PRODUCTIVITY COMMISSION

Research Study on

PUBLIC SUPPORT FOR SCIENCE AND INNOVATION IN AUSTRALIA

Submission by

Australian Academy of Technological Sciences and Engineering

July 2006

Australian Academy of Technological Sciences and Engineering

The Australian Academy of Technological Sciences and Engineering (ATSE) has some 700 elected Fellows, consisting of the leading applied scientists and engineers in the country. The Academy is one of four established learned Academies in Australia (the others being Science, Social Sciences and Humanities). The mission of ATSE is to promote the application of scientific and engineering knowledge to the future benefit of Australia.

Background

Australia has enjoyed recent economic prosperity. By global standards, Australia is an affluent, but relatively small market. However, accelerating global integration is changing forever the volume and composition of international trade. To achieve international competitiveness, many Australian organisations must produce for the global market to achieve the necessary economies of scale and scope. Focussing on the domestic market not only limits growth opportunities, it can handicap competitiveness.[1] In addition, Australia is facing a major intergenerational change that will place significant pressure on Australian society to maintain its economic prosperity. Against this background of global change, intergenerational change and the knowledge economy, Australia must find ways to generate competitive advantage to increase output in order to sustain society. Clearly, one major focus for Australia must be to be a major innovating society to increase wealth for the benefit of society.

Governments play an important role in the national innovation system. Traditionally their missions have been to fund and perform research and thereby expand the pool of scientific knowledge for the benefit of society at large and to support R&D activities in areas where market mechanisms were inappropriate or insufficient to respond to social demands or meet specific government objectives. The fulfilment of these missions has formed the basis of a social contract that bound science and society and provided the main rationale for public investment in scientific research via publicly funded research institutions. A recent statement on the social contract was that "the practice of scientific research and the use of knowledge from that research should always aim at the welfare of humankind and for the benefit of the global environment, and that it should take fully into account our responsibility towards present and future generations."[2]

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[1] Industry Statement, *Global Integration – Background Paper,* Department of Industry Tourism and Resources, July 2006

[2] UNESCO, *Declaration on Science and the Use of Scientific Knowledge*, World Conference of Science, Budapest, Hungry 1999

Over time, and especially in the past decade, science systems in most OECD countries have faced new challenges. These challenges have led to calls for reforms in the Government's role in supporting research and the governance of science systems. The main challenge has been for science systems to respond better to a more diverse set of stakeholders, including the interface between science systems and industrial innovation.[3] The Academy notes the recent House of Representatives report on innovation[4] and broadly supports the recommendations contained therein.

ATSE considers the Productivity Commission's study into "Public Support for Science and Innovation in Australia" as a most important initiative and is very relevant to the focus of the Academy. In recent years the Academy has organised a number of seminars, conducted a National Symposium and made a submission to the House of Representatives inquiry *Pathways to Technological Innovation.*

The Academy's submission is founded on data and information pertaining to the innovation system. A summary of some of the key aspects of the data is contained in the following attachments:

Attachment 1 – The Global Knowledge Economy – the Central Context of Innovation
Attachment 2 – Patterns of Innovation in Australian Businesses, 2003
Attachment 3 – Sourcing Science

Definitions

Innovation

The definition used by the Productivity Commission for innovation, "the introduction of any new or significantly improved goods, services, operational and/or organisational processes" is widely accepted and is supported by the Academy. There are definitions that are much broader relating to other business processes but for this submission only those that are linked with science, technological science and engineering (for brevity referred to subsequently as "science") are considered.

Innovation System

The Academy supports the definition used by the Productivity Commission and notes that the success of the innovation system depends on the ways in which we integrate the various elements of our innovation capability.

Publicly Funded Research Institutions

Publicly Funded Research Institutions (PFRIs) include universities, CSIRO, AIMS, ANSTO, DSTO, Geoscience Australia, Bureau of Meteorology, medical research institutions and so on. State government-funded organisations are also important, particularly in agriculture areas.

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[3] OECD *Science and Innovation Policy, Key Challenges and Opportunities*, Organisation for Economic Cooperation and Development, Paris 2004

[4] House of Representatives Standing Committee on Science and Innovation, *Pathways to Technological Innovation*, Commonwealth of Australia, Canberra, June 2006

Scope of Submission

The Academy's submission is focussed on two terms of reference of the Productivity Commission's study (given in italics below); a brief summary of the Academy's submission is given under each term of reference

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

  Submission Summary:
  a. Provide a whole-of-government approach to innovation; there are too many conflicts and gaps in the delivery of existing programs.
  b. Provide enhanced incentives for organisations to undertake innovation – as organisations are the main drivers of innovation.
  c. Establish enhanced collaboration between organisations and PFRIs, including the establishment of "innovation clusters".
  d. Strategically focus R&D funding in PFRIs to stimulate the growth of knowledge-based industries.
  e. Develop a comprehensive skills strategy that will increase the number of graduates in engineering, technology and science.

