Australian Government

Department of Innovation
Industry, Science and Research

FOCUSING AUSTRALIA'S PUBLICLY FUNDED RESEARCH REVIEW

MAXIMISING THE INNOVATION DIVIDEND

REVIEW KEY FINDINGS AND FUTURE DIRECTIONS

OCTOBER 2011

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ABBREVIATIONS

AAD	Australian Antarctic Division
ABS	Australian Bureau of Statistics
ACFR	Australian Centre for Field Robotics
AIMS	Australian Institute of Marine Science
ANSTO	Australian Nuclear Science and Technology Organisation
ANU	Australian National University
ARC	Australian Research Council
ATN	Australian Technology Network
CoE	Centre of Excellence
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSTACI	Commonwealth State and Territory Advisory Council on Innovation
DEEWR	Department of Education, Employment and Workplace Relations
DEST	Department of Education, Science and Training (replaced by DEEWR and DIISR)
DIISR	Department of Innovation, Industry, Science and Research
DSTO	Defence Science and Technology Organisation
EIF	Education Investment Fund
EOI	Expression of Interest
ERA	Excellence in Research for Australia
ERG	Expert Reference Group
FoR	Field of Research
FTE	Full-Time Equivalent
GBRMPA	Great Barrier Reef Marine Park Authority
GDP	Gross Domestic Product
GERD	Gross (national) Expenditure on R&D
Go8	Group of Eight (universities)
HASS	Humanities, Arts and Social Sciences
HEFCE	Higher Education Funding Council for England
ICT	Information and Communications Technology
IDC	Interdepartmental Committee
IISR	Innovation, Industry, Science and Research
ISI	Institute for Scientific Information (part of Thomson Reuters)
JCU	James Cook University
JRE	Joint Research Engagement
MFP	Multifactor Productivity

MRI	Medical Research Institute
NCRIS	National Collaborative Research Infrastructure Strategy
NHMRC	National Health and Medical Research Council
NICTA	National ICT Australia
NIP	National Innovation Priority
NRIC	National Research Infrastructure Council
NRP	National Research Priority
OECD	Organisation for Economic Cooperation and Development
OPSAG	Oceans Policy Science Advisory Group
PFRA	Publicly Funded Research Agency
PIMC	Primary Industries Ministerial Council
PMSEIC	Prime Minister’s Science, Engineering and Innovation Council
PPP	Purchasing Power Parity
R&D	Research and Development
RD&E	Research, Development and Extension
RDC	Research and Development Corporation
REF	Research Excellence Framework
RIBG	Research Infrastructure Block Grants
SME	Small and Medium Enterprises
TOR	Terms of Reference (of the review)
TPF	Triadic Patent Family
UNESCO	United Nations Educational, Scientific and Cultural Organisation

SUMMARY OF KEY FINDINGS AND RECOMMENDATIONS

The Australian Government ('government') recognises the importance of research, science and innovation for increasing productivity to achieve long term economic growth for the Australian community and to enable Australia to engage effectively with current and future national and global challenges. Research is a key contributor to improving Australia's multifactor productivity over the longer term.

The government's aspirations for publicly funded research are set out in its 10 year innovation agenda, Powering Ideas: An Innovation Agenda for the 21st Century ('Powering Ideas'). Powering Ideas contextualises the dividend from innovation in terms of building new industries and transforming existing industries, protecting the environment, and meeting people's needs. The Focusing Australia's Publicly Funded Research Review ('Review') examined the degree to which the current public investment model for research is effective to meet the government's aspirations, as well as the opportunities to further maximise the returns from the government's investment in research.

Key Finding: There is no evidence of any significant shortfalls in the current framework for publicly funded research

The government makes a significant investment in research, including science. Total government support for research and innovation in 2011-12 is estimated at $9.4 billion. Australia's research system is highly productive and is generally performing well relative to most EU-15 countries. Australia has an above the OECD average number of researchers for every thousand people in our workforce and Australia's research workforce is publishing at a rate and quality comparable to the top OECD countries. Australia also enjoys a positive reputation globally as a world-class research destination for researchers and research students in areas of research strength. It has less demonstrated capability in the translation of research to new products and processes and in collaborations between the university and industry sectors.

Most research involves elements of basic and applied research and in the absence of a strong rationale for change, maintaining the current balance of research activity in the Australian system seems appropriate. The current practice of parallel research teams being funded to work on common areas of research was shown to have had benefits for Australia's overall research capacity and productivity. An appropriate balance between the government's competitive and non-competitive funding for research also needs to be maintained. Competitive processes are generally best suited to support excellence in individual research activities, while top down models are more appropriate for decisions relating to major research investment decisions (including infrastructure), collaboration and capacity building.

The Review found that while there was no evidence of significant shortfalls in the current framework for publicly funded research, there are opportunities for the Commonwealth to achieve a more coordinated, coherent approach to maximise the returns from its investment. In particular, the Review found that a comprehensive account of the extent to which participants in the Australian research system are contributing to the innovation dividend will require detailed and complex work on measuring and assessing the wider benefits of research.

Key finding: There needs to be clarity in the roles of the various participants in the Australian research system.

Australia's policy settings for publicly funded research need to give greater recognition to the key role of universities in human capital development and the roles of Publicly Funded Research Agencies (PFRAs), particularly the Commonwealth Scientific and Industrial Research Organisation (CSIRO), in ensuring national preparedness capability and delivering solutions to deal with emerging industrial, social, health, security and environmental challenges as they arise.

Key Finding: Research activity undertaken by the key participants in the Australian research system is complementary, rather than overlapping and duplicative.

The Review examined many examples of parallel research activity being undertaken by participants in the research system (e.g. universities, PFRAs and medical research institutes). However, these examples demonstrated that the roles of the participants are complementary and that there is not unnecessary or unhelpful overlap of activities. Peer review processes that support funding decisions in competitive research programs also protect against duplication.

Key Finding: A national strategic dialogue and better coordination of research effort and investment are critical to Australia given its need for scale and world-class capability in areas of research of national importance.

The Review identified some examples where there was unhelpful domestic competition for resources to undertake research, which has led to the proliferation of new entities being established in areas where there is already established demonstrated capability. A greater strategic effort is needed across Australian Government research programs to enhance the coordination of research effort, especially where deep productive capability already exists, reducing administrative duplication and transaction costs associated with engaging in research and setting up new entities. There are also opportunities for greater leadership by the government and greater coordination within the Australian Government for research funding in areas of national importance.

The Review found that there would be value in establishing a new governance mechanism to ensure a national strategic dialogue about future investments in research. While some coordinating and oversight mechanisms already exist to guide research investment decisions in particular areas (e.g. the National Research Infrastructure Committee for research infrastructure), the Review found that a separate committee of senior Australian Government officials from key departments and agencies, chaired by the Chief Scientist for Australia, should be established with responsibility for providing integrated advice on investment across the full range of research activities, including human capital, infrastructure and collaborations.

RECOMMENDATION 1: that an Australian Research Committee of senior officials from key Australian Government departments and agencies, chaired by the Chief Scientist for Australia, be established to develop, among other responsibilities, a national research investment plan (with input from the states and territories and industry) to cover the full range of research activities, including human capital, infrastructure and collaborations.

Key Finding: Australia's National Research Priorities (NRPs) are generally appropriate as a broad overarching framework for signalling the government's aspirations in relation to public research. However, to continue to be relevant, the description of the NRPs needs to be revised.

The Review found that the NRPs have been generally useful as overarching framework statements, but they have had limited utility in driving investment decisions. A number of Australian Government agencies have specific priorities that link to targeted research investment strategies. To maintain their continuing relevance, however, the Review concluded there is a need to re-examine and refine the NRPs, particularly to take account of changes to policy settings (since their introduction in 2002) including the introduction of the National Innovation Priorities. Consideration could also be given to refining the priority goals under the NRPs to make them tangible and measurable and ways in which expenditure against the NRPs could be reported.

Key Finding: The NRPs should be augmented to better reflect the priority of the Humanities, Arts and Social Sciences (HASS) disciplines to the national research enterprise.

The HASS disciplines are important to innovation. Moreover, a number of stakeholders considered that there would be value in augmenting the existing NRPs with the inclusion of an additional priority to better acknowledge the priority of HASS in the national research enterprise. This was considered to be an effective way for the substantive contributions of these research disciplines to be acknowledged in their own right, rather than as a 'handmaiden' to the physical sciences. In addition, HASS was seen as essential to ensuring that the Australian community understand and accept current and future innovations.

RECOMMENDATION 2: that the Department of Innovation, Industry, Science and Research (DIISR) consult with the research sector and other relevant stakeholders on:

- changes to the existing NRPs to reflect recent policy changes including the introduction of the National Innovation Priorities;
- the addition of an NRP to better reflect the priority of HASS in Australia's research enterprise;
- refinements to the priority goals under the NRPs to make them tangible and measurable; and options for appropriate reporting of expenditure against the NRPs.

Key Finding: Examining possible models for an assessment tool to evaluate the wider benefits of publicly funded research will be important to provide greater confidence in the value derived from public investment in research.

The government needs to ensure that its investment in research is well spent. Robust evidence on relative research performance arising from the government's investment is therefore essential. The Review found broad acceptance of the government's Excellence in Research for Australia (ERA) initiative as a rigorous method for assessing the quality of research being performed in Australia's universities. There is, however, no systematic process of measuring the broader economic, social and environmental benefits of publicly funded research undertaken across the publicly funded research system as a whole.

Notwithstanding the methodological challenges in doing so, the Review found that there would be value in examining the feasibility of possible approaches for developing a rigorous, transparent, system-wide Australian research impact assessment mechanism, separate from ERA, to evaluate the wider benefits of publicly funded research. This examination could usefully draw on Australian and international experience in this area.

> **RECOMMENDATION 3:** that the Department of Innovation, Industry, Science and Research undertake a feasibility study on possible approaches for developing a rigorous, transparent, system wide Australian research impact assessment mechanism, separate from Excellence in Research for Australia, to evaluate the wider benefits of publicly funded research.

Key Finding: It is critical to Australia's future productivity that Australian businesses are informed by leading edge thinking derived from excellent research.

Collaboration is critical to innovation, particularly given the growing volumes of knowledge internationally, complex technologies and the increasing sophistication of supply chains (DIISR, 2009). The benefits of collaboration are well documented, including the value of collaboration between firms and researchers in universities and other institutions in being able to de-risk innovation and successfully produce new-to-the-country and new-to-the-world innovations. Compared to other OECD countries, however, Australia does not perform as strongly in the intensity of collaboration between industry and universities and this lack of collaboration reduces the potential for Australia to maximise the opportunities available to successfully innovate.

There is a need for mechanisms to encourage universities to more effectively engage industry and other end users in the conduct of research in areas of shared interests, including through direct research investment. Greater incentives, for example, could be considered through changes to the current research funding allocation methods to eligible Australian universities.

> **RECOMMENDATION 4:** that consideration be given, in the first instance, to amending existing Innovation, Industry, Science and Research programs, within existing funding allocations, to encourage, recognise and reward collaboration between universities and end users. Consideration should also be given to future initiatives to focus on ways to encourage and maximise the rewards for successful collaborations.

1. PURPOSE OF REVIEW

Between February and July 2011, the Department of Innovation, Industry, Science and Research (department) undertook a review of publicly funded research and science (Review) with a particular focus on the opportunities and impediments to maximising the innovation dividend derived from the Australian Government (government) investment in publicly funded research. In doing so, it addressed the following issues:

- the roles of publicly funded research agencies to ensure they do not unnecessarily overlap with each other and/or other sectors in the research system;
- the appropriateness of the current level and balance of public funding for different types of research;
- the utility of the current public funding arrangements including the role of the National Research Priorities in meeting national priorities and needs;
- the value of a long-term strategy to provide collaborative research infrastructure; and
- options to develop performance measures to evaluate publicly funded research programs.

The Review was not intended to re-examine or redo the work of previous reviews and reports that have explored issues relating to publicly funded research, although consideration has been given to the findings from previous work, as appropriate.

The Review Terms of Reference (TOR) are provided at:
http://www.innovation.gov.au/Research/Pages/FocusingAustraliasPubliclyFundedResearchReview.aspx.

2. REVIEW METHODOLOGY

An Expert Reference Group (ERG) and an Interdepartmental Committee (IDC) provided guidance to the department in the conduct of the Review. Membership details of the ERG are provided at: http://www.innovation.gov.au/Research/Pages/FocusingAustraliasPubliclyFundedResearchReview.aspx.

The Review primarily involved analyses of available evidence on the quality and value of publicly funded research including international and national expenditure and performance data; mapping of state and territory priorities for research; and an examination of a number of models of common research activity within and between sectors. The compendium of data and analyses that provided evidence to underpin the Review drew on data from the OECD, ABS, Thomson Reuters and ERA 2010 World Dataset and is **Appendix A** to this paper. A summary of strategic priorities for research by state and territory governments, including expenditure and performance information, was prepared by the Review Taskforce and verified by the states and territories (**Appendix B**).

This internal work was complemented by commissioned elements of work to allow a more detailed examination of the coordination of research activity within and across sectors in four broad areas (climate change, including energy, information and communications technologies (ICT), agriculture, and health). Specifically, the Allen Consulting Group prepared a number of case studies in areas of cross-disciplinary research. In each case, the following issues were considered: the nature and purpose of Australian Government and other sources of recurrent and capital funding, including the relative balance of funding for basic and applied research; the respective roles of Publicly Funded Research Agencies (PFRAs), Medical Research Institutes (MRIs), Cooperative Research Centres (CRCs), rural Research and Development Corporations (RDCs), the university sector, the states and territories and the private sector, including any actual or potential duplication; the research teams, centres and institutions that are undertaking the research; and any evidence of the performance – excellence and/or broader benefit – from the research.

Additional bibliometric analyses using Scopus data were undertaken by Elsevier Science and Technology to examine publication output and citation counts for top performing institutions by sector (e.g. top universities, PFRAs, and MRIs), and collaborations between sectors in the following four fields of research: climate change (energy); information and communications technology (ICT); agriculture; and health, which were also the focus of the case studies.

The Review Taskforce developed a Review Consultation Paper with appropriate framing questions to facilitate discussions with a number of key stakeholders (**Appendix C**). A thematic summary of the key issues identified by stakeholders as part of the consultation process informed the Review key findings and recommendations (**Appendix D**).

In conducting the Review, the Review Taskforce noted the data limitations from a system perspective and that the data analyses have not necessarily illustrated or captured the complexity and richness of issues across Australia's research system. The Review Taskforce drew on other sources of information and commentary, including the case studies, the bibliometric analyses and major views and issues raised by stakeholders during this process.

3. POLICY CONTEXT

Publicly funded research is integral to the productivity agenda. The knowledge created from research and the translation of that knowledge to the broader economy builds the skills levels of the Australian workforce, supports Australia's productivity performance, and thus enhances the quality and productivity of working lives. It also enables Australia to engage effectively with current and future national and global challenges, including through research collaboration at both the national and international level (Barlow, 2009; DIISR, 2009).

The Australian Government's aspirations for publicly funded research are set out in its 10 year innovation agenda - Powering Ideas: An Innovation Agenda for the 21st Century ('Powering Ideas') (DIISR, 2009). The Powering Ideas package of reforms in research and innovation, announced in the 2009-10 Budget, was focussed on maximising the benefits of Australian research, promoting excellence, and keeping Australian science internationally competitive. Powering Ideas contextualises the returns from innovation (i.e. the 'dividend') as including:

- **Building new industries and transforming existing industries** – by assisting the movement of investment to more productive uses, by helping companies adapt to operate more efficiently or win new markets;
- **Protecting the environment** – by protecting the environment, by assisting the development of technologies to reduce climate change; and
- **Meeting people's needs** – by streamlining delivery of government services, including health and education, to improve social outcomes.

In particular, the Powering Ideas reforms are aimed at increasing business innovation and business investment in research and development; improving Australia's university research base by increasing the number of areas of research performing at world class levels and increasing the number of students completing higher degrees by research; and increasing the level of collaboration between Australian businesses, universities and PFRAs.

The Review has been undertaken in a context where Australia's multifactor productivity (MFP) – the efficiency with which we translate labour and capital into outputs – has fallen below the average of OECD countries and well below the heights achieved in previous decades. Our declining MFP performance is not something Australia can afford to be complacent about (Garnaut, 2010). According to the Grattan Institute (Eslake & Walsh, 2011): "MFP growth across the 12 sectors for which data is available going back to the mid 1970s peaked at 2.1 per cent per annum over the five years ended 1998-99, but from then on slowed to the point of turning negative during the second half of the 2000s. Much of the same trend is evident for the 16 sectors now comprising the 'market sector' of the economy as defined by the ABS."

This trend indicates the challenges facing Australia's innovation effort. In the shorter term, there is a challenge to lift MFP growth in non-resource sectors. In the longer term, there needs to be substantially improved MFP growth across the whole economy, as Australia moves beyond the current resources boom. In particular, sources of MFP growth include better trained and educated people and both technological and non-technological innovation – to which research and development (R&D) is one contributor.

While there are examples for instance in the Australian mining industry where productivity is being improved through leading edge automation and remote control technologies, including those based on Australian research (see **Box 1**), Australia needs to give greater priority to these types of connections. It is critical to Australia's future productivity that Australian businesses are informed by leading edge thinking derived from excellent, market-applicable research and that they engage in steering the production of such research. Without this, there is a risk that Australia will become increasingly non-competitive and that Australian ideas will continue to make profits for overseas companies rather than the Australian community.

BOX 1: THE AUSTRALIAN CENTRE FOR FIELD ROBOTICS AND AUSTRALIAN RESEARCH COUNCIL CENTRE OF EXCELLENCE FOR AUTONOMOUS SYSTEMS

The Australian Centre for Field Robotics (ACFR) is based in the School of Aerospace, Mechanical and Mechatronic Engineering at The University of Sydney, and is dedicated to the research, development, application and dissemination of field robotics principles. ACFR is also a partner in the Australian Research Council Centre of Excellence for Autonomous Systems (CAS). Amongst other initiatives, the ACFR in 2007 commissioned a major new Centre for Mine Automation. Rio Tinto, a global mining company, has committed $21 million of funding for an initial period of five years for this new Centre. The aim of the Rio Tinto Centre for Mine Automation is to develop and implement the vision of a fully autonomous, remotely operated mine.

In an interview with *Computerworld*, Professor Hugh Durrant-Whyte, then Director of CAS, discussed some of the achievements and opportunities in the work of the centre:

Durrant-Whyte, research director at the *Australian Research Council Centre of Excellence for Autonomous Systems*, has designed robots for industries including mining, sea exploration and agriculture that can outperform human ability in a variety of specialised skills. For instance, some farmers are using his unmanned dwarf helicopter to automatically seek and destroy two plant species over a 500km area, eliminating the need to carpet-bomb crops with dangerous pesticides. The farmers may also soon be able to send out unmanned prime movers to sow fields.

The Department of Defence, research scientists and oil barons are using his small submarines to search for untapped oil and gas fields and map the hostile ocean depths off the Far North coast.

Miners in Western Australia's Pilbara region can leave the canary at home and send in automated drilling machines. And while some may be slightly miffed, his robotic systems are driving those colossal 300-tonne trucks in the West Angelas mine (in Central Western Australia) without human help. In fact, Durrant-Whyte says the entire Pilbara mining industry will use robots, operated remotely, hundreds of kilometres away in Perth. "All mines in the Pilbara will be run from the Regional Operations Centre in Perth, including the process plants, and even trains" Durrant-Whyte said, adding that mines in areas such as Mongolia and West Africa could be run remotely from cities like Sydney.

Source: Review Taskforce, 2011, using extract from Pauli (2010).

The purpose of the Review was not to re-examine the issue of the value of public investment in research. Notwithstanding the measurement and methodological challenges in examining the returns, overall the rationale and the important economic, social and environmental benefits of public investment in research are well documented and accepted. In particular, there is a strong body of international evidence about the widespread benefits from public sector research investment and it is generally now well accepted that public investment in research in Australia and in other advanced economies plays an important role in creating a world class research environment and in building innovation capacity and driving productivity (e.g. DIISR, 2009; Martin and Tang, 2007; Productivity Commission, 2007; National Academy of Sciences, 2010; Gullec and Van Pottelsberghe, 2001).

Powering Ideas also articulated that there is a clear and credible rationale for government to intervene to fund research. This investment helps Australia to develop and deliver solutions to major challenges, contributes to general community well-being and security, and it underpins research training and skills development. These are major public goods that would benefit from government intervention, either because of the presence of an identifiable market failure or because the public good outcome would not be realised without government investment. Government thus invests in innovation, including research, as a way of addressing market and social equity failures, with the aim of translating these investments into realised benefits in terms of solving specific problems and enhancing the national quality of life. Benefits may include specific economic outcomes (e.g. local development of new to the world products and services, faster adoption of overseas technologies, formation of high wage industries, reduced costs) or specific social or environmental outcomes (e.g. reduced dry-land salinity, improved public health outcomes).

In addition, it is generally agreed that the public benefits well outweigh the cost of investment (e.g. Martin and Tang, 2007; Productivity Commission, 2007). Indeed, many commentators have argued that given the increased demands on public sector research institutions – to work closely with business and conduct industrially oriented, regionally important and public good strategic research – the current levels of public funding in Australia to higher education and government research organisations are probably inadequate (Garrett-Jones, 2007).

Notwithstanding the benefits of public investment in research, there is an increasing imperative to ensure a coordinated, coherent approach to maximising the innovation dividend. There are a number of dimensions of relevance to 'maximising the innovation dividend,' including:

- ensuring appropriate alignment and coordination in the resources provided across government to support an effective publicly funded research system;
- having the right balance of the different types of research in the innovation system;
- ensuring the clarity of roles and the effective contribution of all the participants in the research system;
- facilitating the connections between participants to maximise knowledge diffusion, capture spillover benefits and to minimise transaction costs;
- balancing short-term and long-term objectives; and
- evaluating the returns from investment in publicly funded research to guide future government investment.

With *Powering Ideas* initiatives now well underway, it is timely to consider whether the current framework for publicly funded research remains fit for purpose and/or whether there are opportunities to refresh that framework. In particular, the Review examined the degree to which Australian Government funded research is maximising resource effectiveness, ensuring research quality and meeting Australia's strategic needs.

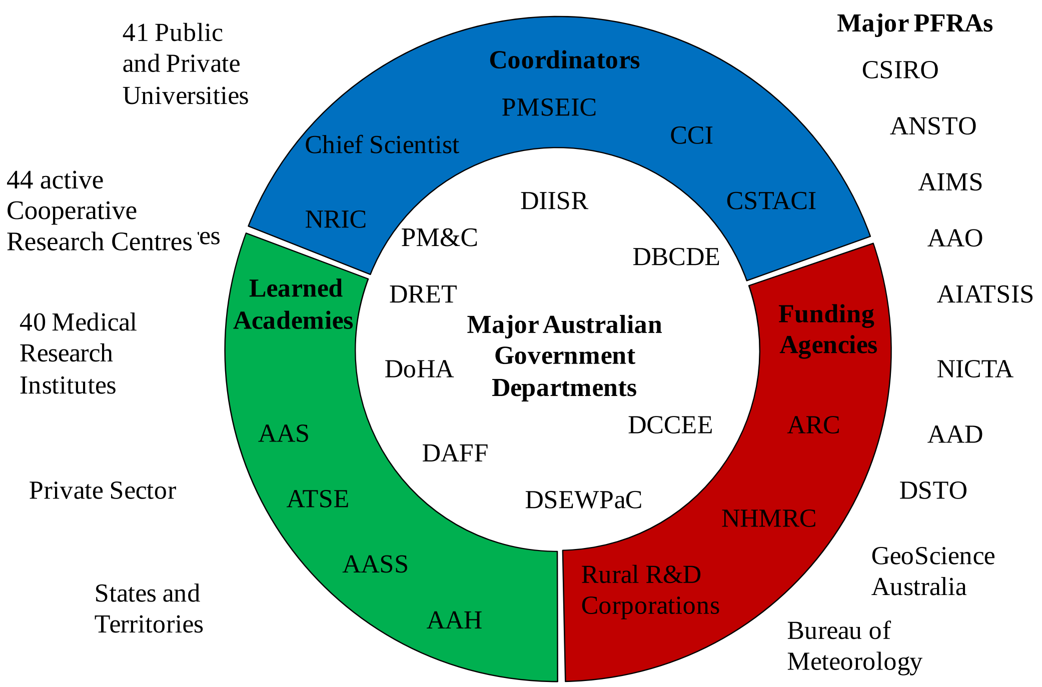
4. AUSTRALIA'S PUBLICLY FUNDED RESEARCH LANDSCAPE – ROLES, PRIORITIES, FUNDING & PERFORMANCE

4.1. ROLES IN PUBLIC SECTOR RESEARCH

Research is conducted in a complex environment and this complexity will only increase as more multidisciplinary research is undertaken to address the large scale challenges that confront Australia. Like other countries, Australia faces a range of issues that are global in nature, such as economic and environmental pressures, as well as longer life expectancies of citizens. The scale of these issues exceeds the capability of any one institution to address. The complex and interactive nature of research, as the Organisation for Economic Cooperation and Development (OECD) notes, has led to researchers and innovators partnering to share costs, find complementary expertise, gain access to different technologies and knowledge quickly, and collaborate as part of networks (OECD, 2009). In this environment, it will continue to be important for there to be clarity relating to the roles of the various participants in the Australian research system and the ways in which they can work together to achieve positive outcomes across the innovation system. In particular, role clarity is important so that institutions and organisations can focus on their core competencies.

