} \theta_i \ln M_{it} \qquad \{1\}$$

Y is market sector GDP. L is labour hours worked, adjusted for labour quality changes over time. K is the physical capital stock. RO is the stock of R&D that would occur in the absence of public support and RS is the stock of R&D that requires public support for the underlying investments to be made. M_i to M_j capture all other factors that affect output growth (for example, foreign R&D, non-technological innovation, any excess returns from ICT investments and business cycle effects).

Not all of the R&D undertaken in higher education or public sector research agencies aims to increase market sector GDP, simply because their value relies on more intangible benefits that are not reflected in market transactions. These benefits need not be any less or more than those realised in the market sector, but in theory

[1] An example is the very large responsiveness of MFP to stocks of standards found by the CIE (for Standards Australia in the attachment to sub. 70). The CIE and Standards Australia make a convincing case that standards can play a useful role in the diffusion of knowledge and productivity growth. But the actual elasticities found in the econometric analysis are too high to be plausible.

the stocks that produce these gains should be removed from an analysis of market sector gains. Otherwise, the *market* rate of return estimated for such stocks will be underestimated. Accordingly, R&D capital stocks exclude any R&D that is not directly relevant to the market sector.

{1} can be re-arranged so that it is in terms of labour quality-adjusted multifactor productivity (MFPQ):

$$\ln Y_t - \varphi \ln L_t - (1-\varphi)\ln K_t = \ln MFPQ_t = \ln A + \sum_{i=1}^{j} \theta_i \ln M_{it} + \gamma \ln RO_t + \eta \ln RS_t \qquad \{2\}$$

Differencing yields:

$$\Delta \ln MFPQ_t = \sum_{i=1}^{j} \theta_i \Delta \ln M_{it} + \gamma \Delta \ln RO_t + \eta \Delta \ln RS_t \qquad \{3\}$$

Let us express $\sum_{i=1}^{j} \theta_i \Delta \ln M_{it} = \xi . CYCLE_t + \lambda_t$ {4}

which represents a decomposition of these other factors into cyclical and long-term components. This means:

$$\Delta \ln MFPQ_t = \xi . CYCLE_t + \lambda_t + \gamma \Delta \ln RO_t + \eta \Delta \ln RS_t \qquad \{5\}$$

Suppose that on average $\lambda_t = \Omega\, \Delta \ln MFPQ_t + \varepsilon_t$ where Ω must be bounded between 0 and 1 and ε_t is the yearly deviation from this, assumed to have an average value of zero.

λ is likely to be a significant source of MFP gains

It is likely that λ_t accounts for a significant share of the long-run change in MFP so that estimates associated with $\Omega<0.8$ are regarded as less plausible. Why? Figure 4.1 in chapter 4 provides the underpinning logic, but it is worth re-iterating the principal mechanisms given the pivotal role of assumptions about Ω.

First, many of the benefits of R&D are private (and therefore already incorporated in output).

Second, non-R&D forms of innovation are likely to be a critical source of gains. As noted by Smith and West (2005):

> Research and Development (R&D) is often not a source of innovation, but an effect of innovation decisions … Innovation and growth impulses are pervasive across the economic system, which would explain why so many so-called 'low-tech' sectors and low-tech companies have been growing rapidly … Growing sectors innovate in different ways, with a great deal of variety in their methods, approaches and results.

A major driver of such non-R&D innovation is competition between firms, which provides an impulse for continual improvement by managers and employees. Changes in trade barriers through reduced tariffs and quotas, and emerging competition from developing economies has probably intensified competitive forces in the last few decades, as has microeconomic reform generally. Shanks and Zheng (2006) found empirical evidence of a link between R&D investment and increased openness. It seems likely that there is a similar link between more intangible forms of innovation and openness/competition.

The importance of such non-R&D innovation has probably intensified with the ascendancy of services and the *relative* decline of manufacturing and agriculture, though non-technological innovation still remains significant in the latter sectors.

Third, foreign knowledge flows — both technological and non-technological — are very important for a small open economy like Australia, and their diffusion and adoption is likely to be a major source of MFP gains. As discussed in Shanks and Zheng (2006), an international literature has confirmed the importance of foreign R&D stocks (which is a more easily observable component of foreign knowledge stocks more generally). It should be noted that Australia's domestically-generated technological knowledge stock is less than 5 per cent of the global stock. Of course, domestic R&D can assist in absorbing such foreign technological knowledge flows. But as discussed in chapter 3, domestic R&D is by no means the only mechanism for effective transfer of foreign knowledge (and even less so in the case of non-technological knowledge).

While we prefer an assumption of Ω=0.8, it could be higher or lower than this, and the consequences for elasticities and rates of return are investigated later.

Calculating elasticities and rates of returns

The gross rate of return (ρ) on the stocks of R&D capital is the multiple of the relevant elasticity and the GDP to R&D stock ratio (Shanks and Zheng 2006):

$$\rho O_t = \gamma\,(Y_t/RO_t) \text{ and } \rho S_t = \eta\,(Y_t/RS_t) \qquad \{6\}$$

It is customary when calculating summary rates of return to use average output to R&D ratios, so that:

$$\overline{\rho O} = \gamma \frac{1}{n} \sum\nolimits_{t=1}^{n} (Y_t/RO_t) \text{ and } \overline{\rho S} = \eta \frac{1}{n} \sum\nolimits_{t=1}^{n} (Y_t/RS_t) \qquad \{7\}$$

In the absence of any other guidance, a tractable assumption is that the average gross rates of return on these market-sector relevant R&D stocks are about the same over the long run (the net returns will be the same if the depreciation rates are also the same); ie $\overline{\rho O} = \overline{\rho S}$.

{7} can be manipulated so that:

$$\gamma = \overline{\rho O} \times n / \sum_{t=1}^{n} (Y_t / RO_t) \qquad \{8\}$$

In that case:

$$\gamma = \overline{\rho O} \times n / \sum_{t=1}^{n} (Y_t/RO_t) = \eta \frac{1}{n} \sum_{t=1}^{n} (Y_t/RS_t) \times n / \sum_{t=1}^{n} (Y_t/RO_t)$$
$$= \eta \frac{\sum_{t=1}^{n} (Y_t/RS_t)}{\sum_{t=1}^{n} (Y_t/RO_t)} = \eta S \text{ since } \frac{\sum_{t=1}^{n} (Y_t/RS_t)}{\sum_{t=1}^{n} (Y_t/RO_t)} \text{ is a fixed number} \qquad \{9\}$$

γ

Accordingly, given observations on the stocks of R&D and market sector GDP, an estimate of can be made from η. Substituting these conditions into {5} and taking note of the definition of λ_t, yields:

$$(1 - \Omega) \Delta \ln MFPQ_t = \xi . CYCLE_t + \eta \{ S \times \Delta \ln RO_t + \Delta \ln RS_t \} + \varepsilon_t$$
$$= \xi . CYCLE_t + \eta R_t^* + \varepsilon_t \qquad \{10\}$$

Where R* is the composite R&D measure $(S \, \Delta \ln RO_t + \Delta \ln RS_t$.

As discussed below, it is possible to estimate {10}. However, a first step is construction of the data.

G.1 Construction of observable R&D stocks

Data on stocks of total business, higher education and public sector agency R&D stocks are available from Shanks and Zheng (2006) (with assumed depreciation rates of 15 per cent). Some assumptions must be made about the shares of these relevant for RO and RS. Reasonable judgments are made about the parameters concerned, but because of the uncertainty, a later section of the appendix uses simulation methods to explore the consequences of different assumptions.

Information compiled by the ABS on the socio-economic objectives of R&D by the performing sector provides some information (table G.1).

Table G.1 **R&D by socio-economic objective**

By R&D performing sector, 2002-03[a]

Objective	*Business*	*Public Sector*	*Higher Education*
	%	%	%
Non-market			
Defence	2.5	11.4	0.3
Health	5.2	9.2	28.3
Education and Training	0.2	0.5	4.7
Social Development and Community Services	0.4	2.4	10.0
Environmental Policy Frameworks & Other Aspects	0.3	1.4	1.0
Environmental Management	0.6	19.1	5.4
Non-oriented Research	0.1	2.0	21.3
Total 'non-market'	9.3	46.0	71.1
Market-oriented	90.7	54.0	28.9

[a] Market-oriented R&D is defined as the sum of data defined by socio-economic codes 620000 to 720000 (such as plant production; energy resources; manufacturing; construction and so on). On unadjusted figures, just over 90 per cent of R&D activity in the business sector fell into this category. It seems reasonable to suppose that all of the activity of businesses relates to market-oriented activities, so that in the business sector, the apparently non-market research actually has market value. The same will apply to non-business sectors. This is clear for health, for example. It is also notable that basic research by universities into general areas of research — non-oriented research — may well produce long-term economic value that shows up in market measured output. Accordingly, actual market-oriented shares are likely to be higher than those shown here — and this is reflected in the subsequent modelling.

Source: Derived by PC from ABS, *Research and Experimental Development All Sector Summary, 2002-03*, Cat no. 8112.0.

It is assumed that around 60 per cent of public sector R&D stocks are relevant to the market sector measure of GDP, reflecting the fact that significant amounts of R&D in these agencies is directed at public good issues, such as defence, environmental or social issues. The choice of 60 per cent rather than the 54 per cent shown in table G.1 is based on the judgment that some notionally non-market research is ultimately realised in gains for the market economy. Of the R&D that is relevant, it is judged that around 10 per cent would have happened without public support. This reflects the fact that businesses and farms contract with some of the agencies to undertake R&D on their behalf and could be expected to undertake at least a component of such research through other avenues (probably within the business sector) even if the public sector research agencies did not exist.

Higher education research has a greater orientation to basic research that expands the global research frontier and less to research aimed at Australia-specific issues than public sector research agencies. This sector also has an orientation to applied research in the social and environmental sciences (chapter 2). There is a less direct orientation to commercially-relevant research, although that has increased in recent years. However, it should be noted that basic research can have longer term impacts in the market sector, so that short-run and long-run effects should be distinguished.

Here, a long-term view is taken so that overall, it is judged that around 40 per cent (compared with the 30 per cent from table G.1) of higher education research shows up as benefits to market sector outputs (and the rest to global knowledge accumulation and intangible benefits). It is judged that around 10 per cent of higher education research would be undertaken in the absence of public support for research in the higher education sector.

Finally, all business R&D aims to increase market sector output. As a whole, this sector receives relatively little public assistance. The revenue costs of R&D benefits provided to the business sector by the Australian Government amount to just over 10 per cent of total business R&D (chapter 2). Supposing that the 'bang for a buck' is around 80 cents (chapter 4), this implies that the share of observed business R&D that can be ascribed to business support (μ) is 0.10×*0.8 = 0.08 (or 8 per cent), as shown in table G.2.

These various sub-components can be added to give estimates of RS and RO.

Table G.2 **Parameters used in constructing relevant R&D stocks**

	Market relevant share	*What share of observed R&D can be ascribed to public support?*	*Contribution to RS*	*Contribution to RO*
	(s)	(μ)	$(s\times\mu\times R)$	$(s\times(1-\mu)\times R)$
Public sector R&D stocks (R_{pub})	0.60	0.9	0.54 R_{pub}	0.06 R_{pub}
Higher education R&D stocks (R_H)	0.40	0.9	0.36 R_H	0.04 R_H
Business R&D (R_B)	1.00	0.08	0.08 R_B	0.92 R_B
Totals			0.54 R_{pub}+ 0.36 R_H+0.08 R_B	0.06 R_{pub}+ 0.04 R_H+0.92 R_B

G.2 Estimation and results

For an assumed value of ρ and given the relationships observed above, an appropriate estimable model is:

$$(1-\Omega)\Delta\ln MFPQ_t = \hat{\xi}.CYCLE_t + \hat{\eta}R_t^* + \varepsilon_t \qquad \{11\}$$

$\Delta\ln MFPQ_t$ is the growth in MFP adjusted for changes in human capital and the CYCLE variable is measured as Δ(Y/HPY-1), where Y is market sector GDP and HPY is the Hodrick Prescott filtered value of Y.

An alternative model can be estimated by using a variant ($\Delta\ln AMFP_t$) of $\Delta\ln MFPQ_t$. This variant is derived by making simple corrections to the conventional measure of the growth in MFP (which is *unadjusted* for changing labour quality). This approach has the benefit of allowing models to be estimated over the longer period from 1969-70 to 2002-04 because labour quality-adjusted data are only available from 1984-85. Using this alternative involves major assumptions, as discussed in box G.1, and accordingly results using this variant should be regarded with greater caution. The model estimated was:

$$(1-\Omega)\,\Delta\ln AMFP_t = \hat{\xi}.CYCLE_t + \hat{\eta}R_t^* + \varepsilon_t \qquad \{12\}$$

where the derivation of AMFP is described in box G.1.

Box G.1 **Using MFP unadjusted for labour quality changes**

$\Delta ln\,MFPQ_t$ is conventional MFP growth ($\Delta ln\,MFP_t$) corrected for changes in the quality of labour. In the absence of an official ABS measure of $\Delta ln\,MFPQ_t$ prior to 1984-85, an alternative is to develop a proxy adjustment for human capital changes and subtract it from $\Delta ln\,MFP_t$. A simple, indicative approach is adopted. A regression was estimated of $\Delta ln\,MFP_t$ against the growth in R&D stocks, a measure of growth in educational attainment ($\Delta ln(education)$) as a proxy for improving labour quality, a constant (to pick up trends in MFP ascribable to foreign R&D stocks and other knowledge flows) and a business cycle variable. Then a new indicator of MFP growth adjusted for changes in labour quality was calculated as $\Delta ln\,AMFP_t = \Delta ln\,MFP_t - \hat{\psi}\Delta ln(education)_t$ where $\hat{\psi}$ is from the auxiliary regression.

This approach makes it legitimate to use the same Ω factor as for $\Delta ln\,MFPQ_t$, but is subject to the limitations of the derivation of $\Delta ln\,AMFP_t$.

It should be emphasised that the goal of the estimation procedure is to find the value for $\hat{\eta}$ *given the restrictions suggested by {11} or {12}*, not the conventional aspiration of deriving the best model for MFP from an initially general specification. This, for example, is why the model is estimated with no constant and why R* enters in its composite form, rather than in its parts.

Given the greater quality of the more recent data, the significant shifts in the nature of Australia's economic landscape between the 1970s and later decades, and the more rigorous basis on which labour quality adjustment is made, model {11} is probably the more reliable. The Commission also estimated the specification {12} over the full sample from 1969-70 to 2002-03 (shown in the table as $\{12\}^*$). If these full sample results were regarded as better, they nevertheless provide estimates that are very close to that of model {11}.

Various statistics of the significance of the included variables are included in table G.3, but these should be interpreted with care for the R&D variable. This is because a constant must be excluded from the regression for the method to make sense. Since CYCLE has a mean of roughly zero and both the R&D variable and (1–Ω) Δlog MFP have non-zero means, the R&D variable can be expected to be significant. This is not necessarily true for the CYCLE variable, though it is, in fact, highly significant. The value of the key coefficient on R&D — an elasticity of around 0.02 — is associated with a rate of return of around 65 per cent. The result is consistent with the preferred conventional econometric model of MFP productivity estimated and discussed in chapter 4.

Table G.3 **Regression results (Ω=0.8)**[a]

	$(1-\Omega)\Delta\ln MFPQ_t$	$(1-\Omega)\,\Delta\ln AMFP_t$	
Variable	*{11}*	*{12}*	*{12}**
CYCLE	0.120	0.116	0.129
	(5.0)	(4.9)	(9.6)
R^* or $\{S\times\Delta\ln RO+\Delta\ln RS\}$	0.0180	0.0213	0.0213
	(4.6)	(5.8)	(6.3)
100SE	0.202	0.187	0.210
DW	1.50	1.51	1.20
Obs	19	19	34
Start	1984-85	1984-85	1969-70
End	2002-03	2002-03	2002-03

a t statistics in parentheses (robust errors).

Source: PC estimates.

Estimates of η from OLS regressions for alternative values of Ω are shown in table G.4, as are the implied rates of return to R&D.

Table G.4 Estimates of the impact on market sector productivity of R&D elicited by public support

Ω	*{11} 1984-85 to 2002-03*	*{12} 1984-85 to 2002-03*	*{12*} 1969-70 to 2002-03*
	Impacts ($\hat{\eta}$)*100		
0.50	4.50	5.32	5.33
0.60	3.60	4.26	4.26
0.70	2.70	3.19	3.20
0.80	1.80	2.13	2.13
0.85	1.35	1.60	1.60
0.90	0.90	1.07	1.07
	Rates of return (%) ($\hat{\eta} \times Y / R_S$)		
0.50	160.8	190.1	190.3
0.60	128.7	152.1	152.3
0.70	96.5	114.0	114.2
0.80	64.3	76.0	76.1
0.85	48.2	57.0	57.1
0.9	32.2	38.0	38.1

[a] The labour quality adjusted estimates of MFP are only available from 1984-85, which is why {11} is estimated over this period. Model {12} has been estimated over the shorter sample for comparisons to {11}, but is also estimated over the full period (model {12*}).

G.3 Implications

The results imply relatively high gross spillover rates of return to publicly supported R&D of around 65 per cent, plus or minus around 20 points.

What does this imply about the contribution of (truly additional) supported R&D to total conventional MFP growth? Conventional MFP growth is:

$$\Delta \ln MFP_t = \Delta \ln MFPQ_t + \kappa\, \Delta \ln QALI_t \qquad \{13\}$$

where $\kappa \Delta \ln QALI_t$ is the effect of changes in labour quality on market-sector GDP. Using the definition of $\Delta \ln MFPQ_t$ from {5} then:

$$\Delta \ln MFP_t = \Omega\, \Delta \ln MFPQ_t + \kappa \Delta \ln QALI_t + \xi.CYCLE_t + \eta\, S \times \Delta\, ln\, RO_t + \eta\, \Delta\, ln\, RS_t + \varepsilon_t \qquad \{14\}$$

Accordingly, in period 1, ln MFP can be expressed as:

$$\begin{aligned} \ln MFP_1 = \ln MFP_0 + \Omega\, \Delta \ln MFPQ_1 + \kappa\, \Delta \ln QALI_1 + \xi.CYCLE_1 + \\ \eta\, S \times \Delta \ln RO_1 + \eta\, \Delta \ln RS_1 + \varepsilon_1 \end{aligned} \qquad \{15\}$$

and in period 2 by recursion as:

$$\ln MFP_2 = \ln MFP_0 + \Omega(\Delta\ln MFPQ_1 + \Delta\ln MFPQ_2) + \kappa(\Delta\ln QALI_1 + \Delta\ln QALI_2) +$$
$$\xi.(CYCLE_1 + CYCLE_2) + \eta S \times (\Delta\ln RO_1 + \Delta\ln RO_2) + \eta(\Delta RS_1 + \Delta\ln RS_2) + \varepsilon_1 + \varepsilon_2 \qquad \{16\}$$

Accordingly, by period T, the long run growth in MFP between period 0 and period T can be expressed as the sum of the changes of each of the parts:

$$\ln MFP_T - \ln MFP_0 = \Omega\sum_{i=1}^{T}\Delta\ln MFPQ_i + \kappa\sum_{i=1}^{T}\Delta\ln QALI_i + \xi\sum_{i=1}^{T} CYCLE_i$$
$$+ \eta S\sum_{i=1}^{T}\Delta\ln RO_i + \eta\sum_{i=1}^{T}\Delta\ln RS_i + \sum_{i=1}^{T}\varepsilon_i \qquad \{17\}$$

Consequently, each of these sums can be expressed as a share of $\ln MFP_T - \ln MFP_0$ and will add to one. For example, the total percentage contribution to MFP change of R&D stimulated by public support from 1983-84 to 2002-03 is:

$$\text{Contribution from supported R \& D} = 100 \times \frac{\eta\sum_{i=1984-85}^{2002-03}\Delta\ln RS_i}{(\ln MFP_{2002-03} - \ln MFP_{1983-84})} \qquad \{18\}$$

At the assumed default value of Ω=0.8, around 5 per cent of conventional MFP change in the market sector from 1983-84 to 2002-03 can be attributed to R&D stimulated by public support, around 10 per cent to other market sector-relevant R&D and the remaining 85 per cent to other factors (table G.5). Were Ω to be as low as 0.5, then the contribution of R&D stimulated by public support is still only 13 per cent, and at the other extreme of Ω=0.9, just 2.5 per cent. Consequently, even though the social rates of return to publicly supported R&D may be high, it should be noted that the actual implications for long-run productivity growth are relatively modest compared with other factors.

Table G.5 **Contribution of different factors to growth in multifactor productivity**

1983-84 to 2002-03

	Ω					
Factors	0.5	0.6	0.7	0.8	0.85	0.9
	%	%	%	%	%	%
Share due to additional publicly supported R&D (RS)	**12.6**	**10.1**	**7.6**	**5.0**	**3.8**	**2.5**
Share due to other R&D (RO)	24.0	19.2	14.4	9.6	7.2	4.8
Share due to business cycle (CYCLE)	1.7	1.4	1.0	0.7	0.5	0.3
Share due to other short-term influences (ε)	3.0	2.4	1.8	1.2	0.9	0.6
Share due to increased quality of human capital (QALI)	17.4	17.4	17.4	17.4	17.4	17.4
Share due to other long-run factors (Ω Δlog MFPQ)	41.3	49.5	57.8	66.1	70.2	74.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: PC calculations.

That said, the implications in terms of *absolute* market-sector GDP are still significant. This is calculated by setting Δln RS to zero in equation {14} so that the counterfactual MFP growth rates from 1983-84 to 2002-03 are:

$$\Delta ln\,\widetilde{M}FP_t = \Omega\,\Delta ln\,MFPQ_t + \kappa\,\Delta ln\,QALI_t + \xi.CYCLE_t + \eta\,S \times \Delta ln\,RO_t + \varepsilon_t \qquad \{19\}$$

Then counterfactual growth in per capita market sector GDP is:

$$\widetilde{g}_t = \Delta ln\,\widetilde{M}FP_t + \Delta Capital\ deepening_t + \Delta labour\ hours_t \qquad \{20\}$$

so that counterfactual per capita GDP in any time period is:

$$YC\widetilde{A}P_t = YC\widetilde{A}P_{t-1} \times e^{\widetilde{g}_t} \text{ where in period 0}: \mathrm{YC\widetilde{A}P_0 = YCAP_0} \qquad \{21\}$$

and counterfactual market sector GDP is $\widetilde{Y}_t = YC\widetilde{A}P_t \times POP_t$. Then the market sector GDP gain from R&D stimulated by public support over the period from 1983-84 to 2002-03 is $\text{Cumulative gain} = \sum_{1983-84}^{2002-03}(Y_t - \widetilde{Y}_t)$, while the gain in just the last year is $\text{Gain (2002 - 03)} = (Y_{2002-03} - \widetilde{Y}_{2002-03})$.

If Ω is 0.8, then the accumulated gross gains to market-sector GDP over the roughly two decades from 1983-84 to 2002-03 is around $54 billion in 2003-04 prices (table G.6). In 2004-05, the gains from R&D stimulated by public support were around $6.5 billion (noting that this, in part, reflects the growth benefits of past supported R&D). It might not be thought that this benefit is substantial given that governments invest around $6 billion annually in R&D. However, it should be recalled that a significant share of R&D stimulated by government is not allocated to activities that affect market-sector GDP. They still make contributions, however, to unpriced, but valuable goods and services (such as the environment or improved health) and these gains are not reflected in table G.6.

Table G.6 **Impacts on market sector GDP of R&D stimulated by public support**

Ω	*Cumulative gain 1983-84 to 2002-03*	*Gain in 2002-03*
	$ million 2003-04 prices	$ million 2003-04 prices
0.5	133 082	16 073
0.6	106 712	12 899
0.7	80 219	9 704
0.8	53 603	6 490
0.85	40 249	4 875
0.9	26 863	3 255

Source: PC calculations.

Simulation analysis

Since there is considerable uncertainty about the values of Ω, s and μ, another approach is to presume some distribution of these and to sample their distributions, re-estimate the above model and then form the distribution of the resulting values of η and rates of return.

The approach taken was to use the beta distribution, which is bounded between one and zero. The shape of the beta distribution is determined by two parameters, α and β. If $\alpha=\beta$ and they are greater than one, then the distribution is symmetric and takes an inverted-u shape. In all cases in the simulation, $\alpha=\beta$. In any given simulation run, the sample taken from distribution was calculated as follows:

$$\text{if } \bar{x} >= 0.5, x_i = \bar{x} + (1.-\bar{x}) * 2. * (\text{ranbeta}(\alpha,\beta) - 0.5)$$
$$\text{else if } \bar{x} >= 0.5 \text{ then } x_i = \bar{x} + \bar{x} * 2 * (\text{ranbeta}(\alpha,\beta) - 0.5))$$

where ranbeta(α,β) provides a random draw from the beta distribution, x_i is the value of the ith random draw of the random variable x and $\bar{x}$ is the mean value of the variable. For example, in the case of values of Ω, $x_i = \Omega_i$, and $\bar{x} = \bar{\Omega} = 0.8$, and $\alpha=\beta=5$. Table G.7 discloses the assumptions about α and β for each relevant parameter in the simulations. Based on 10 000 random draws, the table also shows the characteristics of the distributions of the underlying parameters, the impact elasticity and the rates of return. A graph of the distributions of the returns and elasticities of R&D stimulated by public support from this simulation is shown in figure G.1.

Table G.7 **Characteristics of distributions of parameters and outcomes**

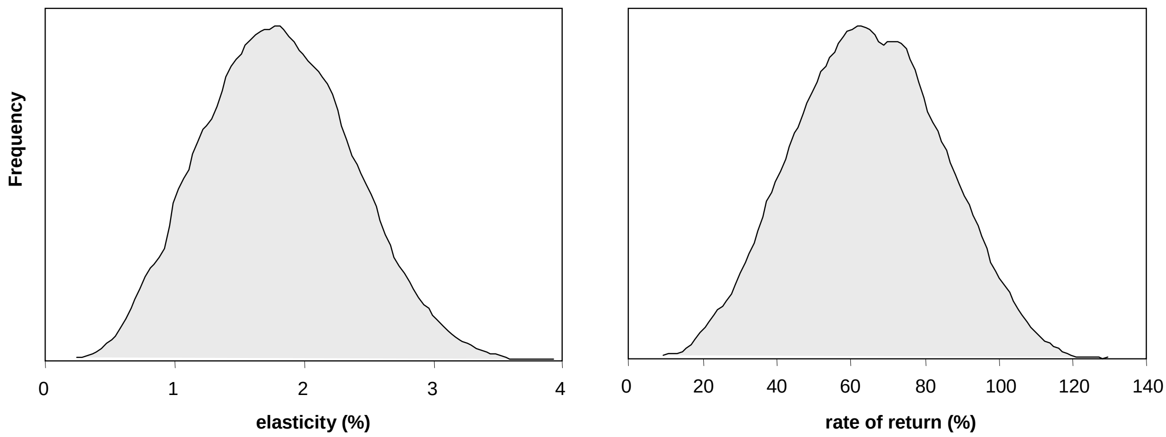
10 000 draws

	Theoretical mean	*5 per cent tail*	*95 per cent tail*	*Mean of draws*	*Median of draws*	$\alpha=\beta$
μ_{pub}	0.900	0.851	0.949	0.900	0.900	5
μ_H	0.900	0.874	0.926	0.900	0.900	20
μ_B	0.080	0.051	0.109	0.080	0.080	10
s_{pub}	0.600	0.399	0.793	0.598	0.598	5
s_H	0.400	0.259	0.546	0.400	0.398	10
Ω	0.800	0.700	0.899	0.799	0.799	5
Elasticity*100	1.80	0.87	2.77	1.80	1.78	..
Rate of return (%)	64.3	32.5	97.3	64.7	64.6	..

a s the share of R&D conducted in various parts of the system that is relevant to the market sector output; μ is the measure of additional R&D relevant to the market sector from support, and pub, H and B are the public sector research agencies, higher education research institutions and business sector agencies respectively.

Source: PC calculations.

Figure G.1 **The distribution of the impact of publicly supported R&D**



a Density estimation using an Epanechnikov kernel based on a 10 000 simulation.

Data source: PC calculations based on the simulation methods described in the text.

Another important issue is which factors are decisive in influencing the rate of return in the simulations. It is apparent from the formulation of the estimation equation, {1}, that Ω must play a significant role, and this is also clearly apparent when a response surface is estimated on the basis of the simulated results. The response surface shows how the estimated rate of return is affected by any parameter, holding other factors constant. Only a simple linear model is estimated below (t statistics are in parentheses), when it is clear from {1} that the actual underlying relationships are non-linear. However, the goal was to see if a very simple formulation provided any useful insights. The simple model explains much of the variation in the outcomes for the rate of return and tests of some non-linear alternatives suggest better models do not qualitatively change the results. The results suggest that, for example, an increase in Ω of 0.1 decreases the rate of return by around 30 percentage points and that other parameters have relatively second-order impacts on rates of return.

$$RateR*100 = \underset{(451)}{310} - \underset{(239)}{20\, s_{pub}} - \underset{(202)}{24\, s_H} + \underset{(69)}{24\, \mu_{pub}} + \underset{(22)}{14\, \mu_H} - \underset{(8)}{5\, \mu_B} - \underset{(1889)}{322\, \Omega}$$

$R^2 = 0.997$; N = 10 000, t statistics in parentheses

G.4 Conclusion

Overall, the results of this semi-parametric method suggest that the marginal rates of return to R&D elicited through public support could easily be as high as 65 per cent. The results are influenced by priors about the substantial significance of other factors contributing to MFP growth — such as diffusion of ideas from foreign knowledge flows; innovation more broadly and the impacts of intensifying competition. Figures higher (lower) than 65 per cent are possible if other factors contributing to MFP growth play a lesser (greater) role. However, even when uncertainty about the parameters is taken into account, rates of return are mostly above 35 per cent and below 100 per cent. Much larger values would imply that the huge flows of knowledge from overseas and from non-technological forms of innovation were unrealistically small relative to the flows from domestic R&D (even after accounting for absorption issues — see chapter 3 and appendix D). Much smaller values would risk ignoring the important role of domestic R&D as a generator of knowledge flows and in absorbing foreign flows of knowledge.

The results demonstrate that it is possible to reconcile high social rates of return on R&D with a modest relative contribution to growth of market sector GDP. We find that even with large rates of return, the actual contribution to Australia's cumulative productivity growth (as measured by conventional MFP estimates) of R&D elicited by public support is relatively small over the last two decades. It is of the order of 2.5 to 7.5 per cent[2] (so that the remaining 97.5 to 92.5 per cent of multifactor productivity growth can be attributed to other factors, including non-supported R&D).

[2] Corresponding to Ω=0.9 to 0.7.

It is this modest relative contribution to MFP growth, against the background of the statistical noise in MFP models, that explains why econometric methods will generally find it hard to pin down the impacts of R&D on growth with any precision — the key finding of Shanks and Zheng (2006). But it is worth noting that even modest contributions are worth many billions of dollars to current GDP — some $54 billion over the two decades in the standard results of this appendix. However, it should not be inferred that significant increases in public support would necessarily realise bigger gains — an issue that is explored in chapter 4.

H State level panel data estimation of the returns to public and private R&D

This appendix provides a statistical analysis of the impact of research and development (R&D) on multifactor productivity (MFP) and economic growth among the Australian States. It is complementary to Commission's recent analysis of business R&D and MFP at the national level (Shanks and Zheng 2006). In simple terms this study addresses three questions:

1. Does the R&D conducted in the private sector have any spillover benefit beyond the private gains to individual firms?
2. Does the total amount of R&D (public + private) influence productivity and economic growth?
3. Can the effects of BERD, GOVERD and HERD be separately identified?

The statistical analysis presented here proceeds in four parts. The first part briefly locates this study within the context of existing work. The second part is concerned with the construction of the state level MFP estimates and the R&D capital stock estimates. The third part graphically inspects this data to see whether any basic relationships or trends can be observed. Finally, econometric techniques are used in order to quantify the effect of R&D whilst controlling for other influencing factors such as the business cycle, human capital or unobserved state specific effects.

H.1 Background

Numerous macroeconomic studies have found evidence of a significant return to aggregate or business R&D, but relatively few specifically consider the impact of public R&D (see Dowric 2003 for a useful survey). Furthermore, Shanks and Zheng (2006) have recently demonstrated the profound difficulties involved in generating robust results within the Australian context. The use of state level panel data can potentially illuminate the macroeconomic return to the various types of R&D through the information contained within the interstate variation.

To the Commission's knowledge, state level panel data has been used on two previous occasions to estimate a return to R&D within the Australian context:

1. Louca (2003) finds evidence of a positive relationship between business R&D and multifactor productivity; and
2. Burgio-Ficca (2004) finds evidence of a positive relationship between higher education R&D and gross state product.

Both a multifactor productivity model similar to Louca and a production function model similar to Burgio-Ficca are estimated in this appendix. However, the sample size and exact variables used are slightly different in order to most appropriately represent the economic relationships whilst taking into account the availability and quality of existing data.

Additionally, the propensity of this type of time series data to give spurious results is given special attention. As such, modern panel data tests of cointegration will ultimately be required to corroborate the relationships suggested in this study. The Commission has conducted preliminary tests in this regard but further analysis is required before any findings can be reported. As Louca (2003) and Burgio-Ficca (2004) use essentially the same data, the results of the cointegration tests will have implications for the findings of those studies as well.

H.2 Data construction

State level MFP estimates

All variables referred to here are available from the ABS State Accounts (Cat no. 5204.0) and the ABS National Accounts (Cat no. 5220.0) with the exception of hours worked which is from ABS Labour Force (Cat no. 6202.0). All dollar variables are measured in chain volume terms. For the sake of brevity, States and Territories are hereafter referred to simply as States.

The state level multifactor productivity estimates pertain to the whole (public + private) economy and were constructed using the Tornqvist index number methodology. This entails taking the ratio of output to an index of capital and labour inputs:

$$MFP_t = \frac{Y_t}{I_t} \qquad (1)$$

where I_t is computed as a Tornqvist index, and is calculated recursively from the geometric mean of the growth rates of the labour input (l_t) and the capital input (k_t):

$$\frac{I_t}{I_{t-1}} = \left[\frac{k_t}{k_{t-1}}\right]^{W_t^k} \left[\frac{l_t}{l_{t-1}}\right]^{W_t^l} \qquad (2)$$

where W_t^k and W_t^l are respectively the average cost share of capital (S^k) and labour (S^l) in periods t and t-1. That is:

$$W_t^k = \frac{\left(S_t^k + S_{t-1}^k\right)}{2}, \quad W_t^l = \frac{\left(S_t^l + S_{t-1}^l\right)}{2}.$$

The cost share of capital (S_t^k) and labour (S_t^l) are calculated as

$$S_t^k = \frac{\text{Gross Operating Surplus}}{\text{Gross Operating Surplus + Compensation Of Employees}} \text{ and}$$

$$S_t^l = \frac{\text{Compensation Of Employees}}{\text{Gross Operating Surplus + Compensation Of Employees}} \text{ respectively.}$$

This implicitly assumes that the share of labour and capital within Gross Mixed Income (unincorporated businesses or self-employed persons) is the same as it is for the rest of the economy.

Labour (L_t) is defined as the total number of hours worked per year. This is calculated by averaging over the 12 reference weeks surveyed by the ABS and multiplying this by 52.

The State capital stocks were calculated using the perpetual inventory method (PIM), which in its simplest form can be represented as:

$$k_t = (1-\delta_t)k_{t-1} + i_t . \qquad (3)$$

The depreciation rate of capital (δ_t) is calculated as:

$$\delta_t = \frac{\text{National Consumption of Fixed Capital}_\text{t}}{\text{Net National Capital Stock}_\text{t-1}}$$

and is assumed to be the same across the States but is permitted to vary through time. Investment (i_t) is real total gross fixed capital accumulation.

Equation (3) requires a starting value (k_0) which is computed based on the assumption that the average growth rate (g) of the observed total gross fixed capital accumulation for the each state adequately describes its annual growth for the indefinitely long preceding unobserved series. In this case the starting value of the capital stock is given by:

$$k_0 = \frac{i_0}{g + \delta}$$

Incorporating k_0 into (3) yields the state capital stocks, which are then normalised such that they sum to the national capital stock calculated by the ABS:

$$k_t^n = \frac{K_t}{\sum_{i=s} k_{i,t}} \times k_t$$

where k_t^n = the normalised capital stock series for State s, K_t = the ABS national capital stock at time t, $\sum_{i=s} k_{i,t}$ = the sum of all un-normalised state capital stocks at time t, and k_t = un-normalised capital stock for state s at time t.

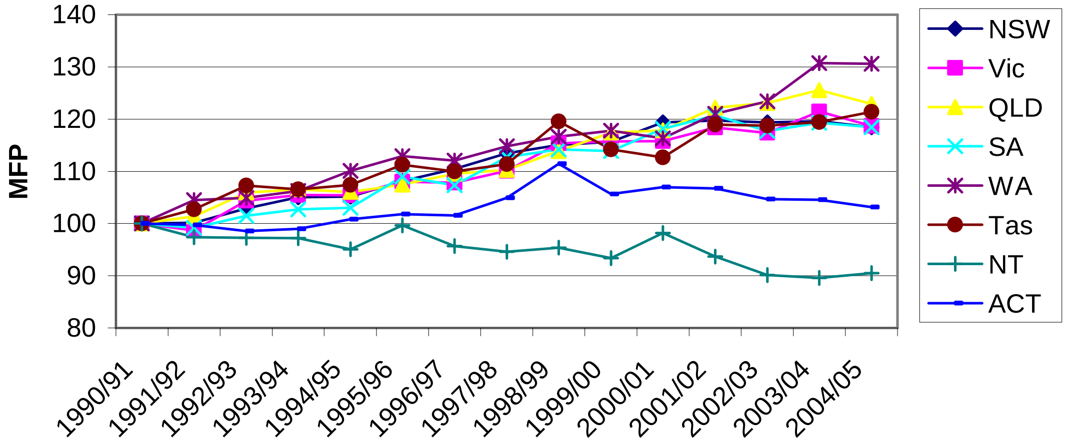
It is important to note at this stage that the state level MFP estimates derived through the calculations above come with caveats. This formulation of MFP assumes a state level constant returns to scale production function and perfectly competitive markets. It is likely that these assumptions are more appropriate for some States than they are for others. Also, the available data constrains the state level MFP estimates to be of the whole state economy. This includes many sectors that are excluded from the ABS national MFP estimates on the basis that the growth in the volume of output is unsatisfactorily measured (Cat no. 5216.0).

The calculation of capital stock has two further limitations. Firstly, the assumption of a homogenous depreciation rate does not take into account the different industry structures, vintages and asset mixes across the states. Secondly, the calculation of the initial value of capital (k_0) is inevitably going to contain some degree of error, which will dissipate over time making it less problematic when long investment series are available. In this case, chain linked real investment series at a state level are only available back to 1989, which will exacerbate this error.

Nevertheless, the estimation of MFP is essentially a question of the extent to which growth in output has outpaced growth in inputs. In this regard, despite the shortcomings of methodology and constraints of data availability and quality, the estimates presented here still provide valuable information concerning the productivity of the States. For the purposes of the econometric exercise, the inaccuracies of the MFP estimates can essentially be viewed as a measurement error of the dependent variable. The implication of this will be a loss of precision as well as estimates that will be biased towards zero, forcing us to be more conservative in our inference than we otherwise would have to be.

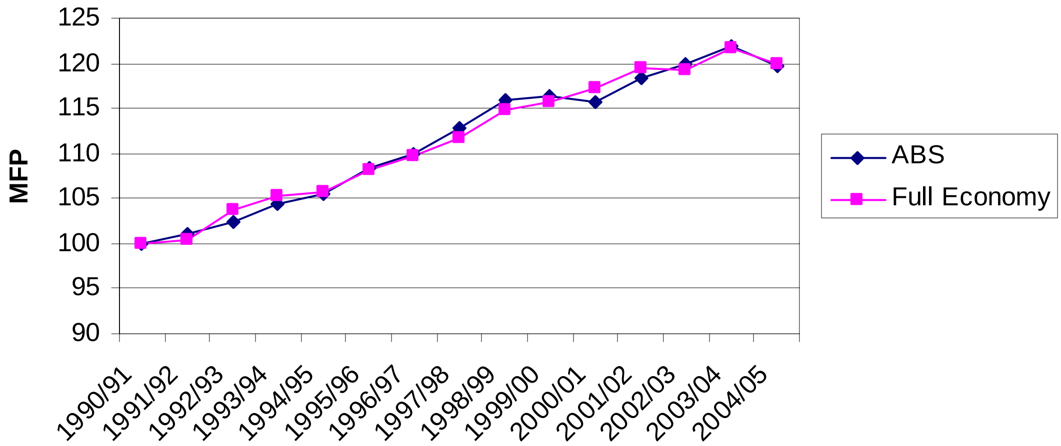
Figure H.1 illustrates the MFP series implied by the above calculations. All States exhibit growth in MFP over the period with the exception of the Northern Territory, which appears to have declined and the ACT where MFP growth appears to have been stagnant. This is interpreted as stemming from an inability to measure MFP accurately in these states given their size and the structure of their economies. Applying the Tornqvist methodology to the Australian economy as a whole results in a MFP series which is close to the ABS market sector measure, as shown in figure H.2. This suggests that the whole economy story reasonably matches the market sector story for Australia in its entirety, although it does not necessarily offer a signal as to the quality of the individual state level estimates.

Figure H.1 **State level MFP estimates**



Data source: Commission estimates.

Figure H.2 **Full economy Tornqvist MFP estimate vs ABS estimate**



Data source: Commission estimates.

R&D stocks

When considering the impact of R&D upon MFP and GSP, simple use of expenditures ignores the cumulative nature of investment in knowledge, as well as the propensity of past investment in knowledge to depreciate or become less useful over time. For this reason some measure of the stock of R&D is usually used in order to reflect both historical investment behaviour as well as current. R&D capital stocks, like ordinary capital stocks, are calculated using the perpetual inventory method as described in equation (3) above. However, there is no obvious way in which the depreciation of the R&D stock can be measured and no theoretical indication of what it should be. Following recent papers by the OECD (Guellec and Pottelsberghe de la Potterie (2001) and Luintel and Khan (2005a)) depreciation is arbitrarily set at 15 per cent.

Whilst BERD is available on a yearly basis at a state level (ABS Cat no. 8104.0**)** HERD, GOVERD and GERD (ABS Cat no. 8112.0) are only available bi-annually. In order to obtain a sufficient time series for the econometric analysis, annual data was generated by replacing the missing R&D expenditures with the average of the previous and following R&D expenditure. These expenditure series were then used to construct the stock series.

Both the ad-hoc selection of the process by which R&D expenditures become stocks, and the manner in which bi-annual data is transformed into annual will have the effect of further introducing measurement error into the econometric model.

H.3 Descriptive statistics

Before proceeding with the econometric analysis it is useful to see whether the raw data bears any evidence of a relationship between R&D and economic growth or MFP. Our effective sample is from 1990 (the earliest date for which MFP can be calculated) to 2002[1]. Looking first at the long term relationship the obvious question is:

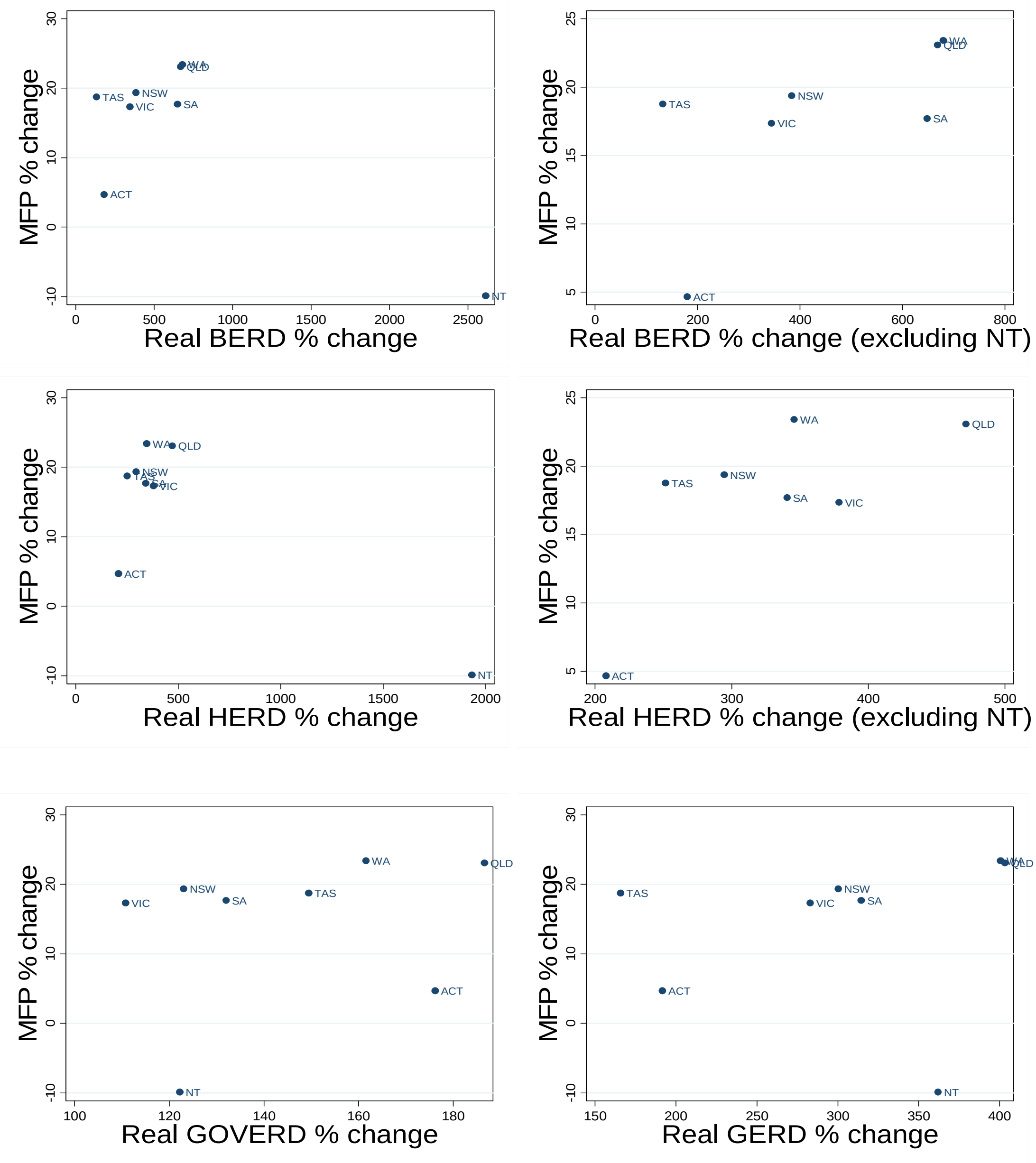
Have the States with the biggest percentage increase in R&D expenditure over the 12 year period also experienced the greatest percentage increase in MFP or GSP?

Figures H.3 and H.4 show that this generally appears to be true with the exception of the Northern Territory which has had considerable growth in all forms of R&D and very poor growth in MFP and GSP. Scatter plots containing BERD and HERD

[1] The recent R&D data became available too late to be incorporated into this analysis. The final report will include this data.

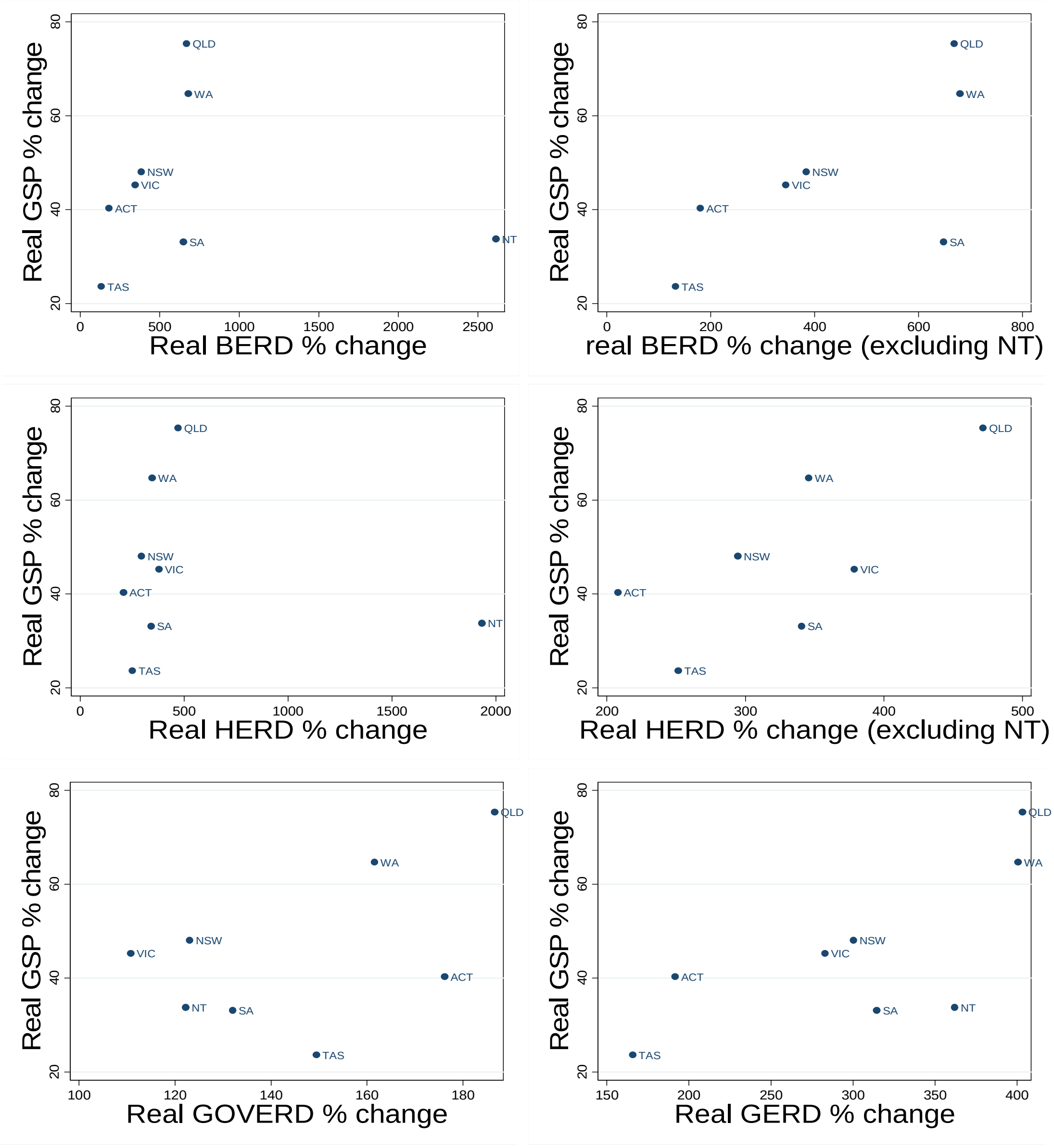
are plotted with and without the Northern Territory as the inclusion of this observation increases the scale of the plot such that the relative positions of the remaining States are obscured.

Figure H.3 **Percentage change in MFP and BERD, HERD, GOVERD and GERD from 1990 to 2002**



Data source: ABS (*Research and Experimental Development, All Sector Summary 8112.0*); *Commission estimates.*

Figure H.4 **Percentage change in GSP and BERD, HERD, GOVERD and GERD from 1990 to 2002**



Data source: ABS (*Research and Experimental Development, All Sector Summary 8112.0), ABS (State Accounts 5220.0).*

Table H.1 displays each State's rank in terms of the growth rates for MFP, GSP, BERD, GOVERD, HERD and GERD. Again we observe that the fastest growing States in terms of MFP and GSP also appear have the been the fastest growing States in terms of R&D with the exception of the NT whose relative economic performance does not seem to have matched its R&D record. The two fastest growers for MFP and GSP (WA and Qld) also hold the top two positions for overall

GERD, whilst the slowest growers in MFP excluding NT (i.e. VIC and ACT) hold the lowest two positions for GERD.

Table H.1 **Ranking of percentage change from 1990 to 2002**

State	*MFP*	*GSP*	*BERD*	*GOVERD*	*HERD*	*GERD*
WA	1	2	2	3	4	2
QLD	2	1	3	1	2	1
NSW	3	3	5	6	6	5
TAS	4	8	8	4	7	8
SA	5	7	4	5	5	4
VIC	6	4	6	8	3	6
ACT	7	5	7	2	8	7
NT	8	6	1	7	1	3

Source: Commission estimates based on ABS (*Research and Experimental Development, All Sector Summary 8112.0) and ABS (State Accounts 5220.0)*

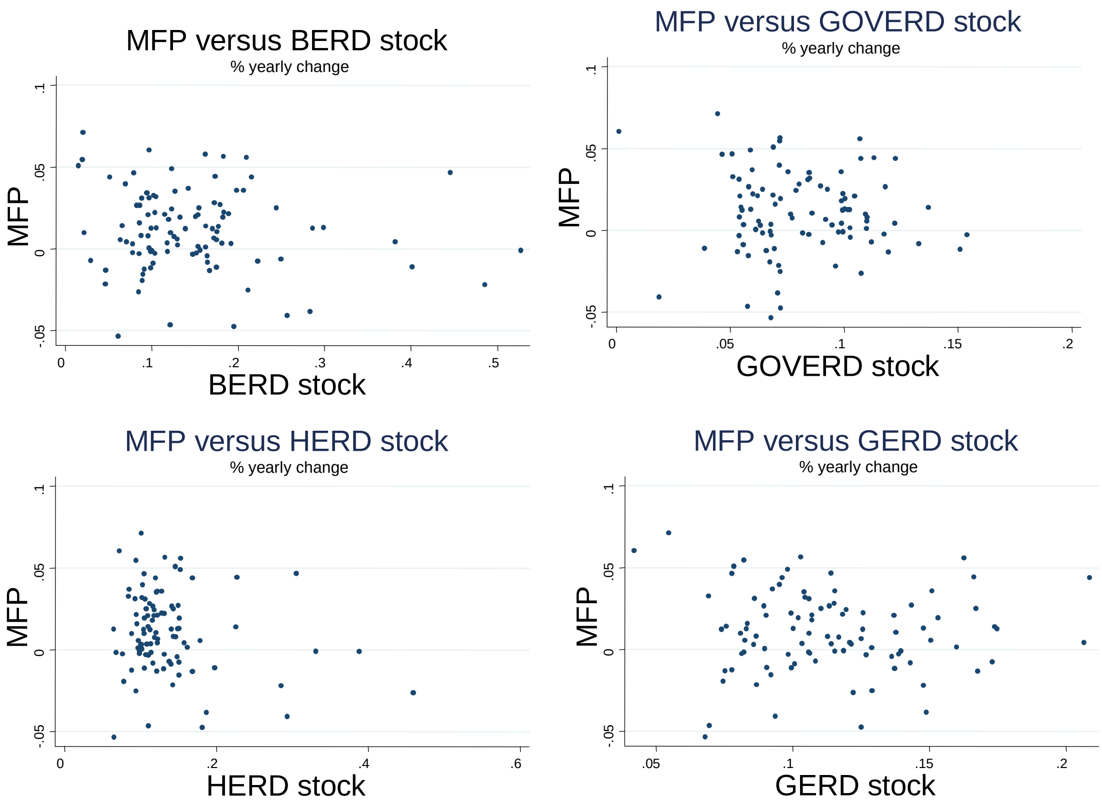
Clearly we do not have sufficient evidence to suggest that R&D expenditures are significantly positively correlated to MFP and GSP, nor do we have any indication from this analysis as to the direction of causation, if any. Nevertheless, it does appear that those States that increased their R&D the most have experienced faster growth in GSP and MFP than those States which have increased their R&D the least. That is, upon casual inspection, the data appear consistent with the existence of a longer term relationship between R&D and productivity and growth.

For reasons noted in section H.2, the return to R&D is usually estimated through the use of R&D stocks. As R&D stocks take historical information into account we can, in theory, capture the immediate impact of changes in these stocks upon MFP and GSP. As these variables all trend upwards over time, simply plotting them against each other illuminates little about their interrelationship. Differenced plots are useful in demonstrating whether a change in one variable is generally associated with a positive or negative change in another. This gives us an observation per state per time period and allows us to ask the question of the group:

Are periods with large increases in R&D stocks typically associated with larger increases in MFP or GSP than periods with only small increases in R&D stocks, regardless of State?

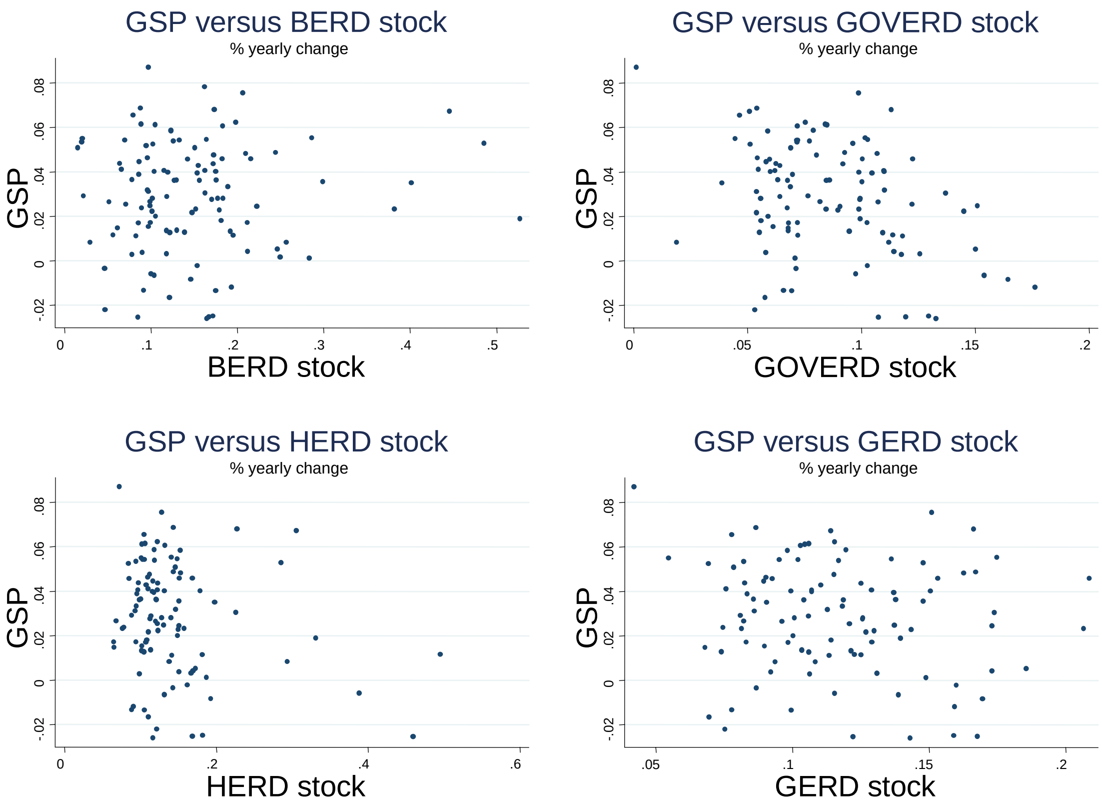
As seen in figures H.5 and H.6 there is little evidence that any form of R&D contemporaneously co-varies with either MFP or GSP in this way. Despite the fact that R&D stocks take historical information into account, it could be reasonably expected that changes in the R&D stock take some time to affect MFP and GSP. However, differenced plots of MFP and GSP upon lagged R&D exhibit the same basic pattern as those shown in figure H.5 and H.6 and are not reported here. This does not necessarily indicate that these variables have no influence upon each other given that we are essentially examining only their unconditional relationship in the short term. In order to control for the many factors that are likely to jointly influence MFP and GSP, more sophisticated econometric techniques are required. This is focus of section H.4.

Figure H.5 **Percentage yearly change in MFP and BERD, HERD, GOVERD and GERD**



Data source: Commission estimates.

Figure H.6 **Percentage yearly change in GSP and BERD, HERD, GOVERD and GERD**



Data source: Commission estimates.

H.4 Econometric analysis

Theoretical Model

The theory and empirical literature associated with the returns to R&D is well established and no further comment upon it is offered here. Interested readers can find detailed discussions in Dowric (2003), Shanks and Zheng (2006) and the Industry Commission (1995). We seek to estimate the following models, both of which essentially yield elasticity estimates from which the returns to R&D can be imputed.

$$\ln MFP_{it} = \alpha \ln R_{it} + \beta XYZ_{it} + \lambda d_i + v_{it} \qquad \text{model (1)}$$

$$\ln GSP_{it} = \gamma_1 \ln K_{it} + \gamma_2 \ln L_{it} + \alpha \ln R_{it} + \beta XYZ_{it} + \lambda d_i + u_{it} \qquad \text{model (2)}$$

Model (1) is a simple specification of the determinants of MFP and model (2) estimates the state level production function. As MFP is calculated as an index, all R&D stocks in model (1) were transformed into an index with 1990 set to equal 100. This was not necessary in model (2). Both models control for individual state fixed effects through the inclusion of state dummy variables d_i.

The two models are theoretically equivalent, aside from the fact that model (1) assumes a constant returns to scale production function whereas model (2) does not restrict the elasticity of capital and labour in any way. The capital and labour information which is explicit in model (2) and embedded within MFP in model (1), includes the capital and labour used in the R&D process. In this sense we are double counting labour and capital which, in the case of BERD, implies that any detected effect will in fact pertain to the 'excess' benefit of R&D beyond its private return. This is otherwise known as the spillover effect. In the case where the social return[2] to BERD is equal to its private return then it would be expected that the estimated elasticities of BERD in both models would be equal to zero. Thus a positive elasticity estimate is indicative of the existence of positive spillovers.

The vector of control variables XYZ_{it} contains the rate of unionisation (*union*), the percentage of state residents with a post schooling qualification (*edu*), and a measure of the business cycle (*cycle*). The cycle variable is calculated using a Hodrick-Prescott filter (Hodrick and Prescott 1997) with the smoothing parameter set to 6.25, as suggested by Ravn and Uhlig (2002).

The vector R_{it} represents the different types of R&D that contribute to MFP and GSP growth including: the BERD, HERD, GOVERD and GERD conducted within each State's jurisdiction, the R&D conducted in the rest of Australia (*AUS*) through which the domestic State benefits, and the R&D conducted in the rest of the world (*FOR*). The rest of Australia R&D variable (*AUS*) is simply the total GERD conducted in Australia minus that conducted in the State in question. The foreign R&D variable (*FOR*) is based on Lichtenberg and van Pottelsberghe (1998) and is taken from Shanks and Zheng (2006).

To avoid making a-priori assumptions about which types of the domestically conducted R&D are ultimately important in impacting upon each State's economy, three different vectors of R_{it} are considered. In all three cases both the interstate R&D stock and the international R&D stock are included.

2 In this instance, social return refers to economic benefit which is captured in the market sector but not necessarily taken into account by the private firms conducting R&D.

Case i: Only business R&D has an effect

It is likely that the imposed mechanism through which R&D expenditures become stocks (as described in section H.2) is less inappropriate in the case of BERD than in the case of HERD and GOVERD. This is because BERD is likely to have a shorter investment timeframe and is more likely to be oriented to market results that will be picked up by GSP and MFP data. As the Australian Government supports BERD through a number of means, estimating this relationship still has value in assessing the potential economic impact of the public support.

Case ii: The total amount of R&D conducted by both public and private agencies has an effect

The hypothesis here is that whilst both private and public research agencies have a significant economic impact, the individual effect of government, university and private sector R&D cannot be separated. This may be driven by the complex nature through which knowledge spills over from the public to the private sector or by increasing tendency by universities, public research agencies and the private sector towards joint partnerships.

Case iii: All forms of R&D have effects which can be separately identified

This formulation separates the R&D stocks into their BERD, GOVERD and HERD components. Whilst the likelihood of multicollinearity will hinder this approach, it offers the opportunity to examine the relative returns to different type of R&D.

The unit root and cointegrating properties of the data

As the macro-economic variables considered here are generally found to be non-stationary, the estimation of models (1) and (2) in logarithmic levels is valid only where the variables exhibit the property of cointegration. That is, the variables must share a common I(1) factor. In the absence of this property, OLS is likely to yield estimates that appear both highly significant and extremely precise, but are, in fact, completely spurious. This point is illustrated in box H.1.

To confirm that the data is in fact non-stationary, a range of diagnostic tests were performed. First augmented Dickey-Fuller tests were performed on ln*GSP*, ln*MFP* and all R&D variables for each state individually[3]. Whilst this generally indicated

[3] The use of information criteria to select the lag structure for these tests typically suggests longer lags than can be supported by the time series. As such, the Dicky Fuller test, as well as the following panel unit root test were tested for sensitivity by separately employing 0 to 4 lags, with and without a time trend

the presence of a unit root in each series, Dickey-Fuller tests are known to have low power in the sense that they are biased towards a finding of non-stationarity. By setting cross series restrictions, panel unit root test can potentially provide stronger evidence of co-integration. Thus the following panel unit root tests were also used: the Multivariate Augmented Dickey-Fuller panel unit root test (Taylor and Sarno 1998), Levin-Lin-Chu test (2002), Im-Pesaran-Shin test (2003) and the Fisher test (Maddala and Wu 1999). These test the hypothesis that all series contain a unit root and with the exception of the Im-Pesaran-Shin test, they will reject this hypothesis if even one series is stationary. They are then, much less likely to falsely accept a null of the data containing a unit root than Dicky-Fuller tests conducted on individual series. The results of these tests generally failed to reject the null hypothesis that all series contain a unit root.

The validity of our regression results rests crucially upon the suggested model specifications exhibiting a long run cointegrating relationship. One simple test of this can be conducted by applying the Engle and Granger Representation Theorem in which nonstationary variables can be said to be cointegrated if and only if they have an error correction representation. Engle and Granger (1987**)** suggest including the lagged residuals from the long run regression, as specified in models (1) and (2), in differenced versions of those same models. Evidence in favour of cointegration can be found if the coefficient on the residual terms is negative and significantly different than zero. The *t* statistics from this procedure are reported in table H.2 below and are found to be highly significant and of correct sign and magnitude, which suggests a cointegrating relationship is present.

In order to confirm the presence of cointegration, residual based tests are also generally performed. The intuition behind these tests is that a regression involving I(1), cointegrated variables should yield I(0) errors. Dicky-Fuller tests on the individual residual series fail to reject the null of no-cointegration, which represents only weak evidence given the known bias in this procedure. The Pedroni (1999) panel cointegration test was used on both model (1) and (2) for each of the three cases. This test is based on heterogeneous panels and does not restrict the cointegrating vector to be the same for all members of the panel in the way that is implied by models 1 and 2. As such this test can be seen as a necessary, but not sufficient, condition of cointegration. Nevertheless the seven test statistics associated with this procedure generally rejected the null of no-cointegration for all models and cases. The Commission is aware of several other residual based testing procedures and at the time of writing is investigating these.

Box H.1 **Spurious regression and cointegration**

Consider two independent variables *x* and *y* for which random shocks do not dissipate over time and are therefore non-stationary. Such variables can represented as

$$x = u_0 + \alpha t + \sum_{j=1}^{t} u_j \qquad (6)$$

$$y = v_0 + \gamma t + \sum_{j=1}^{t} v_j \qquad (7)$$

Putting (6) in terms of the time trend *t* yields.

$$t = \frac{x_t - u_0 - \sum_{j=1}^{t} u_j}{\alpha}$$

and substituting this into (7) gives

$$y_t = v_0 + \gamma \frac{x_t - u_0 - \sum_{j=1}^{t} u_j}{\alpha} + \sum_{j=1}^{t} v_t \quad \text{or}$$

$$y_t = \left(v_0 - \frac{u_0 \gamma}{\alpha} \right) + \frac{\gamma}{\alpha} x_t + \left(\sum_{j=1}^{t} v_j - \frac{\gamma}{\alpha} \sum_{j=1}^{t} u_j \right).$$

It is obvious that regressing *x* on *y* will be likely to find a significant relationship, despite the fact they are independent series. In this case testing for a relationship between *x* and *y* should be done in differences.

However in the case where there exists a vector A such that y_t – Ax_t is I(0) then y and *x* are said to be cointegrated. This implies that the distance between the two variables has a constant mean and they cannot drift arbitrarily far from each other in the long run. In this case the residuals from a regression of *x* on *y* will yield I(0) errors and we can legitimately uses the levels data to estimate the long run relationship. A regression in differences of this data would still yield consistent estimates but would discard information about the long run relationship that is embodied in the levels data. In this instance, the existence of a true relationship between the variables is more likely to be rejected.

Estimation results

The results presented in table H.2 are robust to both model specification[4], and time series sample selection, but are sensitive to the exclusion of certain States.

4 In particular, the key results presented here are robust to the inclusion of a time trend. Inclusion of a trend primarily impacted upon the foreign R&D estimates, which may be caused by this variable behaving in a similar fashion to a linear time trend.

Table H.2 **Results from static regression of all models and cases**
Standard errors in parentheses

	Model 1 MFP eqn Case i	*Model 1 MFP eqn Case ii*	*Model 1 MFP eqn Case iii*	*Model 2 GSP eqn Case i*	*Model 2 GSP eqn Case ii*	*Model 2 GSP eqn Case iii*
$\ln L_t$				0.561***	0.475***	0.515***
				(0.073)	(0.079)	(0.074)
$\ln K_t$				0.441***	0.438***	0.464***
				(0.051)	(0.049)	(0.055)
$\ln BERD_{t-1}$	0.027***		0.015	0.028**		0.016
	(0.010)		(0.012)	(0.014)		(0.015)
$\ln GOVERD_{t-1}$			0.043			0.087*
			(0.047)			(0.052)
$\ln HERD_{t-1}$			0.024			0.009
			(0.032)			(0.038)
$\ln GERD_{t-1}$		0.058***			0.097***	
		(0.018)			(0.030)	
$\ln AUS_{t-1}$	0.031	0.003	-0.012	0.022	-0.037	-0.042
	(0.025)	(0.029)	(0.035)	(0.027)	(0.035)	(0.038)
$\ln FOR_{t-1}$	0.250	0.240	0.234	0.256	0.272*	0.264
	(0.152)	(0.150)	(0.157)	(0.160)	(0.154)	(0.159)
$Cycle_t$	0.913***	0.916***	0.933***	0.896***	0.916***	0.922***
	(0.122)	(0.120)	(0.122)	(0.127)	(0.122)	(0.125)
$Union_t$	-0.116	-0.143*	-0.130	-0.127	-0.158*	-0.167*
	(0.083)	(0.083)	(0.087)	(0.087)	(0.084)	(0.094)
Edu_t	0.002***	0.002***	0.002***	0.002**	0.002**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	3.159***	3.203***	3.182***	-0.911	-0.312	-0.881
	(0.614)	(0.605)	(0.643)	(1.131)	(1.113)	(1.231)
R-squared	0.963	0.964	0.964	0.99	0.99	0.99
N	84	84	84	84	84	84
ECM *t* stat[a]	-5.10	-5.97	-5.10	-3.23	-3.18	-2.85

*** statistical significance at 1 per cent or greater. ** significance at 5 per cent or greater. * significance at 10 per cent or greater. **a** ECM regression output not reported.

In particular the inclusion of the ACT and NT leads to much higher standard errors and counterintuitive results. This is likely to be driven by the fact that the growth in output in these States is less accurately measured given their size and structure. As such, the information they contain about the relationship between R&D and economic growth is likely to be misleading and the assumption of homogenous panels is likely to be compromised in their presence. Thus, these States were excluded from this analysis.

All models and cases were tested for serial correlation using the Arellano-Bond (1991) test and the testing procedure proposed in Wooldridge (2002) These tests suggested the presence of first order serial correlation but did not find evidence of higher order serial correlation. This is unsurprising as the modelling strategy employed here is focused on the long run relationship and omits the short run relationships, which are likely to be poorly defined and difficult to capture using conventional techniques. A variety of GLS techniques were used in order to strengthen the reliability of the inferences made about the estimated coefficients. These procedures typically reduced the estimated standard errors and made little difference to the estimated coefficients. However, in the absence of more conclusive confirmation of the presence of cointegration, the GLS outputs are omitted here in favour of a more parsimonious presentation.

The fact that both models provide similar estimated coefficients adds further plausibility to these results. Also, the estimated elasticities of capital and labour are quite close to summing to 1, which supports the assumption of constant returns to scale that was necessary in calculating MFP. The main difference between the two models is that the production function specification generally delivers slightly higher estimates than the MFP equation.

A prerequisite for the plausibility of the models estimate here is the significance of certain baseline variables for which we have a strong a priori expectation of their relevance. This amounts to getting a positive and significant coefficient for the business cycle variable in the MFP equation and, in the case of the production function, getting positive and significant coefficients on labour and capital that roughly correspond to their factor shares. These variables are all shown to be correctly signed and highly significant and whilst the coefficients on capital and labour are slightly different to their average factor share over the period[5], the average factor shares are within the 95% confidence interval of these estimates.

The estimated coefficients for the other control variables, education and unionisation, are of expected sign and are stable irrespective of specification. Whilst

[5] The average factor shares for labour and capital over the period are 0.62 and 0.38 respectively.

education is highly significant in all models and cases, the rate of unionisation is only marginally significant in one instance.

The elasticity estimates of the various types of R&D appear to be of ‘reasonable’ magnitude and signed correctly with the exception of the rest of Australia R&D stock (AUS), which is found to be insignificant in all equations. Given the likelihood of interstate spillovers, this result may be driven by the small impact of interstate R&D relative to other types of R&D. It is also likely that the simple aggregation of interstate stocks insufficiently captures the relevance of one State’s R&D on another’s. There is limited evidence of international spillovers, with foreign R&D (*FOR*) found to be significant in case *i* and *ii* of model 2 at a 10% level of significance, and bordering on significance at that level in all regressions.

Case *i* for both models presumes that of the domestic R&D conducted in each State, only BERD matters. The MFP model of this scenario most closely resembles the model estimated by Louca (2003) and like Louca, a positive (albeit more modest) elasticity is found for BERD. The smaller magnitude of this estimate is possibly driven by the fact that human capital is ultimately omitted from his final specification whereby the effect of this omitted variable is likely to be picked up in the BERD coefficient. BERD is also found to be positive and significant in the analogous production function representation (model 2 case *i*).

Case *ii* tests the proposition that it is the total R&D conducted domestically in each State that matters, as opposed to that undertaken just by the business sector. The estimation results for case *ii* support this with the coefficient on GERD being positive and significant in both models. Interestingly, the estimated coefficient on GERD is higher than that of BERD from case *i*. Ostensibly, this suggests that the joint effort of public and private R&D agencies have a greater impact on MFP and growth than does the private sector alone. However, it could be that the major reason for this is simply that BERD is the biggest contributor to GERD.

Finally case *iii* attempts to separate the effects of BERD, GOVERD and HERD. The estimated coefficients for these variable are all positive but are all found to be insignificant, even at a 10% level of significance. The production function specification of this case most closely resembles Burgio-Ficca (2004), but does not support her findings. Whereas Burgio-Ficca was to able find significant and extremely large elasticities for both the pure and applied R&D, HERD spending is not found to be significant here.

Whilst evidence is found in favour of a significant effect stemming from BERD and GERD, it does not appear possible to separately identify the effect of BERD, GOVERD and HERD. The high degree of multicollinearity between these variables is likely to play a part in this finding, particularly between GOVERD and HERD which are largely driven by historical factors. Additionally, only a proportion of GOVERD and HERD are intended to have a direct economic impact, making their contribution more difficult to determine. Moreover, it is questionable whether the time period examined here of 13 years is sufficient to capture even the minority of the long term economic impacts of public research done at the basic level. There is anecdotal evidence that the recent trend towards greater interaction between public and private research agencies may result in the former conducting research with shorter time frames. However collaborative R&D, which is likely to have a more immediate term impact, will almost certainly be linked to BERD, further concealing the individual sector's contributions.

There is some cause for concern as to the direction of causality between R&D and MFP and GSP. For example, businesses generating strong profits are likely to have a greater capacity to conduct R&D. Likewise, in times of strong economic growth, public research agencies are likely to face a more generous fiscal budget constraint. Lagging R&D stock by one period addresses this to some extent.

Rate of return estimates

An Australia-wide rate of return can be calculated from the results in Table H.2 by multiplying the estimated elasticities (ε) by the ratio of the R&D stock to GDP:

$$\text{Rate of return} = \varepsilon \frac{\text{R\&D stock}}{\text{GDP}}$$

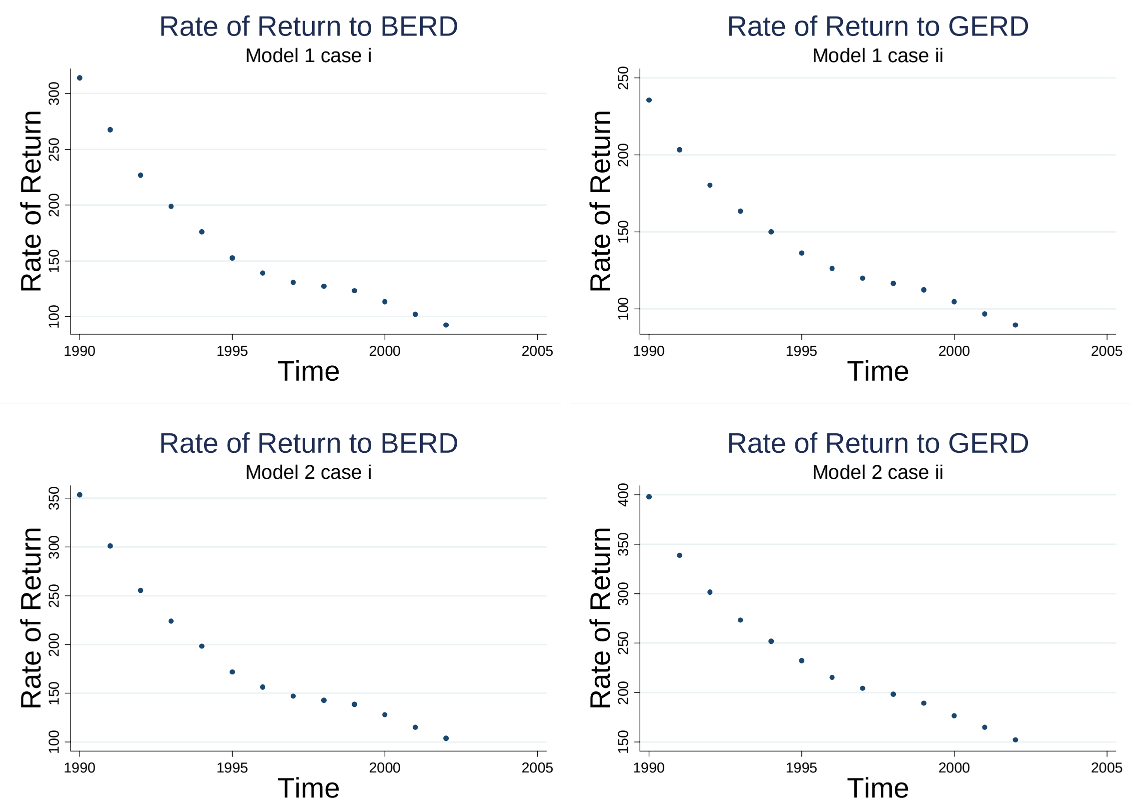
At both a state and a national level this procedure will result in a rate of return series that is declining through time. This is demonstrated in figure H.7 for the BERD and GERD estimates that were found to be significant in case *i* and *ii* for both models.

The observed pattern is driven by two things:

1. The regression analysis implicitly assumes that the R&D elasticities are constant over time.
2. R&D stocks have grown faster than GDP over the period considered.

It is plausible that the dramatic growth in R&D has lead to diminishing returns, however the magnitude of the decline of the return to R&D and its starting point in 1990 are too large to be uncritically accepted. As pointed out by Coe and Helpman (1995) rates of return estimated in this fashion are sensitive to the benchmarking of capital stocks and are therefore less reliable than the elasticity estimates.

Figure H.7 **Rate of return to BERD and GERD**



Data source: Commission estimates.

The average rate of return for all States and Australia as a whole over the entire time period are presented in table H.3. The Australia-wide average returns on BERD are calculated to be 164.8% (model 1) and 140.6% (model 2), whereas the average returns on GERD are 185.6% (model 1) and 238% (model 2). On the surface these rates of return appear very high, certainly higher than the private returns to other types of investments. However as these returns pertain to spillovers, or the 'excess rate of return to society' beyond that considered by those actually making the investment decision, they are at least possible. Louca (2003) presents point estimates of 116% in 1999 which are similar to those found here for the comparable case i in both models. However, Louca's 1990 point estimate of 173.4% is much smaller than figure H.7 suggests.

Conclusion

The econometric analysis in this chapter finds tentative evidence in favour of a positive link between the economic growth and productivity of the Australian States and the amount of R&D conducted in them. Specifically, BERD and GERD are both found to have a statistically significant effect on GSP and MFP. The results support the theoretical conjecture that firms are not able to fully appropriate the returns to R&D, resulting in spillovers. The elasticity estimates also suggest that MFP and GSP may be more responsive to changes to overall R&D (GERD) than they are to private R&D alone. This provides limited evidence that the R&D done by universities and public research agencies also affects measured GDP and productivity. However this effect cannot be separated out into its individual components: BERD, GOVERD and HERD.

The analysis undertaken did not find any significant relationship between both international and interstate R&D, and either MFP or GSP. However, it is far more likely that this stems from our inability to appropriately measure the relevant stocks than those stocks being irrelevant to progress of each State's economy.

Table H.3 **The percentage rate of return for BERD and GERD**

Averaged through time

State	*MODEL 1 case i*	*MODEL 1 case ii*	*MODEL 2 case i*	*MODEL 2 case ii*
	BERD	GERD	BERD	GERD
NSW	157.1	162.3	176.9	274.7
VIC	113.3	121.1	127.6	205.0
QLD	317.2	190.8	357.0	322.9
SA	215.9	122.0	243.1	206.5
WA	201.6	174.5	226.9	295.4
TAS	240.3	110.4	270.6	186.8
AUS	164.9	140.7	185.6	238.1

Source: Commission estimates.

I What can be learnt from cost-benefit case studies?

This appendix examines cost-benefit case studies of research projects undertaken in public sector research agencies. It begins with an overview of cost-benefit analysis (I.1). It then examines the cost-benefit studies: reviewing their methods; reliability; and findings (I.2). The last section summarises the main lessons (I.3).

Chapter 4 distils the evidence from these case studies and considers some regression analysis based on metadata. Chapter 4 also reviews evidence put forward by study participants. This material is not repeated in this appendix.

Cost-benefit studies have a number of advantages over alternative measures of returns to research, such as econometric studies using economy-wide data. The advantages are that they may:

- provide insight into research investment decision processes;
- explicitly list assumptions;
- make an attempt at quantifying costs as well as benefits;
- highlight the relative importance of different groups of beneficiaries — cost savings for consumers, cost savings for industry, industry profits (shareholders);
- reveal the impacts of less obvious influences on net benefits, such as competing foreign research and crowded-out private research;
- allow the implications of benefits for Australians/non-Australians to be separated;
- shed light on the riskiness of scientific research and the need to adopt a portfolio approach in order to generate net benefits;
- overcome many of the problems of macro-level studies of the relationship between scientific research and productivity; and
- shed light on the plausibility of claims of benefits and costs made for varying types of research.