Figure 1 depicts the Australian research system, characterised by multiple funding sources, as well as multiple research performers, consistent with other economies.

Figure 1: Australia's Research System



Source: Review Taskforce, 2011

Government funding processes and well-established peer review (discussed in **Section 5**) work to prevent the direct duplication of research effort and projects, while supporting parallel and complementary activity. This is essential to knowledge production (because research findings within fields are tested and challenged by various research performers), as well as building deep capacity. The various Australian Government funding programs for research have emerged due to different needs in the economy and the community.

In Australia's research system, universities are the institutions that are primarily responsible for human capital development. This was emphasised by the Cutler review of the national innovation system (Cutler, 2008) and in the government's research workforce strategy *Research Skills for an Innovative Future* (DIISR, 2011a). A range of studies have estimated the private economic returns in regards to higher education (noting that the wider contribution of developing Australia's human capital stock is harder to measure). A 2008 AMP NATSEM study found a strong relationship between higher education qualifications and the capacity to earn higher incomes, while a 2009 KPMG study estimated that a higher degree by research (i.e. Masters or Doctorate) is expected to increase an individual's earnings by 59 per cent, compared to the same situation where that individual had no post-school qualification. The more important observation is that the higher lifetime earnings accrue from the enhanced productivity and deeper skills of highly educated individuals, thus contributing to greater organisational productivity (important for economic growth and higher standards of living), rather than just from the attainment of the higher qualifications per se[1]. These studies, overall, are evidence of the dividend from university training, including higher degree by research training.

Universities also provide the platform for the fundamental advancement of knowledge by conducting research across all fields that can lead to future technological advance and addressing national challenges. Modern research orientated universities also have a role in translating quality research into, for example, policy, commercial and/or community outcomes. University research further underpins the quality of education and skills development essential for the rest of the economy. Basic research funding provides links and access to the 97% of R&D not produced within Australia (i.e. produced overseas).

Government PFRAs – including agencies such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (see **Box 2**), the Defence Science and Technology Organisation (DSTO), the Australian Nuclear Science and Technology Organisation (ANSTO), the Australian Institute of Marine Science (AIMS), Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS), Geosciences Australia, and the Australian Antarctic Division (AAD) – conduct long term basic, strategic and applied research across many priority areas for government and the economy. This research is often in areas of public good, where investment by the private sector is low due to uncertain or insufficient commercial outcomes, commercially unacceptable risks or long time-frames. Some PFRAs also play an important role in training and developing researchers.

Businesses have a key role to play in undertaking research, with most R&D self-financed by businesses. This expenditure is directed towards innovation in products, services and processes, as well as new and improved organisational and management practices to improve competitiveness (Productivity Commission, 2007). By taking advantage of the benefits that spill over to other firms and the wider economy, business R&D contributes to national economic gains. R&D in business is also critical to meeting social goals such as responding to climate change.

1 Kennedy, Stoney and Vance (2009) note that human capital accumulation affects productivity both directly and indirectly and that increases in educational attainment may translate into increases in aggregate productivity that exceeds changes in the productivity of individual workers reflected in wage changes.

BOX 2: THE ROLE AND CONTRIBUTION OF CSIRO IN AUSTRALIA'S RESEARCH SYSTEM

CSIRO's contribution to the national innovation dividend can be viewed in terms of three aspects: delivering impact through large-scale, multidisciplinary, mission-directed research; building scientific capacity and preparedness for the nation; and supporting connectivity between the participants in the innovation system. CSIRO is able to bring the breadth and depth of its science to bear, in partnerships with other institutions and industry, to respond to national challenges. It employs a top-down approach to its strategic research management in a way that allows the organisation to re-prioritise and deploy its scientific capability (in terms of skills, capacity and infrastructure across disciplines) to address emerging or pressing issues and opportunities, including issues from an Australian Government perspective.

CSIRO provides a conduit through its networks and relationships for research to be translated into products and services for use and benefit for the Australian economy and community. It actively plans and manages its R&D and technology transfer activities aimed at adoption, use and benefit for Australia. Examples include CSIRO's successful licensing of its UltraBattery technology for automotive applications for distribution in North America, Japan and Thailand, and its strong track record in global wireless systems development. Here CSIRO holds core patents for wireless local access networks (a product of sustained research and licensing effort by the organisation over a twenty year period) and a billion devices are expected to be sold worldwide over the next several years using the technology developed by CSIRO researchers.

Source: CSIRO/Review Taskforce, 2011

The Co-operative Research Centres (CRCs) have a unique role in Australia's research system. They provide an effective, evolving model for long-term, deep collaborations between public research organisations and end users due to their long funding timeframes. The best CRCs produce excellent research driving innovation in industry, government and other sectors. The CRC model also enables concentration of research effort and capacity growth.

The latest review of the CRC program noted considerable change in the focus of CRCs' research activity over time, with the early focus on national research objectives and capability having been replaced by end user driven research and particularly research with commercial potential (O'Kane, 2008). The O'Kane review noted that these changes are consistent with increasing pressure to derive financial returns from publicly supported research, but it highlighted that the emphasis of CRCs should be on end user uptake, rather than commercialisation by the CRC itself. Since the O'Kane review, the CRC program guidelines have changed and now place greater emphasis on collaboration with various end users (not only the private sector) to deliver a range of benefits (economic, environmental and social), recognising that commercialisation is only one pathway to innovation.

The research infrastructure supported by universities and PFRAs also provides key resources for advancing knowledge and industry competitiveness.

ROLE OF COLLABORATION

Collaboration between participants in the conduct of public sector research is crucial. For example, universities and private non-profit MRIs collaborate in health R&D. This is a reflection of Australia's world class capability in this field, the economic opportunities from improved medical care and technologies, and the social and economic challenges the nation faces, including that of an aging population and the threat of pandemics and evolving drug resistance of pathogens.

Powering Ideas (DIISR, 2009) has an explicit aim to double the level of collaboration between Australian businesses, universities and PFRAs over the next decade. However, there is a risk that this goal will not be achieved. Australian businesses report that they have relatively low levels of collaboration with universities or other research institutions within Australia (ABS 8158.0). Compared to other OECD countries, Australia does not perform as strongly in the intensity of collaboration between industry and universities, as set out in **Table 1** (OECD, 2009). While Australian industry does not necessarily see the lack of collaboration with universities and PFRAs as an impediment to innovation (ABS 8158.0), the lack of collaboration between industry and universities reduces the potential for Australia to maximise the opportunities available to successfully innovate. Specifically, as set out in *Powering Ideas* (DIISR, 2009, p. 59): 'As the volume of knowledge grows, complex technologies proliferate, and supply chains become more specialised, it is getting harder and harder to innovate in isolation. Networking and collaboration are essential. Australia's weakness in this area puts us at a serious disadvantage.'

Table 1: Firms (by size) collaborating on innovation with Universities, 2004-06

Country	% of SMEs Collaborating with Universities	% of large companies collaborating with Universities	R&D Investment as % of GDP (2008)
Finland	16.3	59.1	3.7
Slovenia	3.9	41.3	1.7
Belgium	6.0	34.4	2.0
Sweden	5.9	31.1	3.7
France	6.3	24.4	2.1
Denmark	4.2	13.1	2.9
Netherlands	3.3	22.2	1.8
Norway	3.3	16.6	1.6
Australia	3.1 (2006-07)	10.0 (2006-07)	2.2
UK	3.1	9.4	1.8

Source: OECD Science, Technology and Industry Scoreboard, 2009.

Some stakeholders also noted a more general uneasy relationship between public policy and research and the un-tapped potential for academics to be knowledge brokers in policy development (see also Shergold, 2011).

There are, however, examples of successful collaborative arrangements, including through the CRCs and RDCs which demonstrate a focus on joint projects that span sectors, and the co-location of institutes, facilities and researchers (e.g. see DIISR, 2010a; see also **Box 3**). CSIRO, in particular, has ongoing efforts to consolidate activities in core locations aligned with its key partnerships across governments, universities and industry, such as the Queensland Ecosciences and Health and Food Sciences precincts, the Alice Springs Desert Knowledge precinct, the Perth Minerals and Energy precinct, and the CSIRO/Monash University New Horizons manufacturing centre. The Perth Minerals and Energy precinct has around 1000 researchers, 11 centres and institutes, and annual investment of $300 million. CSIRO has developed a roadmap for its national footprint to 2020 to guide similar future developments.

BOX 3: SUCCESSFUL COLLABORATION EXAMPLES

The **University of South Australia is working with SMR Automotive Australia** to produce light-weight car rear-view mirrors, which are expected to capture around eight per cent of the global market. SMR Automotive received $2.4 million from the Australian Government to establish a pilot plant in Adelaide. The company estimates that if the pilot project leads to full production, the new lighter mirrors will save about 400,000 tonnes of carbon dioxide emissions over five years (Carr, 2011a).

The **Victorian Organic Solar Cell Consortium** is a collaboration between CSIRO, the University of Melbourne, Monash University, Securency Limited, and with support from Merck Limited, Bluescope Steel, BP Solar and NanoVic. The Consortium brings together over 50 researchers conducting research into new materials and processes to enable the production of flexible, large area, cost-effective, reel-to-reel printable, plastic solar cells. The technology for the cells is the result of work by CSIRO researchers in advanced polymers, and, if successfully trialled, could underpin the development of a new world-leading industry in Australia in printable electronics. The goal is to have a commercial product available within the next five years (DIISR, 2010a; The University of Melbourne, 2010).

The **CRC for Contamination Assessment and Remediation of the Environment** (CRC CARE) with the support of its industry partners including the Australian Institute of Petroleum, BHP Billiton and Chevron, have demonstrated that contaminated land can be reclaimed, safely and economically (CRC CARE, 2009a). Demonstration sites in historically-contaminated areas are undergoing assessment and remediation using cutting-edge technologies and trials have proven successful. The sites are being used to show that the new approaches offer a more cost-effective way to clean up polluted land. Industrial land in inner city areas, for example, could be made safe for development and it is estimated that the Australian economy could gain as much as $1.8 billion a year (CRC CARE, 2009b).

Boeing has recognised CSIRO's world-leading R&D, performance and customer service by naming the agency as a “Supplier of the Year” from more than 17,500 suppliers from 50 countries. CSIRO has been working with Boeing for more than 22 years on projects, including research into sustainable aviation fuels, aircraft assembly processes and aircraft maintenance management software. Boeing recently established R&D laboratories in Brisbane and Melbourne, employing 37 scientists, many of whom collaborate with CSIRO on projects. Together, these projects have more than 120 Australian scientists engaged on advanced aerospace technologies (Carr, 2011b).

Source: Review Taskforce, 2011

Other government support (e.g. Commercialisation Australia[2] and Enterprise Connect - Researchers in Business programs) have aimed to increase the access to and the connections between firms, researchers and venture capital (DIISR, 2010a). The $10 million Researchers in Business initiative supports the temporary placement of university or PFRA researchers into firms that wish to develop a new idea with commercial potential.

Overall, collaboration is critical to successful innovation and the benefits are well documented, for example:

- Frost & Sullivan (2006) found that collaboration is a bigger influence on business performance than strategic orientation or the opportunities inherent in the market environment and global organisations that collaborate perform better.

2 As of May 2011, nine projects from universities/PFRAs have received support under Commercialisation Australia, with grants totalling $761,477.

- Australian manufacturers who collaborate are much more likely to produce ‘new-to-the-country’ and ‘new-to-the-world’ innovations than those who do not (DITR, 2006).
- Block and Keller (2008) found that in the United States of America, “large firms acting on their own account for a much smaller share of award-winning innovations, while innovations stemming from collaborations with spin-offs from universities and federal laboratories make up a much larger share”.
- A report to the Higher Education Funding Council for England (HEFCE) found that in the United Kingdom, industry-university collaboration has realised “many synergies between knowledge exchange, teaching and research” and “greater recognition, by both academics and external organisations, of the value and benefits or working together on a diverse range of problems and initiatives” (PACEC and the University of Cambridge, 2009).

Note on international collaboration

This Review focussed on the nature and utility of publicly funded research arrangements in the Australian domestic context. Research, of course, is conducted in a highly competitive global environment and participants in the Australian research system collaborate internationally, at the researcher, research group and institutional level. The House of Representatives Standing Committee on Industry, Science and Innovation investigated and reported in 2010 on Australia's international research engagement, including the nature and extent of international research collaborations, key drivers, benefits and impediments to Australia from engaging in collaborations, and strategies for supporting international research engagement. These issues were not in scope in this Review; however, many stakeholders noted the critical importance of international research collaboration, given Australia's modest size, and the need to be able to access the 97% of new knowledge and innovation being produced outside of our national borders. Factors such as scale, capacity and research excellence are key to the ability of Australian research institutions to build profile to attract world leading researchers and foreign investment, and from a system perspective, Australia's international research engagement should be aligned with broader national priorities for research and economic development (Universities Australia, 2010).

See also **Section 4.6**: Complementarity of Research Activity and Collaboration in Australia’s Research System.

4.2. PRIORITY SETTING

The current national level mechanism for focussing public-sector research is the set of National Research Priorities (NRPs), established initially by the Australian Government in 2002 and subsequently enhanced in 2003. The NRPs aim to support the development of critical mass in priority areas. They also provide a mechanism for communicating, both domestically and internationally, those research areas which are of particular interest to the government. The priority areas and related priority goals are set out in **Table 2**.

The NRP framework required relevant government departments and agencies to report how their resource allocations related to NRP areas and goals, and to state how they would increase inter-institutional collaboration within the NRP areas[3]. The framework also required that the NRPs be reviewed every three years.

Table 2: National Research Priority Areas and Associated Priority Goals

Priority areas	Priority goals
An Environmentally Sustainable Australia	Water – a critical resource Transforming existing industries Overcoming soil loss, salinity and acidity Reducing and capturing emissions in transport and energy generation Sustainable use of Australia's biodiversity Developing deep earth resources Responding to climate change and variability
Promoting and Maintaining Good Health	A healthy start to life Ageing well, ageing productively Preventive healthcare Strengthening Australia's social and economic fabric.
Frontier Technologies for Building and Transforming Australian industries	Breakthrough science Frontier technologies Advanced materials Smart information use Promoting an innovation culture and economy
Safeguarding Australia	Critical infrastructure Understanding our region and the world Protecting Australia from invasive diseases and pests Protecting Australia from terrorism and crime Transformational defence technologies

Source: DIISR, 2011b (p. 126)

The first (and also most recent) formal report by government on progress by Australian Government agencies in the adoption of NRPs was produced by an NRP Standing Committee in May 2007 (DEST, 2007). Later, the NRPs were briefly considered as part of the 2008 review of the National Innovation System and through *Powering Ideas* the government endorsed their continuation – updated as required – to be used in conjunction with the seven National Innovation Priorities (see **Table 3**) to help focus public sector research in areas where Australia is genuinely internationally competitive.

3 Australian Government agencies(including the Australian Research Council, CSIRO), RDCs and CRCs, were required to submit plans outlining how they proposed to implement the NRPs using their funding and how they would collaborate with other agencies to accomplish the priority goals.

Table 3: National Innovation Priorities

Priority 1	Public research funding supports high-quality research that addresses national challenges and opens up new opportunities.
Priority 2	Australia has a strong base of skilled researchers to support the national research effort in both the public and private sectors.
Priority 3	The innovation system fosters industries of the future, securing value from the commercialisation of Australian research and development.
Priority 4	More effective dissemination of new technologies, processes, and ideas increases innovation across the economy, with a particular focus on small and medium enterprises.
Priority 5	The innovation system encourages a culture of collaboration within the research sector and between researchers and industry.
Priority 6	Australian researchers and business are involved in more international collaborations on research and development.
Priority 7	The public and community sectors work with others in the innovation system to improve policy development and service delivery.

Source: DIISR, 2009

In its review of public support for science and innovation, the Productivity Commission (2007) examined the NRPs and drew attention to the fact that they were non-prescriptive and not ranked in importance, that they did not provide quantitative goals in measurable terms (for example, in terms of expenditure targets), and that they did not apply to industry R&D programs or to university block grants. Nonetheless, the Productivity Commission supported the retention of the NRPs and their associated reporting arrangements, noted that the NRPs were intended to be a 'light-touch' approach to priority setting, and that performance reporting against them was relatively simple.

The 2007 NRP Standing Committee (DEST, 2007) also noted the low regulatory burden that the NRP framework had placed on reporting agencies, but considered it could be further reduced. It also supported the retention of the 'light-touch' approach as it provided both guidance and flexibility to reporting agencies.

Since their introduction, the NRPs have been used as an overarching framework for national research priority setting, which has guided decision making by government departments and agencies in terms of research investment. For example, the Australian Research Council (ARC) uses the NRPs in its programs in a broad thematic way and supplements them with more specific priorities in particular funding schemes, as required. In addition, the NRPs have been used as broad organising principles in the context of infrastructure planning processes. To illustrate, the current roadmapping process for research infrastructure is utilising the four NRPs as organising principles together with two additional areas of priority - *Understanding Cultures and Communities* and *eResearch Infrastructure* (DIISR, 2011c). The background to the inclusion of *Understanding Cultures and Communities* in the latest roadmapping exercises illustrates the increasing recognition of the important role of the humanities and social sciences (**Box 4**).

BOX 4: THE ROLE OF HASS IN STRATEGIC ROADMAPPING FOR RESEARCH INFRASTRUCTURE

In the 2006 roadmapping exercise, the NRPs were used as organising principles to guide the activities of the Expert Working Groups. For the 2008 Roadmap, the NRPs were again used as an organising framework together with two additional areas identified for specific consideration including the Humanities, Arts and Social Sciences (HASS). The specific inclusion of HASS provided a better opportunity to articulate HASS requirements in the 2008 Roadmap. It also recognised the underpinning role of HASS research in delivering solutions to challenging questions facing cultures and communities and the role of HASS expertise in addressing complex issues, such as in health, the environment, social cohesion and security. The 2011 Roadmapping process, being led by the National Research Infrastructure Council (NRIC), agreed that HASS continues to be included through the Understanding Cultures and Communities Expert Working Group.

Source: Science & Infrastructure Division/Review Taskforce, 2011

The CSIRO National Research Flagships were also introduced as a key mechanism to drive large-scale activity addressing the NRPs in a 'collaborative, cooperative and intensively managed manner.'

The CRCs are not specifically required to address the NRPs; however the CRC program has collected data on the percentage of effort of each CRC against each of the NRP goals. Of the 53 CRCs assessed by DIISR, 37 reported that 100% of their research effort addressed one or more of the NRPs. Of the 16 remaining, an average of 81% of research effort was reported as addressing the NRPs. The CRCs as a collective had a greater focus on the *Frontier Technologies* and *An Environmentally Sustainable Australia* NRPs than *Promoting and Maintaining Good Health* or *Safeguarding Australia*, perhaps demonstrating where collaboration with industry is most required and where other participants dominate the research effort (e.g. MRIs, DSTO), although many of the health-related CRCs record much of their effort under *Frontier Technologies*.

In practice, the NRPs have not necessarily constrained government departments and agencies from setting other (and sometimes more precise) priorities for research investment which are likely to have had greater effect upon allocation outcomes. The National Health and Medical Research Council (NHMRC) manages its programs to address the National Health Priority Areas (in place since 1996). The NHMRC, in its Strategic Plan for 2010 to 2012 and as per its legislative requirement, has also identified the major health issues that are to be the subject of special consideration by the agency over the next three years. The Agriculture, Fisheries and Forestry portfolio has rural R&D priorities (in place since 1994 and reviewed and updated in 2007), which are intended to achieve a national understanding of current critical R&D investment needs and better target agricultural, fisheries, forestry and food industry R&D efforts. The $100 million Commonwealth Environment Research Facilities program was aimed at promoting research in areas of particular strength or need as identified in priority research areas from an environmental perspective, while the replacement program, the National Environmental Research Program, is supporting the establishment of research hubs to examine emerging biodiversity issues. In addition to the research hubs, some funding is to be used to address emerging priorities during the life of the program.

4.3. AUSTRALIA'S INVESTMENT IN RESEARCH

HOW AUSTRALIA PERFORMS INTERNATIONALLY

Gross Expenditure on Research and Development (GERD)[4] is a core statistic of the national innovation system and the primary measure of financial input to the R&D system, aggregating business, government, higher education and other expenditure in a national total. Both the OECD and UNESCO usually report GERD in Purchasing Power Parity (PPP) terms to account for differences in national currencies and economic strengths. Several derived measures relating to GERD, which normalise for the effect of economic and population size, are commonly used:

- Research Intensity (GERD as a percentage of GDP);
- GERD per capita population;
- Percentage of GERD devoted to basic research[5]; and
- Percentage of GERD financed by Industry (or Business).

Total GERD and derived measures for the world's top ten nations are shown in **Table 4**. Australia is ranked 15th of all countries. By comparison to the top 10 average, Australia has higher research intensity but is lower than the average across the (mostly rich, developed) OECD member nations. Australia also has higher GERD per capita population, higher percentage of GERD for basic research and higher percentage of GERD financed by industry.

Table 4: Top Ten Nations by GERD (PPP) in 2008

Country	Rank	GERD (PPP$ million)	Research intensity	GERD per capita population (PPP$)	GERD for basic research (%)	GERD financed by industry (%)	GERD not financed by industry (%)
United States	1	398,194	2.79	1,306.28	17.36	67.3	32.7
Japan	2	148,719	3.44	1,166.33	11.39	78.2	21.8
China	3	120,613	1.54	90.18	3.33	71.7	28.3
Germany	4	81,849	2.68	996.70	N/A	67.3	32.7
France	5	46,262	2.11	721.26	25.40	50.7	49.3
Korea	6	43,906	3.36	903.30	16.05	72.9	27.1
United Kingdom	7	40,096	1.77	653.06	10.83	45.4	54.6
Russian Federation	8	30,058	1.03	211.67	17.89	28.7	71.3
India[6]	9	24,793	0.80	21.30	N/A	29.6	70.4
Italy	10	24,510	1.23	409.65	26.96	45.2	54.8
Top ten average	*N/A*	*N/A*	*2.07*	*647.97*	*16.33*	*55.7*	*44.3*
Australia	*15*	*18,755*	*2.21*	*866.62*	*20.35*	*61.4*	*38.6*
OECD total	*N/A*	*964,412*	*2.34*	*803.21*	N/A	*64.5*	*35.5*

Source: Review Taskforce, 2011.

4 Note that the ABS term is used in this review. The OECD, while using the same 'GERD' acronym, uses the slightly different term 'Gross Domestic Expenditure on Research and Development.'

5 Calculated from OECD, which reports Basic Research expenditure as a percentage of GDP.

6 UNESCO data for 2007.

In addition to comparing Australia with the top 10 countries and the OECD total, analyses were also undertaken to benchmark Australia against similar-sized economies and populations with significant research expenditures (some of which will be in the world top ten for certain measures). This was done in order to provide a reasonable like-with-like comparison for Australian expenditure and performance relative to nations with similar levels of human and financial resources to allocate to R&D.

These comparator countries were selected on the following statistical criteria:

- Population in 2008 (as per OECD or CIA[7]) at least 40% and no more than 250% of Australia's;
- GDP in Purchasing Power Parity (PPP) terms in 2008 (as per OECD or CIA) at least 40% and no more than 250% of Australia's; and
- Gross Expenditure on Research and Development in 2008 (as per OECD or UNESCO) over $1 Billion in PPP terms.

This yielded a comparator set of 12 countries, listed in alphabetical order as follows: Argentina, Belgium, Canada, Chinese Taipei (Taiwan), Korea (South Korea), Malaysia, Netherlands, Poland, South Africa, Spain, Sweden and Ukraine.

In summary, the comparative analysis showed:

- *GERD:* Korea is the clear leader, followed by Canada. In the comparison period, Korea, Canada, Chinese Taipei, Spain and Australia have all seen very rapid growth in GERD compared to the rest of the comparison set.
- *Research Intensity:* Sweden is the leader in Research Intensity with 3.70% of GDP invested in R&D (down from 3.80% in 2002). Sweden and Korea (3.36%) are two of the six countries in the OECD data to invest 3% or more of GDP in R&D in 2008. Korea, Chinese Taipei, Australia and Spain have seen the steepest increases in research intensity, while for the other countries the trends are modest and mixed.
- *GERD per Capita Population:* Sweden is the clear leader followed by Korea, Chinese Taipei and Australia which have seen rapid rises.
- *Percentage of GERD for Basic Research:* Of those countries for which data is available, Poland and Argentina invest the highest proportion of GERD in Basic Research. Australia and South Africa have seen steep falls in this measure.
- *Percentage of GERD Financed by Industry:* Malaysia is the leader followed by Korea, Chinese Taipei, Sweden, Australia and Belgium. The trends have been mixed, with some countries falling during the period while others, notably Chinese Taipei and Australia, have seen strong growth.

The analyses for the comparator countries are provided in **Appendix A - Graphs 1.1.1 – 1.1.5**.

CURRENT GOVERNMENT INVESTMENT

Total government support for research (including science) and innovation is estimated at $9.4 billion in 2011-12, an increase of $307 million or 3.4% over 2010-11.