On the other hand cost-benefit studies also suffer from a number of drawbacks:

- Trying to estimate overall returns to R&D from a small number of cost-benefit studies is likely to be misleading because of selection bias. However, this does not mean that examples of successful projects in particular areas of research cannot be used to compare with overall benefits and expenditures in a more representative way.
- Cost-benefit studies usually do not address the impacts of marginal projects. They tend to provide information about total costs and benefits (that is about average costs).
- They generally do not factor in the excess costs of raising taxes.
- Many cost-benefit studies are undertaken before research is begun (ex ante studies). For these, costs, chances of technical success, paths to market and benefits to end consumers can be difficult to judge.
- There can be difficulties in attributing particular costs and benefits to specific projects.
- Counterfactuals are often hard to judge. Did the project crowd out private research? Would the outcome have been produced eventually by foreign research? Were other groups working on substitute technologies?
- More favourable cost-benefit ratios can be achieved by varying assumptions in reasonably arbitrary ways, which invites bias.

I.1 Overview of cost-benefit analysis

There are several questions to be answered when determining the net benefits of research projects from a social perspective. They include: determining the scope of an evaluation; determining which groups in society are likely to benefit from the projects and what the costs to society are for delivery those projects; determining whether socially valuable projects will not proceed without government intervention; and determining whether alternative research or technologies are likely to displace outcomes before they can generate enough benefits to be worthwhile.

Research stages and evaluation scope

Research projects can involve complex histories from inception to outcomes, usually involve large combinations of inputs, many of which are public good in nature, and often lead to multiple outcomes. All of this complicates the process of determining project boundaries for the purposes of undertaking cost-benefit analysis.

Research projects may have a number of stages:

- pure basic research aimed at extending knowledge in specific scientific fields (usually without specific commercial applications in mind);
- preliminary mission-oriented (applied) research (either strategic or outcome-specific) with small amounts of resources devoted with the aim of testing the feasibility of general approaches;
- strategic applied research to develop a set of related technical capabilities (related techniques/knowledge) with a range of possible applications;
- outcome-specific applied R&D devoted to solving specific problems by applying a set of techniques/knowledge previously developed; and
- adoption of the outcomes of research which may involve additional costs for end users.

Boundaries can be drawn narrowly or broadly, with implications for which costs and benefits should be included.

- Projects may draw upon prior basic research findings. In turn, those basic research findings may draw upon knowledge produced across entire scientific fields.
- Projects may draw upon ideas generated in related research projects being undertaken concurrently by outside groups.
- Organisations may develop general scientific capabilities when conducting research projects (for example in plant genetics or materials technology), which may be used in subsequent research projects.

The purpose of an evaluation will need to be clarified before deciding upon scope. For example, is the goal to determine the benefits of proceeding with a particular applied project or, alternatively, is it to determine the benefits of investing in the development of a set of scientific capabilities (which may eventually lead to involvement in a range of applied projects)?

The majority of the benefits of research are often generated from a few very successful projects. Because of this, it is often more sensible to examine the costs and benefits of numbers of related projects together. One approach would be to examine the entire costs of a broad area of research over a given period and the benefits of commercialised projects arising from that research area over the same period.

In some cases, publicly funded research is an input in further private R&D to produce a commercial product. In these cases, one approach is to compare both private and public costs with the benefits gained. Another approach is to apportion a value to the public research contribution, although this can be difficult in practice.

Another consideration is determining costs and benefits *for Australians*. This can arise when Australian public research is commercialised by foreign firms. If the Australian research was the deciding factor that caused the foreign private R&D effort to go ahead, then the cost of the Australian public research could be compared to the benefits to Australian consumers from the products or services generated and benefits in the form of royalties if Australians hold intellectual property rights.

Determining the social benefits and costs of research programs

Determining social costs and benefits is similar to the kind of process a firm might make when considering launching a new product. A firm might consider how much a product costs to produce and how much consumers are likely to pay. On the other hand, the calculation of net social benefit also includes benefits for which consumers cannot be made to pay and includes costs imposed without compensation. In these cases, methods need to be used to arrive at estimates of willingness to pay and willingness to accept costs in the hypothetical situation where payments can be enforced and compensation is offered.

Because CBA is designed to provide information that allows decision makers to redirect resources from one set of uses to another in an informed way, the benefits of alternative courses of action need to be taken into account.

It is also important to distinguish between gross and net benefits. Net benefits represent the additional benefits that arise from the decision to allocate resources away from less socially profitable uses towards more socially profitable uses. This requires deducting the opportunity cost of resources from a project’s gross benefits. The opportunity costs are the benefits lost by not employing those resources in an alternative use.

Alternative uses for public research expenditures include: tax reductions (that is, not collecting the equivalent of taxes in the first place); other government (non-research) expenditures; or use in other publicly funded research programs.

Gross benefits from research projects may include:

- cheaper product or services for consumers;
- higher quality products or services for consumers where price rises are less than the additional amounts consumers are willing to pay for that additional quality;
- additional profits for Australian firms;

- licensing revenues for public research agencies; and
- positive spillovers — realised as reduced environmental or social costs to the community (for example, reductions in water pollution or diffusion of public health advice) — or realised as knowledge from one research project being used in other research or in the development of other products.

Resource costs are simply measured as expenditures on project inputs. They include labour, equipment, intellectual property and overhead costs. These include the value of resources devoted to research and development activities borne by public research agencies and private partners. They also include adoption costs incurred by end users.

Consumer and producer surpluses

In cost-benefit analysis, social benefits are usually calculated by estimating changes in consumer and producer surpluses. Social benefits can be created in a number of ways, through:

- reductions in production costs that reduce prices and increase consumer surplus;
- reductions in production costs that allow greater profits and increase producer surplus;
- the introduction of products or services of a type that have not previously existed, which result in additional consumer and producer surpluses; and
- direct benefits which add to producer surplus such as profits from sales or royalties.

Methods used to calculate benefits from research projects include: the cost-saving method, which estimates reductions in production costs; the willingness to pay method which estimates consumers' willingness to pay over and above purchase costs; and producer direct return estimates.

The costs of raising funds for public expenditures represent the consumer surplus lost by taxpayers as well as the producer surplus lost when taxpayers reduce their consumption. Consumer surplus is lost in two ways: the first is the direct transfer of income to the government in the form of taxes; the second source is consumer surplus lost when tax-payers reduce consumption because of taxation-induced price rises. The additional loss is referred to as the Marginal Excess Burden of Taxation (MEB).

Estimates of the MEB (which also includes allowances for the administration costs of collecting taxes) vary, but a rough estimate of 20 to 30 per cent has been used in this study (chapter 3 and chapter 9).

Time-preferences

The notion of time-preferences for consumption relies on the observation that people prefer current to future consumption. This introduces a comparability problem between costs or benefits occurring in different years. To produce a standardised valuation, costs or benefits in each year are weighted by a factor that represents the relative value consumption in that year compared to the value of consumption in a nominated base year.[1]

The time-preference rate, or discount rate, is usually set to reflect real interest rates (when discounting real expenditures), although this can vary. It is common in cost-benefit studies to use real discount rates of between five and ten per cent.

General equilibrium framework

General equilibrium (GE) models can be used for research programs that involve large expenditures or produce large benefits. These models calculate impacts on prices, production, consumption and investment across different industries when resources are directed into alternative uses.

The GE models will incorporate direct effects and secondary indirect effects. The direct effects are the same as those included in cost-benefit studies (additional taxes, benefits from increased productivity and so on). An example of indirect effects are increases in production in downstream industries because of innovations that increase productivity in input-supplying industries.

As with cost-benefit analysis, an important choice in the GE approach is whether to model the alternative use of research funds as reductions in taxation (that is, reductions in private activity across a range of sectors) or as reductions in government expenditures.

[1] As an example consider a project that involves spending $1 a year for three years. If the last year were designated as the base year, then a discount rate of five per cent would value the first year's spending at $1.10, the second year's at $1.05 and the third year's at $1.00. The overall base year present value of costs would then be $3.15.

Risk

It is possible to undertake cost-benefit analysis at any point during a research project. This introduces the problem of valuing costs and benefits when evaluations are undertaken before technical outcomes have been finalised or market impact determined.

Where benefits and costs are uncertain, the way of incorporating them into a cost-benefit analysis is to weight them by probabilities of success.

There are two main approaches. One is to consider a project as if it had already finished and treat the decision to go ahead as having been made at the start of the project. The second approach is an options or contingent approach, where decision points at important stages of a project are introduced and a range of probabilities are assigned to each stage of a project. In either case, the expected value of a project is the sum of each outcomes value multiplied by its probability of occurring.

The main problem with these approaches is that the probabilities of success are often very difficult to judge. One approach is to estimate a range of likely values and to conduct a sensitivity analysis.

The options approach (used intensively by ACIL Tasman 2006e) has several major insights and advantages. Its main advantage is a more realistic treatment of research project decision making, in particular, the possibility of stopping research projects and saving costs if interim research outcomes are poor. Since the research process itself will provide better information about a project's chances of success — it makes sense to stage research projects with decisions to increase resources being based upon knowledge generated during initial research periods. Typical stages might include a feasibility period, a period of early research involving only a few researchers, a period of more intensive research where resources are increased and finally periods of development that may require large expenditures. The staged nature of research means that ex ante costs and benefits should be weighted by their probabilities of being incurred or generated, rather than being considered as being fixed once a project has started (as is usual in traditional cost-benefit analysis). Because of this, the options approach will tend to yield lower estimates of the ex ante costs of research projects. Consequently, the options approach tends to produce higher ex ante estimates of net benefits than standard cost-benefit analysis.

Counterfactuals: additionality and technological displacement

The presence of positive spillovers makes it likely that some socially valuable projects will not go ahead without some form of public intervention. That is, even though there would be a net benefit to society if a project were to proceed, private agents may not find it in their interest to invest. This is because they would not be able to appropriate enough of the resulting benefits to cover their costs (chapter 3). In these circumstances, public funding has the potential to produce a net social gain.

Additionality

It is important that public agencies recognise when there are sufficient incentives for private investment. The danger is that public agencies may underestimate private incentives and fund projects that would have been undertaken anyway. If taxes are raised to fund these projects, then this would result in a net social loss, because of the additional costs involved in raising taxes.

When conducting a CBA of the decision to undertake publicly subsidised research, the net benefits are only those additional benefits produced as a result of the public funding, not those benefits resulting from investments private firms would have undertaken anyway.

Technological displacement

It is also important to consider whether competing research may be undertaken anyway by other research groups. Technical change is occurring all of the time at a rapid pace. As technological opportunities emerge there are usually many public research groups around the world pursuing them at any one time. In this context, opportunities for socially beneficial Australian public intervention often require careful targeting.

In this situation, Australian research projects will only be beneficial if, in their absence, overseas research would not have not produced similar results or would have only produced similar outcomes with a significant delay. This counterfactual approach involves a comparison with a judgment about what would have happened in the absence of the research project. One implication of this approach is that the incremental benefits of public intervention are usually displaced after a limited number of years, after which the benefits would have been available anyway. Exceptions are more likely where research is undertaken into Australian-specific problems, which are of little interest to other countries.

Another source of displacement arises when substitute technologies overtake particular technical approaches and render them obsolete. For example, research into more efficient typewriters would not have been sensible by the mid-1980s once personal computers started to take over word processing tasks.

The difficulty with the counterfactual approach is that the actions of overseas research efforts and their chances of success can be difficult to judge accurately. As with risk, the usual approach is to undertake a sensitivity analysis. It would also be useful to consult as widely as possible with relevant experts in the research/technology fields in question.

I.2 Findings from cost-benefit studies of returns to publicly funded research

Overview of available cost-benefit studies

Cost-benefit studies were identified for research projects undertaken by CSIRO, CRCs, RRDCs and some State agricultural departments. These are bodies which specialise in mission-oriented strategic and applied R&D projects, with the goal of generating public good or commercially-useful outcomes.[2]

Evaluation studies of university research did not yield much information on commercialised projects. This reflects universities' greater concentration on curiosity-driven research and applied social research, rather than on fully commercialised outputs. Instead, existing university research evaluations concentrated on evaluating the efficiency with which research outputs (mainly publications) were produced (these issues are discussed in chapter 4 and appendix K).

A variety of CSIRO research areas were the subject of studies. These included: agricultural crop research; entomology; wool manufacturing technologies; automated mining equipment; industrial processing; advanced vehicle technologies; visual processing for road maintenance; pharmaceuticals; and animal health research.

The latest CRC program evaluations (Allen Consulting 2005; Insight Economics 2006) used a general equilibrium (GE) approach to determine the overall impacts generated by CRC research to date. Information collected in the evaluations included identified direct benefits from a number of CRCs and total CRC grant expenditures from 1991 to 2005.

[2] Strategic research is longer term and considered likely to produce a range of applied innovations in broadly related technological areas (such as machine tools or cleaner power generation technologies and so on). Applied research is aimed at generating useable innovations and may be strategic or outcome specific. Applied research differs in emphasis from basic research, which has as its main aim advancing the frontiers of knowledge in various scientific fields.

Other CRC studies separately identified, included studies of minerals processing research and of weed management research.

Detailed information was obtained for grains research projects undertaken by the Grains RRDC and State agricultural departments. Information was also obtained for cattle breeding research undertaken by a variety of public research agencies.

The coverage of the case studies was found to be small compared to the total research output of these agencies. For example, CSIRO successfully produced, on average, 81 new technologies or products per year in the three years from 2002-03 to 2004-05 (while these technologies or products were not yet at the utilisation or commercialisation stage, a significant proportion of these are likely to become utilised/commercialised). The total number of identified cost-benefit studies for research conducted over the 1980s and 1990s was 41 studies.

Methods used to calculate benefits

Cost-savings, willingness to pay and direct returns are various methods used to calculate benefits in cost-benefit studies (table I.1).

The studies generally fall into three main categories: studies undertaken before research has been completed (referred to as ex ante studies); studies undertaken after research has been successfully completed, but before the research outcomes have been have been adopted; and studies undertaken after research has been completed and research outcomes adopted in the market or otherwise utilised. The last two kinds are both usually referred to as ex post studies.

In this appendix we use a different categorisation of cost-benefit studies with two main types. The important point is when research outcomes have been commercialised or otherwise utilised for long enough to determine how widely they have become adopted. Studies undertaken before this are referred to as ex ante utilisation studies and those after as ex post utilisation studies.

Table I.1 Outline of methods used to calculate benefits of selected research projects

Eight Projects in CSIRO's Division of Wool Technologies

- Benefits are usually from increased yields. These reduce costs per amount of production (ie costs per kg etc).
- Adoption periods start between 1995 and 1990 (based on start or planned start of commercialisation).
- Assumptions were made about the year in which maximum adoption will be achieved.
- Assume sales and benefits continue for at least 15 years.
- Counterfactual — Without CSIRO research the process would have been introduced 15 years later.
- Usually assume wool growers will be able to appropriate 30% of the benefits initially accruing to wool processors.

Ten projects in CSIRO's Institute of Plant Production and Processing

- Reduction in cost caused by:
  – increased yields;
  – lower spraying costs; and
  – reductions in labour costs.
- Benefits were counted for 40 years from date of commercialisation.
- Counterfactual was usually the status quo.
- For most case studies there was data on adoption levels in 1990.
- Often this was set as the ceiling adoption level, otherwise a ceiling adoption level was estimated/assumed.
- A linear adoption pattern up to the ceiling level was assumed.

Three weed prevention programs in the CRC for Weed Management Systems

- Potential areas particular weeds can affect were estimated.
- Costs caused per hectare are estimated.
- Reductions in spraying costs per hectare were estimated.
- Proportions of overall weed infestations prevented were estimated.

Five CSIRO robotic mining research programs

- Benefits were from reductions in costs and reductions in down-time caused by deaths and injuries.
- Estimates were made for:
  – the proportion of mines that the process being automated can be used in;
  – the proportion of mines that use the process;
  – the proportion of mine production accounted for by the process;
  – reductions in labour costs; and
  – reductions in down time caused by preventing deaths and injuries.
- Estimates of adoption costs were then subtracted them from estimated cost-saving benefits.

Table Continued

Table I.1 (continued)

Six CSIRO manufacturing, industrial or transport research projects

Solospun

- Solospun is a cheaper process for spinning wool garments.
- Benefits were from reductions in spinning costs and royalty payments.
- The worldwide quantity of yarn used in the process that the Solospun technique can be applied to — warp spinning of wool garments (as opposed to weft spinning) — was estimated.
- The maximum adoption rate of the Solospun process was estimated (7 per cent by 2015).
- Cost reductions from using the process were estimated to be 20 per cent.
- Royalties per Solospun attachment were estimated.
- Reduction in costs could reduce fabric prices and increase demand.
- The increased demand for Australian wool as a result of the price drop was estimated (using an elasticity of demand of -1.1).
- Wool exports and prices were taken from ABARE trend forecasts.
- Benefits from additional sales were then estimated for Australian wool producers (these were found to be very small.

Supercapacitors

- The benefits of the project are from the royalties CSIRO will receive.
- Current sales are known.
- The global market was estimated ($2 billion by 2006).
- Adoption of CSIRO supercapacitors was assumed to be between 5 and 10 per cent of the total market.

$SIRO_2$ oxygen sensor

- Reduction in fuel costs for ceramics producers were estimated.
- Estimated the proportion of ceramics manufacturers using the probes for combustion control, to reduce fuel costs, rather than atmosphere control.
- Specific cost savings from using the sensors were reported by two firms.
- Adoption was estimated from surveys of probe manufacturers.
- The counterfactual was that other techniques that achieve similar outcomes would have been introduced 15 years after initial sales.

Smart test battery tester

- Estimated the reduction in the numbers of healthy batteries incorrectly replaced.
- Estimated the number of vehicle breakdowns prevented when failing batteries are identified early.
- Estimated royalties from overseas sales.
- A maximum adoption of 12 per cent of potential market (battery retailers and mechanics) was assumed to be achieved within 8 years of initial sales.
- A straight line adoption pattern from initial sales to maximum adoption was assumed (starting with initial sales of 20% of maximum).
- The mid-case counterfactual was that the introduction of a similar battery analyser would have been delayed in the absence of the CSIRO research by 12.5 years.

Table Continued

Table I.1 (continued)

Exelogram

- The Exelogram security feature for banknotes and identity-documents (such as passports) makes counterfeiting and forgery more difficult.
- Benefits were estimated from royalties received by CSIRO between 1991 and 2004.
- There were losses from legal challenges made by the firm charter pacific which had initially been given an option to raise funding to commercialise the Exelogram technology.

Road crack testing vehicle

- Quantified benefits include:
  – Reductions in road maintenance expenditures as a result of identifying road damage early enough, before damage becomes more serious, reducing the amount of repair that needs to be done;
  – Reductions in minor accidents caused by poor road conditions; and
  – Reductions in vehicle servicing required because of rough road conditions.
- Assumed RoadCrack vehicles would be adopted in all States within five years of initial introduction.
- National expenditures on road maintenance were estimated.
- The costs of major and minor road repairs were estimated.
- The proportion of early road cracks identified was estimated to be 60 per cent.
- Assumed 5 per cent of minor accidents and one per cent of vehicle repairs will be avoided.

CSIRO pharmaceutical research

Anti-influenza drug research

- Reduction in medication costs were estimated.
- Reduction in the numbers of work days lost were estimated.
- Royalty payments from overseas sales were estimated.
- The estimated costs of purchasing Relenza was deducted from calculated benefits.
- The potential market was assumed to be those visiting a doctor and being diagnosed with influenza and half of those hospitalised with influenza.
- 100% of these individuals were assumed to purchase Relenza within five years of its release.
- A straight line adoption pattern from initial sales to maximum adoption was assumed (starting with initial sales of 20% of maximum).
- The counterfactual was that foreign research would have produced alternative drugs for controlling influenza four years later.

Sources: Collins and Collins (1999); Johnston, Healy, I'ons and McGregor (1992); CIE (2001a,b); CIE (2003a); Mills and Yapp (1996).

Quality of estimates made in selected cost-benefit studies

An analysis was undertaken of the quality of information used in calculating the benefits of the selected projects (table I.2). Higher quality sources included scientific trials (examples include studies that show yield increases for new crop varieties) and company surveys (often used to determine sales volumes). Approximations were considered as slightly less reliable, but still fairly reliable (examples include estimates of yields or prices of new crop varieties based upon yields or prices of older crop varieties). In some cases, the opinions of researchers or industry experts were sought where hard data was not available. The least reliable form of estimation were assumptions made with little supporting data (examples include assumptions of likely market adoption rates where sales have not yet started).

The main outcome of the examination is that projects that take an ex ante utilisation approach are less reliable than those conducted some time after utilisation has occurred. This is not to say that future benefits can never be estimated. In cases where adoption rates have been observed for a number of years, predictions about future adoption rates are less uncertain.

For the adoption/sales estimates, most assumptions with little supporting evidence were made where benefits were being measured ex ante (table I.2). Most of the Institute of Plant Production and Processing studies were measured ex post utilisation, while most of the other studies were ex ante.

There were a greater proportion of assumptions made to produce estimates for average benefits (benefits per unit of production) in the cost-benefit studies of the CSIRO Division of Wool Technologies' research and the CRC for Weed Management Systems' research.

Most of the additionality and counterfactual estimated were based on assumptions with little supporting evidence.

Table I.2 **Counts of estimates made in selected case studies**

Studies		*Estimates of benefits per unit of production*[a]	*Estimates of market size*	*Estimates of adoption or sales*	*Additionality and other counterfactual scenarios*
Eight projects in the CSIRO's Division of Wool Technologies	Studies/surveys/facts	1	1	5	
	Expert opinions				
	Approximations[b]	11	2	2	
	Assumptions[c]	6	1	22	8
	Not stated	1			
	Total	**19**	**4**	**29**	**8**
Eleven projects in CSIRO's Institute of Plant Production and Processing	Studies/surveys/facts	9		13	
	Expert opinions	2		9	
	Approximations	17	1	7	4
	Assumptions	1		14	14
	Total	**29**	**1**	**43**	**18**
Three weed prevention programs in the CRC for Weed Management Systems	Studies/surveys/facts	1			
	Expert opinions	1			
	Approximations	5		3	
	Assumptions	7		6	3
	Total	**14**	**0**	**9**	**3**
Five CSIRO robotic mining research programs	Studies/surveys/facts	1	1		
	Expert opinions				
	Approximations	18	3	4	
	Assumptions	3		5	3
	Total	**22**	**4**	**9**	**3**
Six CSIRO manufacturing, industrial or transport research projects	Studies/surveys/facts	4		4	
	Expert opinions			1	1
	Approximations	8	6	1	1
	Assumptions	5		8	3
	Total	**17**	**6**	**14**	**5**
CSIRO anti-influenza drug research	Studies/surveys/facts	1	1	2	
	Expert opinions				1
	Approximations	2		1	
	Assumptions	2	1	3	1
	Total	**5**	**2**	**6**	**2**

a Includes estimates of yield increases, cost savings, price premiums for additional quality, royalties and adoption costs. **b** Approximation based on relevant knowledge. **c** Assumption with little supporting evidence.

Sources: Collins and Collins (1999); Johnston, Healy, I'ons and McGregor (1992); CIE (2001a,b); CIE (2003a); Mills and Yapp (1996); and Commission estimates.

Estimates of returns from individual case studies

Individual case studies examined in more detail were taken from studies of agricultural research in the CSIRO, GRDC and State agricultural departments as well as CSIRO research undertaken for industrial, mining, transport, animal health and pharmaceutical applications. The calculated returns to selected research projects are shown below in tables I.3 to I.5b.

Table I.3 **Cost-benefit studies from CSIRO's Institute of Plant Production and Processing**
Base case estimates

	Research period	*Dis-count rate*	*Base year*	*Costs*	*Benefits*	*BCR*[a]	*IRR*[b]
		%		$m	$m		%
Take-all control in wheat	1978–1990	5	1990	8.9	822.1	92.2	179.2
Disease resistant lucerne	1973–1986	5	1990	10.9	39.7	3.7	13.5
Nematode-tolerant grape-vine rootstock	1960–1974	5	1990	6.6	169.3	25.5	28.3
Chickpeas	1972–1990	5	1990	15.7	98.5	6.3	18.1
Improved Phalaris grasses	1955–1990	5	1990	49.7	358.8	7.2	20.0
Mechanical grape pruning	1972–1989	5	1990	2.7	227.3	84.0	87.2
Wood fibre for cement sheeting (replaces asbestos)	1978–1982	5	1990	2.2	161.8	72.2	90.8
Break crops for wheat farming	1981–2002	5	2002	48.0	892.0	19.0	54.9
Stylo pastures	1967–1983	5	1990	30.4	142.7	4.7	16.3
Grazfeed — farm management computer program	1985–1990	5	2002	4.5	354.7	79.5	101.8
SIRATAC — cotton pest control computer program (1)	1973–1989	5	1990	17.9	61.2	3.4	16.2
SIRATAC — cotton pest control computer program (2)	1973–1989	5	2002	33.1	68.8	2.1	15.5
ENTOMOLOGIC — cotton pest control computer program	1992–2001	5	2002	11.5	213.2	18.5	103.0
Cotton breeding	1974–1989	5	1990	15.7	289.4	18.4	27.8
Cotton breeding and transgenic cotton varieties	1974–2001	5	2002	58.3	5007.4	85.8	34.0
Biological control of Echium weed species (including Patterson's Curse)	1972–1995	5	2000	19.7	935.7	47.5	19.0

a Benefit Cost Ratio. **b** The internal rate of return (IRR) is the discount rate that when applied to the stream of costs and the stream of benefits, equalises the present value of costs and benefits.

Sources: Johnston, Healy, I'ons and McGregor (1992); CIE (2002); Marsden, Martin, Parham, Ridsdill Smith and Johnston (1980).

Table I.4 **Cost-benefit studies for grains research**
Base case estimates

	Research period[a]	*Dis-count rate*	*Base year*	*Costs*	*Benefits*	*BCR*
				$m	$m	
National chickpea breeding program	1992–1994	5	1991	0.65	11.20	17.1
Suppression of graindust	ns	5	1991	0.29	28.72	101.0
Development of disease resistance in faba beans and peas	ns	5	1991	1.50	115.20	103.0
One-pass sowing and fertiliser application technique	1989–1994	5	1991	0.88	144.00	164.0
Lupin breeding and evaluation	1975–1991	5	1991	24.50	291.00	11.9
Development of a package for brown spot control in lupins	1988–1993	5	1991	1.00	10.50	10.5
Breeding special purpose oat cultivars with resistance and tolerance to cereal cyst nematode	1985–1992	5	1991	1.84	126.62	69.0
Research into yellow spot resistance in wheat	1981–1992	5	1991	2.96	231.55	78.3
high yield wheat package and lupin extension projects	1987–1990	5	1991	1.20	45.80	38.2
Evaluation of noodle quality of wheat	1988–ns	5	1991	2.07	19.36	9.4
Wheat variety improvement in Victoria	1983–1992	5	1991	2.64	8.064	3.1
Quality assessment of central and southern NSW wheat-breeding program	1992–1994	5	1991	0.40	1.391	3.5
Enhanced evaluation of CIMMYT germplasm	1991–1992	5	1991	1.10	30.90	27.0
Regional wheat variety trials in central west NSW	1984–1987	5	1991	0.40	1.70	4.0
Increasing crop production on acidic and compacted soils	1976–1981			0.38	212.38	557.0
Selection of disease-resistant barley variety	1976–1981	5	1991	1.59	108.16	68.0

[a] Where research was continuing studies estimated an end year.

Source: GRDC (1992).

While not always stated, the studies of Institute of Plant Production and Processing and GRDC research projects make implicit assumptions about additionality and uniqueness. They assume complete additionality — that is, they assume private research bodies would not have the incentives to undertake similar research programs. The research was also assumed to be unique to Australia. The plant diseases that necessitated most of the research were largely specific to Australia and so there was no interest overseas in addressing these problems.

In contrast, the non-agricultural studies were more likely to consider a counterfactual in which technological displacement occurred. Usually it was assumed that the technologies developed (or substitutes for them) would have been delayed by only some years in the absence of publicly supported Australian research efforts.

Table I.5a **Other cost-benefit studies**[a]

		Research period	*Dis-count rate*	*Base year*	*Costs*	*Benefits*	*BCR*
					$m	$m	
1	$SIRO_2$ Oxygen sensor	1972–1986	5	1994-95	18.7	71.3	3.8
2	Battery tester	1984–1994	5	1994-95	2.1	53.3	25.4
3	Supercapacitors	1994–2001	5	2001	55.0	491.0	9.0
4	Solospun	1993–1999	5	2002	4.3	0.1	0.03
5	Exelogram	1989–2002	5	2002	33.5	5.1	0.2
6	Bovigam – tuberculosis test	1986–1989	5	2002	30.0	107.0	5.0
7	Beef cattle genetic technologies	1971–2002	7	2001	337.0	9023.0	26.7
8	Rapid roadway development	1995–2001	10	2006	4.5	13.0	2.9
9	Longwall mining automation	1994–2007	10	2006	6.4	261.4	40.1
10	Automated draglines for coal	1997–2001	10	2006	1.3	7.7	25.7
11	Automated underground vehicles	1995–2001	10	2006	13.6	16.2	5.9
12	Road crack vehicle	1993–2001	5	2001	4.8	440.4	91.4
13	Relenza anti-influenza drug	1975–1990	5	1994-95	46	1136.5	24.7[b]
14	PolyNovo medical polymers	2001–2004	6	2006-07	15.7	44.1	2.8
15	Fisheries Harvest Strategy	2005	6	2006-07	range[c]	range[d]	5.0[e]

a The estimates are base-case or mid-point estimates. **b** A preliminary re-examination of the anti-influenza drug study was made using information made available since Relenza and its competitor, Tamiflu, were released in 1999. The re-examination suggested a realised BCR ratio for the project of about one, rather than the previous study's 25. The main reason for finding lower benefits were that only around a quarter of people seeking medical treatment for influenza do so in time to use the drugs (the original study assumed all did), only around one day of work loss is prevented per person taking the drugs (the original study assumed all work loss was prevented) and only those who would have otherwise been sick enough to be hospitalised who seek medical treatment in time are prevented from being hospitalised (the original study assumed half of all hospitalisations would be prevented). The re-examination also added additional benefits for the stockpiling of anti-influenza drugs to treat avian influenza. We have used the original study in the table since the re-examination has been preliminary only, but it suggests strongly that 24.7 is probably a significant overstatement. **c** Several millions of dollars. **d** Several tens of millions to several hundreds of millions. **e** Approximate, minimum value.

Sources: CIE (2001a); CIE (2003a); Mills and Yapp (1996); Farquharson, Griffith, Barwick, Banks and Holmes (2003); ACIL Tasman (2006e).

Table I.5b **Other cost-benefit studies**

		IRR	*Study year*	*Industry sector*	*Ex post or ex ante utilisation*	*Displace-ment period*
						Years
1	$SIRO_2$ Oxygen sensor	ns	1996	Industrial	ex post	14
2	Battery tester	ns	1996	Transport	ex ante	12.5
3	Supercapacitors	34	2003	Transport	ex ante	na
4	Solospun	ns	2003	Manufacturing	ex ante[a]	nc
5	Exelogram	ns	2003	Manufacturing	ex post	na
6	Bovigam – tuberculosis test	43	2003	Animal health	ex post	nc
7	Beef cattle breeding	ns	2003	Cattle farming	ex post	nc
8	Rapid roadway development	ns	2006	Mining	ex ante	5
9	Longwall mining automation	ns	2006	Mining	ex ante	5
10	Automated draglines for coal	ns	2006	Mining	ex ante	5
11	Automated underground vehicles	ns	2006	Mining	ex ante[a]	5
12	Road crack vehicle	ns	2001	Transport	ex ante	nc
13	Relenza anti-influenza drug	ns	1996	Pharmaceuticals	ex ante	4
14	PolyNovo medical polymers	ns	2006	Medical	ex ante	various[b]
15	Fisheries Harvest Strategy	ns	2006	Fishing	ex ante	na

a The technology had been available for only two years at the time of the study. **b** displacement periods varied across a number of medical polymer products. ns — not stated. nc — not considered. na — not applicable.

Sources: CIE (2001a); CIE (2003a); Mills and Yapp (1996); Farquharson, Griffith, Barwick, Banks and Holmes (2003).

The effects of different treatments of displacement

Two case studies involving the same project provide a lucid illustration of different treatments of displacement.

An updated cost-benefit study of CSIRO’s automated mining research projects was recently conducted and found a lower BCR (ACIL Tasman 2006a). The main reason for this was the updated study made the assumption of only a temporary (five year) market advantage, whereas the original study assumed an effectively infinitely-lived one (a secondary reason was that adoption rates were slower than originally estimated, but this was not a decisive factor in the differences between the old and new studies).

The updated study also examined the question of additionality and concluded that, since the great majority of the returns were private and large, industry could have been convinced to support the entire research costs. The costs and benefits of the project, setting aside the additionality issue, are shown in table I.6 — showing that the new estimates of the BCR are about one tenth of the old ones.

Table I.6 **Comparison of automated mining original and updated cost-benefit studies**

	Research period	*Dis-count rate*	*Base year*	*Displace-ment period*	*Costs*	*Benefits*	*BCR*
		%		Years	$m	$m	
Automated mining (old)[a]	1994–2007	5	2001	none	46.9	4520	96.4
Automated mining (new)	1994–2007	10	2006	5	25.7	272.6	10.6

[a] The original study includes an extra research project not covered in the updated study. Three-quarters of the research costs were privately funded.

Sources: CIE (2001a); ACIL Tasman (2006a).

Estimates of returns from portfolio cost-benefit studies

Because large research organisation run many research projects, only a few of which generally contribute to the majority of there returns, portfolio cost-benefit studies give a better idea of overall returns than do individual cost-benefit studies.

The study of CSIRO Division of Wool Technologies research projects was a portfolio cost-benefit study with total benefits being compared to overall divisional research expenditures over a comparison period (1993-94 to 1997-98). Of the 109 projects undertaken within the division over the period, eight were commercialised and were expected to return economic and social benefits.

The studies of the CSIRO Institute of Plant Production and Processing and of the CSIRO Division of Entomology can also be used to estimate minimum portfolio cost-benefit ratios. Aggregated benefits can be compared with total divisional spending over the time period the research projects were being undertaken.

The Institute of Plant Production and Processing cost-benefit studies (Johnston, Healy, I'ons and McGregor 1992) were used to obtain a portfolio estimate for the combined CSIRO divisions of Soils, Plant Industry, Horticulture and Tropical Crops & Pastures (table I.7). These estimates are minimum ones because the cost-benefit studies only covered a subset of the divisions' research projects. Divisions within the Institute of Plant Production and Processing were responsible for at least 24 projects that resulted in new technologies being transferred to industry. Of these, ten were evaluated in the 1992 study, and we have include eight of these in the portfolio comparison (those from the relevant divisions that were undertaken in the comparison period). Most of those not examined were difficult to quantify, since they produced outcomes of a non-market, public good nature. Similarly, the Entomology study will also be a minimum estimate because it examined 13 out of a total of 40 projects (Marsden, Martin, Parham, Ridsdill Smith and Johnston 1980).

Table I.7 **Portfolio cost-benefit estimates**
ex post utilisation studies

	Authors	*Comparison period*	*Dis-count rate*	*Base year*	*Expend-itures*	*Benefits*	*BCR*
					$m	$m	
CSIRO divisions of Soils, Plant Industry, Horticulture and Tropical Crops & Pastures (divisional costs)	Jonston, Healy, I'ons and McGregor (1992)	1970 to 1990	5	1990	2526.6 **a,b,c**	2039.7	0.8-1.0+**d**
CSIRO Entomology Division	IAC (1980)	1960 to 1975	5	1975	107.2	475.1	4.4

a Costs were multiplied by 1.20 to take account of the MEB. **b** Costs were estimated using staffing numbers (obtained between 1983 and 1990) and divisional expenditures (including head office overheads) in 1989-90. It was assumed that real expenditures per staff member were the same over the comparison period as they were in 1989-90. It was also assumed staffing numbers remained the same between 1970 and 1983. Estimated expenditures were then turned into present values in each year and these yearly present values summed to arrive at the total cost figure. One research project was largely conducted within the research period, but had prior expenditures. These expenditures were added to the overall costs. **c** Benefits were included for those research projects conducted during the comparison period (one research project conducted before 1970 was excluded). **d** These figures are based on the costs of all the relevant CSIRO divisions, but benefits for only eight of 22 successful research projects over the comparison period. There were also another 14 successful projects that were not evaluated, so that 0.8 is clearly an underestimate of the BCR for the divisions collectively. If only the costs for the evaluated research projects ($257.8 million) are used then the cost-benefit ratio is 7.9.

Sources: Johnston, Healy, I'ons and McGregor (1992); Marsden, Martin, Parham, Ridsdill Smith and Johnston (1980); and Commission estimates.

Other studies that examined costs from a broad area of research, rather than individual projects, were studies of returns to CSIRO flagships (table I.8).

Table I.8 **Ex ante utilisation studies of CSIRO flagships and divisions**

	Authors	*Comp-arison period*	*Dis-count rate*	*Base year*	*Expend-itures*	*Benefits*	*BCR*	*Benefits taking additionality into account*
					$m	$m		
CSIRO Wool Division	DJ and BA Collins (1999)	1993-94 to 1997-98	6	1999	288.9	582.0	2.0	lower
CSIRO Preventative Health Flagship[a]	ACIL Tasman (2006d)	2003-04 to 2006-07	6	2006-07	87.0	376.4	4.3	same
CSIRO Light Metals Flagship[a]	ACIL Tasman (2006c)	2003-04 to 2007-08	6	2006-07	15.0	466.0	31.1	lower
CSIRO Water For a Healthy Country Flagship[a]	ACIL Tasman (2006e)	2003-04 to 2007-08	6	2006-07	around 175	around 900.0	at least 5.1	same

a Studies use an options approach. That is, possible outcomes are weighted by probability of success and project expenditures are weighted by their probability of being incurred (which take into account scenarios where projects are cancelled).

Sources: Collins and Collins (1999); ACIL Tasman (2006e); ACIL Tasman (2006c); ACIL Tasman (2006d).

Evaluation of benefits produced by CRCs

Estimates of a whole portfolio of research have also been produced for the CRC program — Allen Consulting (2005) and Insight Economics (2006) — but using a different evaluation approach to most of those described above.

Both evaluations use a general equilibrium modelling approach to determine impacts. The evaluations identified various direct benefits associated with a sample of CRCs. These took the form of cost savings to industry, increased sales, income from IP and savings on government purchases. For example, one of the projects for which benefits were used in both evaluations was the Gravity Thickener research project undertaken at the AJ Parker Centre for Hydrometallurgy. Companies involved reported benefits worth $295 million in 2004 net present values. These included reduced operating costs, reduced capital costs, increased production capacity, increased yield and securing additional sales (Stem Partnership 2004).

The Allen Consulting evaluation identified $908 million in direct benefits brought about by CRC innovations ($832 in cost savings to industry, $46 million in income from intellectual property and $30 million in savings on government expenditures). If the direct benefits were the only realised gains this suggests a BCR of about 0.5

(the total costs for the CRC program from 1992-2005 were $1.92 billion) — a significant net resource loss.

However, productivity achievements in specific industries have feedback effects, shifting resources to higher value uses throughout the economy. Using a general equilibrium model, the study compared a base case (with the CRCs) with a counterfactual in which there was no CRC program. In the counterfactual, it was assumed that the public funds released through the absence of the CRC program are spent on some other item of real consumption by governments, rather than funding tax decreases.

The effects of the absence of the CRC program on the supply side was mainly modelled as annual shocks to productivity in a number of industries relative to their levels in the baseline scenario.[3] The productivity gains were calibrated to achieve the savings revealed by various case studies undertaken of particular projects in specific industries. The GDP, consumption and investment changes between the base and counterfactual scenarios were then calculated.

The Insight Economics evaluation contained three estimates of CRC impacts. The first was the minimum impact, which included benefits that had already been achieved and that were entirely attributable to the efforts of CRCs; the second included benefits where CRC research only partially contributed to impacts (the impacts attributed to CRCs was less certain because of this); and the third included seven projects where benefits had just commenced or were just about to commence.

Insight Economics' latter estimate gives the most complete measure of the CRC program, suggesting that every dollar of CRC grants increased GDP by $1.16. To place it on a more comparable basis to the other studies in this appendix, this is equivalent to a BCR of 2.16, that is a *net* gain of $1.16. The BCR for their minimum estimate is 1.5. The Allen Consulting study, which used similar assumptions to that of Insight Economics when calculating their minimum estimate, found an increase in GDP of 60 cents for every dollar of CRC grants, equivalent to a BCR of 1.6.

The main difference between the two evaluations were their counterfactuals. The Allen Consulting evaluation assumed that in the absence of the program other government spending would have been higher (by the amount of CRC grants foregone). The Insight Economics evaluation assumed that in the absence of the program taxes would have been lower. In the Commission's view, the latter approach is the better one.

[3] Effects of the absence of the CRC program were also modelled as shocks to household income and research industry investment.

It should be noted that the benefits and costs identified in the two evaluations relate only to the CRC grants ($2.3 billion of funding) and not to the CRCs as a whole ($11.1 billion over the life of the program).[4] The Commission understands that the benefits associated with the program were scaled down in the studies to reflect the share of grant funding in total spending (Insight Economics, personal communication, October 2006) Accordingly, the studies will underestimate the aggregate economic benefits of CRCs as a distinct institutional form for undertaking R&D (as compared with the grant component of the program).[5]

The two studies used sophisticated approaches to estimating the benefits of a large portfolio of research, but some questions arise.

- Under the counterfactual, there is an assumption of full additionality and zero technological displacement, so that none of the impacts from the CRC projects would have been realised. This appears unlikely as at least some of the projects are likely to have involved rivalrous efforts by foreign teams. Accounting for rivalry, would also tend to lower the BCR.
- Against these two factors, the studies acknowledged that they ignored prospective gains of many kinds, though prima facie many of these may well be significant.