Government allocates R&D funds into four broad categories. In 2011-12, the higher education sector will receive close to a third (29%) of the funding, the business sector 24%, the major Australian government research organisations, e.g. CSIRO, DSTO, ANSTO, AIMS, Geosciences Australia and AAD, receive 19%, and the remaining 28% is to activities that are accessed by more that one sector, i.e. multi-sector. About a third of the multisector category is NHMRC grants which predominantly go to universities and private non-profit MRIs. In regards to health and medical funding, the Minister for Mental Health and Ageing recently

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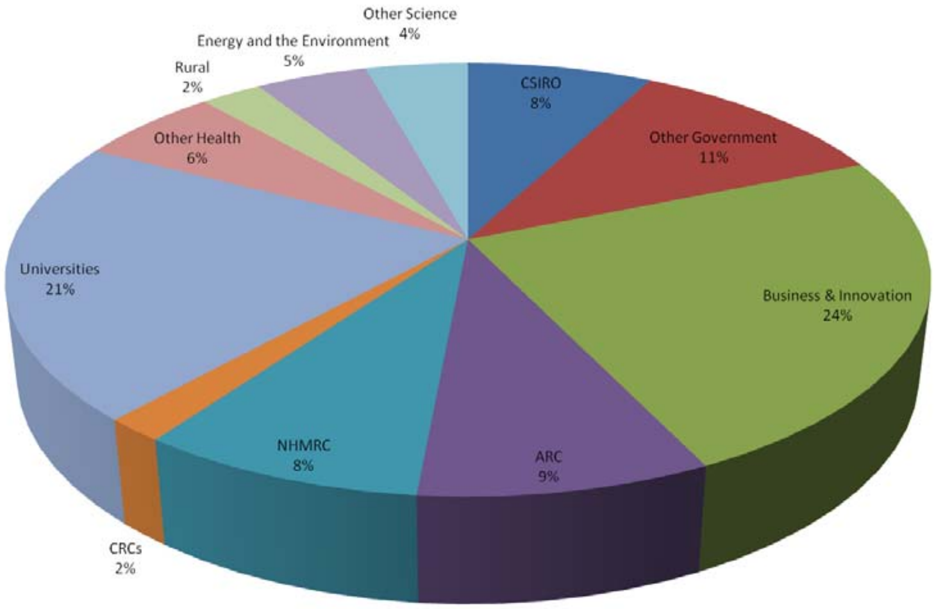
7 CIA World Fact Book (https://www.cia.gov/library/publications/the-world-factbook/).

announced a strategic review to consider how to optimise the future environment for carrying out health and medical research in Australia (Butler, 2011; DoHA, 2011). The CRC and rural funds also have strong university components and also demonstrate a focus on joint projects that span sectors.

A summary of funding distribution by sectors of performance for 2011-12 is provided at **Figure 2**.

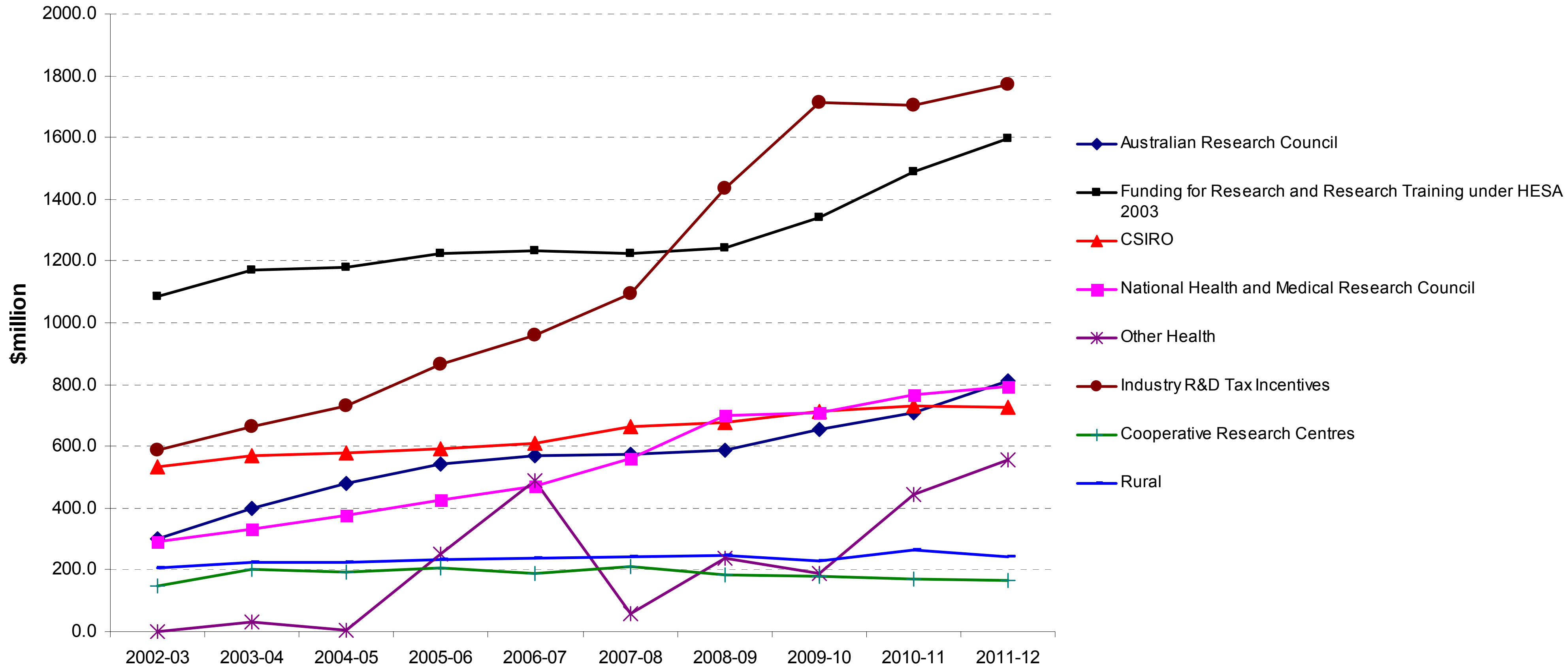
Figure 2: Funding Distribution by Sectors of Performance, 2011-12



Source: ARC, 2011 (based on the Australian Government's 2011-12 Science, Research and Innovation Budget Tables)

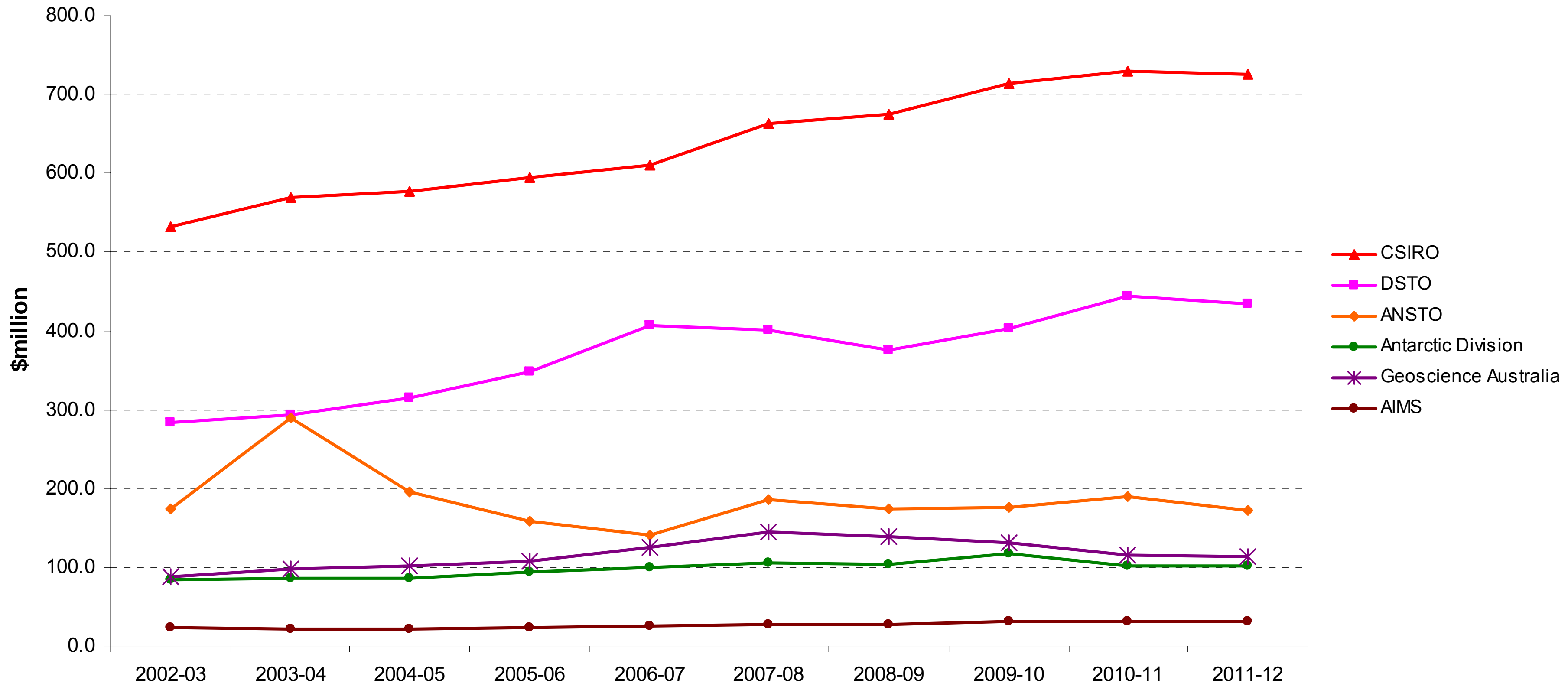
A summary of trends in government support for research and innovation over the past decade is provided at **Figure 3**. Expenditure on industry R&D tax incentives has increased significantly over this period, with increases evident in recent years for the NHMRC, the ARC, as well as performance-based block funding to eligible universities for research and research training under the *Higher Education Support Act* (HESA) 2003. The higher education sector is the single most important direct recipient of research and innovation funding from the government.

Figure 3: Trends in Australian Government Support for Science, Research and Innovation



Source: Review Taskforce, 2011 (based on The Australian Government's 2011-12 Science, Research and Innovation Budget Tables)

Figure 4: Trends in Australian Government Support for Major PFRAs



Source: Review Taskforce, 2011 (based on The Australian Government's 2011-12 Science, Research and Innovation Budget Tables)

Government support for other initiatives has remained largely the same, including for the major PFRAs; see **Figure 4**. In respect of the PFRAs, the Productivity Commission (2007) reported that direct funding of the agencies has barely grown in real terms over the past 25 years, compared with relatively strong growth for other components of funding. This has caused a challenging operating environment and pressures for the PFRAs - especially the major agencies - in terms of funding arrangements for capital and depreciation, acquisition of technology assets and upgrade and maintenance of facilities (including scientific equipment and information technology infrastructure), which are critical to quality research endeavour and application.

GOVERNMENT INVESTMENT RELATIVE TO OTHER PARTICIPANTS

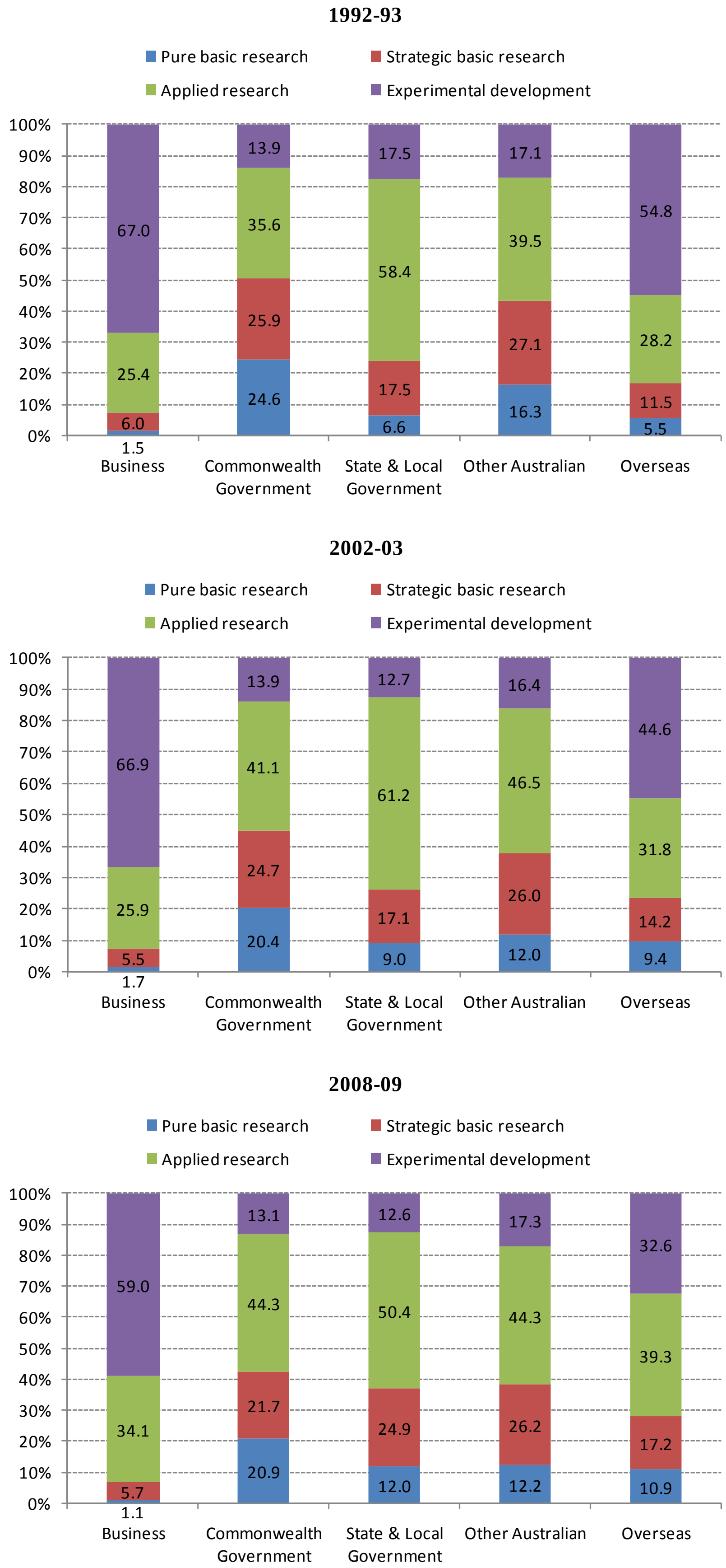
The roles of the various participants in the national research system are illustrated by the scale and focus of their investment in research. In terms of investment, the Australian Government and business are the major funders of research with other sources, including state, territory and local governments, minor and declining in share.

A summary of the type of activity in percentage of expenditure by source of funding at 1992-93; 2002-03 (i.e. data used in Productivity Commission Report, 2007); and 2008-09 is presented in **Figure 5**. (Note: this data was produced by applying the method adopted in the Productivity Commission report to analyse ABS data). Business, the Australian Government and Overseas funders of Australian R&D have all increased their emphasis on applied research, at the expense of basic research and/or experimental development. By contrast, the State & Local Government sector has increased its emphasis on basic research, at the expense of applied research.

In terms of expenditure on research, overall effort is concentrated in a small number of Fields of Research (FoR), particularly *Engineering* and *Information & Computing Sciences* (largely business expenditure) and *Medical and Health Sciences*. Commonwealth Government priorities are strongly focussed on areas of direct public good where risks and lengthy development timelines often discourage business investment, such as *Medical and Health Sciences* and the *Biological Sciences* as well as *Engineering*. It should also be noted that most higher education research is Commonwealth funded. The states place most of their investment in *Agricultural and Veterinary Sciences* and *Medical and Health Sciences*. **Table 5** presents a summary of investment by sector of performance.

Further evidence relating of source of funding, sector of performance and type of activity can be found in **Appendix A – Sections 2.1, 2.2 and 2.3** respectively.

Figure 5: Type of Activity as Percentage of Expenditure by Source of Funding: 1992-93 vs 2002-03 vs 2008-09



Source: Review Taskforce (2011) – applying Productivity Commission (2006) methodology to ABS 8112.0 (2010) data

Table 5: Gross expenditure on R&D ($'000), by sector–by field of research, 2008–09

		GOVERNMENT					
Field of research	Business	Commonwealth	State/territory	Total	Higher education	Private non-profit	TOTAL
Engineering	9,118,212	597,031	13,731	610,762	577,160		10,306,134
Information & computing sciences	4,407,485	260,948	29,570	290,518	218,206		4,916,209
Medical & health sciences	938,374	82,818	368,731	451,549	2,064,348	559,338	4,013,609
Biological sciences	73,342	210,299	100,837	311,136	688,892	117,259	1,190,629
Agricultural & veterinary sciences	361,604	131,095	413,896	544,992	278,811	961	1,186,367
Technology	807,491	112,979	14,128	127,107	170,261	6,214	1,111,073
Chemical sciences	273,379	129,067	2,959	132,025	252,727		658,132
Environmental sciences	171,767	138,253	139,453	277,706	191,111	6,578	647,162
Earth sciences	196,425	193,650	45,772	239,422	194,548		630,395
Physical sciences	19,221	211,087	129	211,215	224,415	0	454,852
Built environment & design	319,252	13,864	1,575	15,439	68,925		403,616
Studies in human society		38,905	10,812	49,716	326,775	5,462	381,954
Commerce, management, tourism & services	100,862	1,958	3,143	5,101	253,793		359,756
Education	12,768	3,373	10,563	13,935	210,112		236,816
Psychology & cognitive sciences	4,088	19,035	3,389	22,424	199,480	6,700	232,692
Economics	12,229	36,076	2,506	38,582	162,719		213,530
Mathematical sciences	24,327	54,749	1,068	55,817	132,378		212,522
Language, communication & culture	1,627	32	2,263	2,295	161,510		165,432
History & archaeology		4,124	2,240	6,364	118,763	0	125,127
Law & legal studies	5,199	12,474	9	12,483	85,502		103,184
Studies in creative arts & writing	9,448	124	1,558	1,682	82,681		93,811
Philosophy & religious studies	0	0	196	196	53,994		54,190
Total expenditure on R&D	**16,858,477**	**2,251,941**	**1,168,527**	**3,420,468**	**6,717,113**	**743,907**	**27,739,965**

Source: ABS 8112.0 (2010)

Note: Blank cells are annotated by ABS as "not available for publication but included in totals where applicable, unless otherwise indicated"; these have been treated for this Paper as zero in the TOTAL column, with an overall anomaly thereby of $42.8 million (undercount compared to the ABS grand total)

FUNDING ALLOCATION MECHANISMS

The Australian Government invests in research through a number of mechanisms including through block grants, untied appropriations and competitive funding to higher education institutions and research agencies, and co-investment with industry, for example, CRCs and RDCs.

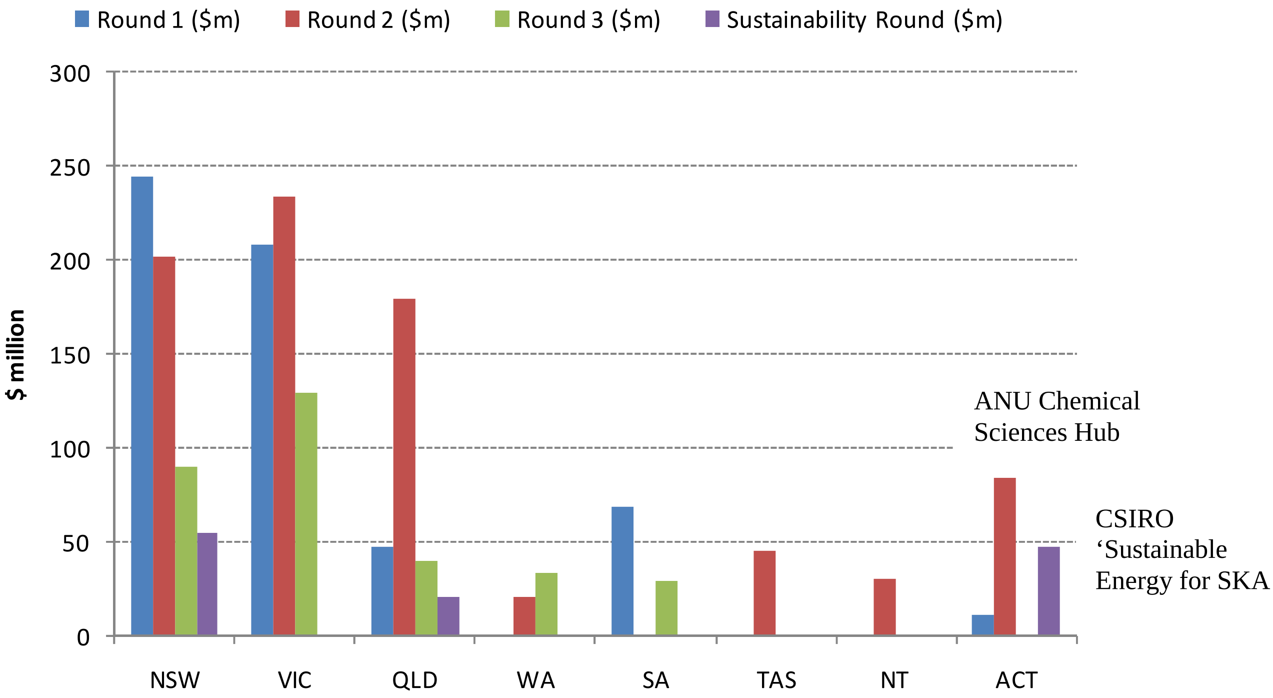
The government has a dual support system for funding of research by higher education institutions comprising Research Block Grants and competitive research grant programs. The Research Block Grants are allocated directly to eligible higher education institutions, using a combination of metrics, primarily to support systemic research capacity. Research Block Grants also help higher education institutions meet the indirect costs of their Australian competitive grants research through the Sustainable Research Excellence and Research Infrastructure Block Grant schemes. The competitive research grant programs, particularly those programs administered by the ARC and the NHMRC, primarily support investigator-led world class innovative research with a range of programs structured to encourage collaboration. Both the ARC and NHMRC have broader roles, including support for collaborations and partnerships, building research scale and focus, and for the translation of research outcomes. Other government departments also administer competitive grant (and other) research programs. In addition, state and territory governments administer their own research budgets, often including competitive programs in addition to untied grants and departmental allocations.

As well as direct investment in university research, the government is also instrumental in laying the foundations that sustain Australia's future research workforce through ongoing support for the higher education institutions that impart knowledge and skills to future generations and the infrastructure that enables both research and learning outcomes. Investment in the higher education teaching workforce, delivered through the Commonwealth Grant Scheme and other teaching and learning grants, is particularly important in this context, as it is this workforce which ultimately trains and develops future generations of researchers for all sectors in the Australian economy.

The government is the primary source of direct funding for the major research agencies (e.g. CSIRO, DSTO, ANSTO, AIMS, AIATSIS, Geosciences Australia, and AAD).

In addition to the untied and competitive research funding to universities and PFRAs, the government has also invested in research infrastructure through the Education Investment Fund (EIF) and other infrastructure initiatives. **Figure 6** shows the breakdown of the successful higher education and research projects under EIF Rounds 1, 2, 3 and the Sustainability Round by location. Long-term planning of infrastructure, facilitated by processes such as the one currently being progressed to develop a Strategic Framework for Research Infrastructure Investment, is also critical.

Figure 6: Successful EIF higher education and research projects by location



Source: Review Taskforce, 2011 using DEEWR published data at
http://www.deewr.gov.au/HigherEducation/Programs/EIF/Pages/FundingRounds.aspx

Funding to promote collaboration between the public and private sectors is a priority and the government's support for, in particular, the CRCs and the CSIRO Flagships Fund, is important in this regard (see **Box 5**). Benefits include identification of opportunities and needs; exchange of ideas and expertise; and development of networks. Factors such as high transaction costs (both financial and effort related) can act as deterrents to collaborative processes, and thus reduce the volume and quality of collaborations occurring, and government programs and business models need to be cognisant of these factors.

BOX 5: ROLE AND IMPACT OF THE CRCS IN AUSTRALIA'S RESEARCH SYSTEM

The CRCs are a long-standing feature of Australia's research system[8] and one of the Australian Government's main programs to drive collaboration between universities and industry. An example of deep collaboration and wider impact – beyond academic publishing – is illustrated by the CRC for Freshwater Ecology, where the CRC provided the conduit for the technical knowledge and research of Professor Peter Cullen and colleagues to influence policy and culture in regards to Australia's waterways. The strong connection between the CRC and the University of Canberra's Institute of Applied Ecology is also regarded as a critical factor in the development of the university's applied ecology research into a high performing research centre as measured by the 2010 Excellence in Research for Australia round. In general, CRCs are regarded as being able to support research over longer timescales, sustain multiple collaborations and help universities to maximise their impact.

Source: Shannon, 2011, CRC Association News

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8 Nature (1995) reported on the Australian research system, noting that "on the principle that the best investments are in success, it would be a great misfortune if the government were to turn its back on CRCs. Whatever happens to this brave experiment in Australia, there is every likelihood that it will be copied everywhere. Or it should be".

The government also co-invests with industry in support of rural R&D through RDCs. The RDC model helps to ensure that public money is not spent on research of little practical value and facilitates greater and faster uptake of research outputs.

Finally, by directly stimulating R&D investment and activity and maintaining the stable macroeconomic conditions that ultimately enable research and innovation to flourish, the government contributes to demand for research skills across the economy. R&D grants and taxation incentives are important elements of this mix, as without such government stimulus, market failures that discourage private investment in research (such as access to seed funding for innovative but high risk projects) and that reduce demand for and utilisation of research skills would not be overcome. In the 2009-10 Budget, the government announced that it would replace the existing R&D Tax Concession with a simplified tax incentive program. The intent of introducing the new R&D Tax Incentive is to:

- encourage more companies to undertake R&D activities;
- increase financial support to companies who conduct eligible R&D activities;
- provide support to companies who are in tax loss through cash refunds;
- redistribute support in favour of SMEs, which are more responsive to fiscal incentives;
- support all eligible R&D undertaken in Australia, regardless of where the intellectual property is owned;
- decouple the incentive from the company tax rate; and
- increase certainty through simpler and improved administrative processes.