I.3 Lessons from cost-benefit case studies

Reliability

The cost-benefit studies examined were of varying reliability. Unreliability could result from a lack of information, which required many assumptions to be made, or from unrealistic assumptions about counterfactuals. One of the main causes of uncertainty that evaluations were conducted before new products or techniques had been commercialised for long enough to determine adoption and benefits in practice.

The use of ex post utilisation studies should increase reliability by reducing the need to make assumptions. On the other hand, a potential danger of the ex post approach is that research organisations could tend to select successful, rather than unsuccessful projects, for evaluation, which would lead to an upwardly biased view of returns. Solutions are random selection of projects or the portfolio approach —

[4] Other contributors include universities, PSRAs, industry and State governments.

[5] Of course, in the absence of CRC grants, the contributing institutions would still spend their contributions on research of some kind.

where returns to all significant research projects are found and are compared with the overall portfolio costs.

Ex ante utilisation studies will, of course, still be required for research management and planning purposes.

The reliability of studies could also be improved by improving transparency through: including independent reviewers; publishing reports; and clearly showing all information sources and calculations.

Returns to publicly funded research

The studies suggested that research had produced positive benefits through the introduction of new crop varieties and farming techniques; improvements to the productivity of cattle through selective breeding; cost-savings for large Australian industrial operations; and through decreased maintenance costs for public infrastructure.

Benefits are also expected from research into: preventative health; improved water management; improved fisheries management; aluminium, magnesium and titanium production; and cost-savings from the automation of large mining operations.

Additionality and displacement

Australian-specific public-good research

In some cases, the issues of international technological displacement discussed earlier are likely to be small. For example, overseas research groups are unlikely to have had sufficient incentives to work on problems associated with Australian-specific agricultural diseases. Without the research, the improved crop varieties introduced to combat these diseases would have been significantly delayed or would never have occurred.

The same was true for cattle breeding research to improve the fitness of Australian herds undertaken by State agricultural departments and CSIRO, as well as for CSIRO research into sustainable fishery practices.

Research with the potential to accelerate the introduction of new technologies

There were a number of examples of public research projects that were able to accelerate the introduction of new technologies with possible net social benefits.

The involvement of public sector research agencies may accelerate the introduction of socially beneficial technologies where:

- they undertake strategic research that involves significant resources but leads to freely available outcomes (private firms may be reluctant to invest where returns from outcomes cannot be appropriated) and where these outcomes allow subsequent innovation by private firms;
- public sector research agencies are able to identify emerging research approaches that allow the development of techniques that overcome previously intractable problems and where they can develop these approaches in ways that encourages them to be transferred to others;
- public research agencies have built up multiple areas of expertise which allow them to solve particular problems more quickly and effectively than outside groups. For instance, the development of a more robust oxygen sensor by CSIRO was based on its experience in high temperature ceramics research; and
- a large number of exploratory research projects are required in order to identify the few with commercial potential. The resulting knowledge of prospective research areas may be of a public good nature in the sense that it could be exploited by a number of firms.

An example of a public research project that fits several of the above situations (research based on emerging science that could be used by several firms and which became freely available) is described in box I.1.

Box I.1 CSIRO research allowed the development of anti-influenza drugs

CSIRO worked with the Australian National University and Biota to develop an anti-influenza drug, *Relenza* using an approach, based on neuraminidase inhibitors, that had previously been abandoned. It was able to do this because of the advent of technologies able to image proteins at high resolution and a breakthrough in the ability to prepare the neuramindase molecule in a form that could be imaged.

CSIRO researchers mapped and characterised the structure of the influenza neuramindase and determined that it would not mutate in response to highly-specific neuramindase inhibitors. Researchers at Biota then developed Relenza based upon this information.

The drug was subsequently licensed to Glaxo Smith Kline for commercial exploitation through clinical trials, production, marketing and distribution.

The CSIRO research, which constituted the bulk of the costs needed to develop a neuramindase inhibitor to the pre-clinical trials stage, was publicly available once it had been completed.

Later research by the firm Gilead in the United States produced the competing neuraminidase inhibitor *Tamiflu*. Clinical trials, production, marketing and distribution were undertaken by Roche Pharmaceuticals.

The CSIRO mapping work underpinned the development of both Relenza and Tamiflu.

It also is likely that the work on Tamiflu was motivated by the success of Biota in developing Relenza and gaining a commercialisation agreement with Glaxo Kline Smith.

For a variety of reasons, the Tamiflu acquired around 97 per cent of the global market. The spillovers from the initial research were very large in this case, albeit largely captured by foreign firms.

Nevertheless, Australians benefit from being able to purchase effective anti-influenza medications — reducing illness, medical expenses, hospitalisations, deaths and work loss. There are also benefits from the Government's current stockpiling of anti-influenza drugs as a preventative measure against a possible avian-influenza pandemic.

Sources: Biota (2006); Moscona (2005); Mendel et al. (1998); Lew et al. (2000); Kim et al (1997).

A major question when public research agencies become involved in research projects with commercial orientations is the identification of the point in a project when the future benefits become sufficiently appropriable by businesses. At this time:

- the intellectual property should be sold to the private sector for their future development;

- full private funding of public sector research should be required on a contract basis; or
- where private partners are difficult to find or intellectual property is hard to negotiate, the best option may be to give research findings away free of charge and allow diffuse private sector development.

Large private returns

There were large private returns to some research efforts, potentially from the start. While these projects involve substantial private contributions, it could be argued that their entire costs should have been provided by industry.

An example was the cotton breeding research projects. These projects produced large returns to farmers in the form of increased yields (reducing costs per kilogram of cotton lint produced) and reduced spraying costs. These benefits also allowed the seed for the improved varieties to be sold at a premium. There is a real possibility that this research could have been fully funded by seed wholesalers or farmer's groups.

Private returns in the form of reduced production costs make up the majority (98 per cent) of the currently anticipated returns from CSIRO's automated mining research projects. The returns were also significant — the majority of which were production cost-reductions which would increase profits. In fact, the majority of the research and adoption costs (75 per cent) were funded from industry sources.

Private returns were also significant in the case of the gravity thickener research programs. Subsequently, these returned a $295 million in cost savings and other benefits for mineral processors in return for a reasonably small outlay.

One possibility is the adoption of a contingent repayment mechanism. Under this mechanism, research organisations could, on a discretionary basis, offer to cover a proportion of research costs upfront, but insist on these costs being returned if projects do turn out to have high private returns. This would be appropriate where private returns are considered large, but private firms are still unwilling to cover all research costs, perhaps because of a lack of knowledge about the true potential of particular research projects.

J Patent and innovation indicators

J.1 Patent indicators

Patent indicators, such as the number of patents granted to residents of a country, are among the most frequently used measures of innovation performance. They are seen as particularly useful in reflecting levels of inventive activity and diffusion of knowledge in countries, firms and industries. Some examples of how patent indicators have been applied are:

- the number of US patents per million population was used in the Australian Innovation Scoreboard 2004 prepared by the Australian Government;
- the number of triadic patent families for each OECD country was used in the OECD Main Science and Technology Indicators 2006 and the OECD Science, Technology and Industry Scoreboard 2005; and
- the number of applications for Australian patents was used in the Australian Patent Applications Scoreboard 2004 prepared by the Intellectual Property Research Institute of Australia and the Melbourne Institute of Applied Economic and Social Research.

Such patent measures provide valuable indicators. Patents by their nature are closely linked to inventions. They cover a broad range of technologies on which there are few other sources of data. The contents of patent documents are a rich source of information, such as on the applicant, inventor and technology category. And, finally, patent data, particularly over time, are reasonably accessible from patent offices.

However, as several participants have noted (for example, Jensen et al., sub. 9, p. 18; the Australian Business Foundation, sub. 72, p. 2; NT Government et al., sub. 23, p. 15; and Macquarie University, sub. 47, p. 4), patent indicators have limitations that make assessments of the level of innovation in a country, over time comparisons, and comparisons across countries, firms and industries quite difficult.

One major limitation is that patents vary in terms of their technological and economic value. Many patents represent marginal technological advancements, which may or may not be realised commercially. Some of these advancements may lead to a major change in an industry.

Various value-adjusting approaches have been used to deal with this limitation to make patents more homogenous. These include using patent citations (references in new patents to earlier patents, which were significant in the development of that area of technological knowledge), 'triadic patent families' (see later), and renewed patents.

A second limitation is that patent indicators do not directly measure innovation but inventions. Patents do not necessarily lead to new products or processes. Rather than being indicators of innovation system performance, they are indicators of inventions or inventive activity.

A third limitation of patent indicators is that they do not provide adequate coverage of inventive activity as many inventions are simply not patented. There are several reasons for this.

- Not all inventions are legally patentable. The basic legal requirements for patentability are that the invention must be novel, contain an inventive step (or be non-obvious), be capable of industrial application and not be in excluded fields (for example, scientific theories and mathematical methods are not regarded as inventions and cannot be patented at the European Patent Office).
- Other forms of intellectual property rights such as copyright and protection of designs might be used to protect the invention. A large proportion of innovations in computer software, for example, is protected by copyright, rather than patent. However, this is as much to do with the legal requirements of patents as firms' strategic choices.
- Inventors may protect their inventions using methods other than patents, such as using secrecy, using complex product design or process systems, or exploiting technological lead time and firm-specific skills. What they do will depend on the costs of patenting relative to using such alternative methods.

A fourth limitation is that patent indicators tend to reflect inventive activity in the private rather than in the public sector. Public sector research agencies and universities will generally have different objectives in regard to their research efforts than that of firms. This may mean that inventive activity in the public sector is not always fully translated into patents.

A fifth limitation of patent indicators is the increasing strategic use of patents by firms in the United States, which has little to do with innovation. One such strategic use is 'patent flooding', where a firm files many patent applications claiming slight variations on a rival's key technology, which increases the credibility of any threat to litigate against infringement (Jensen and Webster 2004, p. 17).

A final set of limitations relates to the use of data from patent offices.

- As patent regimes are not consistent across countries or over time, patent data are also not consistent. Regimes differ in terms of the scope of patents covered, as well as the costs and administrative procedures associated with patent applications. And regimes can change or be amended over time. This limitation can be partly overcome by obtaining data from a single patent office.
- Data from patent offices significantly over-represent domestic inventive activity and, thus, have a 'home advantage' bias. For example, Australian inventors acquire a higher proportion of patent grants in Australia than in other countries. This limitation can be overcome through the use of non-resident patent grants.
- Data from patent offices tend to over-represent dominant trading partners. Because of the cost of applying for patents, inventors seek patents in countries only when they perceive a market to be of particular value. A solution to this problem is to use non-resident patent data from the United States. The United States is the prime market for inventors from all over the world. As DEST (2004a, p. 14) noted, 'Because the US is the largest market in the world, registering a patent there tends to indicate that the invention is capable of competing with the best'.

Bearing these limitations in mind, the remainder of this section looks at Australia's performance in terms of patent indicators using available data from the US Trademarks and Patents Office, the OECD, and the Intellectual Property Research Institute of Australia and the Melbourne Institute of Applied Economic and Social Research.

US non-resident patent grants

Data from the US Patent and Trademark Office show that the number of US non-resident patent grants in 2004 was concentrated within a small number of countries (table J.1). Japan, Germany, Taiwan, South Korea, the United Kingdom, Canada and France accounted collectively for just over 80 per cent of US non-resident grants. Japan alone represented 43 per cent. Australia's share of US non-resident grants was around 1.3 per cent.

Table J.1 **US non-resident patent grants, 2004**

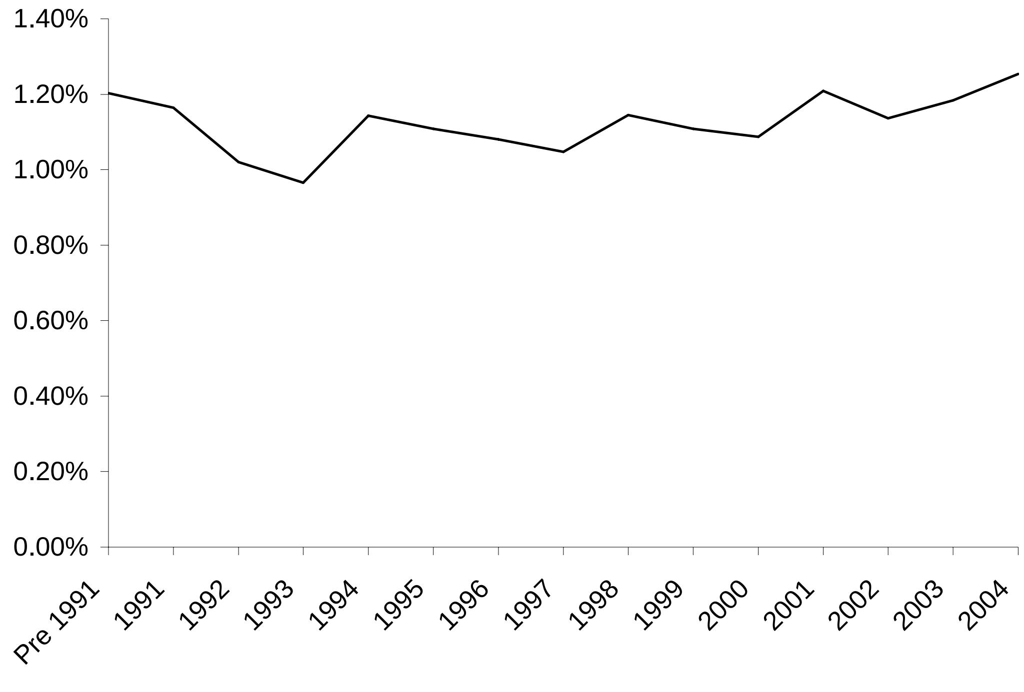
Originating country	*Number*	*Share of US non-resident patents grants*	*Average annual growth in share of US non-resident patent grants 1991 to 2004*
		%	%
Japan	37 034	42.5	-0.5
Germany	11 367	13.0	-1.4
Taiwan	7 207	8.3	19.3
South Korea	4 671	5.4	34.7
United Kingdom	3 905	4.5	-2.0
Canada	3 781	4.3	-0.5
France	3 686	4.2	-2.6
Italy	1 946	2.2	-1.5
Netherlands	1 537	1.8	-1.4
Switzerland	1 405	1.6	-3.2
Sweden	1 388	1.6	-0.4
Australia	**1 093**	**1.3**	**0.5**
Israel	1 092	1.3	6.5
Finland	954	1.1	4.0
Belgium	678	0.8	0.3
China, Hong Kong	641	0.7	5.2
China, Peoples Republic	597	0.7	39.0
Austria	575	0.7	-1.2
Denmark	530	0.6	0.3
Singapore	485	0.6	70.8
India	376	0.4	55.8
Spain	312	0.4	-0.4
Norway	255	0.3	1.5
Ireland	197	0.2	6.7
New Zealand	192	0.2	8.3
Russian Federation	173	0.2	13.1[a]
Brazil	161	0.2	2.7
Other	955	1.1	not estimated
Total US non-resident patents	**87 193**	**100.0**	**not estimated**

[a] Estimated over the period 1994 and 2004.

Sources: US Patent and Trademark Office patent database; OECD patent database.

Between 1991 and 2004, total US non-resident patent grants increased by around 80 per cent, from 49 052 to 87 193, or an average annual increase of 6 per cent. Very strong average annual increases in country shares were experienced by Singapore, India, China, South Korea and Taiwan. But average annual decreases in country shares were evident for Japan, many European countries and Canada (table J.1). Australia's share of US non-resident grants has remained fairly static, experiencing an average annual increase of less than 1 per cent (table J.1 and figure J.1).

Figure J.1 **Australia's share of US non-resident patent grants 1991 to 2004**



Data source: US Patent and Trademark Office patent database.

If data from the European Patents Office were used, the United States would be in the top position in table J.1 with 58 000 patent grants in 2004 relative to countries with US non-resident patent grant. Grants to US residents from the European Patents Office were 57 per cent more than grants to Japanese residents in 2002 (the latest available data). This relativity was then applied to the number of grants to Japanese residents in 2004 from the US Patents and Trademark Office to derive the hypothetical number of patent grants held by the United States. (Data from the US Patent and Trademark Office were not used given that data would have led to an overrepresentation of US inventive activity due to a home advantage bias.)

Rather than using numbers or shares of US non-residential grants, US non-resident patent grants per million population could be used to provide a normalised measure for comparing countries of different population sizes. The Australian Innovation Scorecard 2004 (DEST 2004a), for example, reports US patents per million population for Australia and other OECD countries. According to this indicator, US patent grants to Australian residents fell marginally between 2002 and 2004 from 54 to 53 patent grants per million population. In 2004, Australia was substantially below the OECD leader (the United States) with 340 US patents per million population and the OECD average of 152 US patents per million population. Australia's ranking in 2004 was 18, unchanged since 2002.

Although using US non-resident patent grants can ameliorate the limitations of patent indicators arising from biases due to home advantage and dominant trading partners, the other limitations of patent indicators noted earlier — particularly that of heterogeneity in the technological and economic value of patents — continue. A further limitation with using patent grants, rather than patent applications, is that the number may be unduly affected by the administrative process of the US Patent and Trademark Office.

Triadic patent families

The OECD uses triadic patent families to improve the quality and international comparability of patent indicators. A triadic patent family is a set of patents filed at the European Patent Office and the Japan Patent Office, and granted by the US Patent and Trademark Office.

Using triadic patent families has two major advantages:

- they remove home advantage and trading partner biases, because only patents applied for in the same set of countries are included in the 'family'; and
- they improve homogeneity of the patent data as patents in the triadic family typically have high value. Applicants only take on the additional costs and delays of extending protection to other countries if they deem that to be worthwhile.

Data show that most triadic patent applications by OECD countries in 2003 were by the United States, Japan and Germany, which accounted for around 80 per cent of the total (table J.2). Australia's share was less than 1 per cent. Australia's position relative to top tier countries is shown in figure J.2.

Table J.2 **Triadic patent families, OECD countries, 2003**[a]

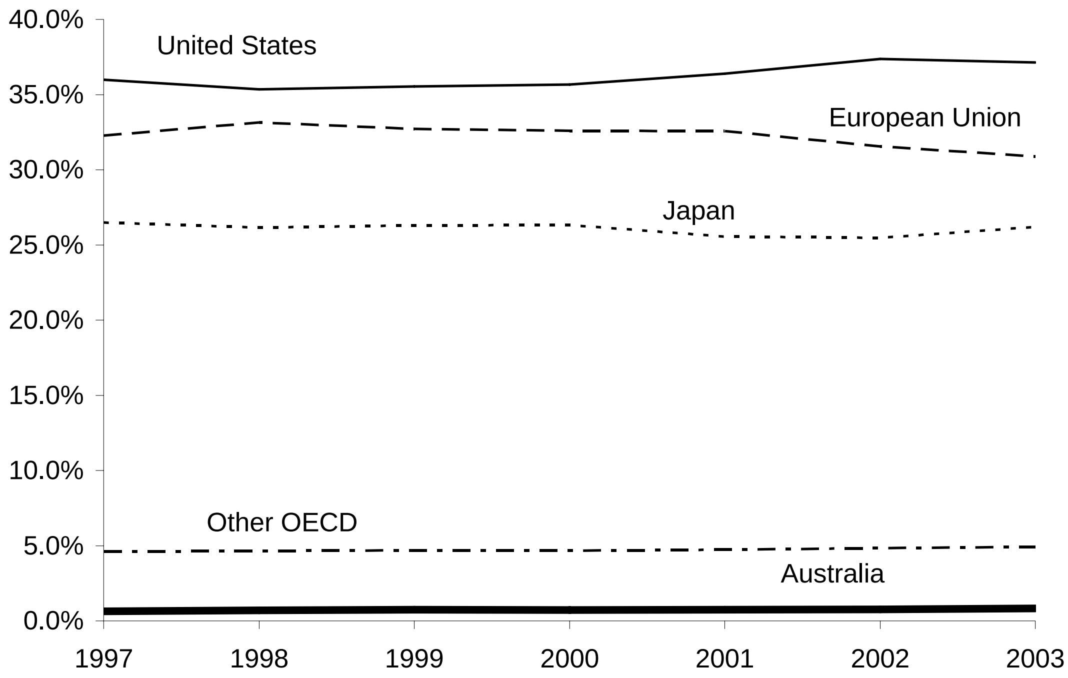
OECD country	*Number*	*Share*	*Average annual growth in share 1997 to 2003*
		%	%
United States	19 222	37.1	0.5
Japan	13 564	26.2	-0.2
Germany	7 111	13.7	0.1
France	2 356	4.6	-1.9
United Kingdom	2 024	3.9	0.2
Netherlands	1 019	2.0	0.1
Switzerland	895	1.7	-1.3
Italy	844	1.6	-1.1
Sweden	809	1.6	-3.5
South Korea	747	1.4	5.8
Canada	710	1.4	0.2
Finland	634	1.2	2.3
Belgium	454	0.9	-2.0
Australia	**431**	**0.8**	**4.7**
Austria	276	0.5	-1.9
Denmark	200	0.4	-3.6
Spain	115	0.2	-1.3
Norway	113	0.2	-0.2
Ireland	59	0.1	4.4
New Zealand	53	0.1	0.8
Hungary	23	0.0	-6.3
Luxembourg	19	0.0	0.7
Mexico	16	0.0	-0.7
Czech Republic	15	0.0	0.8
Poland	11	0.0	-0.8
Greece	9	0.0	-3.2
Iceland	8	0.0	7.9
Turkey	7	0.0	11.5
Portugal	6	0.0	-3.2
Slovak Republic	2	0.0	-6.9
Total	**51752**	**100.0**	**not estimated**

a The reference date for the application is the priority date — the date of the first international filing of a patent.

Source: OECD (2006c, tables 65 and 66).

Between 1997 and 2003, total triadic patent applications by OECD countries increased by around 29 per cent, from 40 108 to 51 752, or an average annual increase of 4.1 per cent. Large average annual increases in country shares were experienced by low patenting countries such as Turkey, Iceland and South Korea. Average annual decreases were evident for Japan and many European countries (table J.2). Marginal increases were experienced by the United States and Germany. Australia's share of triadic patent applications has grown substantially at an average annual increase of 5 per cent (table J.2).

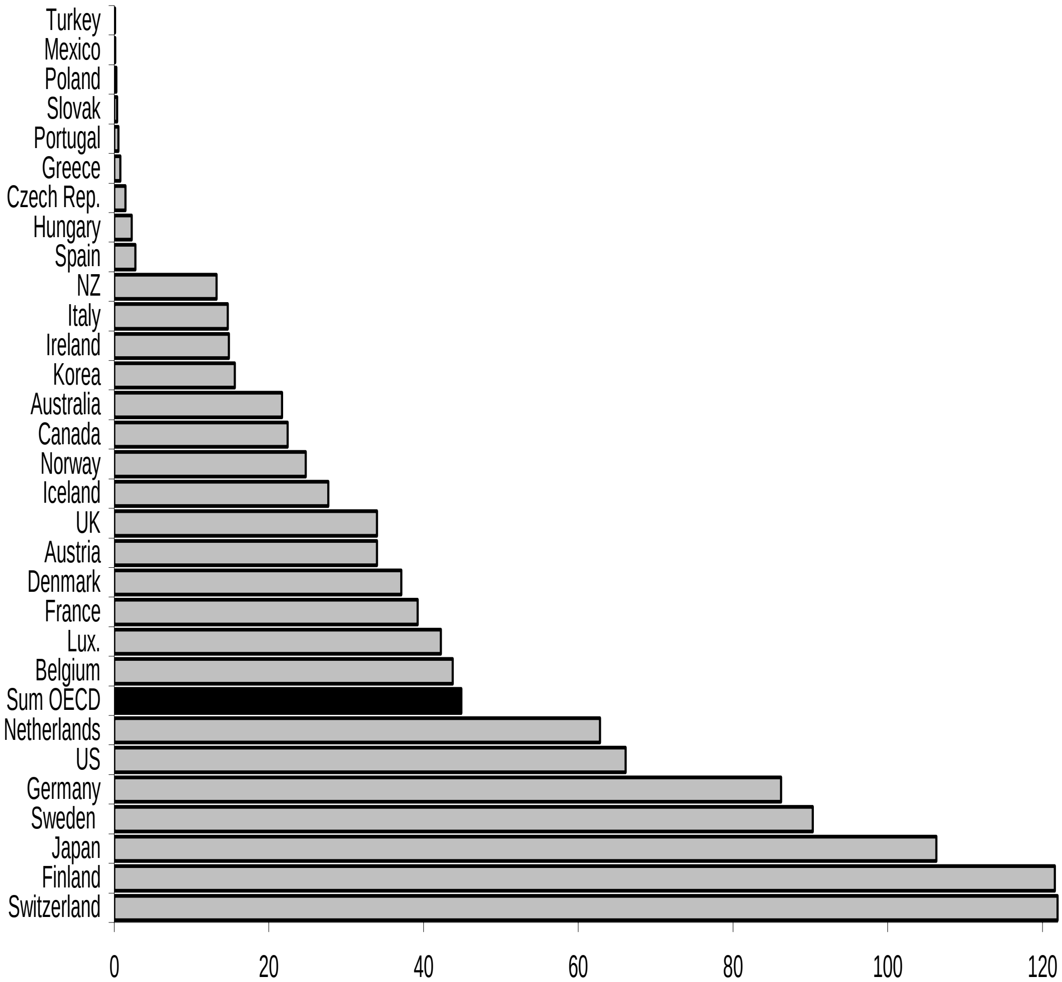
Figure J.2 **Shares of triadic patent families, 1997 to 2003, OECD**



Data source: OECD (2006c, table 65).

The data can also be expressed relative to population (figure J.3) to enable comparisons between countries of different population sizes. Using this indicator, the OECD average was around 45 triadic patent applications per million population. Leading countries were Switzerland, Finland, Japan and Sweden. Countries with very low triadic patent applications per million population (less than one) included Turkey, Mexico and Poland. Australia was below the OECD average, with about 22 triadic patent applications per million population.

Figure J.3 **Triadic patent families per million population, 2003, OECD countries**



Data source: OECD (2006c, table 65; 2005).

Patent applications filed in Australia

A patent indicator that has been used by the Intellectual Property Research Institute of Australia and the Melbourne Institute of Applied Economic and Social Research in their Australian Patent Applications Scoreboard 2004 is the number of patent applications filed in Australia that are PCT and non-PCT, and Australian and non-Australian. A PCT application is an application for an Australian patent filed under the Patent Cooperation Treaty, whereas a non-PCT application is an application for an Australian patent that is filed directly with the Australian Patent Office. PCT applications make it possible to seek patents in a large number of countries by filing a single application. Further discussion of the Patent Cooperation Treaty is given in the appendix N on the intellectual property system.

Table J.3 shows that PCT applications dominated, accounting for around 74 cent of total applications filed in Australia in 2003. This dominance is likely to continue (figure J.4). In the period between 1986 and 2003, the share of non-PCT applications declined by 3.8 per cent per annum on average. On the other hand, the share of PCT applications increased by 24.8 per cent per annum on average.

Table J.3 **Patent applications filed in Australia, 2003**[a]

Type	*Number*	*Share of total applications*	*Average annual growth in share of total applications, 1986 to 2003*
		%	%
Australian non-PCT	1340	6.2	-1.5
Non-Australian non-PCT	4401	20.1	-4.1
Australian PCT	1130	5.2	13.7
Non-Australian PCT	14695	68.1	26.3
Total	21566	100.0	

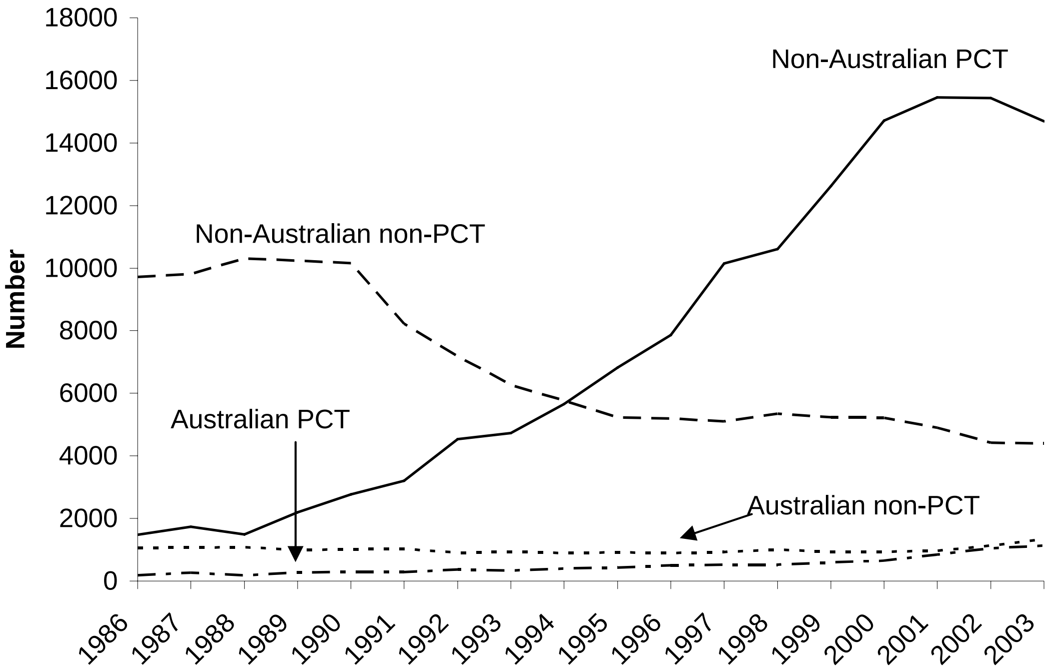
a The table covers standard complete applications in a given year.

Source: IPRIA and Melbourne Institute of Applied Economic and Social Research (2004).

Most patent applications filed in Australia, whether PCT or non-PCT, were by non-Australian residents at about 89 per cent of the total, with the Australian resident share of patent applications at about 11 per cent of the total in 2003. In the period 1986 to 2003, the share of Australian applications in total applications grew by around 0.8 per cent per annum on average, whereas the share of non-Australian applications declined by 0.1 per cent per annum.

However, the Australian share of patent applications is likely to overstate Australian inventive activity, due to the home advantage bias. It would be better if information on Australian patenting applications were derived from a non-Australian patent office.

Figure J.4 **Australian patent applications, 1986 to 2003**



Data source: IPRIA and Melbourne Institute of Applied Economic and Social Research (2004).

Summing up

The patent indicators above tell a consistent story about Australia's performance in this particular dimension — that is, Australia's share of patents relative to other countries, is very small, albeit growing.

The triadic patent-based indicator developed by the OECD appears to be the most useful in terms of reducing biases in patent data due to home country advantage and the influence of dominant trading partners, as well as dealing with the variable technological and economic value of patents. Australia's share of triadic patent applications, although small at less than 1 per cent, has nonetheless grown since 1997 at about 5 per cent per year on average. However, the number of triadic patent applications per million population for Australia is well below the OECD average.

J.2 Innovation Index

For a number of years the Intellectual Property Research Institute of Australia has funded the development and estimation of an Australian Innovation Index (commencing with Gans and Stern 2003), which in turn is based on work done in the United States by Porter and Stern (1999). The Index uses information from a number of countries to establish a relationship between past innovative inputs and more recent innovative output. As Gans noted: '… the resulting measure [the index] will indicate how effective the mix and level of current inputs will be in generating future innovation' (sub. 10, p. 12).

The Innovation Index, as recently presented in Gans and Hayes (2005), was estimated in two stages.

In the first stage, a statistical model of a country's 'innovative capacity' was developed. This involved creating a database of variables relating to innovative capacity for 29 OECD countries from 1973 to 2004. This data were used to perform a time series/cross sectional regression analysis determining the significant influences on innovation output and the weights associated with each driver of innovative capacity (p. 4). Drivers include R&D expenditure, R&D personnel per million people, public expenditure on secondary and tertiary education as a percentage of GDP, IP protection, R&D funding by industry, and R&D performed by universities.

The innovative output of the country was measured by the level of international patenting; specifically, the number of patents granted (per million persons) in a given year to individuals or firms from a country by the US Patent and Trademarks Office. It is a lagged measure in that 'the innovation environment pertinent for the patent grant is the environment that prevailed at the time of application' (p. 3). Based on advice from the Office, a two year lag was used.

The second stage involved calculating the Innovation Index using the results of the regression analysis in the first stage. The Index for a given country in a given year was derived from the *predicted value* for that country based on its weights. This predicted value is then exponentiated (since the regression is log-log) and divided by the population of the country (POP). Thus the Index for each country followed the following formula:

$\text{Innovation Index}_t = \exp(\hat{Y}_t)/\text{POP}_t$ where $\hat{Y}_t = X_{t-2}\,\beta$

where $\hat{Y}_t$ is the predicted value of innovative output, X is the set of variables used to explain innovative output, β is the set of weights derived from the regression analysis in stage I, and POP is the population of the country in millions of people.

Because of the way in which innovative output is measured, the Index literally means the 'expected number of international patent grants per million persons given a country's configuration of national policies and resource commitments 2 years before' (p. 5).

According to Gans and Hayes' estimates of the Innovation Index for 2004, Australia was ranked 15 of 27 OECD countries (table J.4). Over a thirty year period, Australia's Innovation Index peaked in 2001 (figure J.5). It has since declined slightly. Gans and Hayes attributed this to 'stagnating' R&D expenditure, a decline in the 'perception' of intellectual property protection, and a continuing decline in public spending on secondary and tertiary education as a proportion of GDP (2005, pp. 9–10).

Table J.4 **Innovation Index, 2004, OECD countries**

Country	*Innovation Index*	*Rank*
United States	254.7	1
Finland	205.8	2
Sweden	175.9	3
Switzerland	156.6	4
Denmark	156.2	5
Japan	142.6	6
Canada	116.0	7
Germany	103.7	8
Norway	101.3	9
France	73.6	10
Belgium	72.5	11
Netherlands	70.3	12
Iceland	70.0	13
Austria	57.8	14
Australia	**54.4**	**15**
United Kingdom	50.4	16
Ireland	43.6	17
South Korea	28.6	18
New Zealand	27.7	19
Spain	20.9	20
Italy	20.7	21
Greece	10.8	22
Portugal	7.9	23
Hungary	4.0	24
Poland	3.2	25
Turkey	0.6	26
Mexico	0.6	27

Source: Gans and Hayes (2005, p. 8).

Figure J.5 **Australia's Innovation Index, 1975 to 2004**

Data source: Gans and Hayes (2005, table A.5).

The capacity of the Innovation Index to explain how changes in the local policy or industrial environment have led to changes in innovation is its greatest strength, and provides a unique and useful tool in the Australian context. For example, it highlights some of the important links between sophisticated technologically-capable human capital and innovation (Gans, sub. 10, pp. 13–14). It can be similarly useful in assessing what might happen to patenting activity were some of its underlying determinants to be changed through policy (as in Gans and Stern 2003). However, as a summary measure of relative international innovativeness in its own right, the measure has some limitations (box J.1). In this context, it would appear that it might be more simple and valid to use observed patenting per capita as the indicator rather than the estimated Index. This would have the added advantage that in looking at historical movements, it would be possible to include the unexplained changes as well as the explained changes in patenting. These provisos do not in any way limit the real policy value of the Innovation Index approach, which is in the discovery of why patenting rates vary across countries and time.

Box J.1 **Simple might be better**

The Innovation Index measure is really only a predictor of international patenting. Gans and Hayes (2005) are aware this is the case, but argue it should not be interpreted that way:

> … it is important not to interpret the Innovation Index as a tool to predict the exact number of international patents that will be granted to a country in any particular year. Instead, the Index provides an indication of the relative capability of the economy to produce innovative outputs based on the historical relationship between the elements of national innovative capacity present in a country and the outputs of the innovative process. (p. 22)

However, consider the following simple way of representing their model: $\hat{Y}_i = \hat{\alpha} + \hat{\beta} X \quad and \quad Y_i = \hat{Y}_i + \varepsilon_i$ for *i* countries where Y is a patent measure, $\hat{\beta}$ is an estimated vector of weights associated with a set of underlying determinants of patenting and the errors, ε, are the extent to which actual and predicted patenting activity diverge from each other.[1] Gans and Hayes use $\hat{Y}_i$ for each country as the innovation index. The goal of the model building stage was to find a set of variables that usefully explain Y (in effect to discover a reasonable depiction of the underlying data generation process (DGP) for patents). The most compelling basis for using $\hat{Y}_i$ would be if X were observed for all countries and time periods, but not always Y (or if the model was in some sense a latent variables model, like Tobit). Then $\hat{Y}_i$ could be constructed. However, there are no cases where X is available that Y is not.

In that case, whether $\hat{Y}_i$ is preferred to Y as the preferred innovation index will depend on the outcomes from the modelling exercise. First, if it is hard to find a good match to the underlying DGP then ε is large and most of the variation in $\hat{Y}$ over time and between countries represents omitted important factors. Any innovation index constructed this way would risk missing out on the major factors underlying a country's innovative capability.

Second, if the model includes all of the theoretically sensible right hand side variables, but ε is still large because of noise, then the model could be seen as a noise extraction model (smoothing Y). This would still require that ε is statistically well behaved (homoscedasticty, absence of serial correlation etc). (An alternative, however, would be to use any of a range of widely available noise extraction methods to derive $\hat{Y}$.)

Third, if ε is small (which it appears to be in the Gans and Hayes study), then $\hat{Y}$ and Y are nearly the same across time and countries. In this case, a more simple approach would be to use the readily available Y measure as the index.

In this context, it might be simpler and more valid to use actual Y rather than $\hat{Y}$ as at least an alternative innovation index, since they are available anyway. However, the model itself is a very useful contribution because it allows the determinants of Y to be estimated.

[1] This characterisation abstracts from the panel data aspects of the model, but without any consequence for the observations being made.

A complementary approach is to consider multifactor productivity (MFP) models as a broader measure of innovation. In principal, MFP has some advantages. First, MFP is fundamentally achieved from learning and changed practices of one kind or another, which is the essence of broad definitions of innovation (chapter 1). MFP captures innovation that takes the form of daily learning by businesses, catch-up, and technologies that are kept secret in addition to those that are patented.

Second, unlike the Innovation Index, MFP is, by definition realised as gains in economic growth and prosperity, whereas the capacity of patenting to realise such gains depends on other contingent policy and environmental factors. This is revealed the panel data analysis of Luintel and Khan (2005a), which shows that the responsiveness of MFP itself to innovativeness indexes varies considerably from country to country (table J.5). Australia has a level of responsiveness that is 8th out of 20 countries. The Gans and Hayes measure of patenting (in effect, their Innovation Index) might be exploited in a similar model, though the Commission has not attempted to do this.

Table J.5 **MFP and 'new-to-the-world' knowledge stocks**[a]

	Elasticity of MFP wrt domestic knowledge stock measured as PIM[b] *on triadic patents*	*Triadic patents*	*Patents per 1000 researchers*	*Patents per PPP*[c] *billion dollars of R&D*	*Rank: elasticity*	*Rank: patents per researcher*	*Rank: patents per R&D dollar*
Australia	**0.246**	**183**	**4.0**	**35.5**	**8**	**18**	**16**
Austria	0.243	184	15.3	69.9	9	5	8
Belgium	0.218	253	12.7	69.2	10	8	9
Canada	0.205	308	4.4	29.4	11	17	18
Denmark	0.304	138	10.6	68.8	6	11	10
Finland	0.309	198	12.4	90.0	5	10	6
France	0.095	1732	13.5	62.1	17	7	11
Germany	0.067	4254	21.6	107.0	18	2	2
Ireland	1.102	24	4.8	39.4	1	15	15
Italy	0.156	568	8.2	43.6	13	14	14
Japan	0.057	8057	14.3	105.5	19	6	3
Netherlands	0.141	645	21.5	99.8	14	3	4
NZ	1.037	20	3.3	29.1	2	19	19
Norway	0.480	60	4.6	34.3	4	16	17
Spain	0.483	65	1.7	14.2	3	20	20
Sweden	0.159	533	19.0	92.0	12	4	5
Switzerland	0.127	737	40.9	154.5	15	1	1
UK	0.101	1397	10.1	58.6	16	13	12
US	0.048	10280	10.6	55.0	20	12	13
Mean	0.294	1560	12.5	70.8	7	9	7

[a] Based on triadic patents. [b] PIM is purchasing inventory method. [c] PPP is purchasing power parity.

Source: Luintel and Khan (2005a).

J.3 Innovation counts and surveys

Innovation counts (or the number of innovations) provide a more direct measure of innovation performance than patent indicators and the Innovation Index. They measure the ultimate end of a process of innovation. As noted earlier, patent indicators merely represent inventions, which may or may not be transformed into new products or processes.

Sources of data for innovation counts include innovation surveys of businesses and studies that sample the new product sections of trade and technical journals. The oldest example of journal-based innovation counts is the US Small Business Administration's Innovation Data Based complied in 1982 by the Future's Group (Jensen and Webster 2004, p. 18).

The ABS Innovation Survey (for example, ABS 2006a) contains a range of data on innovation by Australian businesses such as the proportion of businesses innovating or the proportion of businesses introducing new or significantly improved goods or services, operational processes, or organisational processes. It does not contain innovation counts as such, but business counts. For example, table J.6 shows that around 35 per cent of businesses between 2001 and 2003 were innovating. Of these innovating businesses, around 20 per cent introduced new or significantly improved goods or services and 45 per cent introduced new or significantly improved operational or organisational processes.

Table J.6 **Selected characteristics of innovating businesses, 2001–03**
Types of innovation and business size

		Businesses which introduced or implemented any new or significantly improved:		
Employment size	*Proportion of businesses innovating*	*Goods or services*	*Operational processes*	*Organisational processes*
	%	%	%	%
5 to 19 persons	30.4	14.3	19.8	17.7
20 to 99 persons	45.7	20.6	29.9	31.3
100 or more persons	60.8	38.4	44.8	39.5
Total businesses	34.8	16.6	22.9	21.4

Source: ABS (2006a, *Innovation in Australian Business 2003*, Cat no. 8158.0, revised, March, table 1.2).