Government also needs to ensure that the operation of its legislative requirements do not hinder or act as barriers to innovation, for example, Intellectual Property (IP) requirements. The government’s Advisory Council on IP is currently investigating whether IP is an enabler or dis-enabler of collaboration between the private and public sectors.

4.4. AUSTRALIA'S RESEARCH PERFORMANCE

HOW AUSTRALIA PERFORMS INTERNATIONALLY

Scientific publications are one of the major outputs of the R&D system. Citations for these publications are the best available measure of research quality (often referred to as 'citation impact'). The Thomson Reuters InCites database, based upon their Web of Science (WOS) database provides reports on peer-reviewed publications[9]. Important derived measures for publications used in this analysis are:

- Relative Impact (number of citations per publication as a ratio of world average);
- Publications per thousand population; and
- Percentage of publications produced through international collaboration[10].

Table 6 presents publications and citation data for the world top ten. In 2008, Australia was ranked 11th in the world and relative to the top 10 average has a higher relative impact, a greater proportion of publications per thousand population and a higher percentage of publications produced through international collaborations.

Table 6: Top Ten Nations by Publications (2008)

Country	Rank	Publications	Relative impact	Publications per thousand population	Percentage produced by international collaboration
United States	1	340,493	1.44	1.12	27
China	2	103,780	0.79	0.08	22
United Kingdom	3	91,226	1.44	1.49	45
Germany	4	87,433	1.42	1.06	44
Japan	5	79,515	1.02	0.62	24
France	6	64,515	1.25	1.01	47
Canada	7	53,286	1.31	1.60	44
Italy	8	50,367	1.26	0.84	38
Spain	9	41,990	1.13	0.92	38
India	10	38,697	0.63	0.03	18
Top ten average	N/A	*95,130*	*1.17*	*0.88*	*35*
Australia	**11**	*36,793*	*1.23*	*1.70*	*43*
OECD total	N/A	*848,708*	*1.13*	*0.70*	*N/A*
World total	N/A	*1,158,057*	*1.00*	*0.17*	*N/A*

Source: Review Taskforce, 2011

9 Coverage differs in the two main publications databases, Thomson Reuter's Web of Science and Elsevier's Scopus, but studies have shown that the results are sufficiently correlated that either may be used with reasonable confidence for national and discipline level studies of major science producers like Australia.

10 That is, publications with authors' addresses in at least two countries.

Against the comparator countries, Australia's performance was as follows:

- *Publications:* Canada, followed by Spain, leads in total publications amongst the comparator countries. Korea is overtaking Australia[11], with both just out of the top ten. Korea's 14-fold growth of more than 33,000 publications was the most dramatic, while most of the high output countries have seen doubling or better (Australia's output rose 146%).
- *Relative Impact:* The pattern in Relative Impact is almost a parallel upward trend for all comparator countries, particularly from 2002. This is partly due to the great increase in publications from countries such as Brazil, India and especially China, which have not yet achieved impacts as high as traditional science producers. The north-western European countries do very well, and Canada and Australia also do well on this measure.
- *Publications per Thousand Population:* Sweden leads in publications per thousand capita population, closely followed by the Netherlands, Australia, Canada and Belgium. The growth patterns in most countries are quite similar, although Canada saw a decline to 2002 followed by a rise more in line with the rest, and the smallest producers have seen slowest growth. It is worth noting that Switzerland leads the world on this measure[12], with 2.73 publications per thousand population.
- *Percentage Produced by International Collaboration:* North-western European countries, led by Belgium, and South Africa, produce the highest proportion of Collaborative Publications. Most countries, including Australia, have seen significant rises in international collaboration since 1992, although there are exceptions (Poland, Ukraine, Malaysia all declined from 2002). The USA, China, Japan and India tend to have lower collaboration levels, while EU efforts to promote collaboration are clearly effective.

The analyses for the comparator countries are provided in **Appendix A - Graphs 1.3.1 – 1.3.5**.

RESEARCH PERFORMANCE BY INSTITUTION

Batterham (2011) reports on a ten year analysis of the top ten institutions in Australia ranked on the basis of total publications and citations listed in the Thomson ISI Essential Science Indicators. His analysis demonstrates that Australian institutions perform significantly better than the global average and confirms CSIRO analysis that CSIRO is the only Australian institution ranked in the top ten institutions in the world in any research field (CSIRO achieves this in three fields; only 18 institutions make the top ten in more than three fields). He also notes that there are some smaller prestigious institutions, including MRIs, performing above world standards.

CSIRO has also analysed its citation performance relative to leading Australian universities and the highest performing institutions globally (**Figures 7** and **8**). For CSIRO's main research fields, its citation rate is, in most cases [13,] similar to the leading Australian university in the field.

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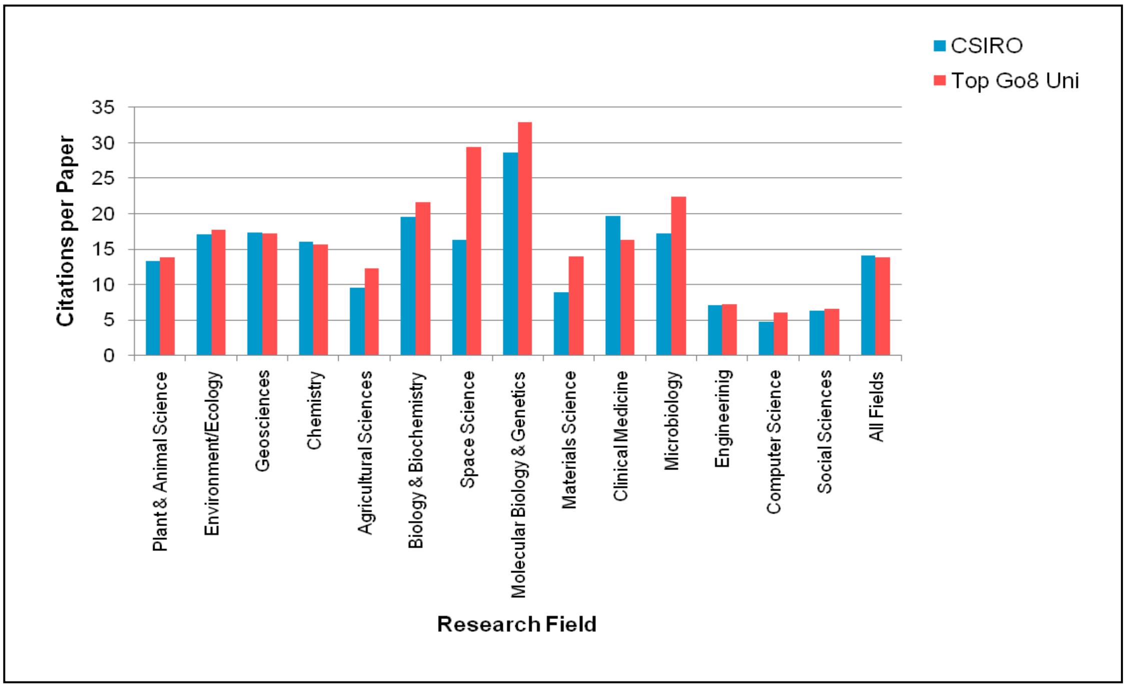
11 According to InCites data, Korea overtook Australia in 2009, with 38,651 publications compared to 38,599. Scopus data shows little difference in output since 2005, with Korea trending slowly ahead.

12 With the exception of the Vatican, with a tiny output but proportionally even smaller population.

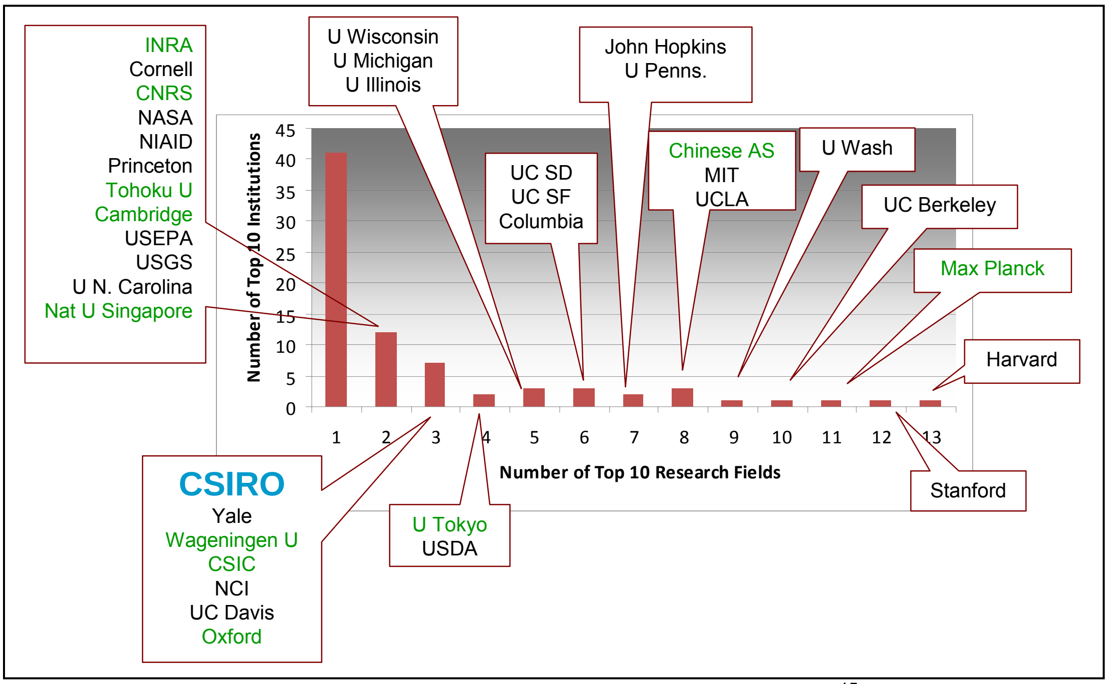
13 Note the discipline of Space Science covers a number of sub-fields of which CSIRO is only active in one (Radioastronomy).

Figure 7: CSIRO versus Australia's Leading Universities (Citations per Paper)



Source: Analysis prepared by CSIRO using the Thompson-Reuters/ISI Essential Science Indicators[14] database for a 10 year period of publications

Figure 8: Number of Fields for which Institutions are in Global Top Ten (Total Citations)



Source: Analysis prepared by CSIRO using the Thompson-Reuters/ISI Essential Science Indicators[15] database for a 10 year period of publications

14 Similar but not identical data are obtained from the SCImago Institutions rankings.

15 Similar but not identical data are obtained from the SCImago Institutions rankings.

To further the analysis of research performance by institution, the Review Taskforce commissioned Elsevier Science and Technology (2011) to undertake bibliometric analyses based on SciVerse Scopus data to focus on publications and citations for the top performing institutions by sector (universities, PFRAs and MRIs) in each year over the period 2005 to 2010. These analyses showed that:

- despite a few minor drops in individual institutional output from one year to the next, the general trend for all the top institutions (even those with small total outputs like MRIs) is a steadily increasing output of publications;
- at the sectoral level, publications output rankings are very stable over time; and
- although citations rankings (and hence citation impact) vary somewhat more than publications, when the effects of small data sets are removed the pattern is fairly consistent over time.

From the Elsevier Science and Technology (2011) analyses:

- *Publications Output by Sector:* For each year from 2005 to 2010, the University of Sydney had the highest publications output, followed by the University of Melbourne, University of Queensland, University of NSW and Monash University. This order did not vary in any year.

  CSIRO, not unexpectedly, dominated the PFRA output, with about ten times the publications per year of ANSTO and DSTO. While ANSTO had exactly the same number of publications as DSTO in 2005, it has since drawn slowly ahead in output. While the Elsevier data did not include other PFRAs such as AIMS, SARDI[16] or Geoscience Australia, Web of Science data (not directly comparable but useful for ranking and percentage comparisons) showed these three PFRAs with outputs of the same order of magnitude as ANSTO and DSTO (generally in the order ANSTO, AIMS, SARDI, Geoscience Australia, DSTO, particularly in recent years).

  While the MRIs had smaller outputs than the leading universities, the output of the most prolific MRIs was similar to (a little higher than) that of the non-CSIRO PFRAs. The same five MRIs were usually the top five in annual output: Queensland Institute of Medical Research, Peter MacCallum Cancer Centre, Baker Heart Research Institute, Garvan Institute of Medical Research and Menzies School of Health Research, usually in that order. The top two were in the opposite order 2005-2007, and the minor placings have changed on occasion, but the order was nearly as stable as that of the university sector.

- *Citation Impact by Sector:* Citation Impact (citations per paper) is susceptible to skewing from a small output of highly cited papers. However, even with this effect, the general pattern of citation impact is fairly stable from year to year.

  The University of Melbourne, followed by the University of Queensland, led Australia's university citation impact. The University of Western Australia and University of Sydney were usually in the top five, with the rest of the Go8 universities swapping places just in or just out of the top five in most years. Other universities made appearances in the top five for a single year (sometimes with small outputs of highly cited publications), and it should be noted that in many years the difference between 5th and 10th was less than 1 citation per paper or 15%. IRU members, particularly James Cook University, usually made up the remainder of the top ten with the Go8 (when outputs of fewer than 200 publications were excluded).

  CSIRO generally achieved citation impact comparable with the Go8 universities, which is confirmed by numerous other studies[17]. The impact of other PFRAs (except for AIMS, a stand-out achiever that often outperformed CSIRO in the WOS data) was usually much lower, often because of their tightly focused

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16 SARDI has been selected to represent State and Territory PFRAs due to its reasonably prolific output for a PFRA (as recorded in WOS), the fact that it is from a medium sized jurisdiction, and the fact that it has strong end user focus in much of its research.

17 Many of these other studies used WOS data rather than Scopus data. While the numbers are not identical, the general patterns are consistent across the two data sources.

research efforts, both in field of science (e.g. nuclear science and technology for ANSTO) and emphasis on end user needs rather than academic impact. ANSTO's impact was usually about 30% behind CSIRO's (varying from 10% to over 40%) and DSTO's about 50% (varies from 40% to 60%). There were some annual spikes in citation impact for particular small PFRAs, which was a symptom of the small datasets involved.

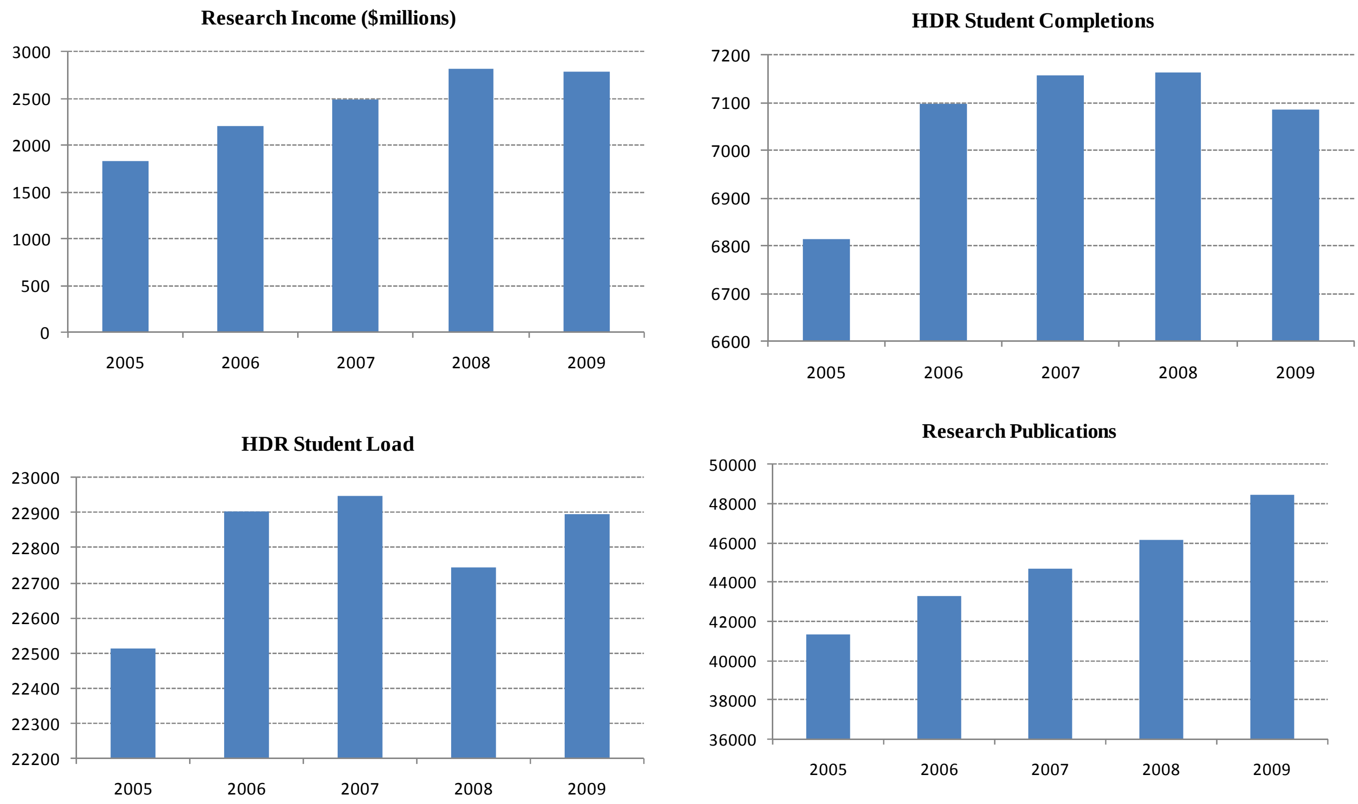
The citation impact rates for MRIs were generally three to four times that of the best performers amongst the less specialised institutions like CSIRO and Go8 universities, with some MRIs in some years even higher[18]. This was partly because medical researchers are known to "publish often and cite often", but also reflects the focus and quality of the top MRIs. While the most prolific MRIs were achieving high impact, there were some with smaller output that often achieved even greater impact. Notably, while the top five MRIs for citation impact in the six years covered in the Elsevier data varied considerably (generally within a set of about ten institutes) due to small datasets, the Heart Research Institute and the Walter and Eliza Hall Institute of Medical Research each appeared in the top five in five of those six years.

18 In 2007, Woolcock Institute of Medical Research was 27% ahead of the second ranked MRI in impact, and achieved 5.7 times the citation impact of the University of Melbourne, which was itself 11.5% ahead of the second ranked university in impact.

RESEARCH PRODUCTIVITY OF UNIVERSITIES

In terms of institutional performance, data is also collected on an annual basis by government from Australia's higher education institutions on a range of research output and quality measures including research income, research publications, and higher degree by research student load and completions, which feed into the research block grant funding formulas (DIISR, 2011d). The productivity of the Australian higher education sector has generally increased over time, particularly in terms of numbers of research publications and research income; see **Figure 9**.

Figure 9: Higher Education Research Data Collection, 2005 to 2009



Source: Review Taskforce (2011) using HERDC data available at www.innovation.gov.au

RESEARCH BY DISCIPLINE PERFORMANCE

In addition to assessing institutional performance, there is increasing recognition of the importance of examining research performance within universities at the disciplinary level. For example, Valadkhani and Ville (2010) have demonstrated that when examining research performance in Australia, an institution may perform very well at an aggregate level but not so well in a particular discipline (e.g. Commerce) or vice versa.

Australia now has evidence of the performance of research undertaken within disciplines across 40 of Australia's 41 higher education institutions. The 2010 Excellence in Research for Australia (ERA) (ARC, 2011) exercise provides a robust assessment of research excellence across the full spectrum of research performance in discipline areas.

ERA ratings were informed by four broad categories of indicators:

- *Research quality* – ranked outlets, citation analyses, ERA peer review, and peer-reviewed Australian and international research income
- *Research volume and activity* – total research outputs, research income and other research items within the context of the profile of eligible researchers
- *Research application* – research commercialisation income and other applied measures
- *Recognition* – a range of esteem measures.

For the ERA indicators involving journals and citation metrics, international and national benchmarks were developed for specific Fields of Research (FoR). In the case of citation benchmarks, these were also created specifically for publication years.

The ERA process evaluated disciplines across eight clusters:

Physical, Chemical and Earth Sciences	Mathematical, Information and Computing Sciences
Humanities and Creative Arts	Biological and Biotechnological Sciences
Engineering and Environmental Sciences	Biomedical and Clinical Heath Sciences
Social, Behavioural and Economic Sciences	Public and Allied Health Sciences

The ERA rating scale was:

5	Well above world standard
4	Above world standard
3	At world standard
2	Below world standard
1	Well below world standard
N/A	Not assessed due to low volume

Approximately 65 per cent of the units of evaluation assessed in ERA 2010 were rated at world standard or above (i.e. received 3s, 4s or 5s). The sector-wide ERA performance at the 4-digit FoR level by Discipline Cluster is provided in **Figure 10**. There were 1179 units of evaluation at the 4 digit level (68 per cent) and 413 units of evaluation (59 per cent) at the 2 digit level that were at world standard or above.

The ERA 2010 results also provide evidence of the selectivity and concentration of world-class research areas in Australian universities. **Box 6** highlights some of the strengths of Australian universities from an ERA perspective.

Box 6: Strengths in Australian Universities

■ Astronomical and Space Sciences	■ Electrical and Electronic Engineering
■ Optical Physics	■ Historical Studies
■ Quantum Physics	■ Cardiovascular Medicine and Haematology
■ Macromolecular & Materials Chemistry	■ Human Movement and Sports Science
■ Physical & Structural Chemistry	■ Immunology
■ Geology	■ Oncology and Carcinogenesis
■ Ecology	■ Pharmacology and Pharmaceutical Sciences
■ Evolutionary Biology	■ Medical Physiology
■ Plant Biology	
■ Zoology	

Source: ARC, 2011

The ERA 2010 results further suggest the benefits of collaboration on research performance, with many examples of disciplines with high levels of CRC income that performed above world standard. A more detailed mapping would be required, however, to trace the precise impact of individual CRCs. See **Figure 11**.

Further evidence of discipline analysis of Australian R&D, including in relation to ERA ratings can be found in **Appendix A – Section 3**.

PATENTS

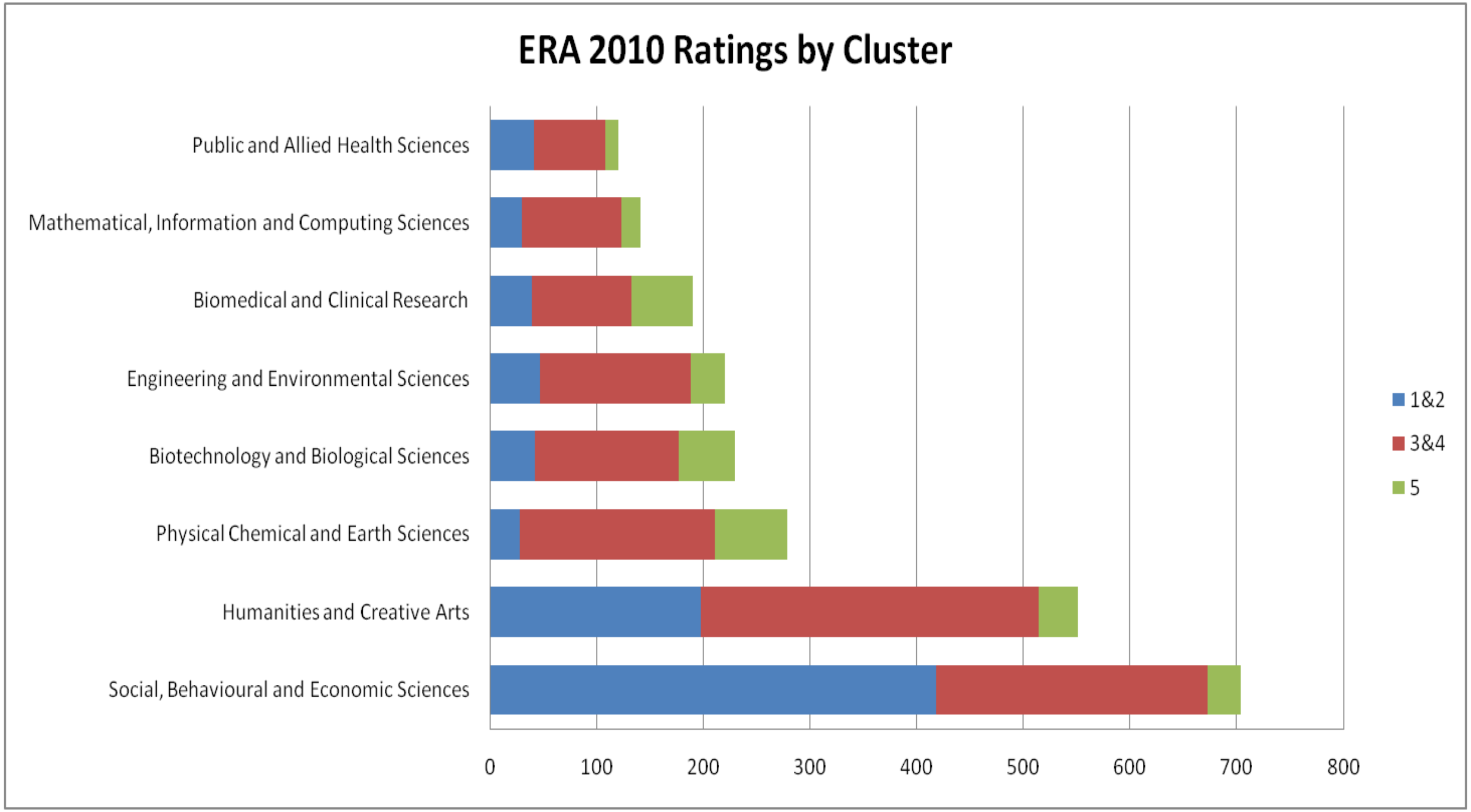
In addition to scientific publications and their citations, which measure academic outputs and outcomes of research, patents are a measure of the commercial and industrial outputs and outcomes of R&D. The OECD often reports registrations of triadic patent families (TPFs)[19] as the major international measure of patenting performance. Important derived measures for publications used in this analysis are:

- Percentage of world triadic patent families (registered in a year)
- Triadic patent families per million capita population.