Like patent indicators, innovation counts also suffer from limitations. One limitation is that the quality of innovations can vary in terms of their technological and economic significance. Thus, the proportion of innovating businesses introducing new or significantly improved goods or services in table J.6 does not reveal much about the economic value of the innovation. Another limitation is that innovation counts can be very costly to produce and may only be available for selected years or countries (Acs et al. 2000, p. 2). The ABS Innovation Survey would be more useful if it were consistently undertaken for a longer period of time. This way it would provide a more useful indication of trends in innovation amongst businesses.

K Publications and scientific performance

K.1 Introduction

The statistical analysis of scientific publications, bibliometrics, has long been used as a performance indicator to gauge the impact and output of scientific knowledge.

The publication of scientific literature is important as it:

- provides scientific knowledge to firms and organisations with the capacity to absorb it;
- is accessible to many users and is easily disseminated;
- provides a permanent store of knowledge that can be exploited years after it is actually produced;
- provides pointers to key researchers and practitioners; and
- certifies the origin of ideas, which is important in determining status and promotion within the institutions producing research outputs.

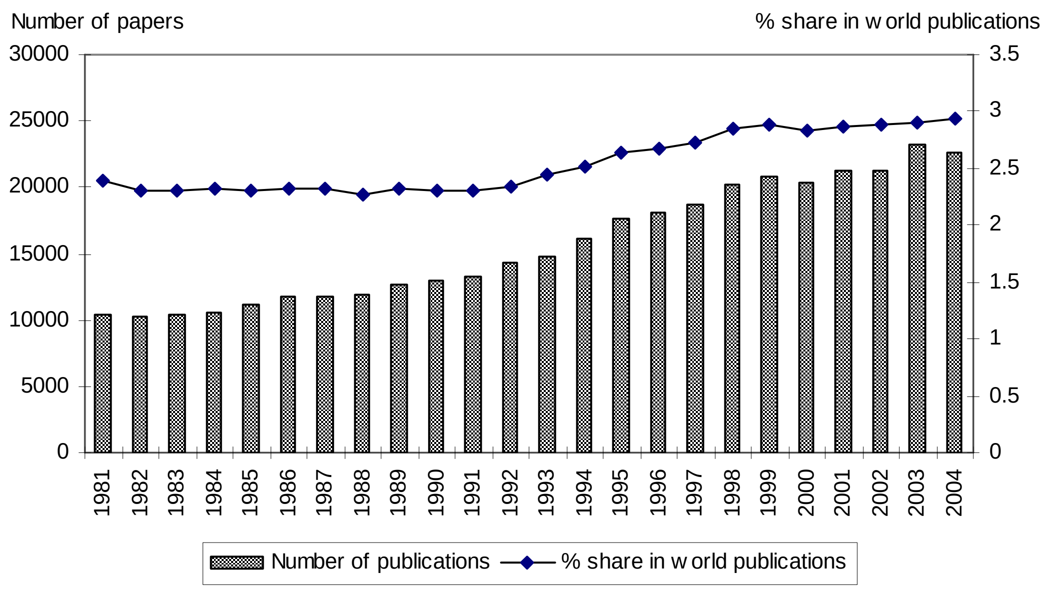
While the output of scientific publications and the citation of these publications provide a useful gauge of performance, they are not able to answer any single evaluative question in their own right (Butler 2001). Also, there may be certain 'counting' problems in using such measures including the overuse of citations of renowned publications at the expense of quality papers by less well-known authors, the sometimes insular view of scientists in citing their own nationals as a first preference, the tendency for 'self citation', 'citation circles' in which a group of academics cites each others work and the inability of such measures to take into account the prestige of the relevant journal.

Nevertheless, the analysis of publications and citations is useful in providing a relative indicator of Australia's scientific performance and output at the international level and by sector.

K.2 Australia's international performance

The total number of Australian scientific publications increased steadily between 1981 and 2004, although the upward trend stalled briefly between 1999 and 2002. Australia's share of world scientific publications increased over the same period from just over 2 per cent to nearly 3 per cent (see figure K.1).

Figure K.1 **Australia's number and share in world scientific publications**



Data source: DEST (2005a).

Relative to other countries' share of world scientific publications, Australia ranks 11th behind the United States, which accounts for a third of the world's scientific publications, Japan, the United Kingdom and Germany and ahead of the Netherlands, South Korea, Sweden and Switzerland. Taking into account population, Australia ranks 9th on the number of scientific publications produced per million population. In relation to the number of researchers, Australia is ranked 9th by scientific publications produced per full-time researcher and Australia is ranked 6th on the number of scientific publications produced per US $million in GDP (see table K.1).

Table K.1 **Australia's relative scientific publication performance**

	Share of world scientific publications, 2000-2004		*Number of scientific publications per million population, 2000-2004*		*Scientific publications per FTE researcher, 2003*		*Scientific publications per $ million GDP (PPP), 2004*	
1	United States	33.63	Switzerland	1930	Switzerland	0.57	Switzerland	0.058
2	Japan	9.38	Sweden	1700	Italy	0.48	Sweden	0.057
3	UK	9.04	Denmark	1467	Netherlands	0.47	Denmark	0.045
4	Germany	8.63	Finland	1435	UK	0.45	Netherlands	0.038
5	France	6.18	Iceland	1272	Belgium	0.34	UK	0.037
6	China	4.68	Netherlands	1212	Sweden	0.33	**Australia**	**0.035**
7	Canada	4.49	UK	1152	Denmark	0.32	Canada	0.033
8	Italy	4.33	Norway	1132	Canada	0.31	Belgium	0.032
9	Russia	3.24	**Australia**	**1114**	**Australia**	**0.31**	Germany	0.028
10	Spain	3.08	New Zealand	1113	Spain	0.26	France	0.027
11	**Australia**	**2.89**	Canada	1092	Germany	0.25	Spain	0.021
12	Netherlands	2.58	Belgium	1013	France	0.25	United States	0.021
13	India	2.39	Austria	925	United States	0.2	Italy	0.020
14	South Korea	2.15	United States	888	Japan	0.11	Japan	0.019
15	Sweden	2.01	Germany	790	South Korea	0.11	South Korea	0.016
16	Switzerland	1.86	France	464	Russia	0.05	Russia	0.016
17	Belgium	1.38	Ireland	738	China	0.04	India	0.005
18	Denmark	1.04	Spain	577	India	na	China	0.004

Sources: DEST (2005a); OECD (2006c); and World Bank 2006, *World Development Indicators Database*.

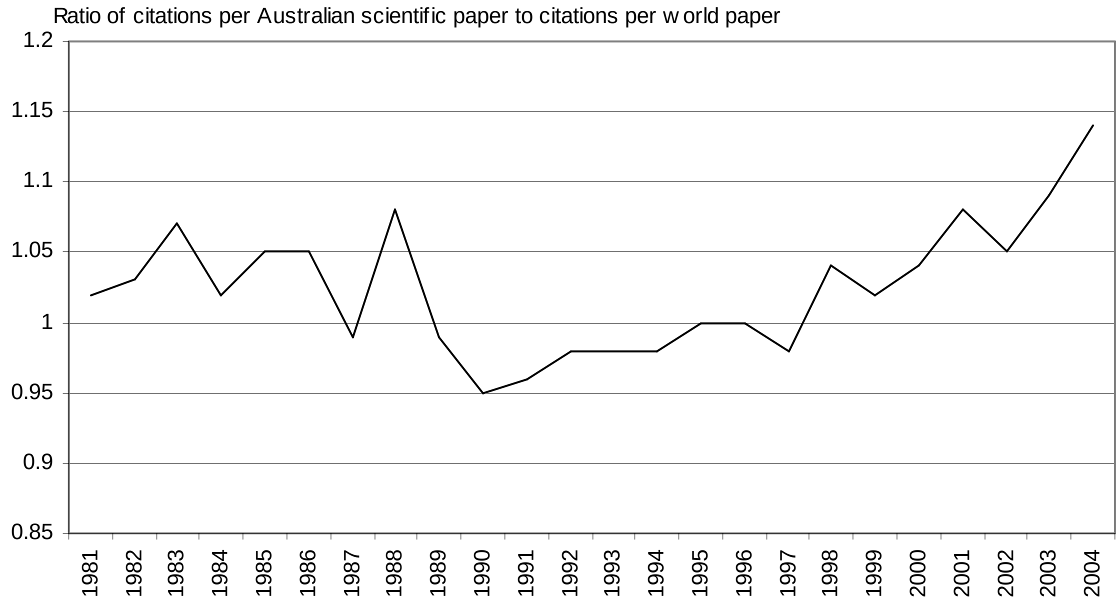
Citations impact, the number of times other scientists within the academic research community cite a research paper, provide an indication of the impact of the paper and an indicator of scientific performance. The CSIRO said:

> … citations provide a fairly direct measure of scientific impact, as the number of citations is a direct measure of the extent to which other scientists are drawing upon the work of the cited scientist in their own work. (sub. 50, p. 70)

One means of measuring this citation impact is from the ratio of citations of Australian scientific publications to the world average rate of citation. For most of the period 1981 to 2004, the Australian citation impact, while fairly volatile, was above the world average. For a period in the early 1990s it fell below the world average and has trended upwards since this period and was 1.14 times the world average in 2004 (see figure K.2).

The ARC (sub. 73) noted that Australia had achieved a relatively high scientific impact, as measured by citations of their published outputs, relative to its wealth.

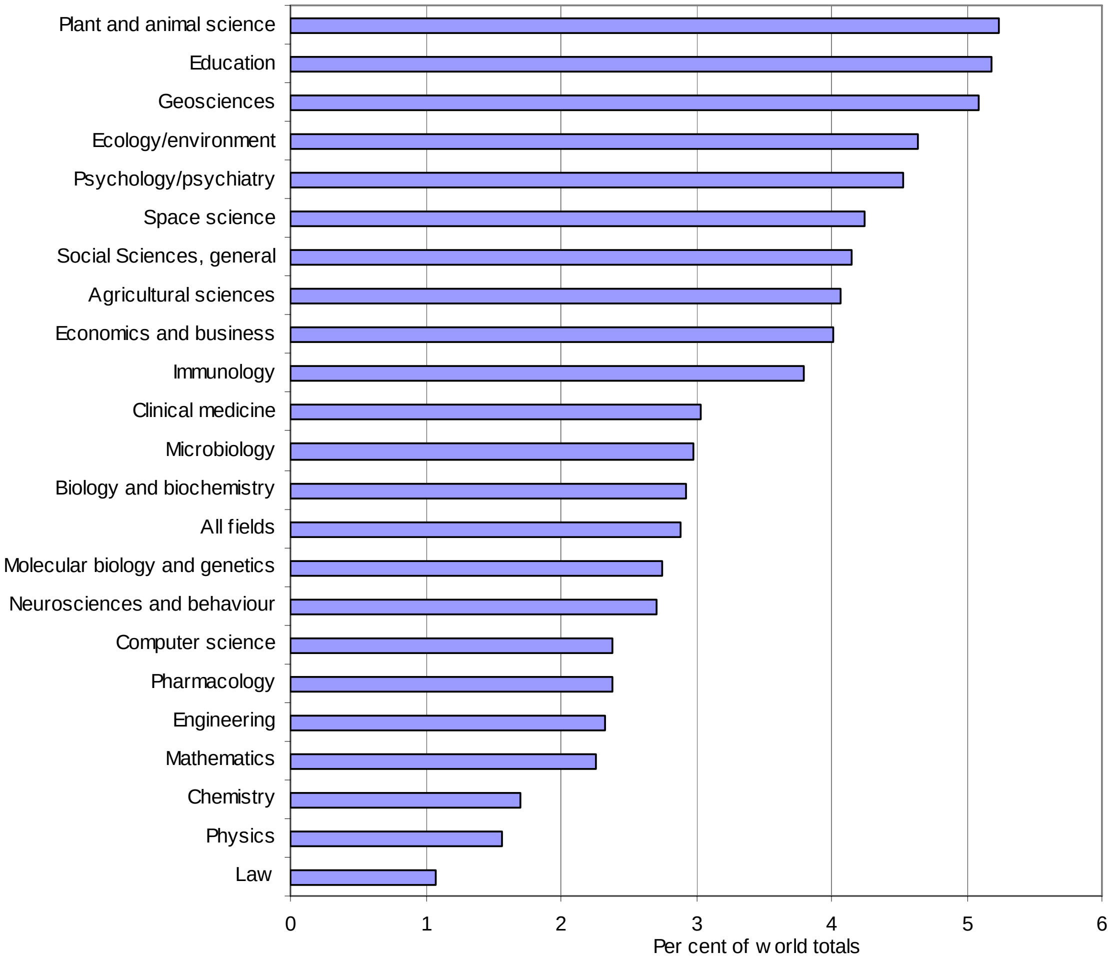
Figure K.2 **Impact of Australian scientific publications relative to the world, 1981 to 2004**



Data source: DEST (2005a).

By field of research, Australian research publications in plant and animal sciences, education and geosciences accounted for over 5 per cent of the world total in these fields between 2000 and 2004. Australian research publications in ecology and environment, psychology and psychiatry, space sciences and agriculture were also relatively numerous accounting for over 4 per cent of the total world publication in these fields over this period (see figure K.3).

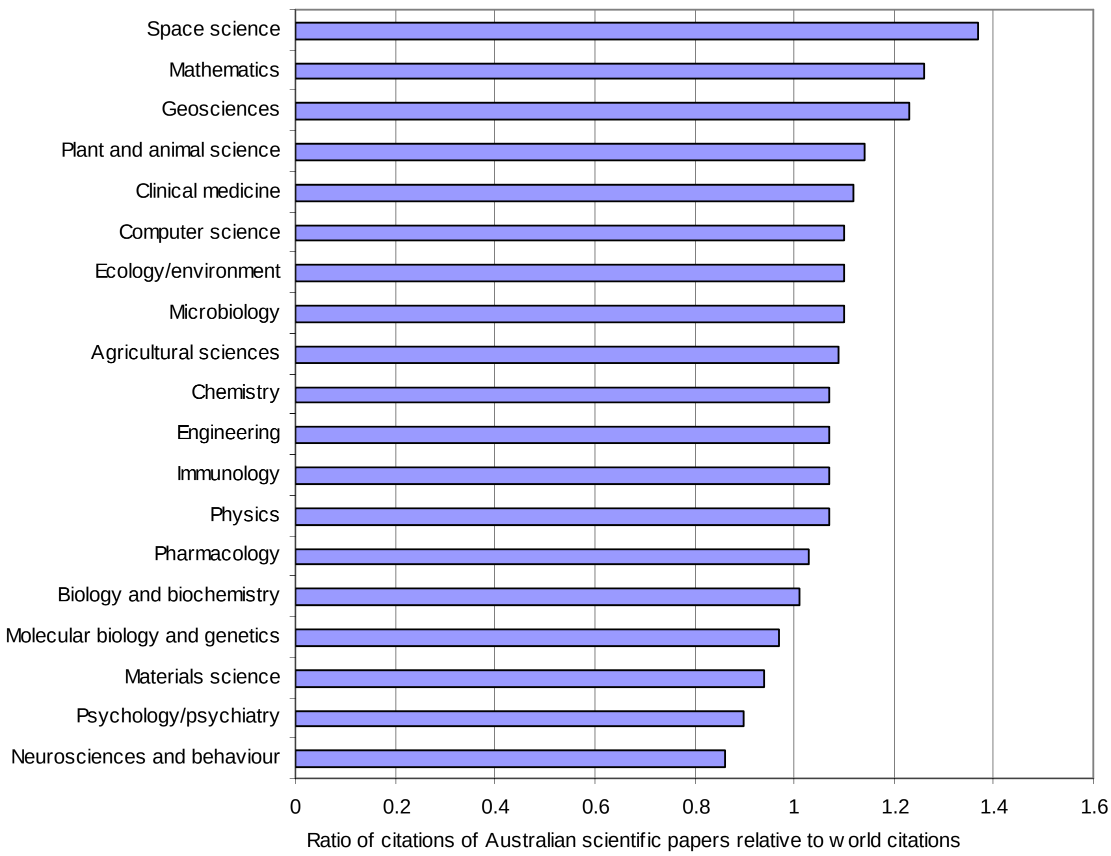
Figure K.3 **Australian scientific publications as a share of world totals — by field of research, 2000-2004.**



Data source: DEST (2005a).

The relative impact of Australian scientific publications by field of research, based on the ratio of Australian citations to the world average in each field, indicates that Australia performed above the world rate in a number of fields, in particular space sciences, mathematics, geosciences, plant and animal sciences, clinical medicine and microbiology between 2000 and 2004 (see figure K.4). For example, in space sciences the index of 1.37 means that Australian research publications in space sciences were cited at 1.37 times the world rate for papers in that field (DEST 2005a).

Figure K.4 **Impact of Australian scientific publications relative to world — by field of research, 2000-2004**



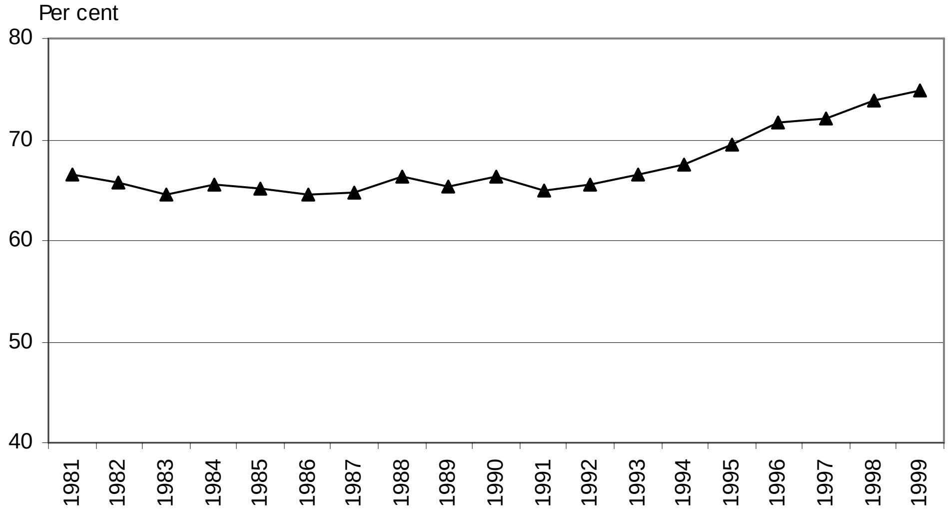
Data source: DEST (2005a).

By field of research, both as a share of world totals and by citation impact, Australia tends to perform well in plant and animal science, geosciences, space science and clinical medicine. Some of these fields of research are linked to Australia's natural endowments, such as plant and animal sciences and geosciences, where as others such as space sciences and clinical medicine indicate that Australia has been able to develop and build on capabilities in other areas.

K.3 Distribution of Australia's research effort

The university sector produces the vast majority of Australia's science publications. Analysis by Butler (2001) of Australian publications in the Science Citation Index found that universities dominated the output of Australian science publications. In the early 1980s universities accounted for around two-thirds of these publications increasing to just under three-quarters by the end of the 1990s (see figure K.5)

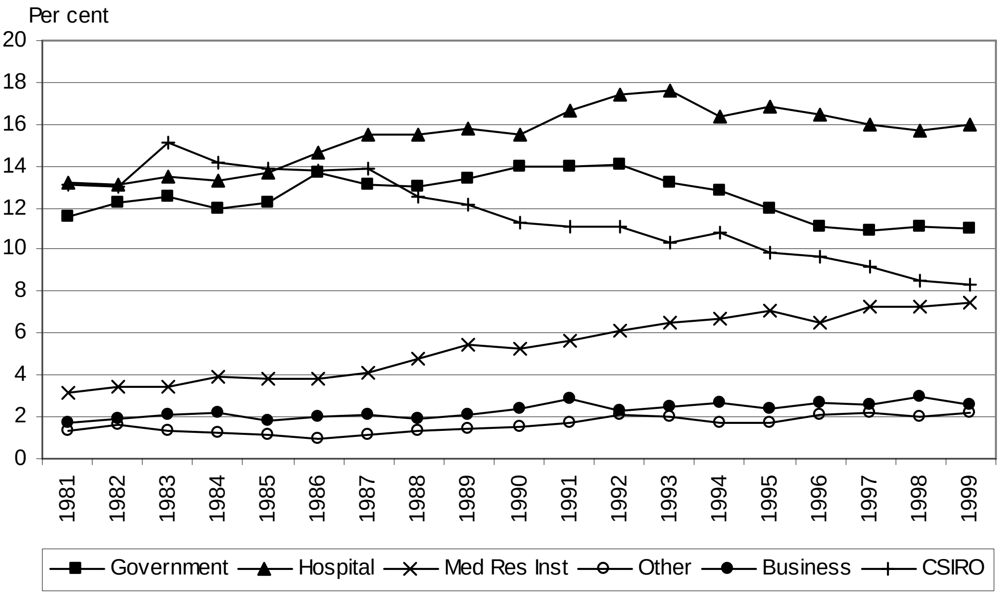
Figure K.5 **Universities' share of Australian publications in the Science Citation Index, 1981 to 1999**



Data source: Butler (2001).

Of the non-university sector, the hospital sector accounted for 16 to 18 per cent of scientific publications during the 1990s followed by government and the CSIRO, although the latter's share declined in this period. The medical research sector's share increased between 1981 and the end of the 1990s and accounted for around 8 per cent of the scientific publications in 1999 (see figure K.6).

Figure K.6 **Non university sector's share of Australian publications in the Sciences Citation Index, 1981 to 1999**

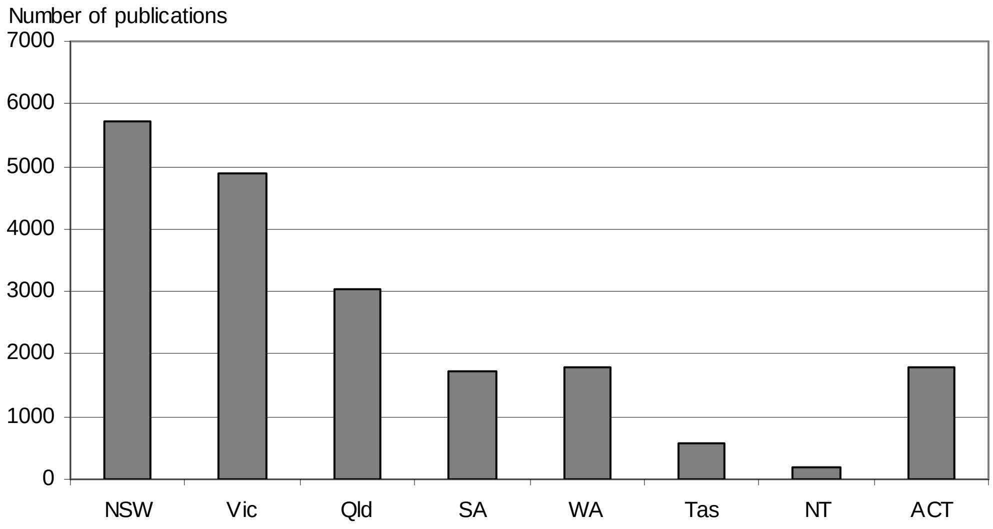


Data source: Butler (2001).

Distribution by State and Territory

By State and Territory, New South Wales and Victoria accounted for the bulk of the Australian scientific publications that appear on the Science Citation Index (see figure K.7).

Figure K.7 **Scientific publications on the Science Citation Index by State and Territory, 2002**[a]



a The analysis is based on 'whole counting'. Where more than one State or Territory collaborated on a publication, each was given a count of 1 for that publication.

Data source: Technical paper no. 1, PC website (http://www.pc.gov.au/study/science/index.html).

By field of science, most publications were produced in New South Wales and Victoria. However, in agriculture, veterinary and environmental sciences, Queensland accounted for the most publications and in the physical sciences the ACT accounted for the second largest number, behind New South Wales and slightly more than Victoria (see table K.2).

Table K.2 **Publication output by field for each State and Territory, 2002**

Field	*NSW*	*Vic*	*Qld*	*SA*	*WA*	*Tas*	*NT*	*ACT*	*Aust*
Mathematical Sciences	220	127	72	46	68	8		83	583
Physical Sciences	894	451	233	163	94	36	19	457	2109
Chemical Sciences	501	445	268	177	135	44	2	177	1524
Earth Sciences	286	286	201	108	206	145	21	219	1245
Biological Sciences	1133	1023	782	411	410	201	60	460	3864
Information, Computing and Communication Science	86	60	68	21	30	5	1	27	278
Engineering and Technology	820	630	414	162	213	31	9	149	2221
Agricultural, Veterinary and Environmental Sciences	487	410	525	189	289	141	36	194	1885
Medical and Health Sciences	2397	2303	1119	782	714	114	63	279	6857
Science - general	316	349	295	122	144	99	18	89	1250
Total	**5718**	**4899**	**3051**	**1729**	**1779**	**590**	**178**	**1792**	**17269**

[a] The analysis is based on 'whole counting' where more than one State or Territory collaborated on a publication, each was given a count of 1 for that publication.

Source: Technical paper no. 1, PC website (http://www.pc.gov.au/study/science/index.html).

K.4 Collaboration

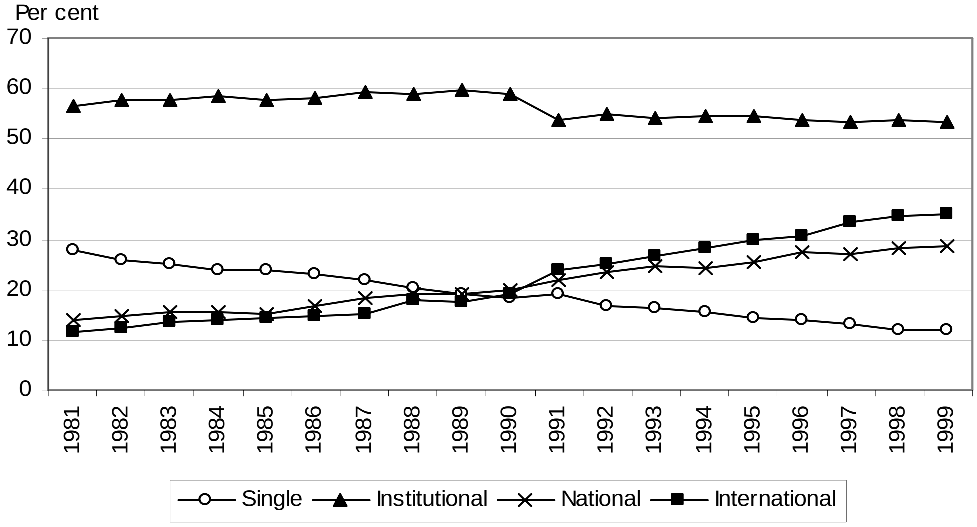
Publications data also provide an indication of the level of collaboration in scientific research. Analysis of the Science Citation Index by Butler (2001) distinguished between different types of authors of scientific publications along the following lines to indicate trends in the level of collaboration:

- Single – one author only (no collaboration);
- Institutional – more than one author from the same institution;
- National – more than one Australian institution listed in the author address; and
- International – more than one country listed in the author address.

This classification system is not exclusive and a publication involving collaboration between several Australian institutions and an overseas institution is included as both national and international.

The analysis found that over time research collaboration had increased. The single author paper was declining rapidly while collaborations between institutions at both the national and international level had increased markedly (see figure K.8).

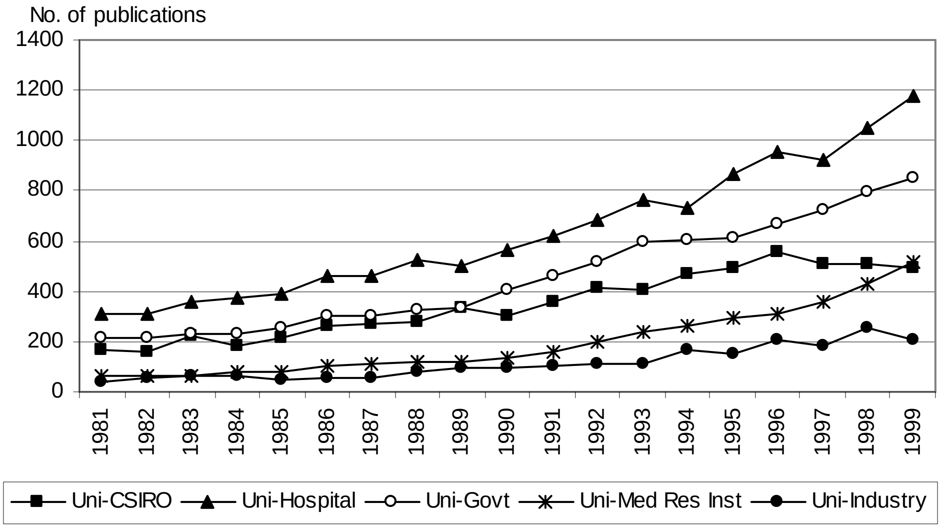
Figure K.8 **Levels of collaboration in Australian publications in the Science Citation Index, 1981 to 1999**



Data source: Butler (2001).

This analysis of authors of scientific publications also found that there had been increasing collaboration between the university sector and other sectors during the 1980s and 1990s. Collaborations between the university sector and government departments and agencies increased in this period and it appears that collaborations between universities and CSIRO began to decline in the latter half of the 1990s. Collaborations between the universities and industry trended upwards over the same period (see figure K.9).

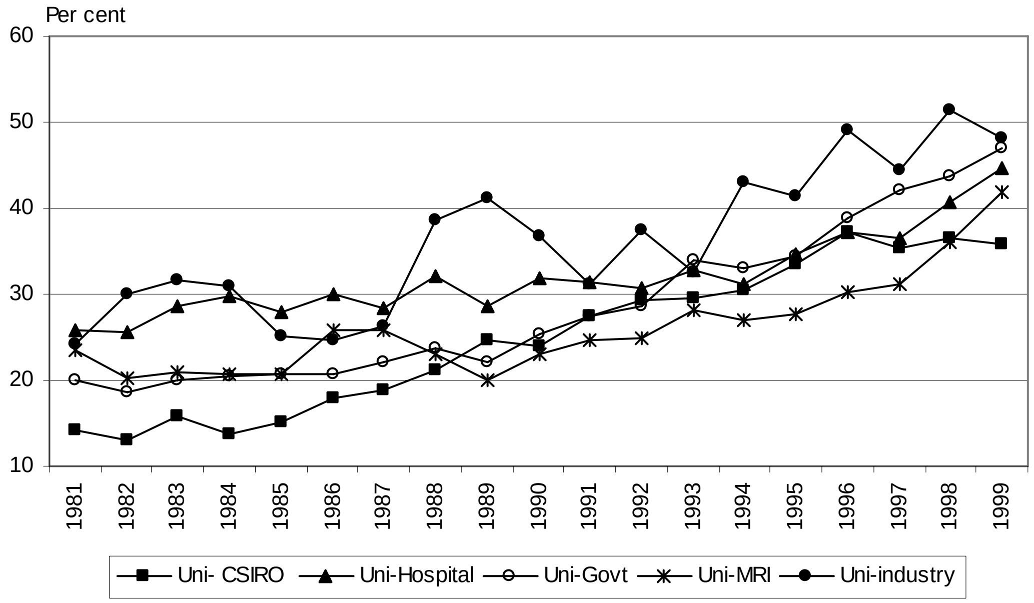
Figure K.9 **Selected sectors collaboration with universities in Science Citation Index publications, 1981 to 1999**



Data source: Butler (2001).

As a share of each sectors' total publications in the Science Citation Index, the level of collaboration with the university sector increased for most sectors between 1981 and 1999, although for CSIRO the level of collaboration remained flat in the latter half of the 1990s. The level of collaboration between industry and the university sector, as a share of industry publications in the Science Citation Index, while above that of the other sectors, was particularly volatile on a year-to-year basis due to the relatively small number of industry publications included in the Science Citation Index (see figure K.10).

Figure K.10 **Selected sectors collaboration with universities in the Science Citation Index publications as a share of their total publications in the Science Citation Index, 1981 to 1999**



Data source: Butler (2001).

L Labour force issues

This appendix looks at the key issues surrounding the science and innovation workforce and their possible implications on the ability of the system to deliver this workforce. These include the decline in the study of science and mathematics in the final years of high school and other school related issues, the number of graduates produced by the university sector, the impact of Australia's so called 'brain drain' and the size of the overall workforce. It then discusses the overall demand for these workers in the context of employment prospects and occupational shortages. A number of employment related issues raised by participants, including the use of term-contracts in employment and the career pathways of researchers are also discussed.

L.1 Supply issues

Many of the issues surrounding the science and innovation (S&I) workforce relate to ensuring that there are adequate numbers of appropriately trained scientists, engineers and related professionals. To a large extent, these issues are encapsulated in the ongoing concern that skill shortages will ultimately affect Australia's ability to create and absorb scientific knowledge and undertake innovative activities.

Problems in the classroom — school related issues

The study of science and mathematics in the final years of high school is important as it provides the pathway to tertiary study in these areas and a broader scientific and mathematical literacy in the wider population. However, there have been widespread concerns relating to the number of students undertaking these subjects, as well as a lack of adequately trained science and mathematics teachers in senior high school (DEST 2003b and 2006c, Harris, Jensz and Baldwin 2005).

Declining year 12 participation in maths and science

There has been a steady decline in the proportion of year 12 students studying science since the mid 1970s. Enrolments in year 12 biology decreased from 58 per cent to 25 per cent between 1976 and 2002, in chemistry from around 30 per cent to

18 per cent and in physics from nearly 28 per cent to 18 per cent over the same period. However, between 2000 and 2004 the participation rates in year 12 science have remained fairly stable. A number of reasons as to the decline in the study of science in the final year of high school have been put forward including poor experiences in earlier years of high school, perceptions that it is 'too hard', not being engaged with the curriculum, poor career advice based on limited knowledge of career options and peer group and/or family pressures (DEST 2003b, 2006c and sub. 87).

In respect of year 12 mathematics, overall participation rates were high and there were increases in elementary mathematics and a moderate decline in advanced mathematics during the 1990s (DEST 2003b).

More recent analysis undertaken for the International Centre for Excellence for Education in Mathematics and the Australian Mathematical Sciences Institute indicates that the move into elementary mathematics was continuing with the proportion of year 12 students studying higher level mathematics (advanced and intermediate) declining from 41 per cent to 34 per cent between 1995 and 2004. Those studying advanced mathematics declined from just over 14 per cent to just under 12 per cent over the same period (Barrington 2006).

However, while the proportion of year 12 students studying science and intermediate and advanced mathematics has declined, because of the strong growth in year 12 retention rates more students are studying these subjects in the final years of high school than was the case 20 years ago. As high school retention rates have increased, a wider range of subjects, including more vocationally orientated subjects, have been introduced to meet the needs of a more academically diverse student body. As a result, students continuing through to year 12 have a wider range of subjects to choose from than in the past which has lessened the appeal of the more traditional senior high school science and advanced mathematics subjects. Nevertheless, these subjects will continue to attract those students seeking to enter university courses — many which due to high demand for places attract the more highly qualified school leavers — where the study of high school science and/or non-elementary mathematics is an entry requirement.

There have been concerns that there will be further declines in students studying advanced mathematics as some universities, such as the University of Sydney and the University of New South Wales, no longer require advanced mathematics, or other specific high school subject areas including science subjects, as a prerequisite for their undergraduate courses. Instead, these high school subject areas that previously were prerequisites are now recommended areas of study or an assumed knowledge with the use of bridging courses provided by the university to acquire this knowledge where students have not studied these subjects at high school.

Of course, while this may appear to be a ‘softening’ of entry requirements in those universities where prerequisites were previously required, it would be extremely difficult to succeed in many undergraduate courses without the required background knowledge in science and mathematics whether obtained through high school studies or through a university bridging course.

Shortages of qualified teachers

Most jurisdictions face shortages in high school mathematics and science teachers, particularly in the area of physics and chemistry (DEST 2003b). These shortages are likely to be exacerbated due to the demographics of the teaching workforce as those older male teachers most heavily involved in teaching science and mathematics retire in the coming years. Such trends are not confined to Australia, with many other OECD countries facing similar shortages of secondary school mathematics and science teachers (MCEETYA 2004).

In addition to shortages, there are concerns that many teachers teaching senior high school science and mathematics are inadequately trained. In a report prepared for the Australian Council of Deans of Sciences, Harris, Jensz and Baldwin (2005) found that many senior high school physics and chemistry teachers lacked adequate qualifications. In a follow up report on the qualifications of mathematics teachers in secondary schools, Harris and Jensz (2006) found that while the qualifications of those teaching high school mathematics was more encouraging than those teaching science, around 20 per cent of all mathematics teachers had not studied mathematics beyond first year at university.

According, to DEST (sub. 87) there was a strong perception that Australia lacked sufficient suitably qualified secondary school science and mathematics teachers which had adverse impacts on student engagement in science, engineering and technology. Importantly, the lack of suitably qualified teachers in these areas limited the ability of the system to expand to increase the number of students studying mathematics and science in the senior years of high school and potential entrants to tertiary studies in science, mathematics and related courses.

The issue of teacher shortages is discussed further in chapter 3.

University entrants and graduates

Lack of well-qualified school leavers entering university science courses?

The decline in the proportion of year final year high school students studying science and the shortage of suitably qualified teachers has led to concerns that there will be a lack of well qualified school leavers to enter science and mathematics courses at university.

In any case, it appears that well qualified school leavers are more attracted to other university courses given the relative levels of demand for these courses. In 2005, according to the Australian Vice-Chancellors' Committee (AVCC), all eligible applicants for university science courses received an offer in contrast to other courses (see table L.1).

Table L.1 **Applicants and offers for selected university courses, 2005**

Field of education	*Eligible applicants*	*Offers*	*Percentage not receiving an offer*
Agriculture	4 161	4 304	0%
Architecture	6 733	4 620	31%
Management and commerce	35 282	29 606	16%
Education	25 308	18 648	26%
Engineering	12 162	10 933	10%
Dental studies	1 776	795	55%
Medical studies	8 316	2 320	72%
Nursing	16 675	10 959	20%
Law	12 372	7 917	36%
Veterinary studies	1 929	479	75%
Natural and physical sciences	15 003	16 519	0%
Information technology	6 810	6 392	6%

Source: AVCC (2005).

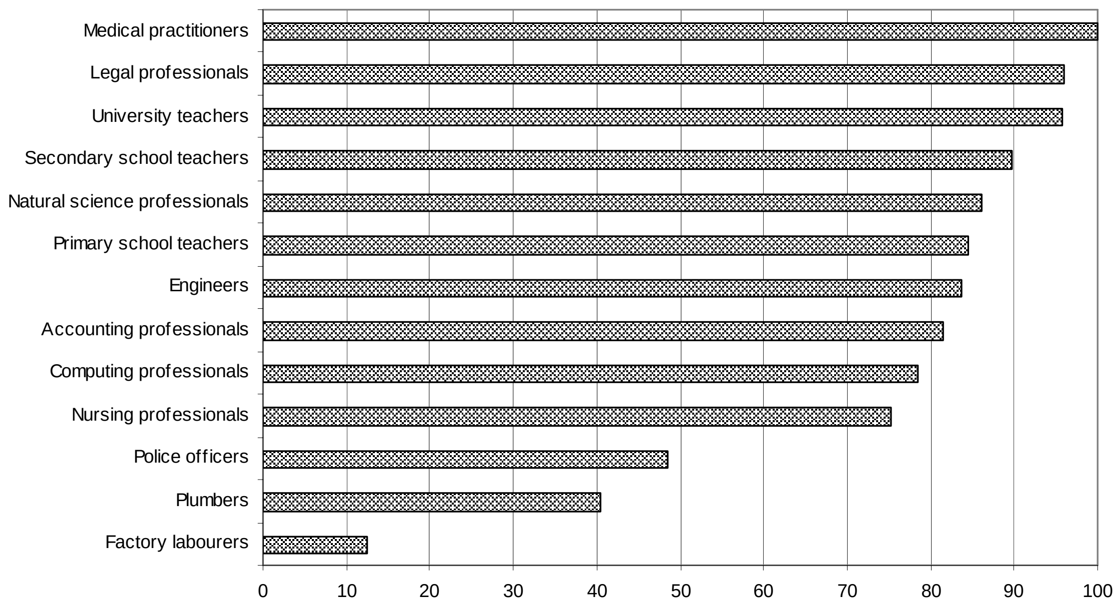
Those students performing well in science and mathematics at high school tend not to be attracted to science courses at university, but rather to other more vocationally orientated careers for reasons which, according to DEST (2003b and sub. 87), may include family or peer group influences, lack of quality career advice, the attractiveness of other career paths and student perceptions of career and lifestyle values available from other courses. Indeed, the perception of many students is that other courses provide direct entry to professions that are better paid and more secure (Australian Science Teachers Association 2005).

As the demand for science courses is not as strong as for other courses such as veterinary science, dentistry and law and there is a larger number of undergraduate places available, the tertiary entrance score to study science at university is lower than these courses. For example, in 2006 the tertiary entrance score for admission to undertake a bachelor of science at the University of Melbourne or Sydney University was just over 80 in comparison to law and veterinary science undergraduate courses where the scores were in the high 90s (VTAC 2006, UAC 2006 website). While this does not mean that only lesser qualified students or those with lower tertiary entrance scores will enrol in science courses, it does mean that science does not have the same status as those courses where entry is restricted to the 'top scoring' school leavers.

However, the lower admission requirements give a misleading impression of the average effective quality of those pursuing a career in science. A post-graduate qualification is often required for a professional career in science and the main selection process occurs following completion of the undergraduate degree as only the most able students proceed to post-graduate study. The National Health and Medical Research Council (NHMRC) (2005c) noted that the entry into post-graduate training reflected the selection of the 'best of the best'.

Moreover, the status of scientists appears to be quite good. In comparing the socioeconomic status of various occupations, science professionals rank quite high, although behind medical and legal professionals and university teachers. Interestingly, secondary school teachers are ranked above engineers, science professionals and computing professionals (see figure L.1).

Figure L.1 **Socioeconomic status of selected occupations and professions — ANU4 scale[a]**



[a] The ANU4 scale links education, occupation and income to provide a 0 to 100 scale of socioeconomic status coded to the ABS's occupational classification system, ASCO.

Data source: Jones and McMillan (2001).

Graduate numbers have been increasing in most areas

Despite being relatively less popular than some other university courses, in the period between 1990 and 2000 there was a substantial increase in the number of Australian citizens graduating in science, computer science and engineering. The number of Australian science and engineering graduates nearly doubled and the number of computer science graduates tripled (see table L.2). However, with the large increase in overall graduates over this period, the number of science and engineering graduates appears to have remained fairly static as a proportion of all graduates.

Table L.2 **Award course completions by Australian citizen students in selected fields of study, 1990 to 2000**

Field of study	*1990*	*2000*	*Percentage change 1990 to 2000*
General science	3 395	5 162	49
Life sciences	2 374	6 513	174
Mathematics	477	649	36
Physical sciences	876	1 457	66
Total science	**7 122**	**13 781**	**93**
Engineering	3 071	5 898	92
Computer science	1 701	5 149	202
Total	**11 894**	**24 828**	**109**

Source: Information supplied by DEST, University Statistics Unit.

In 2000, a different classification system to allocate fields of study was introduced. This created a break in the data, requiring any time series to be presented on a pre- and post 2000 basis. Using the changed classifications, there appears to have been a change to the previous trend.

Since 2001, there has been a very slight increase in the number of Australian citizens graduating in science and a slight decrease in engineering. By specific field of study, there have been large decreases in earth sciences and natural and physical science graduates. In physics and astronomy and those fields of study classified as other natural physical sciences, the trend of increased graduations by Australian citizens has continued along with slight increases in mathematical sciences and biological sciences (see table L.3).

Table L.3 **Award course completions by Australian citizen students in selected areas of study, 2001 to 2004**

Detailed area of study	*2001*	*2004*	*Percentage change 2001 to 2004*
Natural and physical sciences (general)	2 687	2 128	-20
Mathematical sciences	591	603	2
Physics and astronomy	254	326	28
Chemical sciences	495	485	-2
Earth sciences	787	456	-42
Biological sciences	3 313	3 532	7
Other natural and physical sciences	4 344	5 278	21
Total sciences	**12 471**	**12 808**	**3**
Computer science	2 011	2 136	6
Engineering	5 415	5 104	-6
Total	**19 897**	**20 048**	**1**

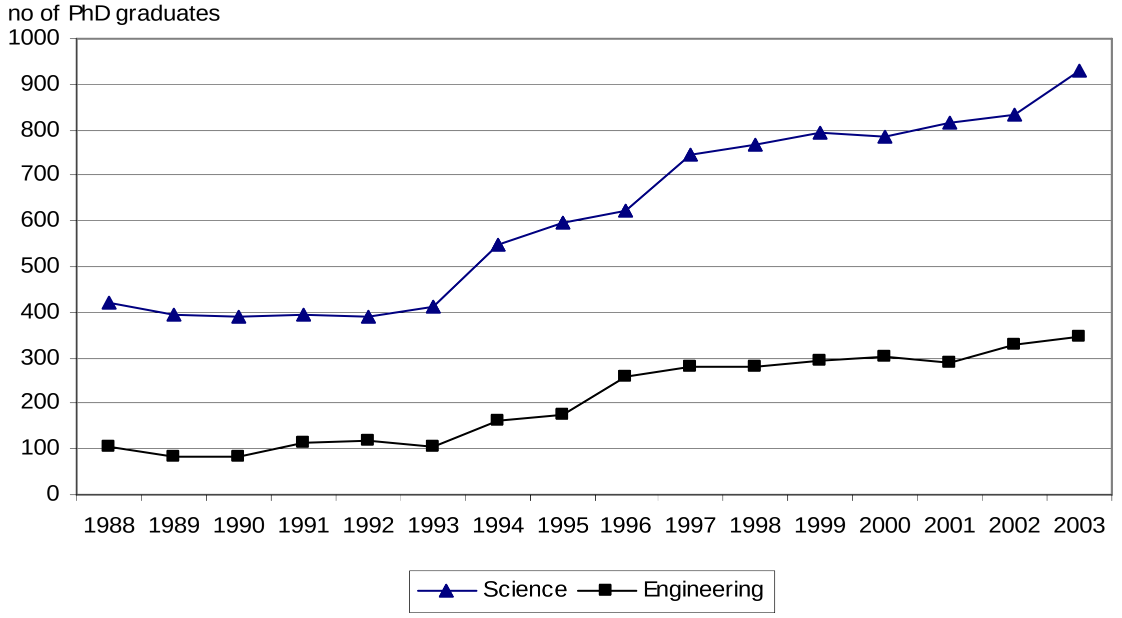
Source: Information supplied by DEST University Statistics Unit.

PhD graduates have increased

The number of PhD students is an important input into Australia's science and innovation system, not only from the research undertaken by PhD students, but also from the ongoing research focus of PhD graduates. The number of Australian PhD graduates in science and engineering has increased significantly. For example, the number of PhD graduates in science more than doubled between 1988 and 2003 from 425 to over 900. Engineering PhD graduates more than tripled over the same period from 104 to 345 (see figure L.2). However, as a proportion of total Australian PhDs awarded, science and engineering PhD graduates declined from 50 per cent to 35 per cent over the same period (DEST, 2005a).

The larger number of science PhDs relative to engineering PhDs most likely reflects the greater research focus of science compared to the more occupational focus of engineering. To be considered a 'scientist' often involves further post graduate education unlike engineering where the undergraduate education provides the entry to the engineering profession.

Figure L.2 **Australian PhD graduates in science and engineering, 1988 to 2003**



Data source: DEST (2005a).

Australia has experienced a brain gain rather than a brain drain

There have been ongoing concerns that Australia has been experiencing a 'brain drain' as skilled professionals, in particular scientists and engineers, move offshore.

However, the academic studies and inquiries generated by these concerns have all shown that Australia has actually experienced a brain gain, as any loss of skilled residents has been more than offset by gains from immigration.

For example, research undertaken for the Department of Immigration and Multicultural Affairs into the movement of skilled workers to and from Australia found that any net loss of skilled residents during the latter half of the 1990s was more than offset for almost every occupation by gains in immigration (Birrell, Dobson, Rapson and Smith 2001). The recent Senate Inquiry, *They Still Call Australia Home: Inquiry into Australian Expatriates* in 2005 similarly concluded that Australia had been experiencing a net gain in skilled workers, as did work on the Australian diaspora by Hugo et al. (2003).

More recent analysis of immigration data through to 2003-04, as with other studies, found that while Australia was losing skilled residents to overseas locations, these losses were exceeded by gains from immigration. It went on to conclude that it was Australia's relative lifestyle advantages — these cover a multitude of dimensions including a pleasant climate, political and social stability, a relatively crime and pollution free urban environment, good housing and other urban amenities and the availability of good quality and low cost education for children — that enabled it to keep the majority of its skilled workforce content to remain in Australia and provided a major attraction to skilled migrants. Moreover, Australia would continue to experience a net gain in skilled workers because of these advantages (Birrell, Rapson and Smith 2005).

More specifically, Australia experienced a net gain in nearly all science occupations and larger net gains in computing professionals and engineers in every year between 1996-97 and 2004-05 (see table L.4).

Table L.4 **Net movement of skilled settlers, residents and long-term visitors by selected occupations, 1996-97 to 2004-05**

Occupation	*96-97*	*97-98*	*98-99*	*99-00*	*00-01*	*01-02*	*02-03*	*03-04*	*04-05*
Chemists	174	64	144	164	151	128	102	70	125
Geologists and geophysicists	132	135	146	260	127	64	136	103	234
Life scientists	100	218	112	106	186	168	221	230	189
Environmental and agricultural scientists	228	138	257	264	98	79	75	51	25
Medical scientists	69	46	73	117	193	167	205	233	246
Other science professionals	143	-184	-87	-177	-206	-312	-96	-26	-35
Total science	**846**	**417**	**645**	**734**	**549**	**294**	**643**	**661**	**784**
Engineers	1 177	1 388	1 478	1 684	1 753	1 588	1 709	1 852	1 781
Computing professionals	1 044	1 125	1 399	2 287	4 057	5 063	4 689	5 890	5 692
Mathematicians statisticians and actuaries	60	57	65	58	37	2	61	76	65
Total	**3 127**	**2 987**	**3 587**	**4 763**	**6 396**	**6 947**	**7 102**	**9 614**	**8 322**

Source: Birrell, Rapson and Smith (2006).

On a trend basis, the net gains for the science occupations declined overall — although on at an occupational level there were increases in geologists and geophysicists, life scientists and medical scientists — and there were increases for engineers, computing professionals and to a lesser extent for mathematicians over this period.

Quality issues surrounding the gains

While Australia has experienced a net inflow of skilled migrants, it is unclear as to the quality component of these incoming and outgoing flows and whether or not those immigrating are adequate substitutes for those emigrating. The quality of human capital encompasses potentially measurable features such as experience, qualifications and achievement levels in courses, but it also includes intangible less measurable facets, like motivation, creativity and inherent ability. Unfortunately, it is only possible to gauge with ease selected aspects of tangible and intangible quality.

To this end, Birrell et al. (2004) assessed whether Australia was losing its most highly educated workers by examining the movements of people who had gained their PhD between 1996 and 2001. They found that, contrary to expectations, the very small loss of Australian residents who had gained their PhD in this period was greatly exceeded by the inflow of migrant PhDs and Australian residents returning with PhDs obtained overseas.

A further way of attempting to gauge the substitutability of skilled immigrants is to compare the productivity of immigrants with comparable Australian-born workers using earnings as a measure of their relative productivity. Analysis undertaken by the Productivity Commission (2006) into the economic impacts of migration and population growth found that immigrants from English speaking backgrounds earned slightly more than comparable Australian-born workers[1]. The similar outcomes in earnings between skilled immigrants and comparable Australian-born workers could also mean that the relatively more productive workers have departed Australia in response to the higher incomes available in some other countries. Of course, in any qualitative comparison there needs to be recognition of the selection bias in these flows as those emigrating from Australia, as is the case for those migrating to Australia, are likely to be more highly motivated and risk taking than those that remain.

Nevertheless, English language ability appears to be a key indicator as to the substitutability of skilled migrants for Australian emigrants across all occupations.

[1] Similarly, analysis on the earnings of immigrants in Canada and New Zealand found that those from English speaking backgrounds achieved fairly similar earnings or experienced only a relatively small difference in initial earnings from native born residents in similar occupations (Glass and Kin Choy 2001, Tockarick 1999).

Do Australians return home?

A critical issue is whether or not those skilled Australians emigrating return to Australia as those who do are likely to return with increased skills and knowledge which would be of benefit to Australia.

The majority of skilled emigrants return to Australia. The overall rate of return of skilled Australian residents, who indicated that they were leaving permanently or on a long term basis, was around 75 per cent (when returns two years after departure were compared). For those moving to the United Kingdom the rate of return was around 85 per cent (Birrell et al. 2004).

There are a range of reasons as to why expatriates did or did not return to Australia according to a survey of Australian expatriates undertaken by Hugo et al. (2003). The major reasons for return were lifestyle and family related, in contrast to work related reasons for leaving. It found that as expatriates aged they were less likely to return, those in the United States and Canada were less likely to return while those in Asia were generally more likely to return. A further factor was the nationality of the spouse, as those with Australian born spouses were more likely to return than those with non-Australian born spouses.

In any case, Australia has benefited from emigration given that the vast majority of its skilled emigrants return home with additional skills and experience.

Australia's science and innovation workforce has been growing

Although there are concerns surrounding high school enrolments in science and mathematics and the quality of students entering university science courses, the actual increase in graduate numbers and skilled migration has produced a net result of a growing science and innovation workforce in Australia. Indeed, the science and innovation workforce has been growing faster than the overall workforce over the past decade, although the experience for particular occupations has been diverse. For example:

- there was strong growth in the employment of computing professionals, engineers and for science professionals as a whole;
- across the science occupations, the number of chemists and geologists and geophysicists in full-time employment increased by over 50 per cent and by nearly 90 per cent for environment and agricultural science professionals;
- in the case of physical scientists, life scientists and mathematicians the increases in employment have been slight; and

- apart from mechanical, production and plant engineers, most engineering occupations have experienced a substantial growth in employment in the past decade (see tables L.5 and L.6).

Table L.5 **Science and related professionals employed full time by occupation, 1996 to 2006**

ASCO Occupation and code	*August 1996*	*February 2001*	*February 2006*	*Change 1996 to 2006*	*Share of the science workforce*
	’000	’000	’000	%	%
Chemists (2111)	5.9	4.4	9.0	52	15.5
Geologists and geophysicists (2112)	4.5	7.1	7.0	55	13.0
Life scientists[a] (2113)	4.6	8.0	4.8	0.4	8.4
Environmental and agricultural science professionals (2114)	11.0	14.4	20.7	88	36.1
Medical scientists (2115)	9.1	13.6	11.5	26	19.4
Other natural and physical scientists[b] (2119)	4.0	5.5	4.5	12	7.6
Total scientists	**39.1**	**53.0**	**57.5**	**47**	**100**
Mathematicians, statisticians and actuaries (2993)	5.4	5.6	5.6	4	
Computing professionals (2231)	93.9	151.6	143.3	52	
Scientists, mathematicians, statisticians and actuaries and computing professionals	**138.4**	**210.2**	**206.4**	**49**	

a Includes anatomists or physiologists, botanists, zoologists, biochemists, marine biologists and life scientists nec. **b** Includes physicists, meteorologists, metallurgists and natural and physical sciences nec.

Source: ABS (*Employed person by occupation, unit group, sex, state, status in employment,* Labour force estimates provided to the PC).

While there has been a smooth upward trend in employment growth for science professionals and engineers in total over this period, at an occupational level employment growth has generally been much more volatile.

By 2006, there were over 57 000 scientists, more than 5000 mathematicians, 143 000 computing professionals and 101 000 engineers employed on a full-time basis in Australia, accounting for around 3 per cent of Australia’s total workforce (tables L.5 and L.6). In addition, there was a significant workforce providing administrative, technical and other support to those pursuing scientific knowledge and undertaking research and development type activities. For example, just over a third of CSIRO’s staff were involved in providing technical, administrative and other support to CSIRO researchers (CSIRO 2005a).

Of the scientists, the majority were environmental and agricultural science professionals and of the engineers, more than half were civil engineers and electrical and electronic engineers (see table L.5 and L.6).

Table L.6 **Engineering professionals employed full-time by occupation, 1996 to 2006**

ASCO Occupation and code	*August 1996*	*February 2001*	*February 2006*	*Change 1996 to 2006*	*Share of engineering workforce 2006*
	’000	’000	’000	%	%
Civil engineers (2124)	18.5	25.5	30.6	65	30.1
Electrical and electronic engineers (2125)	17.1	24.5	26.9	57	26.4
Mechanical, production and plant engineers (2126)	21.1	18.9	17.1	-19	16.6
Mining and materials engineers (2127)	4.4	4.0	5.7	29	5.7
Other building and professional engineering professionals (2129)	9.5	12.2	14.3	50	14.2
Engineering technologists (2128)	0.2	0.6	0.5	150	0.5
Building and engineering professionals — nfd		1.9	6.5	na	6.5
Total	**70.8**	**87.6**	**101.6**	**43**	**100**

Source: ABS (*Employed person by occupation, unit group, sex, state, status in employment,* Labour force estimates provided to the PC).

L.2 Demand issues

The demand for scientists, engineers and computing professionals is determined by a range of factors including the rate of economic growth, technological advance, the level of research and development being undertaken and government priorities in research and development. Just as the supply of various disciplines and occupations within these professions varies, so does the demand for their skills. Workers in each occupation face a specific market for their skills and while one occupation may be in high demand there may be shortages at the same time in another occupation (Borthwick and Murphy 1996).

At present, there appears to be strong demand for most types of scientists, engineers and computing professionals in Australia and, as noted above, employment has been increasing. Projections of future demand and supply undertaken as part of the Audit of Science, Engineering and Technology Skills (DEST 2006c) through to 2012-13 suggested that domestic sources and skilled migration would be adequate to meet Australia’s demand for science, engineering and technology skills. However, it warned that being based on historical data, such assumptions may not reflect potential or planned developments in the resources sector, infrastructure development and renewal or defence material needs (DEST 2006c).

The important issue is whether the system will be able to adjust to meet any shortages now and in the future. In well functioning labour markets, shortages are reflected in higher incomes. Provided that price signals in the form of higher incomes and earnings are able to reflect any such shortages, additional skilled migration and new entrants will be attracted into the sector. Shortages are only likely to become problematic when labour market arrangements fail to deliver higher incomes and earnings to reflect such a situation.

Employment prospects are good

Employment prospects are good for science and engineering professionals. The Audit of Science, Engineering and Technology Skills found that an overall tight labour market and the strong growth in the resources sector, defence needs and infrastructure development had led to recruitment difficulties in respect of certain skills. In particular, employers were facing considerable difficulty in recruiting engineers and to a lesser extent in certain science fields, such as chemistry and earth sciences. In the finance sector, as in other industries, there were difficulties in recruiting individuals with high level mathematical and statistical skills (DEST 2006c).

Recruitment difficulties do not necessarily indicate a shortage. According to Wooden et al. (2004), having only a small field of applications for a position, implies that the market is close to a state of balance whereas having no applications indicates a shortage.

Nevertheless, in the case of engineers, these shortages or recruitment difficulties have been reflected in the rapid growth in salaries for both graduate and experienced engineers and identified by the Department of Employment and Workplace Relations (DEWR) in their compilation of the Migrant Occupations in Demand List (MODL) (DEST 2006c). The occupations on the MODL are discussed below.

Employment prospects are also good for graduates from most science and engineering disciplines. The graduate destination survey, which surveys bachelor degree graduates four months following graduation found that the proportion of graduates in full-time employment ranged from over 87 per cent for geology graduates and nearly 85 per cent for chemistry graduates to 71 per cent for life sciences and 73 per cent for mathematics graduates (see table L.7).

Table L.7 **Bachelor degree graduates in full-time employment by field of education 2005[a]**

Field of education	*Percentage in full-time employment*
Sciences, mathematics and computer science	
Life sciences	71.3
Chemistry	84.7
Physics	78.9
Geology	87.4
Mathematics	72.6
Computer science	73.7
Economics	86.1
Engineering	
Aeronautical engineering	89.1
Chemical engineering	83.1
Civil engineering	65.7
Electrical engineering	87.3
Electronic and computer engineering	78.3
Mechanical engineering	89.5
Mining engineering	98.8
Other engineering	86.9
All graduates	**80.9**

a Based on a survey of 2004 graduates four months after graduation.

Source: Graduate Careers Australia (2005).

For engineering, nearly 99 per cent of graduates in mining engineering and 97 per cent of civil engineering graduates surveyed were in full-time employment compared to the 78 per cent of electronic/computer engineering graduates (see table L.7)

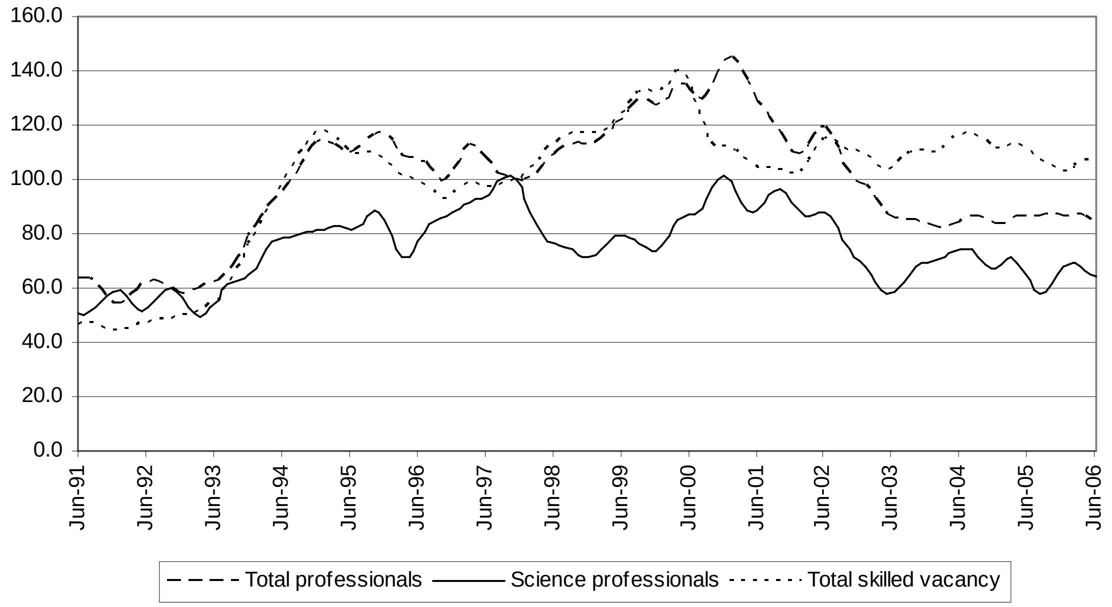
Importantly, these surveys are conducted only four months following graduation and do not indicate whether or not the graduates are in employment related to their qualifications. Also, many science graduates undertake further study. The graduate destination survey indicated that apart from geology, science graduates are more likely to be involved in further full-time study than graduates from other courses.

Employment outcomes for science graduates improve over time. Surveys undertaken further out from graduation, such as the survey commissioned by the Australian Council of Deans of Science (ACDS) in 2001 which investigated the employment profiles of graduates three, five and ten years post initial graduation, provide a better indication of the longer term career paths of science graduates. The survey found that not only were unemployment rates low for science graduates (3 per cent), most graduates were employed in a science and related field (75 per cent) and over half of those surveyed had undertaken further formal study in either a science or non-science area.

In addition, up to 80 per cent of respondents indicated that their undergraduate science degree was directly or indirectly related to their current or most recent employment. According to the survey, those not employed in a science and related fields appeared to be employed in managerial and professional employment outside science and technology. The survey found that over time many science graduates move into professional and managerial positions to further their careers, so that by the seventh year since graduation the number of graduates in technical positions had declined. Similarly, the DEST (2006c) *Audit of Science, Engineering and Technology Skills* found that the proportion of those not working in their field increased over time post qualification.

Demand for science professionals generally reflects the demand for other professionals and skilled workers. The DEWR skilled vacancies index shows that vacancies for science professionals have generally followed the trend of overall skilled vacancies and vacancies for all professionals since 2000, although very recently there has been a slight downward trend in the vacancies for science professionals (see figure L.3).

Figure L.3 **Skilled vacancy index, June 1991 to June 2006**



Data source: DEWR (2006a).

A further indication of demand is the Migration Occupations in Demand List (MODL) which lists those occupations and specialisations identified by DEWR as being in ongoing national shortage. This list is updated twice a year to reflect ongoing and emerging shortages and enables the targeting of these skills via the Government's skilled migration program.

Civil, chemical, electrical, mechanical, mining and petroleum engineers and a number of computing professionals specialising in specific areas were on the MODL for September 2006 (DIMA 2006). There were no science occupations or other engineering occupations on the list.

L.3 Issues in employment

The following section highlights a number of employment related issues raised by participants, such as the use of contract employment, earnings and the career pathways of researchers. These issues mostly relate to researchers working in the higher education sector and in the public research agencies.

Contract employment

The lack of job security as a result of the use of short-term contracts in employment was a major issue, particularly for those employed by the universities and CSIRO. In this regard, the University of New England said:

> The new paradigm of short-term contract employment is failing in the case of science as the dwindling supply of funding jeopardises the prospect of repeat employment. (sub. 17, p. 15)

The National Tertiary Eduction Union (NTEU) noted that the large majority of its members who were employed mainly on research in the university sector were employed on fixed term contracts from research grants or industry grants. This had resulted in increasing frustration at the lack of certainty around future employment and was major impediment to continue working in the university sector (sub. 62).

In summarising its members' views, it went on to say:

> By and large, universities provide them with an environment that gives them the freedom to pursue and explore their ideas, but this freedom is being curtailed by a number of factors, perhaps most significantly lack of employment security. This lack of security seems to be a problematic factor not only on a personal and financial level, in terms of the pay and conditions associated with working in short term contract positions, but also on an intellectual level as the need to secure funding increasingly encroaches on the type and fields of research that is being carried out. (sub. 62, p. 27)

The CSIRO Staff Association commented on the costs of contract employment:

> Non-renewal or possible non-renewal of specified term contracts can have damaging social and human costs on a researcher. Our research indicates that it contributes significantly to disillusionment and lower morale towards the end of a contract, reducing the productivity of the individual at a time when it needs to be high to ensure delivery of outputs. This instability carries through to family and community where contributions to clubs, councils and other community interests are difficult if not out of the question for fixed term staff. In many cases the contingent employment is a reason for skilled scientific staff moving out of careers in science. (sub. 78, p. 15)

These arrangements are ostensibly a response to staffing requirements in an uncertain funding environment in which there is a greater reliance on competitive funding and external source funding (see chapter 2). As additional funding becomes available, contract staff are then engaged on a project-by-project basis as such organisations are reluctant to engage ongoing staff in the absence of ongoing funding. Accordingly, short-term contract staff are generally less prominent in those public research agencies, such as ANSTO and DSTO, which are less reliant on competitive funding and externally sourced funds.

In other organisations, the use of these arrangements has been increasing over time. For example, around 12 per cent CSIRO's research workforce was employed on short-term contract (less than 5 years) in 1992 increasing to around 27 per cent by 2004 (sub. 78). Over the same period, Government appropriation as a proportion of total revenue declined from around 75 per cent to 62 per cent (CSIRO 2005a and IC 1995).

Contract staff can make a significant contribution to the research. They bring the skills and expertise needed for a particular project and provide research agencies and universities with the flexibility to respond to the opportunities provided by the funding bodies. These arrangements can also incur a number of costs. These include lower morale due to the lack of long-term job security, high turnover and loss of expertise, employees searching for other employment in the final months of their contract, training and inducting new staff and a trend towards a short-term focus within an organisation.

Is there a 'best use' of contract staff

The optimal use of contact staff is more likely to be linked to the specificity of their skills rather than the nature of the funding. For example, it would be in an organisation's interests to contract in the specific skills and expertise to meet the staffing needs of a specific project where such skills and expertise were not available 'in house'. Accordingly, the employment history of contract researchers with highly specific skills would be expected to contain 'down time' or breaks between projects. This suggests that there would be a premium attached to employing such researchers which would be factored in by the organisation in its costs in competing for the project.

Alternatively, those researchers with a history of ongoing employment contracts suggests that their skills are more transferable between projects or there is an ongoing need within the organisation for those skills. In that case, offering these researchers ongoing employment would avoid the costs, discussed above, associated with the use of contract researchers.

Is money everything?

In comparison with other professions, earnings for science and engineering professionals were towards the middle of the range, but behind the earnings of computing professionals while school teachers were towards the bottom — based on the average weekly earnings of full-time non-managerial employees in these professions. Interestingly, earnings for university and vocational education teachers were towards the top of the range (see table L.8).

Table L.8 **Average weekly earning and paid hours full-time non-managerial employees, Australia May 2004**

Occupation and ASCO code	*Average weekly earnings ($)*	*Hours per week*	*Earnings per hour ($)*
Medical professionals (231)	1955.40	43.0	45.50
University and vocational education teachers (242)	1283.50	35.5	36.10
Computing professionals (223)	1302.50	38.2	34.10
Building and engineering professionals (212)	1247.70	39.4	31.70
Natural and physical science professionals (211)	1077.10	37.5	28.70
Accountants, auditors and corporate treasures (221)	1097.60	37.5	28.70
Nursing professionals (232)	1048.40	38.0	27.60
School teachers (241)	1036.60	38.9	26.70
Social welfare professionals (251)	885.30	37.4	23.60

Source: ABS Cat. no 6306.0, *Employee Earnings and Hours, May 2004*.

Within each occupation earnings vary considerably by experience and by industry and activity. For example, in 2005 the annual base salary range for scientists was from around $43 000 for a recent graduate to nearly $120 000 for a more experienced scientist and for engineers from $44 000 for a recent graduate to around $110 000 for an engineer with extensive experience. Salaries also differ by activity and industry. For those scientists involved in mining exploration, the average annual salary was $101 000 in contrast to $74 000 for those in research and development and $62 000 for those working in analysis and testing (Association of Professional Engineers, Scientists and Managers Australia 2005).

In any occupation non-monetary factors influence an individual's career choice. Indeed, there has been a generational shift across the whole workforce in attitudes in relation to work/ life balance as younger people in making career choices are placing a greater emphasis on lifestyle and family responsibilities than on income and status (PC 2005a).

It appears that for science professionals non-monetary rewards such as autonomy of research, utilisation of skills, peer group esteem and the ability to add to existing knowledge are important influences on overall levels of job satisfaction. Survey work undertaken by the ACDS found that science professionals rated employment that provided interesting work and valued and used their skills more highly than employment that provided job security and income. It noted that there appeared to be a trade-off for science professionals between finding employment that was interesting and utilised their science skills and employment that is highly paid (ACDS 2001).

The NTEU also noted the non-monetary rewards from pursuing research:

> Nearly all respondents to our survey mentioned the freedom and flexibility to pursue their research interests as a major incentive for working in the sector. Along with academic freedom, a large proportion of respondents also expressed passion for their work, intellectual stimulation and the ability to explore issues more substantively as major incentives for working in the sector. (sub. 62, p. 22)

Of course, this 'trade off' is likely to be evident in a range of occupations where individuals value the non-monetary rewards of particular employment against income. In the case of research activities, there appears to be non-monetary rewards associated with being involved in research that utilises individual skills and interests. The ACDS survey found that those with higher qualifications such as PhDs and Masters degrees do not necessarily earn more than those with a pass or honours degree, but are more likely to be in employment that fully utilises their science skills and on the whole are satisfied with the recognition and use of their skills (ACDS 2001).

A number of participants commented on the increasing non-research workload, such as administration duties and grant applications, being placed on researchers which had reduced the time available for undertaking research type activities. The Community and Public Sector Union (CPSU Group) said:

> There are also the issues of researchers spending an increasing amount of their time preparing applications for grants and contracts rather than on research itself. (sub. 39, p. 6)

The Group of Eight commented that:

> Significant researcher 'down time' is required to prepare funding applications and deal with other regulations. Significant researcher 'dead time' occurs as researchers wait to hear about the success or failure of grant applications. For some graduates and current researchers this uncertainty detracts significantly from the attractiveness of research as a career option. (sub. 68, pp. 10-11)

Increasing the non-research workloads of researchers is tantamount to a reduction in their overall wage as it effectively reduces the non-monetary rewards derived from undertaking research, creating a disincentive for scientists and others to engage in research type employment.

Problems with career pathways

There are a number of career pathways for science graduates into employment. As discussed above, the vocational focus of engineering and computing undergraduate courses generally provides direct entry into the relevant profession. In contrast, science graduates generally require further post-graduate qualifications in science before entering into scientific research related employment. Those with undergraduate science degrees not pursuing further post-graduate studies in science will either enter employment that may or may not be directly science related or undertake post-graduate studies of a vocational nature, such as teaching, to enter the workforce.

For those pursuing a career in research, a considerable amount of training is required, involving the completion of an undergraduate qualification over 4 years, a PhD over a 3 to 5 year period followed by further post-doctoral training. This post-doctoral training may require some time overseas to acquire particular skills and will involve obtaining a post-doctoral position and/or successfully obtaining funding to undertake research in their field.

This had led to concerns over the difficulties faced by young researchers upon completion of their PhD in establishing a career pathway in their field of research. A significant challenge to a PhD graduate seeking a career in academia is to find employment in an appropriate academic position to enable them to establish a research program and develop a profile in that area of research. This is often against a backdrop of a significant teaching load. While they are often able to access some financial support for their research from internal sources, it is difficult to access independent funding from ARC grants as they lack the 'track record' of more established researchers. Mid-career researchers often faced similar difficulties as the NTEU said:

… junior or middle ranked research staff are at a major disadvantage in applying for competitive research grants when they are competing with other staff with established careers and research records. (sub. 62, p. 24)

This 'track record' was also a problem for those researchers moving in and out of academia. AusBiotech said:

There are problems for researchers who step out of academia to pursue careers in industry in that they may find they are unable to re-enter the ARC/NHMRC program due to the criteria to demonstrate recent research success. (sub. 95, p. 35)

Researchers also faced difficulty in obtaining a limited number of post-doctoral training positions. In the area of medical research, the NHMRC (2005), commented on the lack of post-doctoral training positions available and noted that the number of applications was increasing, but the number of training places had remained static. With inadequate training positions the unsuccessful candidates either sought overseas positions or left the medical research field altogether after a decade of post-school education.

The Australian Academy of Science said:

The careers of many young researchers in Australia are in a 'holding pattern'. Some are in their second or third postdoctoral fellowship with low salaries, low status, limited job security and uncertain prospects. This is frustrating for them, but it's also a national concern. This could be resolved in part by increasing the number of Queen Elizabeth II Fellowships and C.J. Martin Biomedical Fellowships. (sub. 24. p. 2)

The number of fellowships in some areas has increased following the additional funding for health and medical research announced in the 2006-07 budget. The Australian Society for Medical Research (sub. 36) noted that the additional funding announced in May 2006 for the Health and Medical Research Fellowships scheme would assist in retaining the very best senior health and medical researchers. However, it is not clear that the additional funding will be able to meet all the demand for post-doctoral medical research training places or that it is intended to.

In contrast, the ARC noted that there was a shortage of suitable researchers to fill certain postgraduate awards.

Participants in the ARC's *Linkage Projects* schemes increasingly report an inability to find suitable postgraduate researchers to fill Australian Postgraduate Awards Industry (APAI) places, even after funding commitments have been made by both the collaborating organisations and the ARC. The problem appears to be worsening with each *Linkage Projects* round. (sub. 73, p. 41)

Others noted that the universities themselves were implementing strategies to retain and attract high quality research staff:

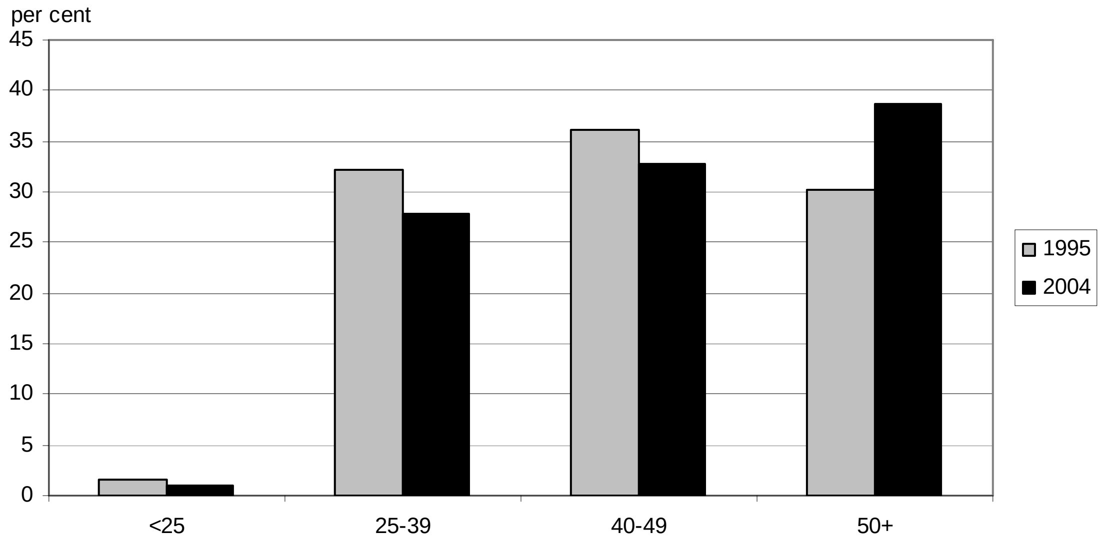
> NTEU also believes that a number of Australia's research intensive universities are in the process of developing policies aimed at providing research dedicated staff continuing employment by attempting to provide funding to allow researchers to be employed between research grant cycles. (sub. 62, p. 25)

The difficulties involved in establishing a career path are not restricted to science and medical science researchers and would equally apply to researchers in other disciplines competing to obtain ARC funding or a limited number of post-doctoral positions. However, such difficulties are likely to have been exacerbated by the increase in the number of PhD graduates in science in the past decade. The use of competitive funding arrangements means that continuous progress along the post PhD pathway can be difficult, while acting as a 'quality filter' on those moving through to senior research positions.

The older academic workforce

The overall academic workforce has been getting older. The proportion of academic staff aged over 50 increased between 1995 and 2004 while those in the 25 to 39 and 40 to 49 year old age groups decreased over the same period (see figure L.4).

Figure L.4 **Proportion of academic staff by age group, 1995 and 2004**



Data source: DEST, http://www.dest.gov.au/sectors/higher_education/publications, Higher Education Statistics 1995 and 2004.

The academic workforce also has an older age structure than the wider workforce. In contrast to the wider workforce, the academic workforce comprises a greater share of workers older than 55 years of age and a smaller share of workers aged under 35 years of age. By discipline, there is no appreciable difference in age between science and engineering academics and other academic staff. However, information technology academics appear to be relatively younger than their science and engineering colleagues (see table L.9).

Table L.9 **Age distribution of selected teaching and academic occupations, 2001**

	Secondary teachers	*Natural and physical science academics*[a]	*Engineering and related technology academics*[a]	*Information technology*[a]	*All academics*[a]	*All workforce*
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Under 35	27	9	10	14	10	41
35 to 54	63	64	66	69	69	48
Over 55	10	27	24	17	21	11

a Full-time equivalent staff with a ‘teaching only’ or ‘teaching and research’ function

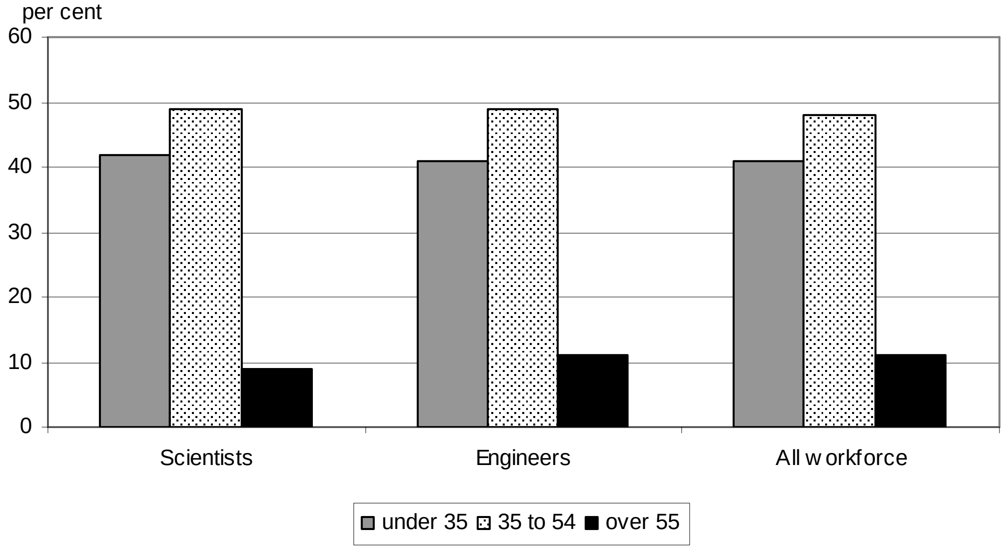
Sources: Information provided to the PC by DEST and ABS *Census of Population and Housing*, 2001.

This older academic workforce presents both opportunities and risks. For example, Anderson, Johnson and Saha (2002) noted that the pressing problem associated with the older academic workforce was ‘bunching’ where several members of a university department retire at the same time. This could either provide an opportunity for a renewal of academic staff or lead to a significant loss of expertise and areas of study.

A further implication of this relatively older academic workforce is that were there to be a significant increase in demand in the future, there may be insufficient academics available to increase the supply of Australian trained scientists and engineers. Such a situation is likely to be exacerbated by the age structure of the secondary school teaching workforce and the lack of appropriately trained and experienced high school science and mathematics teachers discussed previously.

In contrast to the academic workforce, the age structure of the science and engineering workforce more closely reflects that of the wider workforce (see figure L.5).

Figure L.5 **Age distribution of scientists and engineers**[a]



[a] Based on ABS 6 digit ASCO occupations.

Data source: ABS, *Census of Population and Housing,* 2001.

L.4 Summing up

Despite the concerns surrounding enrolments in high school mathematics and science and the relative popularity of university science and engineering courses, the overall science and engineering workforce has grown strongly in the last decade with large increases in graduate completions between 1990 and 2000 and net migration flows. In addition, the number of PhD graduates has increased in both science and engineering. However, there has been a decline in graduate completions in some areas since 2000. Against this backdrop of increasing supply, employment for science and engineering professionals has generally been strong.

There do not appear to be widespread shortages in science and engineering occupations, although there are shortages in specific occupations, such as those identified on the MODL including a number of engineering professions, and of science and mathematics teachers.

In the case of engineers, these shortages have been reflected in the rapid growth in salaries for both graduate and experienced engineers (DEST 2006c). However, in the teaching profession, such price signals have not been able to reflect the shortages at least partly due to the inflexible nature of teachers' pay structures. Possible responses to the teacher shortage are discussed in chapter 3.

As to the future, the system should be able to adjust to meet any shortages provided labour market arrangements are able reflect any such shortages in the form of higher incomes to attract additional workers into these sectors. Of course, the science and innovation workforce is likely to be subject to the same supply constraints facing the overall workforce as a result of the demographic changes resulting from an ageing Australia. In addition, the relatively older academic workforce and the lack of appropriately trained and qualified high school science and mathematics teachers could provide a constraint to increase the supply of locally trained science and engineers in response to any significant increase in demand.

M Does public support elicit additional R&D?