Table 7 presents triadic patent family data for the world top ten.

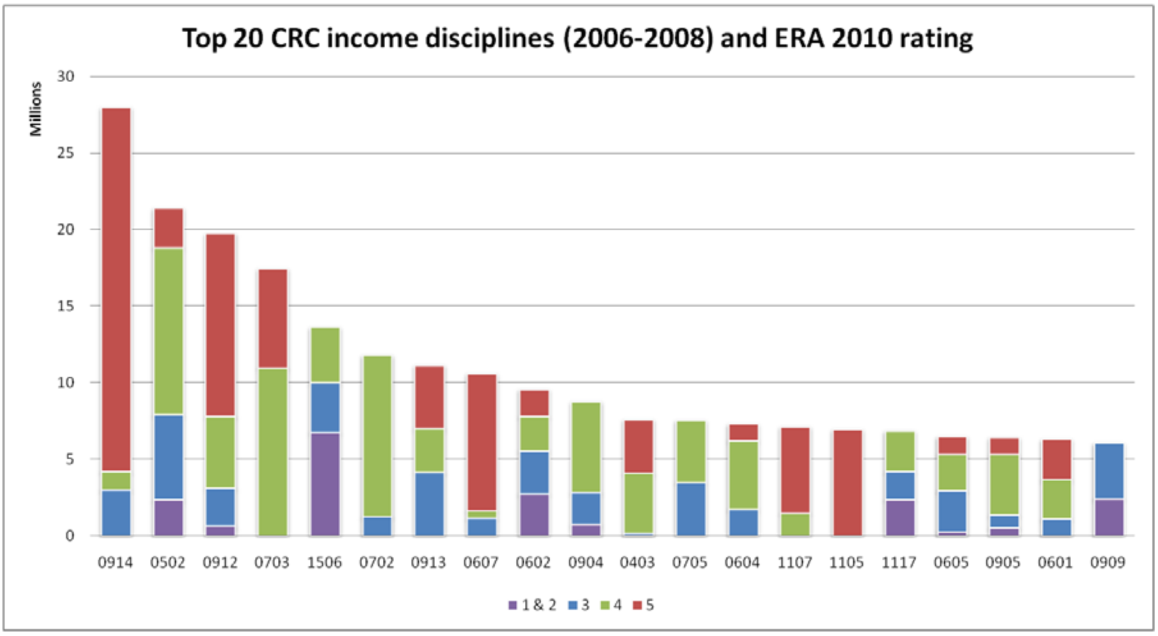
19 A TPF, as measured by the OECD, is a set of patents filed for at the European Patent Office (EPO), the Japan Patent Office (JPO), and granted by the US Patent and Trademark Office (USPTO), to protect the same invention. Note that China, which is now one of the world leaders in single-country patents, had not yet reached the top ten in TPFs in 2008 (473 put China in 12th behind Canada with 609 in 11th), but if China hasn't reached the top ten by 2011 it will probably do so in the near future.

Figure 10: ERA 2010 Ratings by Cluster



Source: ARC 2011

Figure 11: ERA 2010 Potential Benefits of Collaboration on Research Performance



Source: ARC, 2011

Table 7: Top Ten Nations by Triadic Patent Families in 2008

Country	Rank	Triadic patent families	Percentage of world TPFs	TPFs per million capita population
United States	1	14,399	30.03	47.23
Japan	2	13,446	28.04	105.45
Germany	3	5,875	12.25	71.54
France	4	2,423	5.05	37.78
Korea	5	2,006	4.18	41.27
United Kingdom	6	1,621	3.38	26.41
Netherlands	7	979	2.04	59.57
Sweden	8	948	1.98	102.37
Switzerland	9	838	1.75	108.68
Italy	10	730	1.52	12.20
Top ten average	*N/A*	*N/A*	*N/A*	*61.25*
Australia	***18***	***297***	***0.62***	***13.72***
OECD total	*N/A*	*46,691*	*97.38*	*38.35*

Source: Review Taskforce, 2011

Australia's performance against the comparator nations (except for Malaysia and Ukraine for which no TPF data was available) is as follows:

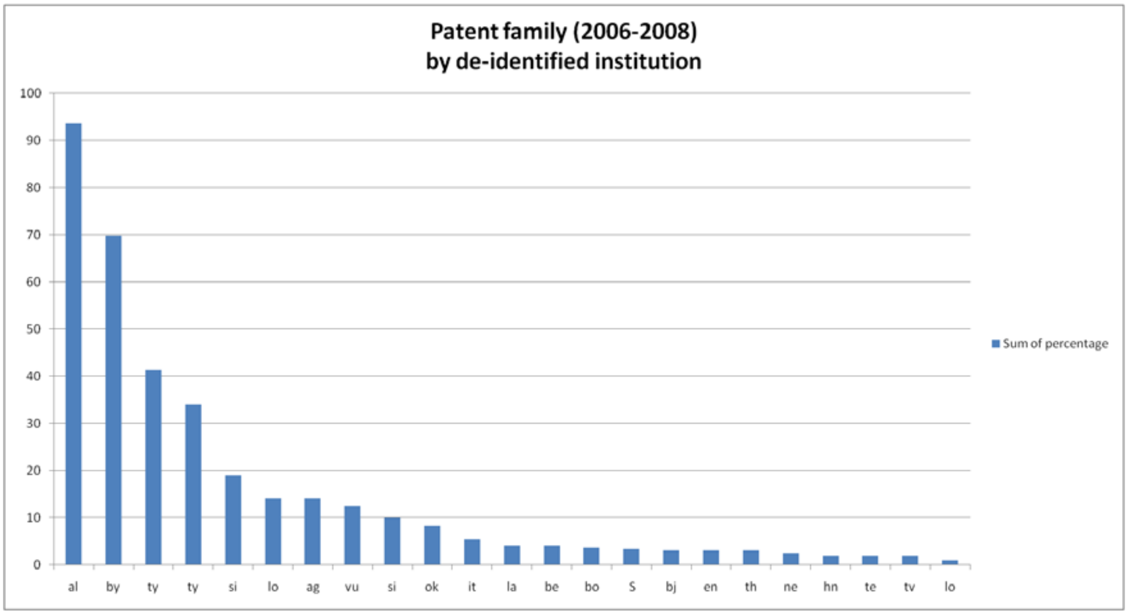
- *Percentage of World TPFs:* Korea, which achieved the fifth highest TPF registrations in the world in 2008, is the clear leader in percentage of world TPFs in the comparator countries, with dramatic growth since 1992. Australia is well down in sixth position (18th globally, behind smaller countries including Austria, Denmark and Finland) and has remained essentially static across the period, with 2002 slightly higher than 1992 and 2008 (note that annual figures for most countries outside the top ten are small and volatile). Spain and Chinese Taipei are rapidly catching up to Australia.

- *TPFs per Million Capita Population:* Sweden (second in the world behind Switzerland and ahead of Japan on this measure) leads by a long way from the Netherlands, with another large gap to Korea and Belgium. Both Sweden and Korea have seen strong growth, while Australia has not progressed.

Within the Australian research system, universities tend to have less demonstrated capability in the translation of research results into new products and processes, as measured by patents, although there are a small number of institutions which have greater capability in this respect. See Figure 12.

The analyses for the comparator countries are provided in **Appendix A – Graphs 1.4.1 -1.4.2**.

Figure 12: ERA 2010 Patent Family by de-identified institution, 2006 to 2008



Source: ARC, 2011

OTHER MEASURES OF THE WIDER BENEFITS OF RESEARCH

To fully understand the nature of the dividend being derived from the government's investment in research, there is a need for a broader evidence base spanning the wider benefits of research. In addition to the metrics described above, there are a range of other measures of performance available to assist our understanding of the performance of Australia's publicly funded research sector. Some of these are provided in: the *Australian Innovation System Report* (DIISR, 2010a); in a range of other review and evaluation reports prepared by research agencies including for example CSIRO (ACIL Tasman, 2006; ACIL Tasman, 2009; Centre for International Economics, 2001) and rural RDCs (Productivity Commission, 2010) and; in other surveys of for example the commercial and economic value of patents (Jensen, Thomson & Yong, 2009).

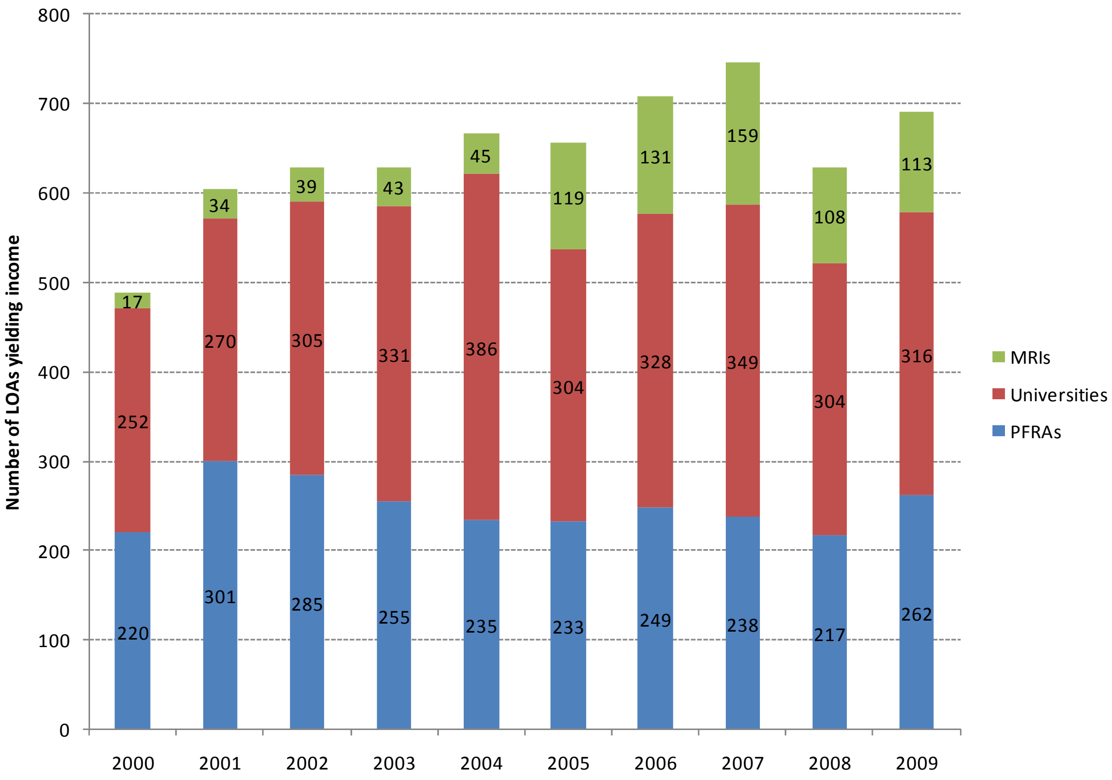
The National Survey of Research Commercialisation is a survey of research commercialisation inputs, activity and outputs for Australian publicly funded research organisations (universities, PFRAs and a range of MRIs). It typically surveys approximately 70 institutions, undertaken on a biennial basis, and the metrics addressed are:

- numbers of research commercialisation staff employed and associated costs;
- levels of patenting activity (filings, grants and holdings);
- volume and value of licensing, optioning and/or the assigning of intellectual property;
- numbers of start-up companies launched and continuing, and the value of associated equity holdings;
- volume and value of contract research and consultancy activity; and

- research commercialisation training inputs and outputs[20].

The current (and fifth iteration) survey 2008 and 2009 shows the public research sector with somewhat poorer financial returns compared with previous years, but with sustained interest in commercialisation and a growing reservoir of IP to support commercialisation activity into the future. A small number of institutions accounted for the majority of patenting activity, and most notably CSIRO (which filed the largest number of new applications for a single institution in the two survey years). A small number of institutions also accounted for the majority (up to 75 per cent) of Licences, Options and Assignments (LOAs) activity. For the PFRAs, the number of LOAs yielding income remained high by reference to the university sector, averaging approximately 80 per cent of that reported for all universities between 2000 and 2009; see **Figure 13**. This outcome indicates, in particular, the importance of CSIRO as a contributor to research commercialisation throughout the last decade (DIISR, 2011e).

Figure 13: Number of LOAs yielding income by sector, 2000 to 2009



Source: DIISR, 2011e

CSIRO has commenced the Impact 2020 project, with the goal to increase the visibility of the agency's future impact pipeline for the next ten to twenty years. The Australian National Audit Office recently reported on the development and administration of the CSIRO National Research Flagships, noting that "while there is evidence that the research of the selected Flagships has influenced policy and investment decisions by government, CSIRO does not have in place systematic processes for measuring the impact of Flagship research" (ANAO, 2011). The RDCs are also undertaking work in terms of how to better evaluate the impact of their R&D investments, and in particular, in regards to a more consistent measurement of environmental and social benefits (noting that not all results are amenable to economic evaluation using current methodologies).

Overall, however, there is no systematic process of measuring the broader economic, social and environmental benefits of publicly funded research undertaken across the publicly funded research system as a whole.

20 Starting with the third iteration of the survey.

4.5. HUMAN CAPITAL DEVELOPMENT

HOW AUSTRALIA PERFORMS INTERNATIONALLY

As set out above, one of the purposes of investment in university research is human capital development. Number of researchers[21] is the primary measure of human resources input to the R&D system. Both the OECD and UNESCO usually report researcher numbers expressed in Full-Time Equivalent (FTE) terms. For the purpose of the Review, the most useful derived measure, which normalises for the effect of population size, is Researchers per thousand labour force. The breakdown of researcher numbers by Business Enterprise, Government and Higher Education sectors is also available for many countries[22].

Total Researchers, the sectoral breakdowns, and Researchers per thousand labour force for the world top ten are shown in **Table 8**. Australia has a higher proportion of Researchers per thousand labour force than the average of the top 10 countries and the average for all OECD countries.

In terms of Australia's performance relative to the comparison group:

- *Total Research Workforce:* Korea has the largest total research workforce in the comparison set, with nearly 100,000 more researchers (FTE) than second-placed Canada. Both these countries are in the world top ten for research workforce. Australia, fifth on the list, has witnessed modest growth.
- *FTE per Thousand Labour Force:* Chinese Taipei has overtaken Sweden, with both just ahead of Korea, in the number of researchers per thousand labour force**.** Australia, with a smaller total research workforce than Canada and Spain, moves ahead of them in this ratio measure.
- *Research Workforce Composition***:** In Australia (like the UK), the majority of the research workforce is in higher education, and for Australia, the higher education sector has also led growth in researcher numbers. However, the business sector is dominant in the largest workforces, Korea, Canada and Chinese Taipei, as well as Sweden and the Netherlands, and has led their growth. Coincidentally or otherwise, these countries are also leaders or emerging leaders in R&D outputs, especially in triadic patent families (TPFs). Argentina has a proportionately large government research workforce, and Belgium, South Africa and Sweden have almost none.

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21 The definition of Researcher is "those involved in the conception and/or development of new products/processes", including postgraduate students. It is not dependent on qualifications held.

22 Note that these numbers will not always equal the national total due to other small sectors (e.g. Private Non-Profit) employing researchers in some nations, including Australia.

Table 8: Top Ten Nations by Researchers (FTE) in 2008

Country	Rank	Researchers (FTE)	FTE per thousand labour force	Business Researchers (FTE)	Higher Education Researchers (FTE)	Government Researchers (FTE)
China	1	1,592,420	2.0	1,092,213	261,237	238,970
United States23	2	1,412,639	9.2	N/A	N/A	N/A
Japan	3	656,676	9.9	492,805	123,549	32,050
Russian Federation	4	451,213	6.0	226,534	76,797	145,988
Germany	5	302,467	7.3	180,295	76,831	45,342
United Kingdom	6	251,932	8.1	86,106	152,551	8,695
Korea	7	236,137	9.7	182,901	34,773	15,552
France	8	229,130	8.2	129,824	68,897	27,372
India[24]	9	154,827	N/A	N/A	N/A	N/A
Canada[23]	10	142,948	7.9	86,368	47,310	8,720
Top ten average	*N/A*	*N/A*	*7.6*	*N/A*	*N/A*	*N/A*
Australia	***14***	***91,617***	***8.1***	***26,941***	***53,340***	***8,285***
OECD total	*N/A*	*4,156,371*[25]	*7.1*	*N/A*	*N/A*	*N/A*

Source: Review Taskforce, 2011 [NOTE: Some fields have been left blank as an analysis was not considered appropriate].

As indicated in **Table 8**, Australia's research workforce contrasts with that of other countries, which on average have a greater proportion of their researcher workforce in the business enterprise sector. As explained in the *Research Skills for an Innovative Future* report (DIISR, 2011a, p 3), these compositional differences are likely to reflect a range of factors, including: the structure of our economy, which is dominated by SMEs (approximately 99.7 per cent of all businesses) including a significant base in the services sector; the focus of our R&D effort, which has a lower technology intensity than other countries in key sectors such as manufacturing; and above OECD average levels of business funded R&D in the higher education and government sectors. There is, however, an increased focus by the government to support better matching of researcher knowledge and skills to business needs, and to promote greater interaction, albeit at a small scale, for example, through the Enterprise Connect Researchers in Business program and the Australian Technology Network (ATN) Industry Doctoral Training Centre. In addition, one of the objectives of the ARC's Linkage Projects scheme is to offer opportunities for postdoctoral researchers to pursue internationally competitive research in collaboration with organisations outside the higher education sector.

The ATN Industry Doctoral Training Centre (Mathematics) pilot will be a national first, with all PhD projects undertaken to have an industry context and emphasis on formally incorporating more relevant industry leadership and innovation skills into the research degrees. This centre will act as a pilot for similar centres in other discipline areas, and is based on a successful UK model. Mathematics was chosen both due to the rise in demand for doctorates in the field, projected to rise 37% between 2011 and 2020, and its application in a wide range of fields (ATN, 2011).

The measures for the comparator countries are provided in **Appendix A – Graphs 1.2.1 – 1.2.3**.

23 OECD data for 2007.

24 UNESCO data for 2005.

25 Composite of OECD data for 2008 (where available) and 2007 (where 2008 data not available) – therefore indicative only and not an official OECD figure.

4.6. COMPLEMENTARITY OF RESEARCH ACTIVITY AND COLLABORATION IN AUSTRALIA'S RESEARCH SYSTEM

BENEFITS OF COMPLEMENTARY RESEARCH OBJECTIVES

While it is recognised that there are occasions when individual researchers and research teams are working in similar broad areas to other individuals and teams without reference to each other and without deep collaboration, the Review found that processes are in place which reduce the likelihood of direct or unhelpful duplication in research effort. Indeed, the Review found that there are many areas of research being conducted in Australia in which there are multiple participants with complementary research objectives. A productive research system intrinsically involves teams in parallel working in the same broad areas. This is the way in which high level research is conducted around the world and has proven to be the most effective. Concerns have been raised that there is potential for duplication in some of the research being undertaken. The case studies featured below show, however, that rather than leading to unhelpful duplication, multiple research activities in priority areas rarely involve duplication and are in fact complementary. There is also evidence that complementary research activities increase the scale and capacity of research skills and enhance research productivity.

Case Studies

A number of examples of complementary and collaborative research activities between universities, PFRAs, CRCs, MRIs, RDCs, states and territories and/or industry were explored during the Review. Some of the case studies were prepared internally based on available information and some by the Allen Consulting Group (2011). The Allen Consulting Group (2011) study concluded that while there is scope for overlap and duplication of effort in some areas of research, there are a number of measures in place to ensure that this is not an issue. Also, while there is always opportunity for greater communication in research, between funders and between performers, the case studies did illustrate purposeful collaboration.

The first three case studies presented are intended to illustrate the nature of research undertaken by teams working in parallel in areas of research priority, as well as some of the significant tangible benefits of complementary research activities between the various partners, particularly when there are well established, deep collaborations in place:

- In marine science, the Australian Institute of Marine Science (AIMS) has an acknowledged collaborative approach, which includes linking to organisations with complementary research capacity and interests, resulting in a strong focus for its research, coordinated effort and clear pathways for the uptake of research.
- The establishment of the National ICT Australia (NICTA) as a world scale research institute addressed a weakness in strategic ICT research, with NICTA now the largest organisation in Australia focussed on ICT research. CSIRO and some of Australia's leading universities are affiliated with NICTA.
- In agriculture, the National Primary Industry Research, Development and Extension (RD&E) Framework is expected to result in greater cooperation between the Australian Government and the state and territory jurisdictions and more efficient use of resources.

The fourth case study on CSIRO's role in the Murray Darling Basin illustrates the strengths of Australia's largest research agency in conducting quality research that informs resource planning, management and investment. It also demonstrates the value of utilising existing organisations in the Australian research system and their networks, R&D structures, and models when addressing complex challenges rather than developing new "fit for purpose" ones.

The fifth case study highlights the positive attributes of the rural RDCs, which represents a unique co-investment model in Australia's research system and one that has led to a strong end user focus to research funding decisions.

The final case study serves to illustrate a well-regarded government process in establishing and funding a collaborative research initiative in bionic vision, and in particular, the efficiencies that can be captured by utilising existing expertise and experience in funding process design and management within government agencies.

Bibliometric analyses

To complement the case studies, the Review Taskforce also commissioned Elsevier Science and Technology (2011) to undertake bibliometric analyses based on SciVerse Scopus data to focus on the productivity benefits of collaboration within the public sector - universities, PFRAs and/or MRIs in four fields of research: climate change (including energy), ICT, agriculture, and health - in each year over the period 2005 to 2010. In summary, those analyses showed that:

- at a sectoral level, the greatest number of collaborations took place between universities and MRIs in the field of health research, followed by university-PFRA collaboration in agriculture, then university-PFRA collaboration in ICT;
- virtually no PFRA-MRI collaboration occurs, even in health;
- at an institutional level, the highest numbers of collaborations are between Go8 universities that are in the same state, followed by collaboration between the University of Melbourne and University of Sydney, Murdoch University, Peter MacCallum Cancer Centre and the University of Queensland (in that order);
- at an institutional level, the highest numbers of collaborations are university-university collaborations in health, followed distantly by MRI-university collaborations in health and then CSIRO-university collaboration in agriculture; and
- CSIRO’s most frequent collaborative partner is the University of Queensland, followed closely by Monash University and the University of Melbourne, however when taking field of science into account, the top partners for CSIRO are the University of Queensland followed by ANU in the field of agriculture.

Results of the analyses can be found in **Appendix A – Section 6**.

CASE STUDY 1: AUSTRALIAN INSTITUTE OF MARINE SCIENCE – COLLABORATING FOR IMPACT

The Australian Institute of Marine Science (AIMS) is Australia's tropical marine research agency and works to generate and transfer knowledge to support the sustainable use and protection of the marine environment through innovative, world class research. AIMS's role is to conduct mission-driven, strategic research to provide a national capacity in research on Australia's tropical marine ecosystems.

AIMS targets problems of national significance and develops its research program in consultation with users. To deliver its research program, AIMS has adopted a strong collaborative approach to build critical mass (skills, shared knowledge and infrastructure) and to maximise its capacity for effective research to improve understanding of complex ecosystems. In planning its research, AIMS directs its effort to where it can have impact, and this includes linking to complementary research where there is mutual capacity (i.e. a clear value proposition for both parties and for end users). The strong linkages developed with complementary research organisations, and government, industry and other end users ensures a strong focus for its research, coordinated effort and a clear pathway for the uptake of research.

Previous reviews have acknowledged the success of AIMS's strategic approach and research efforts. Batterham (2001) reported that:

> *"In focussing to tropical marine research off the coast of Queensland, the Review was impressed by the degree and effectiveness of collaboration among the organisations located in the region: AIMS, James Cook University (JCU), the Oonoonba laboratories of Queensland's Department of Primary Industries, the Great Barrier Reef Marine Park Authority (GBRMPA) and the Cooperative Research Centre for the Great Barrier Reef World Heritage Area. Collaborative endeavours among these organisations utilise complementary strengths, and the result is that the whole is greater than the sum of the parts. The Review considers that this collaborative approach, and the physical proximity of the organisations involved, together serve as a model for replication elsewhere in regional Australia" (Batterham, 2001, page 42).*

Since that time AIMS has continued to build on its collaborative approach. Currently, AIMS has formal collaborative agreements forming hubs of marine science expertise in Townsville (AIMS@JCU with James Cook University), in Darwin (the North Australian Marine Research Alliance with Charles Darwin University, the Australian National University and the Northern Territory Government) and in Perth (the Indian Ocean Marine Research Centre with the University of Western Australia and CSIRO). One of the key goals of the hubs is the development of early career scientists. In addition AIMS co-invests and takes a leadership role in several large multiagency research collaborations and research infrastructure partnerships including The Western Australia Marine Science Institution, the Integrated Marine Observing System and the Marine Tropical Sciences Research Facility. The latter is soon to be replaced by the Tropical Ecosystems Hub and AIMS will also be part of two other National Environmental Research Program hubs, the Marine Hub of Oceanography. These joint ventures and multi-agency programs combine the research strengths of universities, research organisations and industry partners ensuring the necessary skills, capabilities and infrastructure are efficiently and effectively applied to prioritised research.

AIMS, in its own right, has demonstrated the high quality and impact of its research. It reports and measures performance regularly through agreed performance indicators of research quality and impact, and includes a rolling program of external peer review. Independent analysis of the citation of AIMS journal publications by ISI Essential Science Indicators consistently ranks AIMS highly, including as the number two research institution for coral reef ecology internationally and in the top 1% in the fields of "Environment and Ecology" and "Animal and Plant Science". In 2009, an analysis of the Scopus® (Elsevier) database of international research literature, undertaken by the European research consortium SCImago, ranked AIMS first among Australian non-medical research organisations and universities in terms of several of their measures of citation of scientific papers. Further assessment of research quality and impact is undertaken by a rolling program of external peer review.

CASE STUDY 1 (CONT…)

In addition to research excellence, AIMS research has delivered positive outcomes to users of marine science and has demonstrated the value of public good environmental research. An independent assessment of the economic impact of AIMS research undertaken in 2006 showed that public good focused research, such as that conducted by AIMS, can generate dramatic regional economic benefits (Insight Economics, 2006). In particular, the benefits from research on the Great Barrier Reef and the importance of the reef to the north Queensland economy were reflected in analysis which showed that, in the absence of AIMS, economic growth (annual gross value) in the Far North region would be halved.

The collaborative approach used by AIMS has allowed it to punch above its weight and coordinate its research effort, value-adding to government investment. The Oceans Policy ScienceAdvisory Group (OPSAG) provides another mechanism to help coordinate marine research in Australia. The complementary nature of the research capacity in respective agencies provides further strength to the nation's marine research capabilities. While AIMS undertakes mission-driven strategic research to provide broader system-level data on tropical marine coastal and shelf environments (e.g. regional scale studies, longer-term, specialised), the universities' capacity tends to basic research in site-focussed and shorter-term studies. CSIRO capability in blue water research and fisheries provides another set of complementary capabilities. The growing collaboration among these agencies provides a powerful national capability.

Source: AIMS/Review Taskforce, 2011

CASE STUDY 2: INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT) – MAXIMISING FOR SCALE

National ICT Australia (NICTA) is Australia's ICT Centre of Excellence. It is in the business of research, commercialisation and research training. NICTA was established by the Australian Government as part of the Backing Australia's Ability initiative, following a competitive bid process. The government's objective in establishing this new research organisation was to address a long-term structural under-investment in strategic information and communications technology research that had impacted on Australia's ability to fully capture the productivity and transformational benefits that ICT capability can deliver. NICTA has been developed as a world-class and world-scale ICT research institute, aiming to raise the standard of ICT research and post-graduate training in Australia. In the process, it has sought to attract world-class researchers to Australia including Australian researchers currently working overseas. NICTA is now the largest organisation in Australia dedicated to ICT research and a number of leading universities and major national and international organisations are affiliated with it.

NICTA is an independent company funded by the Department of Broadband, Communications and the Digital Economy and the ARC. In addition to the Australian Government, NICTA has been supported and funded by its four founding members: the Australian Capital Territory Government, the Australian National University, the New South Wales Government and the University of New South Wales. Since 2002, The University of Sydney, the Queensland Government, Griffith University, Queensland University of Technology and The University of Queensland have become funding and contributing partners. In 2011, the Victorian Government and the University of Melbourne became NICTA members. The Australian Government has provided $379 million to NICTA from its establishment in 2002 to 2011. NICTA's founding members and alliance partner organisations have contributed an estimated $190 million in cash and in-kind to the organisation over the period 2006 to 2011.

In the 2009-10 Budget, NICTA received Australian Government funding of $185.5 million for an additional four years from 2011 to 2015. This additional funding brought the total Australian Government commitment to NICTA to $564.6 million from 2002 to 2015. There is also some modest state government funding of ICT research, generally to NICTA and its state-based partners. Several states have invested in ICT infrastructure, to support research (eResearch) though the National Collaborative Research Infrastructure Strategy (NCRIS), the Super Science Initiative, or as part of high performance computing consortia (see Victorian Government 2010, South Australian Government, and Queensland Government). The Victorian Government plans to release a new ICT Strategy in 2011. State governments have recognised the importance of ICT as key enabling technologies underpinning many different fields of research. Some have also provided funding for high speed capacity computing. However the major focus of the state government strategies is assisting the growth of ICT businesses.

NICTA's focus is on research to address the technology challenges facing industry, community and the national interest. NICTA aspires to be one of the world's top-ten ICT research centres by 2020.

In addition to NICTA, CSIRO is another major performer of research in ICT, with its ICT Centre. Two-thirds of the Centre's scientists work with the National Research Flagships on areas of national priority. This involves working in multi-disciplinary teams that combine ICT research with deep knowledge in such areas as water, climate change, health and mining. Areas of specialisation within the Centre's laboratories include: field robotics, sensor networks, adaptive systems, vision-controlled systems, health data management, biomedical imaging, user modelling, database management, web services, security and privacy, network science, immersive environments, virtualisation, human factors, antennas and propagation, microwave and millimetre-wave technologies, wireless communications and signal processing. Each year, the ICT Centre focuses on specific research themes that aim to secure future success for CSIRO outcomes in science, delivery of impact with the Centre's partners and commercialisation opportunities. Current focus areas being led by the ICT Centre for CSIRO include wireless broadband, e-health and sensor and sensor networks research.

CASE STUDY 2 (CONT…)

CSIRO’s ICT Centre is considered to be positioned in different areas of research activity, compared with NICTA: CSIRO’s ICT Centre has an enabling role in supporting CSIRO’s research programs, while NICTA seeks to grow Australia’s ICT industry. The affiliation between NICTA and CSIRO works to ensure that there is shared understanding of research programs and objectives. CSIRO, NICTA and the New South Wales Government have established the Australian Centre for Broadband Innovation, a collaborative research initiative to investigate, demonstrate and promote applications and services that enable, and are enabled by, widespread availability of broadband. Both organisations provide for the scale and profile in Australia's ICT research effort and ensure that other research groups have access to state-of-the-art technologies.

Universities undertake ICT research and are also linked to NICTA (including as founding partners). For example, universities in Queensland are the home to six Queensland Government-supported ICT-related research centres. Universities in other states also have small centres undertaking ICT-related research. NICTA’s efforts to collaborate with university researchers are commendable. The Allen Consulting Group (2011) concluded that it is difficult to see how present arrangements in ICT research funding could be improved.

Source: (based on) Allen Consulting Group, 2011

CASE STUDY 3: AGRICULTURE RESEARCH – COLLABORATING ACROSS SECTORS

Through the Council of Australian Governments Standing Council on Primary Industries (previously the Primary Industries Ministerial Council (PIMC)), the Australian, State and Northern Territory Governments, rural R&D corporations (RDCs), CSIRO, and universities are jointly developing the National Primary Industries Research, Development and Extension (RD&E) Framework to encourage greater collaboration and promote continuous improvement in the investment of RD&E resources nationally. In November 2009, PIMC endorsed the Framework including the overarching statement of intent between the parties. To date PIMC has endorsed RD&E strategies for the pork, wine, dairy, beef, sheep meat, poultry, fishing and aquaculture, forest and wood products, grains, horticulture and sugar industries, as well as the cross-sectoral strategies of climate change, new and emerging industries and animal welfare.

Major sources of R&D funding include the RDCs, state and territory primary industries departments, the CRC program and the ARC. RDCs are a means of funding agriculture research applicable to subsectors such as grains and horticulture, funded in part through a levy on producers. The RDCs work together through a council to provide collaborative, effective and efficient investment in rural R&D. The RDC co-funding model provides an efficient mechanism through which Australian farmers share research costs and results.

State and territory primary industries departments perform (as well as fund) research. Universities with agriculture faculties undertake research, participate in CRCs, and some partner with CSIRO. The Universities of Adelaide, Melbourne, Sydney, Queensland and Western Australia, as well as Charles Sturt University, are all well regarded for their agricultural research.

CRCs provide an important collaborative mechanism for a deep focus on specific issues and CRC partners contribute funds and participate in research. Collaborative research is a useful substitute for what might otherwise be duplication of effort. Currently, there are 11 CRCs with a predominant agricultural focus: Australian Seafood CRC; Cotton Catchment Communities CRC; CRC for an Internationally Competitive Pork Industry; CRC for Beef Genetic Technologies; CRC for Forestry; CRC for National Plant Biosecurity; CRC for Sheep Industry Innovation; Dairy Futures CRC; Future Farm Industries CRC; Invasive Animals CRC; and Poultry CRC. Partners include state and territory primary industries departments, universities, CSIRO and agri-food companies. CSIRO has a long history of success across the full breadth of agricultural research. The CSIRO Food Futures Flagship aims to transform Australia’s agri-food sector through new technologies and collaborations with research and industry partners. The Flagship adopts a whole industry approach in key research areas such as grain-based foods and feed; engineering better Australian seafood and beef; and quality biosensors.

Given the various participants, including the role of the states and territories, there has always been scope for some duplication of effort. The RDCs have played a key role in limiting any duplication by funding research on a subsector basis (e.g. grains, or meat and livestock). RDC research effort is not constrained by state borders. In the future, the RD&E Framework will ensure that there is even less scope for duplication of effort. The Rural R&D Council has also released its National Strategic Rural Research and Development Investment Plan for consideration by government. The plan outlines a rationale for balancing Australian Government investment in rural R&D and identifies major themes against which investment should be determined.

Source: (based on) Allen Consulting Group, 2011

CASE STUDY 4: CSIRO'S ROLE IN THE MURRAY-DARLING BASIN – BUILDING ON EXISTING STRENGTHS

The Murray-Darling Basin generates 70% of Australia's irrigated produce. The Basin supports agricultural production of the order of $15 billion annually and is the primary water supply for urban centres, including Adelaide and Melbourne. However, the Basin is under enormous stress due to past water-allocation decisions, prolonged drought, and climate change resulting in a loss of water security for communities and the environment. The Murray-Darling Basin Authority is developing a Basin Plan to manage water resources and ensure there is sufficient water available and the key environmental assets and functions of the Basin are not compromised, while optimising social and economic outcomes.

CSIRO has long been engaged in research on and management of the Basin. In 2008, CSIRO's Murray-Darling Basin Sustainable Yields Project provided the first rigorous assessment of the potential impacts of development and climate change on surface water and groundwater availability across the Basin. This research provided governments, industry and communities with unprecedented information to guide future resource planning, management and investment.

CSIRO is undertaking research on:

- the potential impacts of changes in water availability on Indigenous communities of the Basin;
- the relationships between watering strategies and the health of vegetation, fish and other animals in the Basin to help water managers to improve and justify delivery of environmental water;
- groundwater resources in the Basin to support its future management;
- social and economic effects of changing water availability; and
- the impact of a changing climate on future water resources of the Murray-Darling Basin.

ACIL Tasman (2010) completed an independent assessment identifying and quantifying the expected economic impact of this research. Environmental and social benefits were also anticipated. The present value of improved water use efficiency was estimated at $2.8 billion. The project itself was revenue positive for CSIRO as the work was done as a consultancy, but it drew heavily on the substantial investment in the Water for a Healthy Country Flagship. The work on the Murray-Darling Basin raises very substantially the conservative estimate of the value of the whole of Flagship developed by ACIL Tasman in 2006 of over $700 million.

Although the research and policy issues associated with the Basin are complex, the relationships in terms of research collaborations, industry partners and areas of government supported are well understood and are mature. All partners have clearly defined roles and are therefore able to focus on their core competencies. In this project CSIRO engaged a variety of partners from research institutes, industry, government and end users to ensure that great science was generated, impact delivered, and that the capability of the region was improved.

Some of the outcomes from CSIRO's partnerships and programs in the Murray-Darling Basin include:

- At least 57 joint publications over the last 10 years with 65 partners from 10 countries and 435 citations;
- Numerous PhD students co-supervised through the Water for a Health Country Flagship;

CASE STUDY 4 (CONT…)

- Research expenditure valued at $5.9 million through the Flagship Collaboration Fund for the Ecological Response to Altered Flow Regimes Cluster with the University of New South Wales, Charles Sturt University, Monash University, La Trobe University, and the Australian Rivers Institute at Griffith University;
- Research expenditure valued at $5.2 million through the Flagship Collaboration Fund for the ecology of the Coorong, Lower Lakes and Murray Mouth with the University of Adelaide;
- At least 110 contracts with 11 partners totalling over $7 million;
- The eWater CRC involving 27 research and industry organisations;
- The Cotton Catchment Communities CRC involving 10 research and industry organisations;
- Four collaborative enterprise projects with a total value of $1.3 million; and
- Joint appointments with the Murray Darling Freshwater Research Centre (Murray-Darling Basin Authority), La Trobe University and the Department of the Environment, Water, Heritage and the Arts.

CSIRO's focussed effort and leadership has enabled it to extract high value from existing scientific knowledge and networks and can speed the rate of progress and the impact of the research.

Source: CSIRO/Review Taskforce, 2011

CASE STUDY 5: RURAL RESEARCH AND DEVELOPMENT CORPORATIONS – A CO-INVESTMENT MODEL

The rural Research and Development Corporations (RDCs) model was established and supported by the Australian Government to provide an industry-driven, market-responsive approach to rural research, development and innovation. At the core of the RDC model is co-investment by government, industry and research partners. For every $1.00 contributed by the Australian Government, industry levies and contributions add a further $1.50, on average. This serves to leverage the total investment and create far greater benefits for Australia than would otherwise be the case. The model also brings industry and researchers together to establish strategic directions for research and development (R&D) in specific agricultural industries. RDCs commission and manage targeted investment in research as well as the subsequent adoption of R&D outputs, on behalf of primary producers and government.

The 15 RDCs in Australia's research system each fund a mixture of applied and basic research including short-term, low risk, adaptive research as well as longer-term, riskier and potentially higher-reward research. A higher proportion of activity is focused on the applied end of the spectrum with RDCs striving to deliver high rates of return on R&D investment by influencing the full range of interactions along the innovation chain. The RDCs apply significant resources to translating research outputs into practical outcomes and to directly encouraging uptake of research.

The Productivity Commission, in its recent inquiry into the RDCs , reported several important strengths of the RDC model (Productivity Commission, 2011):

- The strong linkages with producers, and the significant contribution that those producers make to the cost of the R&D, helps to ensure that money is not wasted on ill-conceived research, or work likely to be of limited practical value.
- Those same linkages and financial contributions can encourage greater or more rapid uptake of research outputs by producers. This increases the overall value to the community of the research concerned.
- By virtue of their research brokering function and the large amount of cash funding they have at their disposal, the RDCs play a valuable 'systems integrating' role. For example, their capacity to influence the projects funded through other rural R&D programs has helped to prevent wasteful duplication of research effort.
- Over the past two decades, the RDCs have accumulated and retained very considerable expertise in the funding and management of rural research. This would be difficult to quickly replicate within a completely different funding vehicle.

Source: Rural RDCs/Review Taskforce, 2011

CASE STUDY 6: RESEARCH IN BIONIC VISION SCIENCE AND TECHNOLOGY INITIATIVE

One of the proposals from the Australia 2020 Summit, which was held in April 2008, focussed on promoting better commercialisation of intellectual property, and in particular, in the area of innovative health technologies where Australia could take the lead. It was suggested by stakeholders that Australia take the lead in inventing a 'bionic eye' by 2020, given the national track record and world leadership in bionics based on bionic ear development. This new development in bionic vision would be a critical advancement for millions of vision-impaired Australians, as well as underpinning the development of technologies to translate into other areas of need.

The Australian Government committed to fund this proposal via a competitive grants process, and following the 2020 Summit, inter-departmental discussions were held on how best to deliver on this commitment to support Research in Bionic Vision Science and Technology as part of A Long Term National Health Strategy. Taking into account program management expertise, available decision-making processes and track record, the government made a strategic decision to give responsibility to the Australian Research Council (ARC) in December 2008 to lead and manage this funding process for the government.

In 2009, the ARC funded a new collaborative research initiative to develop a functional bionic eye through funding to be administered under the ARC's Special Research Initiatives scheme (under the National Competitive Grants Program). Via this initiative, the government committed funding of $50 million over four years. The ARC was able to draw on existing program structures to design a robust selection process and to draw together the appropriate expertise in fields of relevance to the development of implantable bionic medical devices for the eye (i.e. commercialisation/development of medical technologies, engineering of medical devices, neurology and ophthalmology) to consider and judge the merits of the applications. The initiative's documentation was released by the ARC in July 2009 and the outcomes of the competitive process were announced by the Minister for Innovation, Industry, Science and Research in December that year.

Source: ARC/Review Taskforce, 2011

REDUCING THE RISK OF DUPLICATION

There are a number of processes and mechanisms within the Australian research system which help guard against direct or unhelpful duplication in research activities. These include the competitive peer review processes of the funding councils (i.e. the ARC and NHMRC), as well as the use of funding rules in competitive schemes to reduce overlap and inefficiencies. The ARC's funding rules, for example, do not allow for the same researchers to be funded for the same research by different funding sources (see **Box 7**).

BOX 7: ARC FUNDING RULES TO REDUCE DUPLICATION

ARC Funding Rules contain clauses to ensure that there is no duplication of funding. For example, in the Centres of Excellence Funding Rules (for funding commencing in 2011), there is a specific reference: “The ARC does not duplicate funding for research that has already been funded by the ARC or other Commonwealth bodies. The ARC reserves the right to determine if an EOI or a Proposal duplicates, or is likely to duplicate, research being funded by another Commonwealth source. In such circumstances, the ARC may, in its absolute discretion, decide not to recommend the EOI for short-listing or the Proposal for funding.” Further, “ARC Centres of Excellence funded in this round must relinquish any ARC funding as at 1 January 2011 that would result in duplication”. Centre Directors and Chief Investigators named in successful Centres of Excellence (CoE) proposals can retain other ARC grant funds, but only if the CoE proposals clearly explain, to the ARC’s satisfaction, the complementarity between the respective research programs and that their proposed CoE budgets do not cover funding of any overlapping research for the duration of their other ARC grant funds.

Source: ARC/Review Taskforce, 2011

A further example is the approach to the provision of research infrastructure adopted under the National Collaborative Research Infrastructure Strategy (NCRIS) which explicitly addressed the need to avoid unnecessary, overprovided or duplicated infrastructure and to minimise gaps in infrastructure delivery (DIISR, 2010b). A number of benefits have been identified from the NCRIS approach to funding national-scale research infrastructure (summarised in **Box 8**).

COLLABORATION – EVIDENCE AND BENEFITS

National and international collaboration, as measured by co-publications, has increased over time both in Australia (Matthews et al, 2009; Review Taskforce analysis of Scopus and InCites data, 2011) and internationally (The Royal Society, 2011; Review Taskforce analysis of Scopus and InCites data, 2011). CSIRO has also focused heavily on collaboration, particularly international collaboration to increase its impact.

Review Taskforce analysis of Incites data shows that the major research institution groups in the Australian research system gain a benefit from their multidisciplinary research in terms of academic citation impact. In particular for the Group of Eight universities, CSIRO and MRIs, citations for multidisciplinary publications are double or more (triple for MRIs) the average for all publications; see **Figure 14.**

Matthews et al. (2009) showed that Australian-based researchers achieved a higher relative citation impact when collaborating with the US or Europe than without international collaboration, and their highest relative citation performance came from collaboration with both the US and Europe. Review Taskforce analysis of InCites data shows citation impact benefits from collaboration with other major science producing countries as well, and the benefits tend to increase with the number of countries (although there are limits and exceptions to this). Internationally, collaboration has been shown to have significant benefits including building scale and capacity, increasing citation impact, providing access to new markets and broadening of research horizons (The Royal Society, 2011).

BOX 8: THE NCRIS APPROACH TO FUNDING NATIONAL-SCALE RESEARCH INFRASTRUCTURE

The National Collaborative Research Infrastructure Strategy (NCRIS) is a research infrastructure program that is focused on making national scale, collaborative and accessible research infrastructure investments using a broad definition of research infrastructure. Investments are funded as “capabilities” – a collection of connected research infrastructure investments that share a common research domain or research infrastructure need. In order to achieve its goal of providing collaborative and accessible national-scale research infrastructure, NCRIS includes a number of unique elements that did not exist in previous research infrastructure programs, including:

- an independent NCRIS Committee to advise and direct the planning and implementation activities;
- the NCRIS Roadmap, which outlined an agreed view of national collaborative research infrastructure investment;
- the concept of a capability – a holistic collection of investments in a broad research domain;
- flexible definition of research infrastructure and associated funding rules; and
- a facilitation process that allowed the development of the most efficient and effective collaborative investment in each capability in a non-competitive manner.

NCRIS Committee: The NCRIS Committee, consisting of an independent chair; the Chief Scientist for Australia, Geosciences Australia; DSTO; ARC and NHMRC CEOs; an industry representative; and a university representative, formed the decision making body. The Committee developed the first NCRIS Roadmap, recommended priority areas for investment, assessed and challenged the outcomes of the facilitation processes, and was an independent arbitrator for the project management reporting provided by funding recipients. The NCRIS Committee was dissolved in late 2008 and its role largely subsumed by DIISR, although the creation of the National Research Infrastructure Committee (NRIC) to strategically guide future investments in research infrastructure expanded a key aspect of the former NCRIS Committee’s role.

NCRIS Roadmap: The Roadmap encompassed the broad definition of research infrastructure to be used in the program, the concept of a capability, and identified a number of priority capability areas for potential investment. The Roadmap represented the first attempt to identify areas of national scale research infrastructure need within a holistic framework of an accessible and collaborative research infrastructure system. Critically, this process allowed the research sector, the government, and all stakeholders to see the broad direction the NCRIS Committee had identified for national collaborative research infrastructure at a system-wide level, and to work with their funding bodies and other stakeholders to investigate how they may fit into any particular capability. The original NCRIS Roadmap has since been updated by the 2008 Strategic Roadmap for Australian Research Infrastructure, which itself will be succeeded by the 2011 Strategic Roadmap for Australian Research Infrastructure (in development at time of writing).

Capability Areas: The NCRIS Roadmap pioneered the concept of a “research infrastructure capability”, known as a capability. A capability, although not explicitly defined, is a set of investments in a broad research infrastructure domain that, through the construction, integration and facilitation of new and existing pieces of research infrastructure, will develop or enhance a national-scale, accessible, collaborative research infrastructure ability or capability. A key part of a capability is drawing together research infrastructure investments in similar but not yet integrated research infrastructure domains into a single collaborative and integrated whole. By drawing together research infrastructure investments into broader collectives, a capability offers integrated access to infrastructure encompassing a conceptual ‘research infrastructure value chain’ and facilitates researchers working together across broader domains. The key success factor for a capability is that the whole of the capability is greater than the sum of its individual pieces. The non-competitive nature of NCRIS was considered essential to the concept of a capability being successful.

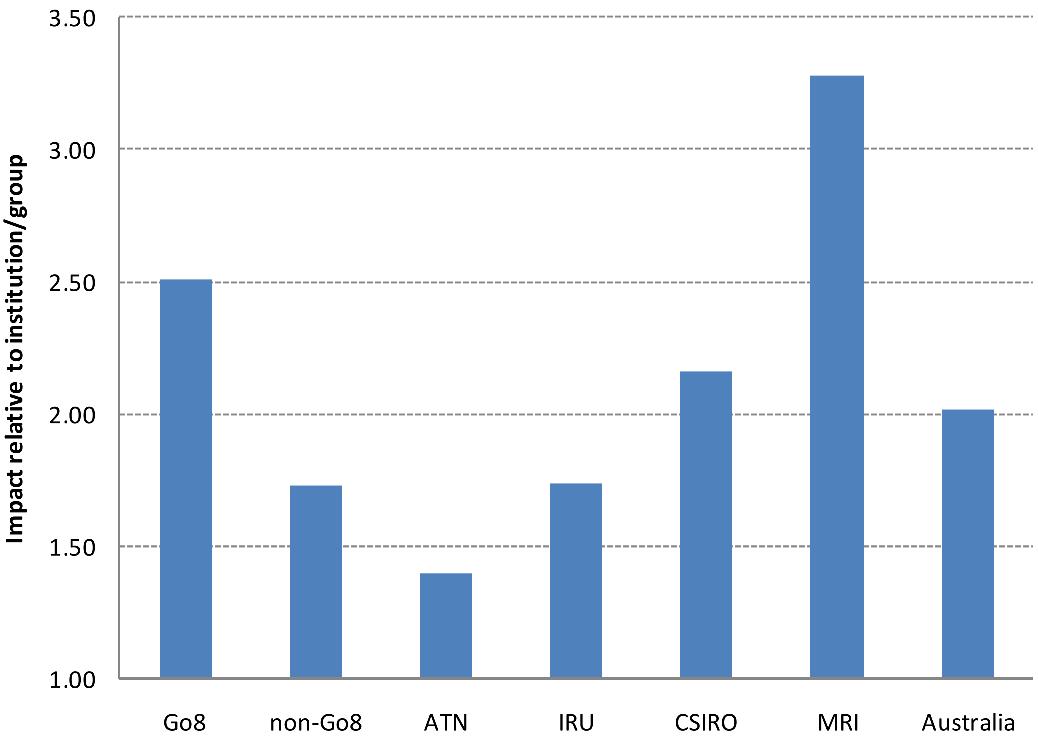
BOX 8: THE NCRIS APPROACH TO FUNDING NATIONAL-SCALE RESEARCH INFRASTRUCTURE

Use of Research Infrastructure Funding: NCRIS funds are able to be used flexibly to ensure that funding is being provided to where it is most needed. Co-investors were also able to provide their resources in the manner they desired. As a result, NCRIS was considered to very successful in encouraging collaboration (by providing running costs and trained personnel in exchange for infrastructure access), encouraging utilisation of NCRIS infrastructure (by making infrastructure, and the required technical expertise, accessible and available at marginal cost for meritorious researchers), and in drawing formerly fragmented research communities and infrastructure providers together under one capability (by providing funds for overarching governance bodies).