M.1 Introduction

A recurrent theme in this report is that public funding does not necessarily translate to new dollars of R&D — the issue of additionality (box M.1). This is critical to the issue of impacts since it is only R&D *induced by policy* that can potentially produce any economic, social or environmental impacts. To understand the nature of the issue, policy relevant impacts are:

$$\text{Policy Impact} = govtSPEND \times (1+v) - displacedR\&D \times (1+r) \qquad \{1\}$$

where *govtSPEND* is total government support, *displacedR&D* is the value of any private sector R&D displaced as a result of government-financed R&D; and v and r are the respective spillover rates of return associated with the two forms of R&D.[1] These rates could be the same as each other. But they could also be different from each other because governments may, on the one hand, target projects with a premium spillover rate of return or, on the other, have poor selection methods that result in projects of low social worth.

We can represent displaced R&D as a constant fraction of supported R&D $DisplacedR\&D = \alpha \times govtSPEND$ and v as an excess return, $v = r + \rho$ where ρ is the premium rate of return. In that case:

$$\begin{aligned}\text{Policy Impact} &= govtSPEND\,\{(1+r)(1-\alpha)+\rho\} \\ &= govtSPEND\,\{(1+r)\times additionality+\rho\} \qquad \{2\}\end{aligned}$$

where *additionality* is the R&D induced by support per dollar of revenue lost. For generic business programs, such as the R&D Tax Concession, businesses, not government, choose the R&D projects, so that ρ=0. In that case, it is clear that, as well as the spillover rate, the rate of additionality is the determinant of the policy

[1] Private rates of return are ignored in this analysis, with the simplifying assumption that supported projects displace private investments (not necessarily R&D investments) that have the same marginal private rate of return.

impact. Were additionality to be zero (complete crowding out), then policy impacts would also be zero. The spillovers on supported R&D may exist, but since the R&D would have happened anyway, so would the spillovers, with no net policy impact.

Box M.1 What does additionality mean?

Additionality can occur at several levels, which can sometimes be the source of semantic confusions.

At the most basic level, additionality refers to the extent to which R&D *eligible* for at least partial public support is truly additional. For example, if businesses receive tax concessional treatment for R&D of only around $6 billion, but only $400 million is actually elicited by the measure, additionality is around 7 per cent.

At a higher level, additionality relates to the extent to which the entire *quantum of public support* elicits new R&D. This is also referred to in the literature as the ‘bang for a buck’ (Lattimore 1996), and in some cases as the benefit-cost ratio (Hall and van Reenan 1999), though the latter term may be misleading since the ratio is not a conventional benefit-cost ratio. In the example of the tax concession above, the subsidy rate is around 7.5 per cent, so the extension of concessional treatment to $6 billion of R&D amounts to total support of around $450 million. If this support elicits $400 million of additional R&D, then the ‘bang for a buck’ is about 90 cents, or ‘additionality’ of 90 per cent.

In this chapter, we concentrate on the latter measure of additionality. This is similar to the approach adopted by CIE (2003b) in its review of the R&D Tax Concession.

For any additionality rate greater than zero, there are at least some policy impacts. Were additionality to be greater than one (supported R&D is then a complement to private sector R&D), then the policy impact arises not only because of the benefits directly associated with value of government spending, but also stimulates additional private sector spending.

It is important to distinguish three types of support when gauging the economy-wide responsiveness of R&D to government support of R&D:

1. Government generic support measures for business R&D, such as the R&D Tax Concession, that allow the businesses to choose the R&D projects and which work by lowering the after-tax cost of investments in R&D.

2. Government grants for business R&D, such as the *Commercial Ready* program, that are capped and based on merit-based selection of R&D projects.

3. Government-funded R&D in universities and public sector research agencies.[2]

M.2 The first mechanism — lowering the price of business R&D investments

The first alters the tax cost and, therefore the price of business R&D investments, and can therefore be expected to elicit a normal demand response to lowered prices. In that instance, the effects of subsidies acting through (1) can be inferred from firms' own price elasticity of demand for R&D,[3] as well as event studies and survey methods. Tax price elasticities refer to the same concept as the own price elasticity, but assess the responsiveness of R&D to measures that work specifically through the tax system.

The results of international studies are not precise. Looking across the international literature, Griffith (2004 et al.) concluded that own price elasticities of R&D were in the range of 0.3 to 2.0. Table M.1 summarises some of the elasticity measures based on recent reviews and other papers, which confirms the imprecision among different studies. However, the ultimate effect is determined by long-run elasticities, which tend to be considerably higher than short-run elasticities. This reflects the fact that it takes firms time to gear up and adjust to the presence of subsidies. This is particularly relevant to assessing whether new government policies have impacts over the short run. For example, Bloom et al. (2001) use panel data to find that long run price elasticities are around 1.1, compared with a short-run elasticity of only 0.16. The average of the (higher) elasticities in table M.1 suggests an average of just below one.

It is conceivable that some types of businesses are more or less responsive to subsidies than these estimates. For example, Parisi and Sembenelli (2001) used a censor panel-data regression model with random effects to a balanced panel of over 700 Italian firms over the 1992-1997 period incorporating a sizeable number of unlisted small and medium sized firms. The paper estimated an elasticity in the range of 1.5 to 1.77. In periods of recession it found evidence that the elasticity is greater (2.01) than in expansion (0.87). Lattimore (1996) investigates the BIE's 1993 survey data and finds that firms with less than 20 employees had bangs for a

[2] A fourth category might be R&D funded by government, but contracted to private firms. This is more common in defence contracts, particularly in the United States. It is a relatively minor area of public spending in Australia and is not covered here, except where it is relevant to understanding the international literature.

[3] This is the proportional increase in R&D spending associated with a proportional decrease in the price of R&D inputs. If a 1 per cent decrease in the price of inputs associated with a public support measure induced an additional 1 per cent in R&D, the elasticity would be unity.

buck around 50 percentage points higher than the average.[4] Firms with a limited R&D focus, on the other hand, had bangs for a buck about 30 percentage points lower than the average. This suggests that eligibility criteria for participation in programs can have a marked effect on additionality, and therefore their impacts.

The actual level of *new* R&D stimulated by subsidies per dollar of revenue lost — the additionality parameter in equation {2} above — depends on the design of R&D incentive mechanisms. Depending on the effectiveness with which they target marginal R&D investments, the use of incremental R&D incentives can considerably lower the cost to revenue for the same price effect of the subsidy (Russo 2004; Bloom at al. 2001, p. 4). As a consequence, for a given price elasticity of demand, the associated additionality can be much higher if more marginal investments are subsidised. For example, Bloom et al. (2001) find that standard R&D tax concessions that allow concessional treatment of every dollar of business R&D have additionality rates of 83 cents per dollar, which climbs to as high as $2.94 for some kinds of incremental R&D credits. This is the major motivation for re-balancing of the Australian R&D Tax Concession sought by the Commission (chapter 9).

The evidence on additionality rates for tax concessions — incremental and otherwise — reveals rates that vary significantly (table M.1). Measures of central tendency (the mean and the median) suggest that rates are probably between 70 cents and $1.20. Accordingly, for every dollar of revenue forgone by government, private R&D investment rises by between 70 cents and $1.20. The Australian evidence on orthodox tax concessions to date (BIE 1993 and CIE 2003b) suggests rates more towards the lower end of this range, perhaps because of the continued importance of a non-incremental component of the tax concession.

A technical challenge affecting some of these studies is re-labelling of business costs. Firms face an incentive to re-categorise other business expenses as R&D to attract concessional treatment. For example, this was a problem in Australia in the mid-1990s, when pilot plants and feedstock that were essentially unrelated to R&D were sought as deductions under the tax concession. These loopholes were subsequently closed, but various studies that consider how R&D changes as the user costs alter with concessional tax treatment may be biased upward because of the presence of similar re-labelling phenomena.

[4] At the 150 per cent concessional rate applying at the time.

Table M.1 **Studies of price elasticities and additionality rates**[a]

Country	Additionality Low	Additionality High	Additionality Mean	Author	Elasticity	Source
US	..	..	<1	Collins 1983	..	Hall & van Reenan
US	0.3	0.6	0.45	Mansfield 1986	0.35	Hall & van Reenan
US	..	..	1.74	Berger 1993	1-1.5	Hall & van Reenan
US	..	..	1.3	Bailey & Lawrence 1987,1992	0.75	Hall & van Reenan
US	..	..	2.00	Hall 1993	1.00-1.50	Hall & van Reenan
US	0.29	0.35	0.32	McHutchen 1993	0.28-10.7	Hall & van Reenan
US	1.3	2	1.65	Hines 1993	1.2-1.60	Hall & van Reenan
US	0.95	1	0.98	Nadiri & Mamuneas 1996	0.95-1.00	Hall & van Reenan
US	0.35	0.93	0.64	Cordes 1989	..	Sawyer
Canada	..	..	0.60	McFetridge & Warda 1983	0.60	Hall & van Reenan
Canada	0.38	0.67	0.53	Mansfield & Switzer 1985	0.04-0.18	Hall & van Reenan
Canada	0.83	1.73	1.28	Bernstein 1986	0.13	Hall & van Reenan
Canada	..	..	..	Bernstein 1998	0.14-0.30	Hall & van Reenan
Canada	..	..	0.98	Dagenais et al. 1998	0.40	Hall & van Reenan
Canada	..	..	1.38	Department of Finance Canada and Revenue Canada 1998	..	Sawyer
Sweden	0.3	0.4	0.35	Mansfield 1986	..	Hall & van Reenan
G7 & Australia	..	..	..	Bloom et al. 1999	0.16-1.10	Hall & van Reenan
France	..	..	..	Asmussen & Berriot 1993	0.26	Hall & van Reenan
France	..	..	3.16	Mulkay & Mairesse 2003	..	Sawyer
Italy	..	..	..	Parisi & Sembenelli 2001	1.50-1.77	Parisi & Sembenelli
Australia	0.6	1.0	0.8	BIE 1993	..	BIE
Australia	0.5	0.9	0.7	CIE 2003	..	CIE
Australia			2.64	BIE 1994[b]	..	BIE
Australia	1.7	1.8	1.75	Price Waterhouse & AIRG 1996[c]	..	Lattimore
Average[d]	**0.58**	**0.96**	**0.77/1.18**	**..**	**0.82**	**..**
Median[e]	**0.44**	**0.92**	**0.67/0.98[f]**		**0.68**	

[a] .. means not available. [b] Relates to tax loss trading provisions under the Syndicated R&D program and so is an unusual measure compared to standard tax-based measures. [c] This relates to the apparent bang for a buck from shifting the R&D Tax Concession from 125 per cent to 150 per cent. The survey was based on strategically chosen respondents, which might introduce bias. [d] The averages for the additionality rates ignores the Price Waterhouse/AIRG study, because of concerns about bias. The first figure of the average of the mean is over the same sample from which the high and low estimates are drawn, and the second over the full sample (still excluding the Price Waterhouse/AIRG study). The average shown for the price elasticity is of the high value (usually the long-run value), but excluding the extreme value of McHutchen. [e] The median value is the middle value. The samples selected for the calculations follow the same convention as in (d).

Source: Hall and van Reenan (2000); Sawyer (2004); Parisi & Sembenelli (2001), BIE (1993); BIE (1994), CIE (2003b) and Lattimore (1996).

As additional issue, raised by the IPA (sub. 30) is that of the marginal burden of taxation. Subsidies of any kind[5] must be financed through taxes. Those taxes

[5] Including those that fund competitive grants or R&D undertaken directly by government and universities, as discussed in the next sections.

impose distortions on private consumption, work and investment decisions, whose costs are implicit in the 'marginal excess burden' of taxation. The IPA raise this burden as a curb on additionality. It could be conceived of in this way, or equally it could be accounted for as a separate cost — as we do in chapter 9 in cost-benefit analysis of business programs. Either way, it provides a constraint on the impacts of publicly funded support for R&D that should not be omitted. Its cost is around 20 per cent of the magnitude of public funding for R&D.

M.3 The second mechanism — competitive grants

An alternative business subsidisation measure (2) is based on merit-based assessment, usually by experts, of alternative business bids for grants. These grants usually stipulate a maximum grant per firm and overall finance for the grant program is also often capped. Subsidy rates are often much higher than generic tax concession or credit arrangements. In theory, such programs allow the potential to:

- select projects with higher spillover rates — to the extent that these can be judged ex ante; and
- to finance projects that would not otherwise have been undertaken. This can be accentuated for smaller firms facing finance constraints, since the grant can be big enough to act as a de facto form of independent finance.

But they also involve risks for additionality too. The presence of grant caps means that the reduction in the effective price of investments achieved by generic subsidies is also capped and the incentive effects for additionality can therefore vanish. Firms would prefer to receive subsidies for non-marginal investments because these offer the highest private returns and can save shareholders' funds.[6] Consequently, firms have strategic incentives to put forward projects that they would have done otherwise. This may be a viable strategy for two reasons:

- the selection committees on panels providing grants cannot tell easily which projects are truly additional; and
- selectors may wish to choose firms that are likely to be commercially successful to avoid the impression that they are wasting public funds on very risky projects. They may then pick projects with the greatest private returns, which are those that are more likely to proceed anyway.

[6] Incentive compatible mechanisms that provide for contingent repayment of grants, as in Israel (Lach 2002), probably do not suffer this limitation because they reduce the risk of selection biases that are the threat to additionality.

Accordingly, among possible applicants, those firms with non-marginal investments that otherwise appear to meet the eligibility criteria for a grant have the strongest interest in applying and good prospects of being selected, suggesting risks of selection biases that act against additionality (Lach 2002, p. 371, Klette et al. 2000 and Wallsten, 2000).

As a result, for competitive capped grant arrangements — and unlike general tax-based or other R&D subsidies — a minimum level of additionality cannot be estimated from the price elasticity of demand. The issue of additionality then must be determined empirically from studies of particular grant programs.

Such studies need to take account of the presence of selection biases, although, as noted by Klette et al. (2000), most have not done so. Ali-Yrkkö (2005) undertook a study of Finnish companies that controlled for such biases, as well as usefully summarising the existing literature that also attempts to control for selection bias. Ali-Yrkkö found large additionality rates of around 2.0. This substantiated the general, but not universal, finding that competitive grants induced additional R&D. An evaluation (Czarnitzki and Fier 2001) of a German R&D subsidy program for innovative expenditure in the services sector that provided subsidies of up to 50 per cent of firms' expenditure found that a 1 DM of public subsidy produced DM 1.37 of private R&D expenditure, which declined to DM 1.26 in the second year. On the other hand, a review (Lach 2002) of the effectiveness of an Israeli matching grant program at the firm level found that an extra dollar of subsidy generated new R&D spending of 23 cents, though the effect was much larger for small firms (and was negative for large ones).

In an Australian context, there have been several assessments of competitive grants. the Productivity Commission's review (2003a, p. 5.29) of the Australian Pharmaceutical Industry Investment Program represents one of the few formal studies to control for selection bias in a competitive grant program. It found an additionality rate between 1.25 to 3.65. The Productivity Commission (2002a) also examined the Automotive Competitiveness and Investment Scheme (ACIS), which provided competitive grants to that industry alone. No numerical estimates were made, but the Commission judged that the large nature of subsidy was likely to have had some effects.

Allens Consulting (2000) reviewed the R&D Strategic Assistance for Research and Development (R&D Start) program. They based their assessment of additionality on survey questions. This did not reveal a single additionality measure, but did suggest reasonable inducement:

- 3 per cent of firms said there had been no impact on new R&D;
- 8 per cent said the impact was low;

- 26 per cent said the impact was moderate;
- 42 per cent said the impact was high; and
- 20 per cent said the impact was very high.

A number of other studies are described in chapter 9 that suggest that many projects receiving grants would have still proceeded, but these studies did not report the bang for a buck.

There are an insufficient number of studies on competitive grants to be as clear about additionality rates as for uncapped tax credits and concessions. However, the total share of public funding support offered through competitive grants is relatively small compared to the R&D Tax Concession and both are relatively small compared to total public funding of R&D in higher education and PSRAs, to which we turn to next.

M.4 The third mechanism — publicly undertaken R&D

There has been considerable concern that public support for R&D conducted outside business might crowd out business R&D. In principle, this could occur through several mechanisms, though in fact, it is not clear that either seems likely to hold in the long run in Australia.

The R&D type is substitutable

The type of R&D undertaken outside business might be relatively substitutable with that which might otherwise be undertaken by businesses. For example, PSRAs and universities may undertake R&D into mining or manufacturing technologies that are directly applicable to these sectors.

However, much of the R&D undertaken in higher education institutions and PSRAs in Australia is undertaken in basic research and non-commercial applied fields (such as environmental research) that has little immediate application to business-oriented problems. The former type of research activities can build up general capabilities for R&D in business and on, a priori grounds, could be expected to be complementary to private R&D activities.

Data from the ABS on spending by socio-economic objective substantiates the importance of non-business-oriented R&D activities for higher education (appendix G), revealing that only around 30 per cent of their activities are in market-oriented areas. It is considerably higher in PSRAs at about 54 per cent.

These estimates cannot, however, be used as reliable measures of crowding out since the fact that research has a potential use in markets does not mean that it would otherwise be undertaken in businesses. Research of this kind may:

- reflect the complementarities between specialist skills within these institutions and market applications. It could not be effectively undertaken in businesses lacking the complementary skills;
- be of the strategic basic kind that has *potential* future business uses, but is still too uncertain and far from commercial development to be undertaken within businesses; and
- be of the generic kind that can be cheaply imitated by many businesses and so suffers from standard appropriability problems for individual businesses (chapter 3). A significant share of agricultural research undertaken within CSIRO fits into this category.

Resource constraints

There are finite specialist resources — particularly talented scientists — available for R&D, so their use in one application may deny their use elsewhere. Where this resource constraint binds, additional public spending on R&D will tend to raise scientists' wages, rather than scientific activity per se. Any increase in wages of specialist R&D labour inputs raises the costs of business R&D investment since such labour inputs are the most important component of R&D. This prompts the conventional negative effects on investment. There is empirical evidence of the importance of this phenomenon overseas (Goolsbee 1998 for the United States).

However, some aspects of Australian circumstances should be distinguished from other countries. First, Australian PSRAs and higher education institutions tend to employ those specialist labour inputs where labour constraints are least — scientists not engineers. It could be that part of the reason defence-related R&D spending by government has apparently bigger crowding out effects than other R&D spending (as discussed later) is that defence-related spending tends to use more engineering skills. Second, Australia is a small open economy that has, so far, been able to attract many professionals from overseas without having to offer large wage premia. The United States could not do the same because of its scale relative to global S&T resources.

A more general observation is that resource constraints of this kind are much greater over the short-run than the long run. Long-run labour supply elasticities for specific occupations are higher than short-run ones, as students shift between subjects in response to future incomes and as net migration inflows increase.

In any case, even if there is ultimately some binding limit to the availability of scientific resources, the experiences of those other countries where scientists per capita ratios are much higher than Australia suggests that it has not been reached here yet.

The econometric evidence

The empirical evidence on this issue is incomplete. This is because, as noted by Guellec and van Pottelsberghe (2001, p. 5) most studies of crowding out have concentrated on (1) and (2): fiscal subsidies and government grants to, or contracts with business. Where studies have been more general than this, they have not distinguished public support given *to* business from publicly supported R&D undertaken within universities and PSRAs. For example, the definitive meta study in the crowding out literature area so far is David, Hall and Toole (1999)[7], which considers the overall links between public spending and business spending. They undertook a survey of 33 empirical studies at different levels of aggregation undertaken since the early 1960s to evaluate the evidence of whether public R&D support as a whole was complementary or additional to private R&D spending or crowded it out. Their overall conclusion was equivocal:

> The findings overall are ambivalent and the existing literature as a whole is subject to the criticism that the nature of the 'experiment(s)' that the investigators envisage is not adequately specified.

This study is an influential one — and for example, was cited by the IPA (sub. 30) in drawing attention to the questionable impacts of government spending on R&D.

However, several observations should be made about the study:

- the presence of some crowding out was more prevalent for those studies carried out at the firm level than for those undertaken at the industry and higher levels of aggregation;
- some crowding out was a common feature of studies based on the United States, but an uncommon characteristic of others, a feature that could be ascribed to the peculiarly dominant influence of defence spending in the United States;
- quite different types of funding modalities and R&D types are lumped together making it harder to determine its relevance to the particular questions relating to spending within PSRAs and higher education institutions;
- crowding out is not interesting as a dichotomous variable. For example, were government spending of one dollar in a PSRA to reduce business spending by 10

[7] And complementary econometric meta analysis undertaken by Garcia-Quevedo (2003).

cents, then crowding out is said to be occurring. However, if the marginal excess burden of taxation is, say, 20 cents in the dollar, the spillover rate to achieve a net social benefit from spending in the PSRA is anything greater than 22.2 per cent (a relatively small rate).[8] In contrast, suppose that government spending of one dollar in a PSRA were to *increase* business spending by 10 cents (*complementarity*). In that instance, the spillover rate to achieve a net social benefit from spending in the PSRA is anything greater than 18 per cent — hardly much different from the outcome with some crowding out. So the lower the crowding out the better, but some crowding out per se is not that damaging to R&D policy.

Guellec and Van Pottelsberghe (2001)[9] present the results of econometric analysis that provides (the first) explicit separation of crowding out effects by type of funding support. The study used a 3SLS panel data design based on a 17 country panel of OECD members. It controlled for business cycle, country and time dummies among other things.

The long-term results (table M.2) suggest that a 10 per cent increase in government funding through fiscal measures (B) reduces business own funded R&D by around 3 per cent.[10] Business grants (RG) have small complementarities. Every dollar of government R&D spending within government (GOVERD) crowds out 38 cents of business R&D spending (an economy-wide net bang for a buck of 62 cents) and support through higher education (HE) has neither complementary or crowding out effects (an economy-wide net bang for a buck of one dollar).

The finding for government own R&D spending would, if it were valid, seriously bring into question the impacts associated with that spending. However, as in previous analyses that have probed this question, Guellec and Van Pottelsberghe (2001) note that government spending on defence-related R&D (concentrated in three countries, the US, France and the UK) distort the findings. If the adverse impacts of defence spending are accounted for, the crowding out effects associated with government own R&D spending disappear. Australia undertakes relatively little defence-related R&D so the defence-adjusted model appears more appropriate.

[8] Calculated as spillover rate >= MEB/(Bang for a buck).

[9] Also summarised and interpreted in Van Pottelsberghe (2005).

[10] In the study by Guellec and Van Pottelsberghe (2001) — unlike those described above for fiscal measures — the bang for a buck cannot be directly inferred because the fiscal measure is the Warda B index.

Table M.2 **Long-run effect of government R&D spending on business funded and performed R&D**

By type of government spending, OECD countries[a]

Model and result	*λ*	*B*	*RG*	*GOVERD*	*HE*
Simple model					
Short run elasticity[b]	0.083	-0.281	0.072	-0.063	0
Long run elasticity[c]	nr	-0.306	0.079	-0.069	0
Marginal effect on RP[d]	nr	nc	0.70	-0.38	0
Economy-wide effect on R&D[e]	nr	nc	1.70	0.62	1
Defence effect adjustment					
Short run elasticity[b]	0.098	-0.29	0.07	0	0
Long run elasticity[c]	..	-0.32	0.076	0	0
Marginal effect on RP[d]	.	nc	0.67	0	0
Economy-wide effect on R&D[e]	..	nc	1.67	1	1

[a] The model estimated was:

$$\Delta RP_{it} = \lambda \Delta RP_{it-1} + \beta_1 \Delta VA_{it} + \beta_2 \Delta RG_{it} + \beta_3 \Delta B_{it} + \beta_4 \Delta GOV_{it} + \beta_5 \Delta HE_{it} + \tau_{it} + \mu_{it}$$

where RP is business-funded and performed R&D (ie excludes the value of R&D funded by government but performed in the business sector), VA is business sector value added, RG is government grant funding of R&D implemented in business, B is the B-index (fiscal generosity for R&D), GOV is government intramural R&D expenditure, HE is higher education R&D outlays, τ are time dummies, μ is a residual, i denotes countries, t is years, β are short-term effects, [β/(1-λ)] are long-term effects and Δ is the 1st logarithmic difference operator. Variations in the specification took account of the role of defence-related R&D spending by government. All results are averages over time and countries. [c] The short run elasticity is the β value for the regression shown above or $B_X = (\partial RP / \partial X) \times (X / RP)$ for the Xth type of government spending on R&D. [d] The long run elasticity is calculated as β/(1–λ). [e] The marginal effect on business funded and conducted R&D of the Xth government funded form of R&D is $\rho_X = (\partial RP / \partial X) = \beta_X \times (RP / X)$. This is the *business* R&D bang for a buck of government spending. [f] The economy-wide effect is the sum of the subsidy value and the marginal effect on business, so it is (1+ ρ_X). nc means not calculated due to the unavailability of RP/X data. nr means not relevant.

Source: Guellec and Van Pottelsberghe (2001) and PC calculations.

M.5 Summary

When considering the question of additionality, it is important to distinguish three types of publicly supported R&D: that mediated through tax measures; competitive grants to businesses; and through spending in public research agencies and universities. In many discussions of the risks of crowding out, the three modalities are conflated, with the potential for misdiagnosis of the true effects.

The broad conclusions from this strand of work is that:

- Tax measures for business R&D have been intensively analysed, though only recently has analysis attempted to empirically differentiate the degree of additionality associated with different designs of scheme. The evidence suggests that it is likely that every dollar of public support generates somewhat less than a dollar of new business R&D, though this may well rise above one dollar for well-designed incremental schemes.

- Competitive grants to business have been much less studied and less is known about their likely additionality. But additionality rates are probably greater than one dollar per dollar of revenue lost. However, poor designs risk lower additionality than tax concessions and could also support R&D with low returns.
- There appears to be little crowding out (or for that matter, apparent complementarities[11]) between government-funded R&D support for its own R&D activities in PSRAs and higher education institutions and business-performed and financed R&D.

[11] Complementarities may take many years to materialise, so their absence in a study of this kind should not be regarded as definitive evidence against their existence. On the other hand, it is unlikely that long-run crowding out is greater than short-run crowding out, so the same bias is probably not present.

N Intellectual property system

Intellectual property (IP) consists of the ideas generated by the mind or intellect. Unlike normal property, the idea itself is intangible embodying the thoughts and knowledge created by a person.

IP rights confer ownership to the creator of the IP, akin to a farmer having ownership of his crop. They include patents, trade marks, copyright and designs. Each of these mechanisms gives exclusive, albeit limited, property rights over IP. As with any property rights, IP rights can be bought and sold in the market, their price reflecting the value of what is embodied in the property.

In making IP excludable, IP rights increase the incentives for businesses to invest in innovation and commercialisation. However, because IP rights confer an ability on holders to exclude others from making, using or selling the IP, there is a risk that they may be cast too restrictively so as to confer undue monopoly power. This could, for example, manifest in holders extracting excessive licensing royalties or placing unnecessary restrictions on knowledge dissemination with further knock on effects for the rest of the innovation system.

This appendix gives a brief snapshot of the current IP system in Australia — the institutional setting and legal environment within which IP rights operate and are administered. Two key facets of the IP system considered are:

- patents — the main form of IP rights used in Australia; and
- domestic and international regulatory and support agencies.

Other IP-related issues dealt elsewhere in this report are the potential for IP rights to impede the operation of the innovation system (chapter 5), the management of IP in universities and public sector research agencies (chapter 6), and the use of patent data as indicators of innovation system performance (appendix J).

N.1 Patents

Patents give protection over ‘any device, substance, method or process, which is new, inventive and useful’ and are used by private firms and public research agencies alike (IP Australia 2006a).

Standard and innovation patents

There are standard and innovation patents (covered under the *Patents Act 1990*). The main points of difference between these two types of patents are the level of inventiveness needed to gain certification and the maximum level of protection. The innovation patent, replacing the petty patent from 2001, requires a lower level of inventiveness and is aimed at protecting innovations which are not greatly different from existing technologies but still have a significant commercial value. In line with the lower inventive threshold, the innovation patent is cheaper to obtain, requires less certification testing and has a faster approval process. However, it is also shorter and gives a lower level of protection compared to the standard patent (table N.1).

Table N.1 **Standard versus innovation patents, as at July 2006**

	Standard patent	*Innovation patent*
Maximum duration (years)	20	8
Application costs[a] ($)	770	440
Maintenance costs[b] ($)	7830	900
Inventiveness or innovativeness test	A new invention not obvious to an expert in that field.	A substantially new use of an existing invention.
Main industry users	Life science and ITC industries	Consumer goods, mining and transport industries.

[a] Assumes online application. [b] Assumes fees paid for maximum life of patent, standard patent can be extended past 20 years for $1200 per year.

Source: IP Australia (2006a).

Application process

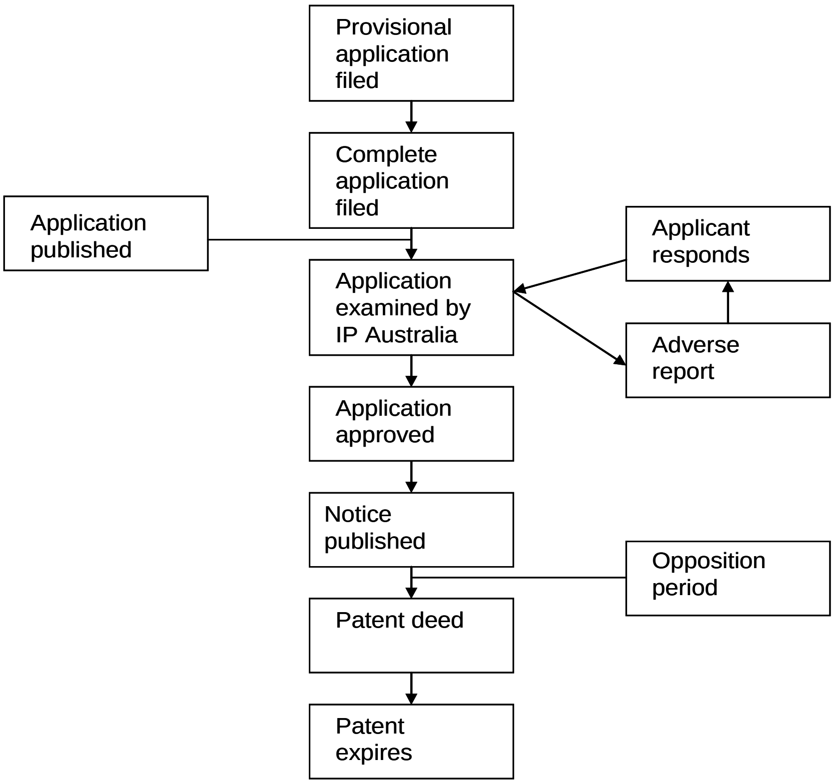
The basic process for attaining standard patent approval is shown in figure N.1. Upon issuance, patents are enforceable from their priority date[1]. The optional provisional application (which attracts an additional fee) gives the inventor a twelve month window to file the complete application. This application facilitates the granting of a priority date without fulfilling all the requirements of the complete application in the short term. The earlier priority date means that the information can be publicly disclosed sooner and still defendable for infringements. In addition to priority dates, Australia offers academics a 12 month grace period between disclosure of research and filing of patent application. This aims to address the problem, common to academia, of researchers disclosing information without

[1] The first date the patent application is filed. If the application is successful, the patent is enforceable from this earlier filing date, rather than the approval date. The application can be provisional or complete.

knowledge of its potential. Annual patent fees are only payable from the point the application is accepted.

Applying for a patent is a complex process. As such, many creators of IP utilise advisory services, such as technology transfer offices or patent attorneys, to assist in the application process and, ultimately, give them a greater chance of attaining patent approval.

Figure N.1 **Standard patent approval process, Australia**



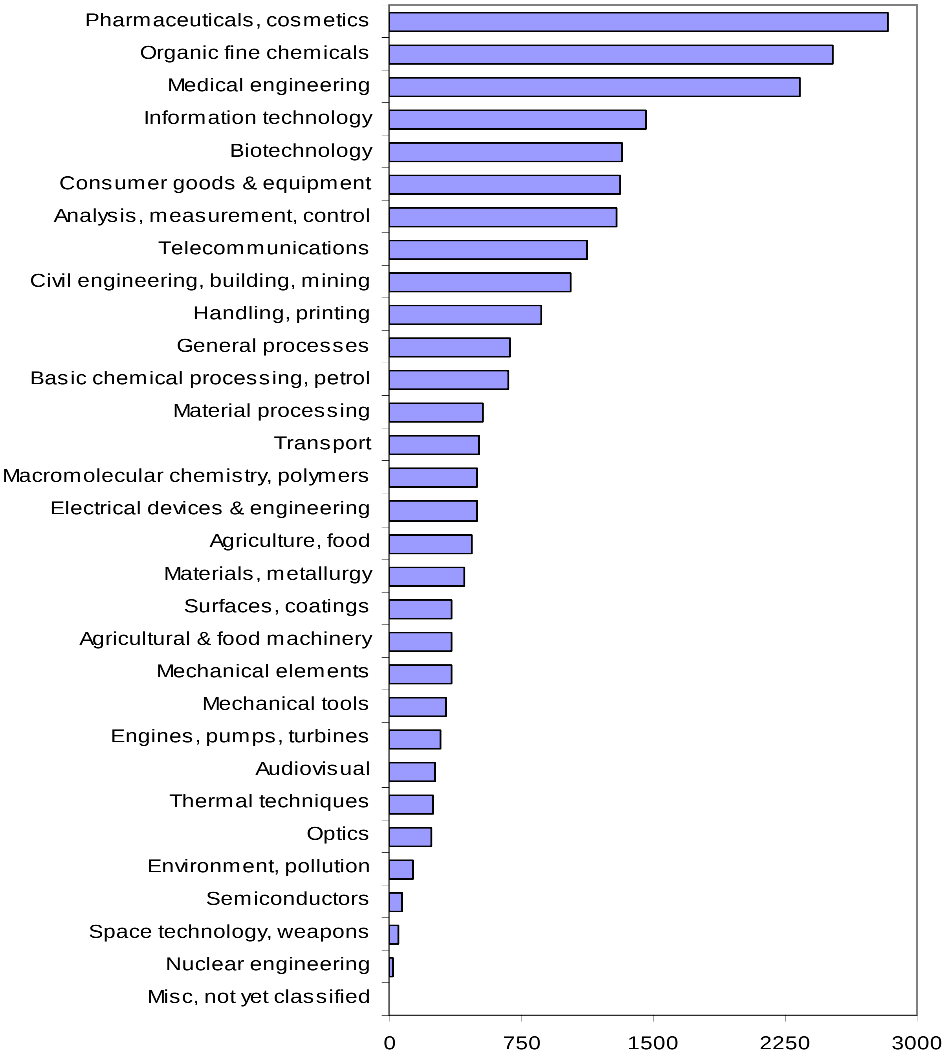
Source: IP Australia (2006a).

Patent usage

Industry usage of standard patents varies (figure N.2), with the pharmaceuticals and cosmetic industry having the highest number of standard patent applications and the nuclear engineering industry the lowest. This variation in industry usage reflects Australia's industry structure.

In the public research sector, universities are by far the largest users of IP (table N.2). This is mostly attributable to their dominance in public research.

Figure N.2 **Standard patent applications[a] by industry group, 2005**



a Patents filed in Australia from domestic and foreign sources. Data includes PCT applications in the national phase.

Data source: IP Australia (2006a).

Table N.2 **Standard patents issued for Australian publicly funded research, 2002**

	Universities	*CSIRO*	*CRCs*	*Medical research institutes*	*Other public sector research agencies*	*Total*
International patents[a]	123	148	26	15	7	319
Australian patents	72	27	35	9	3	146
Total	195	175	61	24	10	465
(%)	(41.9)	(37.6)	(13.1)	(5.2)	(2.2)	(100)

[a] Patents issued to domestic agency in other countries.

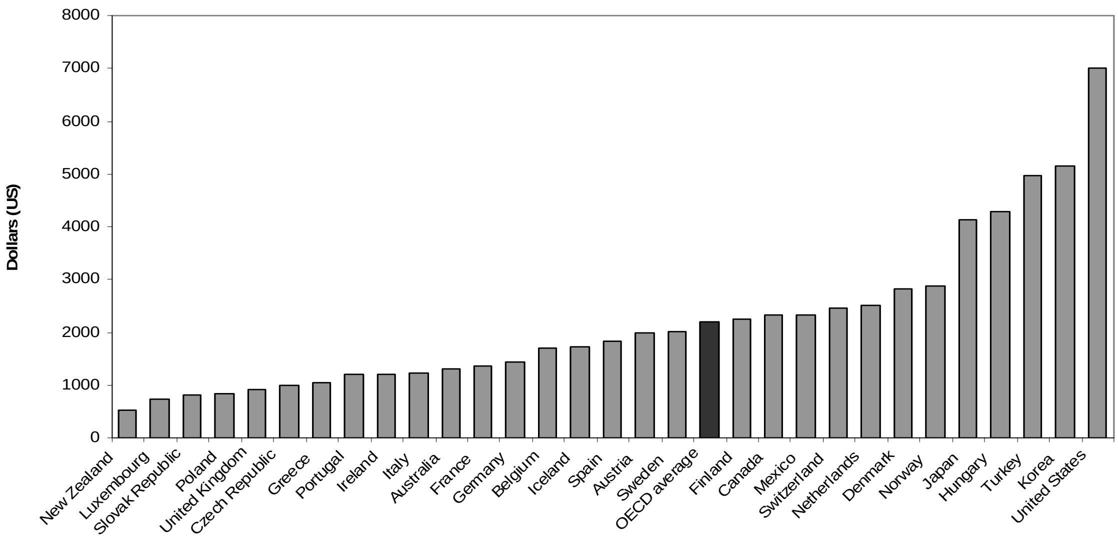
Source: DEST (2004d)

Patent application costs

As outlined in table N.1, there are certain costs associated with applying for a patent. These include both the official application fees and, quite often, patent attorney fees. Although fees vary greatly between countries, Australian fees, at $US1320 are below the OECD average of $US2200 (figure N.3). Patent attorney fees are estimated at between $5000 and $8000 per application, varying with complexity of the innovation (IP Australia 2006a).

Figure N.3 **Standard patent fees, OECD countries**

Fees[a] as at September 2005, patent grants for 2004



[a] Total fees, assuming annual fees paid for 8 years and using September 2005 exchange rate of 0.76

Data source: IP Australia, unpublished data.

The international patent system

A standard patent application only affords protection against competitors in the original country of application. Hence, IP rights must be applied for in every country the product is to be marketed for protection to be comprehensive. The main (and, often, most cost effective) avenue for gaining cross-jurisdictional protection is through the Patent Cooperation Treaty (PCT).

The PCT came into effect in 1978 and currently has 128 member states. Basically, the PCT gives innovators the option to patent in other countries where they believe there will be a market for their product. This option does not guarantee approval in each country, there being no such thing as an 'international patent'. Hence, the innovator must still pursue patent applications in individual jurisdictions separately. So, while the complexity of multiple patent applications remains, the advantage of PCT applications is that they allow the innovator to obtain a priority date in each country that is a member of the PCT. The applicant is then able to perform additional market research to ascertain in which countries their product will be marketable and proceed with the normal patent application process in those countries (called the national phase). Given that patent applications are a costly process, the opportunity to conduct market research could result in significant long run cost savings. However, these costs savings must be weighed against the initial higher fee for PCT patent applications.

N.2 Institutions

The IP system is administered and supported by several domestic and international institutions.

Domestic institutions

There are a number of public and private institutions that implement and support the IP system. These generally fall into the categories, or are a combination, of regulatory, research, advisory or public or private sector support.

IP Australia

IP Australia is an independent agency of the Department of Industry, Tourism and Resources and is the central regulatory and administering body for IP in Australia.

Its primary function is administering Australian IP.[2].Within this, and its other auxiliary roles, IP Australia processes IP claims, collects IP application and maintenance fees, maintains the Australian IP register, provides information, liaises with international bodies, and undertakes policy research and analysis.

Technology transfer offices

The commercialisation and technology transfer offices of universities and public sector research agencies offer advisory services and expertise to the research community within these institutions. While the specific service charter may vary from office to office, they generally bridge 'the gap between basic research performance in universities and the development of new products and processes in industry' (Uniquest 2006). Other aspects of their operation include liaising with business to sell patents, forming start up companies and encouraging business engagement of research services. These agencies are becoming increasingly common as commercialisation strategies are employed to ensure research output utilisation.

There are many examples of technology transfer offices in universities (table N.3). Over all technology transfer offices, there were 194 full-time equivalent staff, 462 patent applications filed and 225 licences executed in 2002 (DEST 2004d). The most notable of these is Uniquest, which oversees the IP portfolio of the University of Queensland and, recently also, the University of Wollongong (box N.1).

Table N.3 **Selection of university technology transfer offices**

Technology transfer office	*University*
Uniquest	University of Queensland
Melbourne Ventures	University of Melbourne
Research and Development Office	James Cook University
Flinders Technologies	Flinders University
Monash Commercial	Monash University
Access Macquarie	Macquarie University
ANU Enterprise	Australian National University

[2] Copyright and circuit layout rights are administered by the Attorney General's Department and plant breeder's rights are administered by the Department of Agriculture, Forestry and Fisheries.

Box N.1 **Uniquest**

A subsidiary of the University of Queensland, Uniquest began operation in 1983, initially focusing on licensing of technologies to third parties. The operations of Uniquest expanded into the formation of start up companies and spin offs with the help of a $5 million investment from the University of Queensland in 1995. Uniquest now offers its services to the University of Wollongong. Uniquest's experience and size of operations has allowed it to fine tune the commercialisation process.

Uniquest's method of granting licenses to private industry involves three options;

- finding a suitable existing domestic company; or
- finding a suitable existing foreign company; or
- forming a new company

The company has been involved in the establishment of 54 start up companies (46 still active) and, in 2004, filed 34 patent applications, negotiated 28 licence deals and contracted 39 R&D projects. The company generated a net profit of $3.45 million.

Source: Uniquest (2004).