Facilitation Process: The facilitation process adopted as part of NCRIS was the key process in identifying the main players and co-investors in the capabilities identified in the Roadmap. This process involved the NCRIS Committee, with the department, identifying a Facilitator for a particular capability. The Facilitator, an ‘honest broker’ within the research sector, would then consult heavily with all the stakeholders in the capability area to identify the best manner in which to achieve the goal of the capability. Supported by the department, and a ‘mentor’ from the NCRIS Committee, the Facilitator identified the key facilities and participants that should be involved in a capability, potential co-investors, key new infrastructure investments to be made, the preferred governance mechanism for the capability’s investments and, crucially, how the capability would come together as a coherent whole. These activities were collated into an Investment Plan, which was then presented to the NCRIS Committee for their comment and approval or rejection. The facilitation process has been identified as the ‘competitive element’ of the NCRIS process, as the Facilitator had to make prioritisation decisions for the cohesiveness of the capability based on offers of equipment, cash or in-kind contributions from stakeholders. The process was considered to be very successful in developing collaborative capabilities.

Source: Science & Infrastructure Division/Review Taskforce, 2011

Figure 14: Multidisciplinary impact (using Incites data for 2005 to 2009)



Source: Review Taskforce, 2011, using InCites Data

As reported in **Section 4.1**, however, there are relatively low levels of collaboration between Australian businesses and research institutions, especially universities. This reduces the potential for building and maintaining effective connections within Australia's national innovation system to build critical mass and improve productivity across the system as a whole. The low level of collaboration also presents challenges in meeting the government's goal to double the level of collaboration between Australian businesses, universities and PFRAs over the next decade (DIISR, 2009). A 2010 report to the Australian Industry Group further noted the limited collaboration between businesses and research organisations, surmising that this indicated that Australia's innovation capability is not yet realised throughout the national economy, with a possible over-reliance on external trade factors (National Innovation Review Steering Group, 2010).

Internationally, there appears to be more explicit acknowledgement and support for university collaboration with firms and involvement in technology transfer and commercialisation. Advocates of the 'triple helix' model[26], in particular, assert that universities have "embraced economic and social development as a new mission, in addition to their traditional missions of teaching and research". In doing so, universities are said to "become part of a coherent system that includes industry and government and underpins innovation and economic progress" (D'Este and Perkmann, 2010, referring to Etzkowitz and Leydesdorff, 2000).

Owen-Smith (2003), in analysing the publishing and patenting activities of research-intensive US universities, reports this type of convergence towards a 'hybrid system' where the best universities excel in both scientific research and technology commercialisation (D'Este and Perkmann, 2010).

Sörlin (2007), in examining trends in funding regimes for higher education systems, notes that "it is quite likely that governments will seek ways to secure the financial security of their higher education institutions, and at the same time, make sure, through reliable principles of differentiation, that a reasonable proportion of them attain results at the top level, which qualifies in providing globally visible hubs for firm localisation, attractiveness of top researchers, good students and investment by R&D performing firms".

Further evidence of the occurrences and benefits of collaboration can be found in **Appendix A – Section 6**.

26 Sörlin (2007) discusses the logic of the triple helix model, under which, to achieve improved competitiveness, high quality university research needs to cater to economic interests. The model would "also increase the quality of research, balancing academic drift in institutions with an 'economic imperative' innate in the new types of funding reaching universities, either from firms, the state, or by strategic intermediary funding agencies".

5. REVIEW KEY FINDINGS AND FUTURE DIRECTIONS

The Review found that while there was no evidence of significant shortfalls in the current framework for publicly funded research, there are opportunities for further maximising the innovation returns from publicly funded research. Below is a summary of the key findings and proposed future directions against the issues identified as the focus for the Review.

5.1. POTENTIAL OVERLAP BETWEEN PUBLICLY FUNDED RESEARCH AGENCIES AND WITH UNIVERSITIES, STATE AND TERRITORY FUNDED AGENCIES OR THE PRIVATE SECTOR

KEY FINDINGS

Concerns were raised during the Review about the clarity of the roles of the participants, particularly in relation to the human capital development responsibilities of universities and the role of PFRAs in ensuring research capability in areas of national importance. The degree of additionality from government investment in research was also raised as an issue. While there was recognition that good efforts had been made to reduce duplication in the system, there were a range of suggestions for improving the efficiency of the models used to distribute and coordinate research funding. The Review, however, found considerable evidence to demonstrate the benefits of multiple participants undertaking related research in priority areas; such activity was found in general to be complementary, rather than involve direct duplication, and increasing the scale and capacity of research skills. The Review also confirmed the benefits of collaboration; Australian institutions co-publishing with other institutions in Australia or overseas tend to achieve greater research productivity in terms of increased citation impact (see **Section 4.6**).

The Review found, overall, that there are opportunities for greater Australian Government leadership in a national strategic dialogue to better support government consideration of future research investments, as well as to increase the efficiency in decision-making processes about investments and enhance the effectiveness of coordination between elements of the system. Opportunities for enhancing the links between the Australian Government and the states and territories in terms of the overall research effort were also discussed.

In particular, many stakeholders noted that a more strategic dialogue and better coordination of research effort and investment were critical to a country like Australia where there is a need to ensure that there is scale and world-class capability in areas of research of national importance. Such strategic consideration could be underpinned by a national research investment plan and should aim to avoid unnecessary domestic competition and creation of new institutions or groupings, where deep capability may already exist in Australia’s research system.

Role clarity

Stakeholders agreed that there was a need to ensure clarity of the roles of the various participants in the research system. There was agreement that human capital development, national research capacity in areas of priority need and collaboration were important and that it would be useful to more explicitly describe the roles of various participants in relation to these.

As set out in **Section 4.1**, universities play a critical role in the development of human capital. As such, a primary purpose of investment in university research is to develop the next generation of Australian researchers. There was general agreement that the role of universities in the development of human capital needed to be given greater prominence. While other participants in the system, including the CSIRO and the CRCs were considered to be extremely useful in supporting the quality of research training in partnership with universities, this was viewed as a secondary purpose of the activities of these groups rather than their core function.

While the focus of the current higher education base funding review (DEEWR, 2010) is on higher education learning and teaching, the review aims to establish enduring principles to underpin public investment in higher education which may have implications for public investment in research. Some stakeholders noted the need to ensure alignment between the outcomes from this Review and the establishment of any principles arising from the DEEWR review of base funding.

Many stakeholders also noted the importance of ensuring that Australia has the research capability necessary to address challenges now and into the future. The PFRAs and in particular, CSIRO were seen as making an important contribution to maintaining national research capability in key areas to enable Australia to effectively respond to emerging industrial, social, health, security and environmental challenges. While CSIRO's special place in the system is well recognised (DIISR, 2009; Marceau, 2007), particularly in terms of assembling and managing large multidisciplinary teams of researchers to tackle pressing needs or challenges from a national perspective (i.e. the flagship model), it was considered important for this role to be made more explicit. In particular, the work and investment CSIRO has made in transformational capability platforms over recent years and the development and operation of national research facilities (the Australian Animal Health Laboratory, the National Marine Research Facility and the Australia Telescope National Facility) are examples where the capacity building of PFRAs is a direct outcome of both anticipating future demand and contributing to national preparedness.

Supply of researcher skills

The critical importance of skilled research graduates as a contributor to economic well-being and future success is well documented (e.g. Salter and Martin, 2007) in terms of their knowledge of recent research and their ability to perform research (including use of advanced equipment and techniques), use knowledge in new and powerful ways, develop new ideas and deal with complexity. Many studies identify the recruitment of skilled graduates as a key mechanism through which firms derive economic benefits from public research (Salter and Martin, 2007). Some stakeholders during this Review also noted the benefits to be derived from training students in institutions engaged in industry-related research, as well as the importance of the mobility of trained researchers between universities and industry. Researchers, too, embody knowledge and skills, but to a much greater extent and Salter and Martin (2007) note that the considerable benefits involved in such cases in biotechnology have been extensively studied.

Concerns were raised about the future viability of Australia's research workforce and in particular, the supply of researchers and engineers needed to drive our economy (e.g. Cervantes, 2003; DIISR, 2011a; Andrews, 2004). These are complex issues, especially in respect of the true nature of industry demand for higher degree by research skills in the Australian economy. There is, however, a heightened awareness in Australia about the impact that a shortage of scientists will have on the overall health of Australian science and research. The Chief Scientist for Australia is currently progressing consideration of issues relating to the health and vulnerability of Australian science, including supply issues.

Need for enhanced focus on collaboration

Enhancing collaboration between the various participants in the system was seen as important by stakeholders. While the CRCs were viewed by many as being a very effective mechanism for ensuring deep collaboration, many stakeholders considered that there needed to be an enhanced focus on collaboration across the research system as a whole. Another issue that was raised was the important contribution of industry end users in driving collaboration. It was seen as critical that industry was involved from the beginning of the research endeavour. This aligns with evidence from the US experience (Maricle, 2011). Consistent with the findings from the Research Skills for an Innovation Future report (DIISR, 2011a), a number of stakeholders highlighted the need in Australia, given our proportionally smaller concentration of researchers in the business enterprise sector, to build strong collaborative linkages between industry and universities and other public sector research organisations. It was also seen as important to ensure that impediments to knowledge diffusion and movements of highly skilled people between sectors were minimised (see also **Cross-sectoral and International Collaboration**).

Reducing the risk of duplication

While the Review found that there were not obvious signs of duplication in research activities, several mechanisms were identified which reduce the risk of duplication. There was general consensus amongst stakeholders that rigorous peer review processes to select competitive grant scheme participants, which are already a feature of the assessment processes for competitive funding programs in many agencies, protect against duplication. This was considered to be particularly important in the context of limited competitive research funding and the low application success rates for competitive research grants. For example, the ARC's application success rates are around 20 per cent. There was general support for the continuation of rigorous peer review for competitive grant programs that fund individual research projects and large scale collaborative research projects and initiatives.

The Review also noted the existing efforts of the ARC and the NHMRC to reduce any overlap in competitive funding schemes and found that efforts need to continue across all government research programs to reduce any inefficiencies in administration. The Review further noted the approach to the provision of research infrastructure adopted under the NCRIS which was designed and managed to avoid unnecessary, overprovided or duplicated infrastructure and to minimise gaps in infrastructure delivery (DIISR, 2010b).

A number of stakeholders raised the importance of ongoing Australian Government leadership in regards to research infrastructure and the utility of a top-down approach to continue to guard against any unhelpful overlapping administrative processes and to ensure the physical connection around infrastructure which is considered necessary for deep capability and collaboration. **Section 5.4** provides further detail.

Links with state and territory governments

As part of the Review, the roles of the states and territories were explored, including their roles respective to the Australian Government (**Appendix B**). Overall, states and territories were seen as playing a complementary role to the Australian Government. However, there was agreement that there would be benefit in improving the strategic dialogue between governments and for the Australian Government to show stronger leadership in some decision making processes. It was noted that there were risks that duplication and inappropriate competition could arise when goals, roles and processes are not properly clarified.

Nature of research investments

The Review found that each jurisdiction was focusing on different areas of strategic research priority with varying levels of investment in basic and applied research. In New South Wales, information and communication technologies research and nuclear science and technology are prominent, while in Victoria, there is deep capacity in regards to health and medical research and biotechnology. In Queensland, tropical research and marine research are regarded as two of the state's key strengths, South Australia has a major focus on climate change and water (being the driest mainland state), and Western Australia has significant expertise in regards to mining and resources. In Tasmania, Antarctic and marine science are natural areas of focus, the Northern Territory regards tropical and desert knowledge as comparative strengths, and for the Australian Capital Territory, the R&D activities of CSIRO and the Australian National University (in particular) have contributed to the establishment of research capability in scientific sectors, including biotechnology, plant phenomics and climate change. These research areas have emerged due to economic, industrial and geographic factors and circumstances, as well as the presence and level of activity of Australian Government publicly funded research agencies and/or the prominence of universities in the jurisdictions.

Analysis also revealed that the larger states generally have a greater focus on basic research than the smaller jurisdictions. The exception is the Australian Capital Territory, which undertakes the highest proportion of basic research of any jurisdiction. However, this is primarily Australian Government funding and reflects the Australian Government priorities. In terms of R&D expenditure, State Government expenditure is roughly proportional to population and has not grown dramatically in any state since 2002-03 and has fallen in Tasmania and the Northern Territory. In terms of R&D expenditure by location, Western Australia has grown most significantly, with eight times as much R&D expenditure in 2008-09 compared to its 1992-93 level. In terms of total expenditure by sector of performance, Business R&D is concentrated in Victoria and New South Wales while Australian Government R&D is concentrated in Victoria, New South Wales and the Australian Capital Territory. Victoria dominates Private Non-Profit performed research.

Priority setting and governance

A common feature is the use of priorities (structural, as well as topical) to guide R&D investment and activity, which tend to reflect or be linked to economic development priorities or industrial areas of focus. Queensland, in particular, has also identified R&D investment criteria to guide government investment decisions in R&D activities. A number of jurisdictions have overarching policy statements in place, which aim to facilitate a whole-of-government approach to research and innovation (e.g. Queensland's R&D Investment Strategy 2010-2020; South Australia's 10-year Vision for Science, Technology and Innovation; Tasmania's proposed Economic Development Plan; Northern Territory's Backing Territory Research).

Many of the jurisdictions also have governance arrangements in place to guide policy decisions in relation to R&D and innovation, including through the roles of their Chief Scientists and advisory councils.

Leveraging of Australian Government funding

The state and territory governments have a range of programs (varying in amount of funding available) to support research, including direct funding for their own state agencies conducting R&D, and broader innovation objectives. Leveraging of Australian Government funding, and in particular, infrastructure funding, is a common attribute of state and territory government funding support, with the level of leveraging often identified as a key performance metric. As part of the Review, however, some concerns were raised that some states might achieve large leverage (of Australian Government funding) off small investments, which may not be in the national interest. In general, Australian Government leadership, in relation to infrastructure decisions in particular was considered to be important to ensure that the needs of Australia and all jurisdictions, were taken into account, not just those with the capacity to co-invest, and that the infrastructure ends up where it is best placed from the national interest perspective.

Opportunity to enhance strategic dialogue between Governments

The Review found that there could be further opportunities to build effective links with state and territory governments through the Australian Government compacts with universities. It was further suggested that the compacts, as an evolving mechanism, could identify deep research capability which might be utilised to contribute to Australia's efforts to assist its regional neighbours, including in response to emergencies. It was also suggested that the agreements between the Australian Government and the PFRAs in the form of the Statements of Expectations and Intent negotiated between the IISR portfolio's four research agencies and the portfolio Minister could include specific reference to the role of these agencies in maintaining capability to enable Australia to effectively respond to emerging industrial, social, health, security and environmental challenges.

Additionality from Australian Government funding

Concerns were raised about the degree to which government funding to support research in some areas is increasing actual research effort. The consensus view was that the government's investment needed to be going towards those research areas where there was clear evidence that the investment was buying additional research[27].

27 Additionality is also considered to have a behavioural dimension, with government investment motivated by wanting to create deep linkages that are long lasting between researchers and research users and ensure persistent beneficial effects.

This issue is not new[28]. For example, in its submission to the Productivity Commission review of public support for science and innovation, the ARC (2006) noted that: “Government funding agencies and research users traditionally have different objectives in funding research and fund different kinds of research. However, the increased focus of governments in many countries on improving links between academic researchers and final users (particularly business users) appears to be reducing those distinctions. The potential for government funding to replace, rather than complement, the efforts of private investors in research 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”.

Opportunities were identified to ensure that government funding is provided to activities that would not have occurred without that investment. Reducing co-investment by Australian Government agencies and increasing investment by industry in CRCs was seen as one way by which Australian Government funding could be utilised for additional research that would not have occurred without government support. Co-investment by Australian Government agencies in CRCs (e.g. CSIRO and RDCs) was viewed by some stakeholders as reducing the opportunity for government to maximise the return from its investment as it reduced the opportunity for other partners to be involved in supporting the CRCs and reduced the availability of Australian Government funding to be directed towards other research initiatives.

The opportunity for CRCs to achieve better co-investment from industry was seen as important as it would enable the Australian Government to act more in a catalytic role with an ability to exit from providing funding support after a shorter period.

Cross-sectoral and international collaboration

Australia ranks lowly in the OECD (2007) in terms of collaboration between researchers and industry. Stakeholders speculated that such low levels of engagement may result from the lack of an innovation culture in Australian industry and/or arise as a consequence of the nature of research undertaken in Australia’s higher education institutions which may not have a sufficient focus on industry needs. The Review confirmed that increasing the number of research trained personnel in industry and encouraging greater mobility between universities, industry and other end users was seen to be important to building the type of industry culture that is more willing to look at public research organisations for solutions to their problems or for innovation that leads to new opportunities. This has also been identified in the context of the government’s research workforce strategy (DIISR, 2011a).

Many stakeholders noted that there is a need to provide additional incentives for higher education institutions that successfully engage industry in the conduct of research in areas of shared interests, including through direct investment in research activities. Stakeholders also noted that big cultural shifts are needed in higher education institutions and in industry to engender effective collaboration. Linked to this, concerns were raised about the lack of mobility between higher education institutions and industry and as mentioned previously, there was support for the removal of any impediments to knowledge diffusion and movements of highly skilled people between sectors. Stakeholders also identified the lack of incentives including in the reward and promotion practices of universities for such interchanges to occur between universities, business enterprises and governments.

There was some support for government to consider future initiatives based on a model of explicit third stream funding for universities for outreach and collaboration, as used in some other countries. There was also support for refocussing the available incentives to drive collaboration between universities and industry

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28 A 2003 Howard Partners evaluation of the CRC program explored the issue of additionality, noting the complexity of this issue. On the one hand, the industry view that the CRC program was far too ‘researcher-oriented suggested that the additionality of the program was low from an end-user perspective. In this view, much CRC research might also have been possible using research funding from other sources. On the other hand, CRCs are a vehicle of excellent research of relevance to potential end-users. In those cases where this system works well, the additionality of the program in terms of research excellence of relevance is high. This tends to be associated with situations in which industry and government are able and willing to work in partnership with researchers (as in medical science and the environment).

and other end users, particularly in relation to Research Block Grants. The Joint Research Engagement (JRE) block grant program aims to reward higher education institutions that focus on end user research and their ability to attract funding from sources outside of the competitive grants schemes[29]. The Review found that consideration should be given to amending the current research funding allocation methods, including through the JRE[30], to provide greater recognition to those higher education institutions that successfully engage industry in conducting research. Amending JRE in this way is consistent with external analysis which concluded that if the government's policy objective was to reward the universities most engaged in end user collaboration rather than to distribute research infrastructure more widely across institutions then the changes to JRE had been insufficient to achieve those objectives (Larkins, 2011).

In addition, government could provide further incentives to universities to undertake strategic basic and applied research in areas that are relevant to their local and national context. Government is already supporting some initiatives to grow cross-sectoral collaboration including the ATN Industrial Doctoral Training Centre (Mathematics) pilot which was announced as part of the suite of follow up work arising from the government's research workforce strategy. Other options would be to increase the funding base for the ARC Linkage and/or Centres of Excellence scheme and the CRCs. There was also support for looking at innovative ways to utilise the ARC's Linkage and Centres of Excellence schemes in parallel to more effectively encourage, recognise and reward collaboration between universities and end users.

It is well recognised that international collaboration is essential to ensuring critical mass in research activity, as well as being beneficial in optimising the use of costly infrastructure and creating opportunities for leveraging off national research funding. Some stakeholders raised concerns that the current system of research funding does not give sufficient focus and support for international research linkages with the result that Australia lacks the scale in research capability necessary to engage in global research activities. For example the European Union delivers a significant proportion of its research funds through subject-based themes, and currently Australia does not have a comparable mechanism for funding research, limiting the potential for co-investment with the EU in areas of mutual interest and strength. A summary of the EU's cooperative research model is provided in **Box 9.**

Opportunities to enhance coordination

The Review found that there are opportunities for a national strategic dialogue to better support future government consideration of research investments (including the level and balance of investments; **Section 5.2** refers) as well as to increase the efficiency in decision-making processes about research investment and for enhancing the effectiveness of coordination between elements of the system.

Improving consistency of research initiatives

As part of Powering Ideas, the Framework of Principles for Innovation Initiatives (DIISR, 2009) was developed and subsequently endorsed by the Commonwealth State and Territory Council on Innovation (CSTACI) for use by jurisdictions to guide policy development for innovation initiatives. The framework could be adopted (in a modified form as needed) to assist in research investment decisions as the principles set out in **Table 10** are consistent with the types of considerations that need to be made to guide future investments in major research initiatives, including for infrastructure.

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29 From 2010, the JRE replaced the previous Institutional Grants Scheme and the allocation formula was changed by removing the Australian Competitive Grants research income metric, while retaining other public sector, CRC, industry and other research funding as eligible research income. The JRE formula retained the structure of the IGS formula with weightings of 60% research income, 30% research student load and 10% research publications.

30 JRE program guidelines give greater incentives to those institutions that are effectively engaging with end users in research. One option was to remove the student load and publications elements of the formula and include only elements of research income that relate to end user engagement. As well as Categories 2-4 research income, consideration could also be given to including the ARC Linkages funding element of Category 1 funding.

BOX 9: THE EUROPEAN UNION'S COOPERATIVE RESEARCH MODEL

The European Union's major current mechanism to fund research is the Seventh Framework Programme for Research and Technological Development (FP7). The total FP7 Budget is more than €50 billion over seven years (2007 to 2013). By far the largest component of funding is the Cooperation programme, which supports collaborative research, 'with the objective of establishing excellent research projects and networks able to attract researchers and investments from Europe and the entire world' (CORDIS, 2011). The Cooperation programme is divided into ten subject-based themes (e.g. Energy, Space, Transport). Calls for proposals on topics within each theme are made periodically, and funds are awarded through a range of schemes such as collaborative projects and networks of excellence. These usually involve at least three different teams from different countries working in research institutions as well as industry. One of the Cooperation programme themes is 'Food, Agriculture and Fisheries, Biotechnology' and was designed to specifically support research related to building a Knowledge-Based Bio-Economy (KBBE). As part of the KBBE Forum collaboration, in which Australia is involved, the EU hopes to move from twinning research projects to twinning research programs, and even to multi-lateral programs with harmonised national funding. The purpose of this would be to allow strategic, long-term international collaborative arrangements to form with relative funding certainty for research within a subject area.

Source: Innovation Division/Review Taskforce, 2011

Table 10: Principles of the Framework

1. The innovation initiative supports the development and effectiveness of the National Innovation System
2. The innovation initiative reflects and responds to identified demand side needs and/or priorities
3. The rationale for intervention and the role of government are clearly identified, and supported by the best available evidence, where relevant
4. The best placed jurisdiction(s) will be responsible for design and delivery
5. Innovation risk is assessed, accepted and incorporated into the design of innovation initiatives
6. The innovation initiative is well designed with clarity about; purpose, expected outcome, key performance indicators, evaluation processes to assess return on investment (financial, economic, environmental or social) and user/target groups
7. The innovation initiative is designed with end users in mind, taking into consideration issues such as; accessibility, eligibility criteria, application processes, compliance burden and the responsibilities of successful applicants
8. The innovation initiative is evaluated against its own objectives and for impact on the regional or national innovation system

Source: DIISR, 2009

Improving governance arrangements to prioritise major national research initiatives

There was general agreement amongst stakeholders that the government needed to get the balance right between bottom-up competitive processes and top-down directive processes. There was general acceptance that the competitive grants programs that are underpinned by robust peer review processes should stay as they are. The top-down approach was seen to have greater potential to drive reform and many stakeholders supported the need for an appropriate governance model that supported government to make informed decisions in terms of major research investment. Appropriate research investment planning was also considered essential.

In particular, many stakeholders noted the need for a more strategic dialogue about research investment in the national interest and canvassed options for governance mechanisms, from which government might seek advice about future major research investment decisions. Options included a forum of senior Australian Government officials or a forum between the Chief Scientist for Australia and his state counterparts (augmented by representatives from those jurisdictions without Chief Scientists and relevant agency heads). There was also some support to utilise the Prime Minister's Science, Engineering and Innovation Council (PMSEIC), with appropriate changes to ensure that it was reengaged with the public sector, for a strategic dialogue. An alternative model was for the creation of an Australian Research Committee of senior Commonwealth officials, chaired by the Chief Scientist for Australia, which would have responsibility for, among other things, the development of a forward national research investment plan (with input from the states and territories and industry). The plan could be used to inform new policy proposals and ensure coherence of research investment in key areas e.g. human capital, infrastructure and collaborations.

A number of stakeholders noted that a governance model should be guided by considerations of the effectiveness of current arrangements and if there is value in adaptation of any forum, the need for longevity in governance, clear identification of the governance model's purpose and operation, and the involvement of representatives who can consider issues from the national system perspective.

Reducing transaction costs

While as set out in **Section 4.6** there is a lot of very good, complementary research being undertaken in areas of priority, better coordination of efforts at a national level could reduce wastage costs associated with duplication. Good coordination of research activities, including through cooperative partnerships between the participants in the research system is essential to maximising the dividend derived from public research. A number of stakeholders noted opportunities to improve the coordination of research activities across government departments and agencies – see **Box 10**.

BOX 10: OPPORTUNITIES FOR BETTER COORDINATION AND REDUCED DUPLICATION

Stakeholders raised the issue that currently many universities and states are keen to set up their own energy institutes which may lead to unhelpful duplication. In addition, there are eight groups in CSIRO which are involved in eight solar flagships. Having the energy effort coordinated nationally would ensure the development of high quality national research infrastructure in this critical area. It would also reduce transaction costs associated with setting up new entities to undertake research where there are already identified participants with the relevant capacity to conduct the research. In addition, many stakeholders noted the proliferation of small competitive funding programs, and in particular, inefficiencies and unnecessary costs associated with those programs leading to the creation of new small research entities, especially in areas where world-class capability might already exist in established institutions (for example in medical research). Again, many stakeholders noted the need for greater Australian Government leadership in relation to decisions about funding programs to ensure that the best use is made of the research investment.

A number of international examples were given to illustrate the potential value of Australia adopting a more whole of government approach to the coordination of its research system. One example was the Research Council of Norway (Council), which offers whole-of-government oversight of Norway's research system. The Council acts as a government adviser, identifying present and future needs for knowledge and research. In addition, all of Norway's Ministries direct a high proportion of their strategic research spending through the Council and the Council in turn manages research programs on their behalf. Approximately one third of Norway's public sector research investment is channelled through the Council, with most of the remaining funding representing core institutional funding for higher education institutions and public research agencies, which is channelled directly from the relevant Ministry (ERAWATCH, 2010). The Biomedical Sciences in

Singapore offers another example where government has led an integrated approach to developing capability in a key area in terms of research, infrastructure and industry development; see **Box 11**.

BOX 11: SINGAPORE – BUILDING INTERNATIONAL BIOTECHNOLOGY EXCELLENCE

Many international life sciences companies have made Singapore a major R&D hub and their base for expansion into the rest of the Asia-Pacific region. However, the rapid growth of Singapore's biotechnology industry is driven by the public sector and underpinned by government policy initiatives.

Singapore adopted an integrated approach, the Biomedical Sciences (BMS) initiative, to develop the Biomedical Sciences cluster as a key pillar of its economy. The initiative is led and coordinated by a Steering Committee comprising the Ministers for Trade & Industry, Health, and Education, and comprises 3 phases to date. *Phase 1: Building the Foundation* (2000-2005) focused on establishing core public research capabilities in key areas and world-class research infrastructure. *Phase 2: Strengthening Translational and Clinical Research Capabilities* (2006-2010) focused on translational and clinical research to 'bridge the gap between bench and bedside', while continuing to build up basic research capability. *Phase 3: Capturing Opportunities for Greater Economic and Health Impact* (2011-2015) focuses on three main areas to capture the growing opportunities arising from global trends in the BMS industry: enhanced industry engagement, mission-oriented programmes with high growth potential, and seamless integration and translation.

Regulatory issues are also an important plank of government policy. Singapore became the first Asian country to accede to the Pharmaceutical Inspection Co-operation Scheme, enhancing its position as the regional pharmaceutical and life sciences hub. Singapore has been ranked by the Political and Economic Risk Consultancy (PERC) as having the best IPR protection in Asia since 1997. Singapore also offers favourable tax structures, tax rates and tax incentives for manufacturing or service enterprises, including in biotechnology.

Source: Review Taskforce, from Singapore Agency for Science Technology and Research (A*STAR) and PERC original documents.

FUTURE DIRECTIONS

Consideration should be given to:

- ways to give greater recognition to the crucial role of universities in human capital development
  - findings from the current review of higher education base funding (DEEWR, 2010) that relate to the principles to underpin public investment in higher education teaching will need to be taken into account in any future public investment in higher education research to ensure consistency in approach
- clarifying the roles of the publicly funded research agencies in terms of maintaining Australia's publicly funded research capabilities, particularly in terms of generating and translating knowledge to have impact in economic, environmental and community terms
  - making explicit the expectations of government in relation to the appropriate focus of the PFRAs to maintaining national research capability in key areas to enable Australia to effectively respond to emerging industrial, social, health, security and environmental challenges
- ways to increase the strategic dialogue within the Australian research system and support future government investment decisions in research through:

- implementing an appropriate governance mechanism, for example, a committee of key senior Australian Government officials, led by the Chief Scientist for Australia, to effect this national dialogue and develop a national research investment plan, with input from the states and territories and industry, to maximise the productivity gains from investment in research
  - opportunities for greater involvement of states and territories in future compacts discussions with universities and more explicit focus on institutional missions and associated institutional performance measures and their alignment with both Commonwealth and state/territory priorities and needs
  - adoption by all jurisdictions of the Framework of Principles for Innovation Initiatives to guide major research investment decisions in the future
  - opportunities to reduce unnecessary administrative duplication and reduce transaction costs associated with setting up new entities to undertake research in areas where there are already identified participants with the relevant capacity to conduct the research or to administer the funding on behalf of the government

- options to amend the funding arrangements for government programs, as well as future initiatives, to encourage, recognise and reward collaboration between universities and industry and other end users should be considered. This could include changes in the first instance, within existing funding allocations, to the ARC's Linkage and/or Centres of Excellence initiatives and DIISR's Research Block Grant schemes, particularly the JRE scheme.

5.2. APPROPRIATENESS OF THE LEVEL AND BALANCE OF PUBLIC FUNDING FOR BASIC vs. APPLIED RESEARCH

KEY FINDINGS

Government makes a significant investment in both basic and applied research through funding to universities and PFRAs. As set out in **Section 4.3**, the Review noted that there is a clear trend in expenditure patterns over recent years for there to be less focus on basic research and more on applied research in Australia.

Balance between basic and applied research

The Review agrees with the Productivity Commission's conclusion from its 2007 research report, *Public Support for Science and Innovation*, that there is no absolute standard by which to judge the relative level and balance of public funding for basic and applied research. However, as per the Productivity Commission's findings, the consensus of the stakeholders consulted as part of this Review was that the current balance was about right. In terms of overall balance, the case studies (see **Section 5.1**) also demonstrated that Australia would appear to currently have a satisfactory balance between basic and applied research.

That said, the Review noted however that there is no clear delineation between the types of research conducted by different sectors with PFRAs and higher education institutions conducting both basic and applied research. Indeed, most stakeholders considered that the distinctions between various forms of research were anachronistic. In practice, all research was considered to have elements of both basic and applied research with some research leading to incremental change while other research was leading to quantum change. There is other evidence that supports the need to move on from the discussion about the relative balance between basic and applied research and to focus instead on the ways to improve the overall links within the research system (Pannell, 1999).

There was also recognition by stakeholders that much of the research that is conducted may not produce evidence of wider benefit until many years later. For example, in disciplines such as physics, benefits may not be evident until up to 25 years later (HEFCE, 2010). A number of stakeholders also considered that the public value of research in which research is translated into desirable social outcomes needs to be given appropriate recognition in the research enterprise. This view is also reflected in recent US analyses of the public values failure of climate science (Meyer, 2011).

Overall, the conduct of basic research was seen as being critical in higher education institutions to the training and development of highly skilled researchers, which is a core goal of those institutions.

Stakeholders generally agreed that the traditional linear model of innovation was no longer relevant. The criticism of the so-called linear model is of course well known (Balconi, Brusoni, and Orsenigo, 2009) and what is meant by this term often varies. Most stakeholders characterised the challenge in terms of ensuring that basic research was not viewed as a necessary precursor to research application. However, basic research was still widely recognised as having an important role to play in Australia's innovation system for two key reasons: first, the conduct of basic research ensures that there is diversity in the national research base and a ready capacity to expand into new and emerging fields of research; and second, the conduct of basic research may inspire researchers, including those in training, to create new knowledge and/or lead to novel research applications.

Balance between competitive and untied funding

In addition to the issue of the relative balance of public funding for basic vs. applied research, a key issue in research funding is the appropriate balance between direct granting schemes and indirect support through general institutional operating funding from the government. Many stakeholders noted the importance of ensuring that there is an appropriate provision of both competitive (or tied) and capacity building (or untied) block funding to higher education institutions and PFRAs. This balance was considered necessary to ensure that Australia's innovation system can continue to draw upon the balance of basic and applied research needed to sustain and maximise the returns from government investment.

The Review found that there was no consensus on the issue of where best to put future investment in public sector research with some arguing that more funding should be provided through competitive schemes and others arguing that an increase in untied grants would be more effective. Some stakeholders also raised the opportunity to streamline competitive grant application and selection processes.

In the absence of a clear policy rationale for changing the balance between direct and untied funding, the current balance should be maintained. However, in any future government decisions about the allocation of additional public funding for research, consideration should be given to the relative benefits of funding for excellent research through competitive grants and for capacity building through untied grants.

Improved governance

Consistent with the findings at **Section 5.1**, stakeholders generally agreed that there would be value in an appropriate governance mechanism being established which could provide government with ongoing advice about issues relating to the overall balance in the system.

FUTURE DIRECTIONS

Consideration should be given to:

- as per **Section 5.1**, an appropriate governance mechanism to effect a national strategic dialogue and to support future government investment decisions in research, including the level and balance of research investments
- opportunities to streamline competitive grant processes.

5.3. THE UTILITY OF PUBLIC FUNDING ARRANGEMENTS, INCLUDING THE NATIONAL RESEARCH PRIORITIES, FOR ENSURING APPROPRIATE COORDINATION AND EFFICIENT USE OF RESOURCES

KEY FINDINGS

Current Utility of National Research Priorities

The Review found that the existing National Research Priorities (NRPs) were generally appropriate as a broad articulation of Australia's key interests in public research. In some instances, the NRPs have had a positive effect in terms of setting system priorities. For example, the CSIRO's National Research Flagships were established in the context of these priorities and are still considered useful to guide decisions regarding future Flagships.

The NRPs are given some weighting in ARC grant decision making processes but are not generally used to drive research investment. As such, some stakeholders raised concerns about the degree to which the NRPs were useful in their current form to be used in grant decisions. There was a general perception that the NRPs are too broad in their current form to be usefully included as selection criteria in grant decision making processes. Some concerns were also raised about the current process for monitoring and reporting research effort against the NRPs and suggested that there needed to be greater transparency in relation to this.

While the stated aim of the NRPs was to concentrate the nation's research resources and to support the development of critical mass in key areas, in practice this has not occurred. As such, many stakeholders believed that the NRPs in their current form are too broad and do not appropriately highlight priority areas. For example, concern was raised that the NRP of Safeguarding Australia does not adequately cater for non-defence national security, which has grown in prominence since the NRPs were introduced. Concerns were also raised that the area of energy research is not properly encompassed within any of the NRPs.

Additional Priority to Acknowledge the Strategic Goals of HASS in the Research Enterprise

Most stakeholders agreed that Humanities, Arts and Social Sciences (HASS) disciplines were important to innovation. Moreover, a number of stakeholders considered that there would be value in augmenting the existing research priorities with the inclusion of an additional priority to better acknowledge the strategic goals of HASS in the research enterprise. This was considered to be an effective way for the substantive contributions of these research disciplines to be acknowledged in their own right, rather than as a 'handmaiden' to the physical sciences. In addition, HASS was seen as essential to ensuring community acceptance of current and future innovation.

In acknowledgement of the role of HASS, the recent infrastructure roadmapping exercises have ensured that explicit consideration is given to issues relating to collaborative infrastructure priorities in the HASS disciplines.

Other possible options to enhance the NRPs

In addition to the option of including an additional NRP to recognise the role of the HASS disciplines in contributing to our innovation dividend, a range of other suggestions were made to enhance the current NRPs. One option is for the priority goals under each of the NRPs to be refreshed and made explicit to ensure that appropriate priority is being given to areas within each of the NRPs.

Several stakeholders suggested that consideration be given to adopting a set of structural priorities, which would relate to those areas that Australia needs to focus on to achieve a world class research and innovation system and provide a focus for investment (e.g. attracting and retaining higher degree by research qualified people; establishing the highest quality research infrastructure; and developing and maintaining global networks). The Review noted that the government's current National Innovation Priorities (NIPs) are already in place as clear statements of the government's policy ambitions in regards to a achieving a world class innovation system. The Review found, however, that some stakeholders did not see the current NRPs and NIPs as explicitly linked or complementary.

Other stakeholders suggested that the government first establish priorities for government investment in areas of national need e.g. defence and security; sustainability; quality of life; capacity for wealth creation and then determine appropriate investment strategies e.g. in human capital formation; innovative capacity of the nation; growing businesses in society.

There was general agreement that whatever model was adopted, clear priorities should guide large-scale research infrastructure decisions of government.

The Framework of Principles for Innovation Initiatives may also have utility in terms of priority-setting (see also **Section 5.1**). A further observation was the need for strategic fit between top-level priorities and more specific priorities identified by research agencies and departments.

The Review also noted the need to ensure a regular process of review of the NRPs and the associated NIPs so that the priorities remain useful to coordinate national research effort and investment.

FUTURE DIRECTIONS

Consideration should be given to:

- the addition of a fifth NRP to more explicitly take into account the contribution of the HASS disciplines to the national research enterprise
- refreshing and refining the priority goals under the NRPs
- examining links between the NRPs and the NIPs
- establishing an appropriate mechanism for regular reporting of expenditure against the NRPs and review of research and innovation priorities. This could include greater transparency in terms of how institutions are contributing to the realisation of explicit goals under the priorities and the strategic fit of institutional-led priorities.

5.4. THE NEED FOR A LONG-TERM STRATEGY TO PROVIDE NATIONAL COLLABORATIVE RESEARCH INFRASTRUCTURE

KEY FINDINGS

The Review noted the considerable work over many years to ensure that Australia has a long-term strategy to provide national collaborative research infrastructure. The strategy has included identifying priority research infrastructure needs within the research community, securing funding and developing and executing detailed implementation plans. The various development processes for collaborative research infrastructure plans involving a range of participants in the national innovation system and the successful implementation of these plans attests to the value of long term planning of public investment in national collaborative research infrastructure. The recent evaluation of NCRIS (DIISR, 2010b, p.1) concluded that the NCRIS model was an “appropriate, effective and efficient mechanism for establishing critical research infrastructure for Australia.”

The Review found that the current process for developing a new Strategic Roadmap for Australian Research Infrastructure was generally considered to be providing an appropriate mechanism for long-term investment decisions in collaborative research infrastructure. The Review also found that there were opportunities for greater leadership by the Australian Government and greater coordination within the Australian Government for infrastructure funding in areas of national priorities. Consistent with the findings of **Section 5.1**, in the case of collaborative research infrastructure decisions, the Review supports the establishment of an appropriate governance mechanism to ensure that Australia continues to maximise productivity gains from the national investment in research infrastructure.

Meeting the Full Costs of Infrastructure and Research:

Stakeholders agreed that both the initial costs to establish infrastructure and the ongoing costs associated with maintaining infrastructure (e.g. access arrangements, people to run and maintain it) needed to be fully met to ensure that the infrastructure was fully utilised. Concerns were raised about the short-term nature of some funding arrangements and the lack of clarity in some funding rules. Again, Australian Government leadership was seen as important to ensuring that suitable infrastructure funding models were developed, including allowing flexibility in approaches to maximise returns from the investment. Concerns were also raised that the failure to meet the full cost of research was making it difficult for institutions to appropriately maintain their research infrastructure.

Meeting System-Wide Infrastructure Needs:

While there was support for a long-term strategy to provide national collaborative research infrastructure, many stakeholders raised concerns about the degree to which there was a sufficient focus on national interest considerations in making major research infrastructure decisions. This was in the context that some Australian Government programs for infrastructure emphasised competition, which may have been at the expense of collaborative, strategic decisions in the national interest and which risked fragmentation in infrastructure effort. A number of stakeholders also raised the importance of ongoing Australian Government leadership as a critical condition for ensuring a nationally coordinated approach to funding collaborative research infrastructure and guarding against any unhelpful overlapping administrative processes. As set out at **Section 5.1**, some stakeholders expressed concern that some states were getting enormous leverage off small investment which may not be in the national interest.

It was considered important that in making its investment decisions about major collaborative research infrastructure, the Australian Government work with the states and territories to ensure that the investment is considered strategically for the nation and that the jurisdictions view the investment as a collaborative opportunity, rather than a point of competition.

The National Research Infrastructure Council (NRIC) will be providing advice to government in the form of a Strategic Framework for Research Infrastructure Investment. It is intended that the Framework will help guide future policy with respect to research infrastructure and the design of future funding programs, and be sufficiently broad and flexible that it will be able to be used by other agencies involved in research infrastructure funding, and provide the basis for a more coordinated and integrated approach to investment across the sector (DIISR, 2010b). Stakeholders believed that it was important that states and territories were also fully engaged throughout this process.

Many of the considerations set out in relation to the other issues considered as part of the Review are relevant to future strategies to provide collaborative research infrastructure. In particular, the Review found that:

- there were opportunities for greater leadership by the Australian Government and increased coordination within the Australian Government for infrastructure funding in areas of national importance that involve multiple participants in the research system (e.g. universities and MRIs in health and medical research); and
- an appropriate governance mechanism to support future government decisions about the level and balance of research investments could also encompass national collaborative research infrastructure decisions.

FUTURE DIRECTIONS

Consideration needs to be given to:

- ways in which future collaborative research infrastructure funding processes can take account of system capability building and existing deep capacity including through a greater leadership role of the Australian Government in ensuring that infrastructure expenditure is directed to areas of national importance.
    - This could be achieved through an appropriate governance mechanism to effect a national strategic dialogue and to support future government investments decisions in research (as set out in **Section 5.1**).

5.5. DEVELOPMENT OF PERFORMANCE MEASURES TO PERMIT RIGOROUS EVALUATION OF PUBLICLY FUNDED RESEARCH PROGRAMS

KEY FINDINGS

Robust evidence on relative research performance arising from government investment is important for ensuring that investment in research is well spent. Measuring research performance has become an increasingly important policy issue in Australia (e.g. Australian Financial Review, 2011a; Australian Financial Review, 2011b) particularly with the prospect that increasing amounts of research funding will be tied to performance results. There is general agreement that measurement linked to funding is very influential in driving behaviours. That said, there is no straightforward connection between financial incentives and research productivity (Auranen & Nieminen, 2010; Bourke and Butler, 1999).

Assessing Research Excellence

The Review noted the wealth of bibliometric and other data that is already available to assess the intrinsic academic worth and relative impact of academic outputs from publicly funded research. The Review also acknowledges the wide variety of evidence from individual program evaluations including from PFRAs. However, there is very little systematic evidence regarding the broader economic, social and environmental benefits of publicly funded research undertaken across the publicly funded research system as a whole.

The Review also noted the broad acceptance of ERA as a rigorous method for assessing the research excellence in disciplines within and across Australia's higher education institutions. The value of ERA in guiding research funding to higher education institutions was also recognised in terms of properly rewarding research excellence. Allocation of Australian government funding in support of research by higher education institutions will incorporate the use of ERA outcomes, including under the SRE and RTS block grant schemes and the Collaborative Research Networks program. However, the dominant view from stakeholders consulted as part of the Review was that measures of excellence should not be used as a sole or dominant driver of funding.

Concerns were raised that applied research, multidisciplinary research and Australian research issues, including Indigenous research are not appropriately assessed by ERA. Many of these concerns will no doubt be addressed as a result of the recently announced changes to the ERA methodology for the 2012 assessment process (Carr, 2011c). Moreover, ERA does not evaluate the economic return on research investment or the volume of social goods associated with that investment (Wells, 2011), nor does ERA show the links between excellence (as measured in ERA) and impact relating to innovation.

Most stakeholders considered that in addition to excellence, research needs to make a difference and this should be measured to change and drive behaviour. Concerns were also raised that over-reliance on excellence may pervert or degrade capacity building in the longer term, which would compromise Australia's innovation dividend.

Assessing the Wider Benefits of Research

As set out above, ERA provides good evidence about where Australia is performing excellent research in the higher education sector. However, it was not intended to show where the strengths in the research system are in terms of generating the innovation dividend. While excellence is important, almost all stakeholders considered that there would be value in Australia giving consideration to the development of a measure of impact leading to innovation. There are a wide range of impacts in the form of innovation that have been identified in various studies, many of them difficult to quantify (Siegfried, Sanderson and McHenry, 2006). A particular challenge in assessing the wider benefits of research relates to the reference period over which wider benefits can be demonstrated. As set out previously, evidence of wider benefit of research may not be evident until many years later (HEFCE, 2010). In addition, given the length of time that it takes to demonstrate wider benefits in some areas of research, there are inevitably methodological challenges relating to both the quality of data available to assess these benefits and the appropriate attribution of effort to achieving those benefits.

The Review identified some stakeholder support for Australia to trial a case study approach to evaluating the impact of research, which might be informed by the approach used by the Higher Education Funding Council for England (HEFCE). The HEFCE model builds on work from other countries, including Australia (Grant et al., 2009). For 2014, the four UK higher education funding bodies will recognise and reward excellent research that has led to wider social and economic benefits. Specifically, in the 2014 Research Excellence Framework (REF) exercise, 20 per cent of the assessment result will be based on the economic and social benefits of excellent research. HEFCE will also allocate 20 per cent of its funding based on outcomes from the research assessment exercise.

In announcing HEFCE's decision to include explicit assessment of impact in the REF for the first time, HEFCE (2011) noted that this was a demonstration of the importance placed on research outside the research community and enables universities to rigorously demonstrate the success of their research and the contribution it makes to the economy and society. The UK has also recently announced the establishment of a new task force, set up by the Council for Industry and Higher Education, to examine how the UK can maximise the value of publicly funded research. The taskforce will produce reports and action plans outlining what businesses and universities can do to get "maximum economic impact" from research (Matthews, 2011).

There is also activity occurring in the Australian context which could prove instructive. With its mandate to "improve aspects of Australia's future economic, environmental and community well-being", CSIRO has considerable experience in assessing the benefits of its research beyond the academic sphere, examining its benefits for business, industry, community and/or government end users. For instance, for the reviews of flagships and divisions, CSIRO has assembled panels of eminent Australian and international experts to assess, amongst other criteria, the extent to which the flagship or division has:

- clear objectives and realistic paths towards adoption and use of research results;
- strong and effective collaboration with organisations likely to adopt research results (in addition to research partners and other stakeholders of influence);
- the potential of research results to set the pace of scientific, commercial, environmental, community or policy development in the user community; and
- the potential of research results to beneficially distinguish adopting organisations from their peers.

The Australian National Audit Office (ANAO) recently reported on the development and administration of the CSIRO National Research Flagships, noting the program's focus on delivering economic, social and environmental impact. The ANAO noted the reliance by CSIRO on externally prepared individual case studies on the estimated impact of research, rather than a systematic process of measurement. The ANAO also noted the findings of the 2010 Lapsing Program Review, which recommended that CSIRO improve its measurement of the social, environmental and economic value of its research. CSIRO responded by establishing its Impact 2020 Project, which is designed to improve the way impact is measured and increase the visibility of CSIRO's future impact pipeline for the next 10 to 20 years (ANAO, 2011).

In addition, CSIRO considers that in designing research projects, value must be put into assessing the level of research knowledge at present (or what it is likely to be in the next few years), any powerful new technologies to apply to the research, as well as the needs and opportunities as perceived by commercial, environmental and community stakeholders. The inputs from both the science and the stakeholder side need to be considered in setting up a strategic research program. It is also critical that a good level of communication be maintained with stakeholders through the research process. CSIRO's experience in this area offers the opportunity for Government to critically examine the issues of research benefits assessment, including the complexities, pitfalls and advantages of various approaches.

There are also opportunities to learn from the joint work of CSIRO and the RDCs aimed at identifying the key principles and features of a conceptual framework for triple-bottom-line (economic, social and environmental) impact evaluation. The university sector, through the ATN, and utilising the UK's case study methodology, will undertake a trial of research impact measurement in parallel with the 2012 ERA exercise (Mather, 2011).

Notwithstanding the obvious methodological challenges in doing so, the Review concluded that there would be value in conducting a feasibility study on the development of possible assessment tools to more rigorously evaluate the wider economic and social benefits that are derived from Australia's publicly funded research investment. Depending on the results of the feasibility study, one or more models could be trialled to examine the potential utility in the Australian context. A field of research could be chosen for the trial where the innovation dividend is most likely to be evident in the Australian context e.g. engineering and technology.

The development of a robust model to assess the wider benefits of research is likely to require extensive technical work and stakeholder consultation as well as trialling prior to implementation. Additional funding to support the development of an assessment tool that would have the confidence of the government and the higher education and research sectors may be required.

FUTURE DIRECTIONS

Consideration needs to be given to:

- undertaking a feasibility study to examine options for the development of performance measures to assess the wider benefits of publicly funded research
  - any models developed for trialling would take into account the outcomes from international exercises to assess wider benefits from research, including in the UK, and the learnings from the experience of CSIRO in undertaking reviews of its performance in terms of the assessment of benefits beyond the academic sphere
- ways to increase the recognition and rewards for research collaboration and capacity building.

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