Other agencies

Other agencies playing a role in the IP system include the Advisory Council on Intellectual Property, the Intellectual Property Research Institute of Australia and, previously, the Intellectual Property and Competition Review Committee.

The Advisory Council on Intellectual Property and the Intellectual Property Research Institute of Australia both undertake research on a wide range of topics in the field of IP. The Advisory Council has performed a number of reviews on certain aspects of the IP system, resulting in policy changes. For example, the replacement of the petty patent with the innovation patent was due to recommendations in the Advisory Council's report *Review of the Petty Patent System* (ACIP 1995). The Intellectual Property Research Institute of Australia focuses on making contributions to the general understanding of the optimal settings for IP policy and how these interact with levels of innovation.

The Intellectual Property and Competition Review Committee was established by the Australian Government to review the impact of IP policy on competition. The resulting report, *Review of Intellectual Property Legislation Under the Competition Principles Agreement* (IPCRC 2000), gave a raft of recommendations that have resulted in changes to IP and competition policy including, for example, repealing parallel importation bans.

Another agency involved in the IP system, is the Australian Institute of Commercialisation. Its role, however, is one of monitoring IP-related issues in relation to commercialisation.

International institutions

Two main bodies that assist in harmonising the interaction of individual countries are the World Intellectual Property Organization (WIPO) and the World Trade Organization (WTO).

WIPO

The WIPO is the primary, international IP body whose focus is the facilitation of IP rights that transcend national borders. It is one of 16 specialised units under the United Nations system. It administers 23 international treaties (including the PCT), that are applicable to its 183 member states. The Organisation originated from the bureaus established to administer the Paris and Berne Conventions. The former Convention, dating from 1883 was designed to protect industrial property (patents, trade marks and designs) over international borders. The latter Convention, established in 1886, performed the same task for copyright.

WTO

The protections afforded under international treaties (administered under the WIPO) became increasingly insufficient with increased international trade. Specifically, there was little incentive for nations importing technology and entertainment to adhere to international agreements, as in the absence of such constraints, they were able to access to cheap imitations. The main industries susceptible to such threats are those with little know-how required for reproduction, including pharmaceuticals and chemicals, publications, entertainment and certain technologies vulnerable to reverse engineering.

These factors considered, the WTO (then the General Agreement on Tariffs and Trade) introduced the Agreement on Trade Related Aspects of Intellectual Property (TRIPS) in 1994. The TRIPS Agreement extends the treaty-based protections of the WIPO, making IP laws stronger and with greater penalties for breaches. Specific changes enacted under the TRIPS Agreement include the extension of patent life to

20 years, extension of copyright protection to 50 years after the death of the author, 'compulsory licensing'[3] and enforcement provisions (for example, trade sanctions).

The main change affecting Australia was the extension of maximum patent life from 16 to 20 years. All other Australian IP laws met the minimum TRIPS standard. Because the TRIPS Agreement was introduced to mitigate IP infringements, it has mainly benefited developed countries, arguably at the expense of developing nations. This is most commonly highlighted using the example of restrictive access to patented pharmaceutical products in developing countries (for example, AIDS drugs in Africa). To address such problems compulsory licensing, least developed country exemptions and other flexibility provisions were included in the TRIPS Agreement.

3 'Compulsory licences' are given out by the government in the event that the actual patent holder abuses their rights, for example by not supplying to the domestic market. Hence the licence is sold to a competitor, allowing it to produce the good under certain conditions.

O Research infrastructure expenditure

Table O.1 **Key research infrastructure, capital works and equipment programs, 2005-06**[a]

Program (administering agency)		*$m*
Australian Government		
Medical Research Infrastructure Projects (DHA)		215.0[b]
Research Infrastructure Block Grants (DEST)		199.9
Systemic Infrastructure Initiative (DEST)[c]		61.4
Capital Works for John Curtin School of Medical Research (DEST)		50.0
Major National Research Facilities Programme (DEST)[c]		42.3
National Competitive Grants – Linkage Infrastructure (Equipment and Facilities) (ARC)		35.8
Health and Medical Research — Overhead Infrastructure Support (DHA)		27.0
Independent Research Institutes Infrastructure Support Scheme (NHMRC)		21.9
National Collaborative Research Infrastructure Strategy (DEST)		13.2[d]
Equipment Grants (NHMRC)		8.6
Enabling Grants (NHMRC)		8.0
Building Information Technology Strengths — Advanced Networks Programme (DCITA)		7.0
Commonwealth Environment Research Facilities (DEH)		4.8
Capital Works for Medical Institutes (DHA)		2.0[b]
Special Facilities (NHMRC)		0.2
States[e]		
NSW	Infrastructure Grants Program[f]	15.6
	Capacity Building Infrastructure Grants Program[f]	3.0
	Other (health) infrastructure funding[f]	2.2
Vic	Health Futures: The Victorian Life Sciences Statement	68.0
	Science, Technology and Innovation Initiative — Infrastructure Grants Program	49.8
	Australian Synchrotron	40.6
	Operational Infrastructure Support for Medical Research Institutes	26.4
Qld	Smart State Research Facilities Fund[g]	23.7
	Queensland Brain Institute[h]	10.0
WA	WA Major Research Facility Program	5.1
	Centres of Excellence in Science and Innovation Program	8.8
	Medical and Health Research Infrastructure Fund	5.0
	New Independent Researcher Infrastructure Support	0.0[i]
	Other infrastructure funding	1.0
SA	Research Grant (health and medical projects)	6.0
	Premier’s Science and Research Fund	3.0[j]
	Commercial Infrastructure Grant and Research Infrastructure Fund	0.6
Total		**965.9**

[a] This table does not cover expenditures by public sector research agencies and universities under block funding arrangements. [b] Nil expenditure is estimated for 2006-07. [c] This program will be replaced by the National Collaborative Research Infrastructure Strategy. [d] Budget estimate for 2006-07 is $98.2 million. [e] Spending on research infrastructure in Tasmania, the Northern Territory and the ACT is not significant. [f] From 2006-07, the Medical Research Support Program has replaced these programs. [g] This program has been replaced by the Innovation Building Fund which will allocate spending of $128 million over four years. [h] One-off expenditure. [i] Expenditure was $80 000. [j] Program funds both infrastructure and research.

Sources: Australian Government (2006a); DEST (2006f); State Government personal communications.

P Privacy Act 1988

P.1 Introduction

The Australian Government's Privacy Act, first introduced in 1988, is intended to protect the personal information of individuals and give them greater control over how that information is collected, used and disclosed. It sets out privacy principles that Commonwealth and ACT public sector agencies, private sector organisations and individuals must observe in collecting, storing, using and disclosing personal information. It also gives individuals rights to access and correct their own personal information. The Act was extended to cover private sector organisations in 2001.

There are two sets of privacy principles in the Act. The *information privacy principles* cover the collection, storage and security, use, disclosure and access to 'personal information' held by Commonwealth and ACT public sector agencies. The *national privacy principles* set out how private sector organisations across Australia should collect, use and disclose personal information, maintain data quality, keep personal information secure, maintain openness, allow for access and correction of personal information, use identifiers, allow anonymity, conduct trans-border data flows and collect sensitive information. Private sector organisations include all health services holding 'health information' such as private hospitals and health practitioners.

P.2 Provisions applying to health information and medical research

As the Office of the Privacy Commissioner noted, there is a 'social interest' in enabling medical researchers to have access to health information in certain circumstances. Accordingly:

> … while health information is afforded extra protection, the Privacy Act recognises the desirability of medical research by providing mechanisms that allow health information to be collected, used and disclosed for medical purposes, including in some circumstances, without the consent of the individual (sub. 63, p. 3).

Privacy principles

Allowing for variations in wording, the basic effect of the privacy principles in the Act is that, unless a limited range of circumstances applies, personal or health information cannot be collected, used or disclosed for the purpose of research without consent.

The information privacy principles do not permit public sector agencies to use or disclose in identifiable form records of personal information for research and statistical purposes, unless specifically authorised or required by another law, or the individual has consented to the use or disclosure.

The national privacy principles do not permit private sector organisations to use, disclose or collect information required for research (including compilation or analysis of statistics) relevant to public health or public safety; or the management, funding or monitoring of a health service, unless consent is impracticable and de-identification of information will not achieve the purpose of the activity.

Guidelines

In accordance with the Act, guidelines have been developed by the NHMRC, and approved by the Privacy Commissioner, to enable the use of personal or health information in the conduct of specific activities (including research of various types) without consent following an assessment by a human research ethics committee that the research and other activities are, on balance, substantially in the public interest and outweigh concerns about privacy protection (NHMRC 2000, 2001).

- Guidelines under section 95 (public sector agencies) address aspects of the collection, use and disclosure of health information in medical research.
- Guidelines under section 95A (private sector organisations) address research relevant to public health and public safety; compilation or analysis of statistics relevant to public health and public safety; and the management, funding or monitoring of a health service.

Compliance with the guidelines is reported annually to the NHMRC through its Australian Health Ethics Committee. In turn the NHMRC reports this information to the Office of the Federal Privacy Commissioner.

P.3 Recent reviews

The Act has been subject to several reviews in recent years including by: the Senate Legal and Constitutional References Committee (SLCRC 2005) on, among other things, the overall effectiveness of the Act as a means by which to protect the privacy of Australians; the Office of the Privacy Commission (OPC 2005) on the private sector provisions; and by the Australian Law Reform Commission and the NHMRC's Australian Health Ethics Committee on the protection of human genetic information (ALRC and NHMRC 2003).

There is currently a wide-ranging review of the Act by the Australian Law Reform Commission into the extent to which it provides an effective framework for the protection of privacy (ALRC 2006). This review is expected to be completed in March 2008.

Q Privacy legislation

The following table covers Australian Government as well as State and Territory legislation or, if that does not exist, administrative requirements directly governing the privacy of personal information. There are also privacy, confidentiality and secrecy provisions in other legislation — such as freedom of information legislation, telecommunications interception and spent convictions legislation — as well as privacy/confidentiality obligations under the common law and industry codes. These latter type of provisions are not included.

Jurisdiction	*Public sector - generally*	*Public sector - health*	*Private sector - generally*	*Private sector - health*
Commonwealth	Privacy Act (Cth)	Privacy Act (Cth)	Privacy Act (Cth)	Privacy Act (Cth)
New South Wales	*Privacy and Personal Information Protection Act 1998*	*Health Records and Information Privacy Act 2002*	Privacy Act (Cth)	*Privacy Act (Cth) Health Records Information Privacy Act 2002*
Victoria	*Information Privacy Act 2000* (except health information)	*Health Records Act 2001*	Privacy Act (Cth)	Privacy Act (Cth) *Health Records Act 2001*
Queensland	No privacy laws but Information Standards 2001, No. 42	No privacy laws but Information Standards 2001, No. 42A (Queensland Health)	Privacy Act (Cth)	Privacy Act (Cth)
South Australia	No privacy laws but Information Privacy Principles (reissued 1992)	No privacy laws but Information Privacy Principles (reissued 1992) and Code of Fair Information Practice	Privacy Act (Cth)	Privacy Act (Cth)
Western Australia	No privacy laws[a]	No privacy laws[a]	Privacy Act (Cth)	Privacy Act (Cth) Confidentiality of Health Information Committee

(Continued on next page)

Jurisdiction	*Public sector - generally*	*Public sector - health*	*Private sector - generally*	*Private sector - health*
Tasmania	*Personal Information Protection Act 2004*	*Personal Information Protection Act 2004*	Privacy Act (Cth)	Privacy Act (Cth)
Northern Territory	*Information Act 2002*	*Information Act 2002* Health Information Privacy Code of Conduct	Privacy Act (Cth)	Privacy Act (Cth) Health Information Privacy Code of Conduct
Australian Capital Territory	Privacy Act (Cth)	*Health Records (Privacy and Access) Act 1997*	Privacy Act (Cth)	Privacy Act (Cth) *Health Records (Privacy and Access) Act 1997*

a Although there are no privacy-specific legislative or administrative arrangements in Western Australia, various privacy, confidentiality and secrecy provisions exist in the *Freedom of Information Act 1992*, *State Records Act 2000*, *Spent Convictions Act 1988* and other Acts.

Sources: ALRC (2006); OPC (2006); Thomson (2004).

R Business innovation determinants

This appendix analyses influences on product innovation, process innovation, non-technological innovation and the acquisition of advanced manufacturing technologies by Australian manufacturing businesses.

R.1 Background to the data

The data sources are the two ABS innovation surveys of manufacturing businesses covering the periods July 1991 to June 1994 and July 1994 to June 1997. The unit record data from these surveys were supplemented with basic sales, employment and capital stock unit record information from other ABS collections.

Table R.1 provides basic information on the datasets. Regressions were based on business units surveyed in both innovation surveys (the 'overlap' dataset). Businesses with fewer than 10 employees were excluded as only a small percentage of these businesses were included in both survey samples.

The overlap dataset consists of 1048 responding businesses with 10 or more employees of which 762 businesses self-identify as technological innovators (defined below).

Table R.1 **Datasets used in the analysis**

File	*Period*	*Number of responding businesses (all)*	*Number of responding businesses (10 or more employed)*	*Technological innovators (10 or more employed)*
1st Innovation Survey	1991-94	3 813	2 553	1 630
2nd Innovation Survey	1994-97	4 690	3 279	2 009
Overlap	1991-97	1 101	1 048	762

Source: Datasets constructed by the ABS for the Commission.

The overlap dataset is skewed towards larger businesses. The number of responding businesses included in both surveys as a percentage of all businesses which responded to each individual survey is substantially higher for larger firm sizes (column 3 of table R.2).

Table R.2 **Characteristics of responding businesses (RB) in the overlap dataset versus the full samples of the two innovation surveys**

Dataset	*Stratification*	*RB included in both surveys as % of all RB*	*Technological innovators as % of RB - full sample*	*Technological innovators as % of RB - overlap*
1993-94 - By employment	0 to 4	3.2	25.4	26.1
	5 to 9	4.7	29.8	26.9
	10 to 49	21.6	46.5	55.0
	50 to 99	39.7	62.7	62.5
	100 to 499	58.0	76.9	78.9
	500 or more	65.4	86.5	90.2
	Total	*29.2*	*51.8*	*71.7*
1996-97- By employment	0 to 4	2.7	21.4	12.5
	5 to 9	4.9	29.7	26.9
	10 to 49	13.1	47.7	52.0
	50 to 99	31.5	65.1	71.8
	100 to 499	52.4	72.3	74.3
	500 or more	65.7	89.2	90.9
	Total	*23.5*	*50.2*	*70.1*
1993-94 By sub-division[a]	21	39.3	56.9	70.8
	22	26.9	46.7	69.9
	23	26.8	30.0	50.7
	24	25.1	47.9	55.8
	25	43.6	69.1	81.1
	26	25.9	50.2	76.3
	27	27.9	50.9	75.3
	28	34.9	62.5	75.7
	29	12.0	39.7	68.9
1996-97 By sub-division[a]	21	36.4	61.0	71.3
	22	34.8	47.9	68.9
	23	14.0	32.9	55.7
	24	27.6	45.1	60.2
	25	25.2	64.6	78.6
	26	34.1	56.3	73.1
	27	20.9	47.1	71.1
	28	19.1	52.0	72.6
	29	15.8	34.2	60.0

a Manufacturing sub-divisions are: Food, Beverage & Tobacco (21); Textile, Clothing, Footwear & Leather (22); Wood & Paper Product (23); Printing, Publishing & Recorded Media (24); Petroleum, Coal, Chemical & Associated Product (25); Non-metallic Mineral Product (26); Metal Product (27); Machinery & Equipment (28); and Other Manufacturing (29).

Source: ABS unpublished data.

The percentage of firms defined as technological innovators in the overlap dataset is substantially higher than in either of the full 1993-94 or 1996-97 samples. The propensity to be a technological innovator is positively correlated with firm size. Comparison by employment size indicates that 70.1 per cent of businesses in the overlap dataset were technological innovators versus 50.2 per cent for the full 1996-97 sample. The proportion of businesses which are technological innovators in the overlap dataset is higher for each manufacturing sub-division.

The technological acquisition and innovation indexes

Influences on the innovation performance and technological acquisitions of Australian businesses during 1994-95 to 1996-97 were analysed using four indexes constructed from responses to the second innovation survey:

- an indicator of product innovation intensity;
- process innovation;
- the breadth or intensity of advanced manufacturing technologies 'in-use' (while seeking to hold firm size constant); and
- non-technological innovation.

A business was defined to be a technological product and/or process innovator (TPP innovator) if the business provided a 'yes' response to any one of questions 8, 9 or 10 (table R.3). The data was used to construct the innovation indexes IP2, I2A and I2C described in table R.4.

Detailed information on the use of advanced manufacturing technologies (AMTs) was collected. Businesses were asked to provide information on thirty technologies under five categories:

- design and engineering (CAD/CAM, rapid tooling, etc.);
- fabrication, machining and assembly (Computer numeric controllers, robots etc.);
- automated material handling;
- automated inspection and testing equipment; and
- communications and control (LANs, EDI, etc).

Table R.3 **TPP innovation measures from the second innovation survey**

	Survey question	*Period*	*Data*
Q8	Did the business evaluate, develop or produce any *new* products which could be identified as potential, abandoned or implemented innovations?	1994-95 to 1996-97	Binary response = yes/no, for each of potential, abandoned and implemented
Q9	Did the business evaluate, develop or produce any *changed* products which could be identified as potential, abandoned or implemented innovations?	1994-95 to 1996-97	Binary response = yes/no, for each of potential, abandoned and implemented
Q10	Did the business evaluate, develop or produce any new or changed processes which could be identified as potential, abandoned or implemented innovations?	1994-95 to 1996-97	Binary response = yes/no, for each of potential, abandoned and implemented

Source: ABS 'Innovation in Industry' manufacturing survey forms (1993-94 and 1996-97).

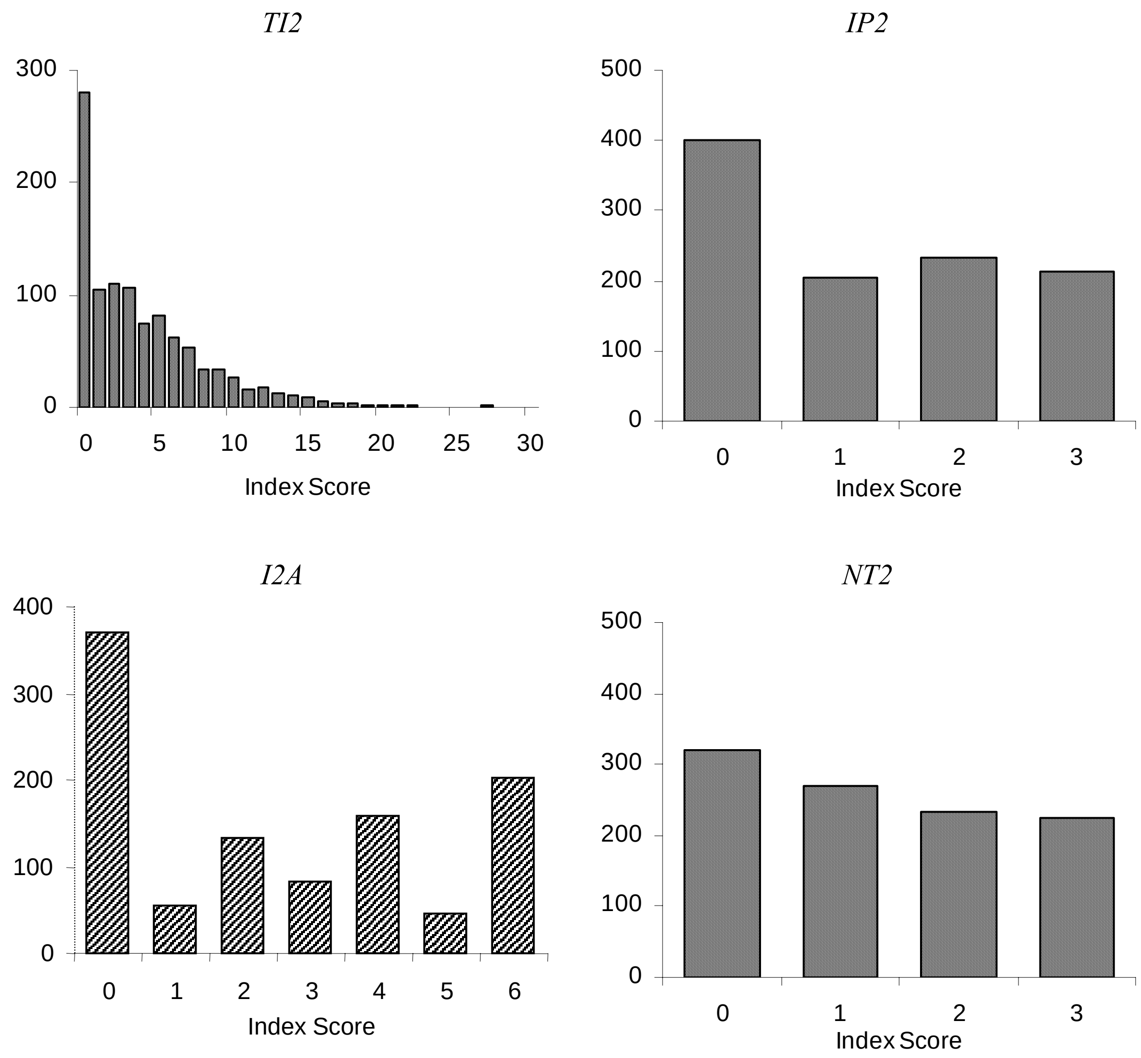
For each technology, businesses were asked to indicate whether the technology was 'in use', 'being installed', and/or 'planned to be installed within two years'. The index is a simple sum of the number of AMTs 'in-use' (TI2). A high index score indicates that a firm uses a greater number of different types of technologies. It is intended that the index provide an indicator of the 'vintage' of a firm's capital stock. The non-technological innovation index (NT2) is based on whether the business restructured or reorganised its physical layout, management structure or workgroups.

Table R.4 **Definition of dependent variables**

Description		*Data – survey question*	*Range*
Incidence of 'in use' advanced manufacturing technologies	TI2	Q61: index = 1 point for each technology 'in use'. Technology groups included are: design and engineering (CAD/CAM, rapid tooling, etc.); fabrication, machining and assembly (Computer numeric controllers, robots etc.); automated material handling; automated inspection and testing equipment; and communications and control (LANs, EDI, …).	(0 – 30)
Process innovation	IP2	Q10: no process innovations (= 0), then 1 point for each of potential, abandoned and/or implemented process innovations	(0 – 3)
New and changed product innovations	I2A	Count of Q8_1 to Q9_3 including potential, abandoned and implemented new and changed products	(0 – 6)
Implemented product innovations	I2C	Q8 and Q9: no implemented product innovations (= 0), implemented changed product (= 1), implemented new product (= 2), implemented changed and new product (= 3)	(0 - 3)
Non-technological innovation	NT2	Q12: 1 point for each of restructured or reorganised physical layout, management structure or workgroups	(0 – 3)

The number of firms with ten or more employees in each category is shown for the TI2, IP2, I2A and NT2 indexes in figure R.1. Each distribution sums to 1048 firms.

Figure R.1 **Frequency distributions for the innovation indexes**
Number of firms with ten or more employees



Data source: ABS unpublished data and Commission estimates.

Explanatory variables

The surveys collected a large range of business characteristics information which could be used to investigate influences on decisions to acquire AMTs, and the TPP and non-technological innovation performance of businesses. 'Performance' refers to the firm's ordering or ranking on the index and not the efficiency with which it achieves innovations.

Table R.5 provides background information on the explanatory variables used in the regressions under the following headings[1]:

- opportunities to innovate;
- incentives to innovate;
- domestic linkages;
- international linkages;
- strategic and identification, organisational and learning capabilities; and
- resources to innovate and other firm characteristics.

[1] There are a number of groupings which could be employed to help organise the large quantity of innovation survey data. Cabagnols and Le Bas (2002) use six lines of inquiry: characteristics of a firm's demand (price elasticity, level, evolution and homogeneity); conditions for appropriation of innovation benefits; sources of technological knowledge; market structures (concentration level, intensity of technological competition); characteristics of the firm (size, market share, diversification level); and firm strategy (towards quality, marketing and so on).

Table R.5 **Definition of the explanatory variables**

'IS1' denotes the data is from the first innovation survey

Description	*Mnemonic*	*Data – survey question*	*Range*
Opportunities to innovate			
Technological opportunities	tech_opp	Q8 - Q10: proportion of firms identified as technological product and/or process innovators by 2-digit ANZSIC	Per cent
Incentives to innovate			
Presence of dominant businesses	conc	Q18: potential market dominated by established businesses as reason for not starting innovation projects ('n.a.'/'not important' = 0 and 'crucial' = 2)	(0 – 2)
Market power	mkt_pwr	Q5: if ind_conc = 0, then mkt_pwr = 0. Q6: Whether the business is one of the dominant players. If Q6 = 'Yes', then mkt_pwr = 2, otherwise mkt_pwr = 1	(0 – 2)
Domestic linkages			
Knowledge and abilities acquisition methods utilised	know_acq	Q31: count of knowledge acquisition methods utilised (for example, obtained rights of invention from other businesses, contracted out R&D, take-over of another business, and used consultants)	(0 – 11)
Methods used to transfer or sell knowledge and abilities	tech_trf	Q32: count of knowledge transfer methods utilised (for example, transferred skill staff within business, offered invention rights to other businesses, performed R&D for others)	(0 – 11)
Current period acquisition of external technologies	acq_int2	Q50 expenditure on acquisition of external technologies (patents, trademarks and licences) as a per cent of total sales during 1996-97	Per cent
Prior-period acquisition of external technologies	acq_int1	IS1 Q24: expenditure on acquisition of external technologies as per cent of total sales during 1993-94	Per cent
International linkages			
Degree of foreign ownership	foreign	Q4: per cent of foreign ownership in company equity	Per cent
Export intensity of the firm	exp_int	Q7: per cent of the firm's product which entered export markets	Per cent

(continued on next page)

Table R.5 **(continued)**

Description	*Mnemonic*	*Data – survey question*	*Range*
Strategic, identification capabilities			
Importance of organisational and production flexibility to firm strategy	stg_flex	Q62: importance of flexibility in new product development and production as a reason for acquiring AMTs ('n.a.' or 'not important' = 0 and 'crucial' = 4)	(0 – 3)
Time/quality based strategy	time_stg	Q25: strategy in undertaking business innovative activity - importance of improving the quality or speed of service ('n.a.' = 0 and 'crucial' = 3)	(0 – 3)
Customer focus at the forefront of strategy	cust_fcs	Q25: importance of increasing ability to be responsive to customers	(0 – 3)
Strategic integration with suppliers: importance of suppliers as source of ideas and information for innovation projects	supp_ing	Q36 – count of suppliers of raw materials, components or parts and equipment as a source of ideas and information for initial idea, throughout the project and technical information or advice)	(0 – 8)
Strategy of total quality control - feedback, evaluation and revision	qltyctrl	Q26 – count of regularly revised and evaluated customer requirements, customer satisfaction, supplier agreements, business practices, business strategy, business culture and other	(0 – 6)
Organisational capabilities			
Cross-unit information and knowledge flows: degree of organisational and systems integration	ideas_i	Q36: count of internal sources of ideas and information used in innovation projects for initial idea, throughout the project and technical information or advice	(0 – 14)
Learning capabilities			
R&D intensity	r&d_int2	Q50: R&D expenditure as a percentage of total sales during 1996-97	Per cent
Prior-period R&D intensity	r&d_int1	IS1 Q24: R&D expenditure as a percentage of total sales during 1993-94	Per cent
Experience - years established	age_firm	Q1: number of years the firm has been established	Integer
Experience in present range of activities	age_mkt	Q2: number of years the firm has been undertaking its present range of activities	Integer
Resources to innovate and other firm characteristics			
Insufficient retained earnings as barrier to starting innovation projects	r_e	Q18: importance of insufficient retained earnings for firms which had innovative activity which did not proceed beyond the evaluation or feasibility stage ('n.a.'=0, 'not important'=1, 'important'=2, 'crucial'=3)	(0 – 3)
Control for size of firm	size_emp	Number ('000) employed	Integer

R.2 Estimation strategy

The models were estimated as ordered probit models with the five indexes on the left-hand-side of the regressions. The ordered probit model takes the general form

$$y^* = \beta' x + \varepsilon$$

where y^* is unobserved, x is a vector of explanatory variables, β represents the corresponding vector of coefficients to be estimated, and ε represents unobservable factors.

The mapping from y^* to y is captured by a non-linear function. For a model with five response categories, Y is observed as follows

$y = 0$ if $y^* < \tau 1$ or

$y = 1$ if $\tau 1 \leq y^* < \tau 2$ or

$y = 2$ if $\tau 2 \leq y^* < \tau 3$ or

$y = 3$ if $\tau 3 \leq y^* < \tau 4$ or

$y = 4$ if $y^* \geq \tau 4$.

where τ_1 to τ_4 represent various thresholds which, along with the regression coefficients β_i, are estimated from the data. The intuition is that whenever the actual y is above the threshold value τ4, then y will be ranked in the highest value of the index, and so on.

Under the assumption that y is normally distributed, it is possible to compute the probabilities with which, for a given set of characteristics, the firm will report the observed y in each of the above categories.

$\text{prob}[y=0] = \Phi(\tau 1 - \beta`x)$

$\text{prob}[y=1] = \Phi(\tau 1 - \beta`x) - \Phi(- \beta`x)$

$\text{prob}[y=2] = \Phi(\tau 2 - \beta`x) - \Phi(\tau 1 - \beta`x)$

$\text{prob}[y=3] = \Phi(\tau 3 - \beta`x) - \Phi(\tau 2 - \beta`x)$

$\text{prob}[y=4] = 1 - \Phi(\tau 4 - \beta`x)$

where Φ is the cumulative distribution function for the standard normal distribution.

The regression coefficients and values of the explanatory variables can be used to compute marginal effects. The marginal effect is often computed to give an interpretation like, 'A one unit increase in the variable x is associated with a z per cent change in the probability of observing the firm in the top category of the index'.

The marginal effects in this appendix are calculated differently. The marginal effect from equation (1) is the expected number of response categories shifted by a one unit increase in an explanatory variable.

$$\frac{\partial E(y_i)}{\partial x_i} = -\sum_{j=1}^{J-1} \frac{\partial F_\varepsilon(\tau_j - S)}{\partial x_i}$$

$$= \beta_i \times \sum_{j=1}^{J-1} f_\varepsilon(\tau_j - S) \qquad (1)$$

where y_i is the marginal effect of explanatory variable x_i, f_ε is the standard normal distribution used in the probit model, j is the number of cut or threshold points, $S = \sum S_i$, and $S_i = \bar{x}_i \beta_i$ which is the product of the mean of each explanatory variable x_i and its estimated regression coefficient β_i.

R.3 Regression results

Regression results in table R.6 are based on the overlap dataset with marginal effects calculated as per equation (1) (the regression coefficient estimates are provided in table R.8). Non-innovators are excluded from the regressions as the surveys were structured to 'skip' non-innovators past many of the business characteristics questions. This means that the results below should be interpreted as applying to businesses who self-identify as technological innovators, and not the broader population of businesses, or the propensity to innovate.[2]

After controlling for the effect of the size of the business (size_emp) and whether the business is in a low or high innovating industry, the main results were:

- the number of methods used to acquire knowledge and abilities, which could help the business undertake innovative activity, is positive and highly significant in all models;
  - for product innovations (I2A), a one unit increase in the knowledge acquisition index is associated with a probability of being observed 0.2 response categories higher on the index;

[2] The models were not specified with a 2-stage selection equation which is sometimes used when analysing innovation survey data to support inferences about the broader population of firms when analysis is based on a sub-set of firms (see Crepon *et al* (1998), Mairesse and Mohnen (2004), Therrien and Chang (2003), or, for an Australian application, Brunker and Salma (2006)). This issue of scope can arise for two related reasons: innovation surveys usually collect a reduced information set for non-innovators; and multiple equation models are utilised to, in part, address the possible 'simultaneity of R&D'. This can result in a sample of firms being used in some part of the model that is not randomly drawn from the larger population of firms.

Table R.6 **Average change in response categories [a]**

Evaluated at sample means. Probability > Chi2 in brackets.

Model:	*TI2*	*IP2*	*I2A*	*I2C*	*NT2*
TI2		0.029 ***			0.043 ***
		(0.006)			(0.001)
tech_opp	7.385 ***	0.196	6.400 ***	2.455 ***	-0.847
	(0.003)	(0.757)	(0.001)	(0.000)	(0.176)
size_emp	1.067 ***	0.231 ***	0.556 ***	0.241 ***	0.105 *
	(0.001)	(0.001)	(0.001)	(0.004)	(0.077)
conc	-0.297	-0.061	0.187 *	0.119 **	0.023
	(0.172)	(0.284)	(0.086)	(0.050)	(0.685)
mkt_pwr	0.311 **	0.009	0.022	0.039	-0.007
	(0.038)	(0.820)	(0.770)	(0.327)	(0.849)
know_acq	0.209 ***	0.100 ***	0.202 ***	0.072 ***	0.043 **
	(0.003)	(0.001)	(0.001)	(0.001)	(0.016)
tech_trf	0.312 ***				0.062 ***
	(0.001)				(0.010)
acq_int2	0.000				
	(0.297)				
acq_int1	0.196				
	(0.263)				
foreign	0.760 ***				0.029
	(0.001)				(0.487)
coop_ovr	0.149				
	(0.529)				
exp_int		0.002	-0.005	-0.005 ***	
		(0.195)	(0.108)	(0.005)	
r&d_int2	0.000	0.000	0.000	0.000	
	(0.882)	(0.431)	(0.159)	(0.103)	
r&d_int1	0.113 **	-0.005	0.071 ***	0.050 ***	
	(0.015)	(0.716)	(0.009)	(0.007)	
age_firm	0.025 ***	-0.001	0.008 **	0.002	
	(0.001)	(0.598)	(0.023)	(0.292)	
age_mkt	-0.021 ***	0.001	-0.005	-0.001	
	(0.009)	(0.593)	(0.179)	(0.722)	
r_e		-0.013	0.112	0.018	
		(0.745)	(0.132)	(0.658)	
stg_flex	0.473 ***	0.001			
	(0.001)	(0.971)			
time_stg	0.933 ***	0.030			
	(0.001)	(0.452)			
ideas_i	0.085 ***				
	(0.007)				
cust_fcs			0.181 *	0.100 *	
			(0.065)	(0.060)	
time_stg				0.000	
				(0.998)	
supp_ing				0.059 ***	
				(0.007)	
qltyctrl					0.118 ***
					(0.001)

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Table R.6 **(continued)**

Model:	*TI2*	*IP2*	*I2A*	*I2C*	*NT2*
Test statistics					
Response levels	23	4	7	4	4
Observations	594	741	741	741	741
AIC	2875	1896	2563	1444	1940
SC	3046	1975	2646	1523	1995
-2LogL	2797	1862	2527	1410	1916
R-Square	0.400	0.149	0.194	0.145	0.167
Max rescaled R-Square	0.402	0.160	0.199	0.166	0.178

* denotes significance greater than 10 per cent. ** significance greater than 5 per cent. *** significance greater than 1 per cent. [a] Marginal effects as per equation 1.

Source: Commission estimates based on unpublished ABS data.

- R&D intensity is positively associated with both product innovation and the acquisition of AMTs, but not process or non-technological innovation. Prior-period intensity appears to drive the results which, at least for product innovation, could be consistent with a gestation lag of two to three years:
  – for product innovations (I2A), a one unit increase in R&D intensity (for example, an increase from 0.5 per cent of sales to 1.5 per cent of sales) is associated with a probability of being observed 0.07 units higher on the index;
- businesses with higher AMT scores also tended to have higher process innovation and non-technological innovation scores, providing evidence of a positive relationship between embodied technological knowledge and the organisation of economic activity;
- retained earnings as a barrier to starting innovation projects was not significant in predicting technological (product or process) or non-technological innovation:
  – insufficient retained earnings also did not explain technological innovation performance on models based on the full second innovation survey, suggesting that the bias towards larger firms in the overlap dataset is not driving the result;
  – however, as noted above, the results should be interpreted as applying to firms self-identifying as TPP innovators and not the broader population of firms. It is possible that 'insufficient retained earnings' may be a more significant barrier to starting innovation projects for those firms classified as non-innovators;
- the importance of flexibility and time-based strategies, and higher degrees of foreign ownership, were strongly positively associated with the acquisition of AMTs; and

- differences in export intensity did not predict rankings on the ordered AMT index or the innovation indexes.

A range of other explanatory variables were tested in the models under various specifications and were not significant (table R.7).

The model results have several policy implications for this study. First, they substantiate the point emphasised in chapter 1 that it is important not to see R&D intensities as an indicator for all types of innovation. Second, the results suggest that R&D is just one way of absorbing external knowledge and that acquisition of advanced technologies also appears to be important (appendix D). Third, it is at least suggestive that finance barriers to R&D investment, and the constraints on investment imposed by insufficient retained earnings highlighted by some formal models and empirical work, may be less binding than thought (chapter 3). Finally, domestically oriented firms do not appear to be intrinsically less innovative (after accounting for other factors) than those with an export orientation, weakening the commonly-stated view that export-oriented firms should be special targets for innovation policy.

Table R.7 **Explanatory variables which were insignificant**

All indicators based on questions from the second innovation survey

Description	*Mnemonic*	*Data – survey question*	*Range*
Operating environment			
Degree of regulatory uncertainty in the firm's environment	reg_unc	Q18: importance of government standards and regulations for not starting innovation projects	(0 – 3)
Domestic linkages			
Horizontal technological collaboration	coop_dom	Variety of cooperative innovative activities with domestic partners. If Q37 = 'No', then coop_dom = 0, otherwise coop_dom = sum of variety of domestic arrangements from Q38	(0 – 8)
Variety of external sources of ideas and information	Ideas_e	Q36: count of domestic external sources, excluding suppliers and technologies as this information is used separately. 1 point for each source for initial idea, throughout the project and technical information or advice	(0 – 81)
Technology markets	tech_mkt	Q36: Patents, licenses and technical know-how as important sources of ideas and information used in innovation projects	(0 – 2)
International linkages			
Overseas parent company	ovrs_par	Q36: overseas parent company as an important source of ideas and information used in innovation projects (initial idea, throughout the project, technical information or advice)	(0 – 3)
International horizontal technological collaboration	coop_ovr	Variety of cooperative innovative activities with overseas partners. If Q37 = 'No', then coop_ovrs = 0, otherwise coop_ovrs = sum of variety of overseas arrangements from Q38	(0 – 8)
Overseas innovation expenditure	ie_ovrs	Q51: proportion of total innovation expenditure undertaken overseas	Per cent

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Table R.7 **(continued)**

Description	*Mnemonic*	*Data – survey question*	*Range*
Organisational capabilities			
Degree of devolution of innovation project decision making	hierarch	Q27: for new projects and for ongoing projects. Hierarchy = 1 (parent company, company board, managing director)	(0 – 1)
Cross-unit information and knowledge flows: degree of organisational and systems integration	ideas_i	Q36: index of internal sources as important sources of ideas and information with sources being management, production staff, technical staff, R&D staff and marketing staff. Source is for initial idea, throughout the project and technical information or advice (a higher index value indicates greater importance)	(0 – 15)
Learning ability			
Intensity of formal training activities	train_int	Q50: expenditure on training and further education as a percentage of total sales	Per cent
Intensity of other innovation expenditures	oi_int	Q50: innovation expenditure as a percentage of total sales less R&D and training and further education expenditures	Per cent
Resources to innovate and other firm characteristics			
Lack of appropriate sources of finance	finance	Q18: importance of appropriate sources of finance as barrier to starting innovation projects (not applicable = 0 and crucial = 4)	(0 – 3)
Non-linear firm size effect	$size\_emp^2$	Square of number of employed	Integer

Table R.8 **Regression coefficients, Pri > Chi^2 in brackets [a]**

Model:	*TI2*	*IP2*	*I2A*	*I2C*	*NT2*
TI2		0.032 (0.006)			0.048 (0.001)
tech_opp	2.258 (0.003)	0.220 (0.757)	3.661 (0.001)	3.019 (0.000)	0.948 (0.176)
size_emp	0.326 (0.001)	0.259 (0.001)	0.318 (0.001)	0.297 (0.004)	0.118 (0.077)
conc	-0.091 (0.172)	-0.069 (0.284)	0.107 (0.086)	0.147 (0.050)	0.025 (0.685)
mkt_pwr	0.095 (0.038)	0.010 (0.820)	0.012 (0.770)	0.049 (0.327)	-0.008 (0.849)
know_acq	0.064 (0.003)	0.111 (0.001)	0.115 (0.001)	0.089 (0.001)	0.048 (0.016)
tech_trf	0.096 (0.001)				0.069 (0.010)
acq_int2	0.000 (0.297)				
acq_int1	0.060 (0.263)				
foreign	0.232 (0.001)				0.032 (0.487)
coop_ovr	0.046 (0.529)				
exp_int		0.002 (0.195)	-0.003 (0.108)	-0.006 (0.005)	
r&d_int2	0.000 (0.882)	0.000 (0.431)	0.000 (0.159)	0.000 (0.103)	
r&d_int1	0.034 (0.015)	-0.005 (0.716)	0.041 (0.009)	0.061 (0.007)	
age_firm	0.008 (0.001)	-0.001 (0.598)	0.005 (0.023)	0.003 (0.292)	
age_mkt	-0.006 (0.009)	0.001 (0.593)	-0.003 (0.179)	-0.001 (0.722)	
r_e		-0.014 (0.745)	0.064 (0.132)	0.022 (0.658)	
stg_flex	0.145 (0.001)	0.002 (0.971)			
time_stg	0.285 (0.001)	0.033 (0.452)			
ideas_i	0.026 (0.007)				
cust_fcs			0.104 (0.065)	0.123 (0.060)	
time_stg				0.000 (0.998)	
supp_ing				0.073 (0.007)	
qltyctrl					0.132 (0.001)

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