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

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

  Submission Summary:
  a. Maintain the funding support for basic science.
  b. Provide enhanced collaboration between organisations and PFRIs, including additional funding for linkage grants and access to human capital (for example, placement of students and graduates in innovating organisations).
  c. Introduce greater flexibility into the existing funding mechanisms that support innovating organisations (and be prepared to accept greater risk).
  d. Provide greater capability within institutions to engage with organisations in the innovation process and thereby deliver increased performance.
  e. Provide mechanisms for institutions to access funding for research that has potential high commercial outcomes.

The major issues addressed in the Academy's submission are given in the following sections.

List of Major Issues

The Academy has identified a number of policy issues that demand attention. A list of the major issues is given below:

- ***Maintain support for basic science***
- ***Need for investment in knowledge in Australia***
- ***Ensure that industry is the major driver for innovation***
- ***Encourage more collaboration between organisations and PFRIs***
- ***Increase the capability to use knowledge generated elsewhere***
- ***Stimulate the transition from the science base to the business sector***
- ***Introduce flexibility in the innovation pipeline***
- ***Address conflicts and gaps in the innovation system***
- ***Increase the national investment in the skills required to prosper in a knowledge economy***
- ***Review national research priorities***
- ***The role of PMSEIC***

Details on each of these major issues are given in the following section.

Major Issues

• *Maintain support for basic science*

Much of the funding of the PFRIs, and in particular, funding for universities, is an investment in the future. The two principal outputs from universities are graduates and advances in scientific and technological knowledge. These contributions are largely indirect and non immediate – they are hard to measure but substantial.[5] These contributions are easily overlooked. The most obvious indirect contribution is through the education of graduates who are then employed in organisations to apply the knowledge or skills that they have acquired at university. Specialist knowledge can also be called on from public institutions to provide consultancy services to

[5] Tether, B S & Swann, G M P, *Sourcing Science – The Use by Industry of the Science Base for Innovation*; Evidence from the UK's Innovation Survey, Version 1.2, 8 August 2003

businesses in their efforts to innovate. Other indirect contributions follow from the circulation of information or knowledge.

There is a need to be mindful that expanding direct interactions between the PFRIs and industry must be done while at least maintaining the indirect and longer-term contributions of the PFRIs. It is essential that universities and the PFRIs continue to undertake independent and long-term research, most of which will be in advance of, and different from, the current needs of industry. There are two issues here.[6]

> ***The first is the need to at least maintain funding for long-term research of the sort that industry will not fund because of the uncertainties involved or it is too early stage and because of the difficulties of appropriating the returns to the new discoveries. Many highly significant technologies were initially developed without initial thought of their industrial application. Secondly, there is a need to at least maintain funding to undertake independent science that serves the public interest particularly in areas such as environment, climate, public health and so on***.

R&D undertaken by organisations in their own private interest does not necessarily always coincide with the public interest such as research into the environment, water, climate and so on. Accordingly, the science research system should not be made more responsive to identifiable opportunities at the expense of creativity and diversity in exploring the knowledge frontiers over the long term. As changes in business R&D strategies focus on short term performance there is a reduced interest by private industry to invest in fundamental research, and the consequential need for government support increases. Securing support for fundamental research is therefore a priority for most governments, even if some have found it difficult at times to meet this objective.[7]

- ***Need for investment in knowledge in Australia***

Australian investment in R&D, one key generator of knowledge, is approximately half that of the OECD average. This outcome is largely due to a relatively low business investment in R&D. However, it must be recognised that business has been funding an increasing share in recent years. Further, as noted in the Productivity Commission's Issue Paper (April 2006), Australia's total investment in knowledge (R&D, software and education) is similar (but somewhat below) the OECD average.

A recent Business Council of Australia report[8] argued that criticism of Australian industry for its relatively low investment in R&D, compared to other OECD countries, was inappropriate, essentially for two reasons: the R&D was comparable on a sectoral basis (given that Australian industry happens to be concentrated in low R&D sectors), and there is significant investment in other, non-R&D types of innovation.

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6 *Ibid*

7 OECD *Science and Innovation Policy, Key Challenges and Opportunities*, Organisation for Economic Cooperation and Development, Paris 2004

8 Business Council of Australia, *New Concepts in Innovation – The Keys to a Growing Australia*, March 2006

These findings may be correct, but they tend to reflect a view that the current industry mix constrains Australia to the current levels of R&D intensity without searching for strategies to improve performance and thereby meet Australia's future needs for economic and social development in a global economy.

Two broad determinants of national investment in R&D have been established: intrinsic factors which address the propensity to invest, and structural factors, which reflect the above argument that different industry sectors require different levels of R&D investment to remain competitive. The ICT and pharmaceutical sectors are the highest investors in R&D (typically 10 per cent of turnover) and they barely exist in Australia.

The Academy considers the evidence is clear with regard to both factors in Australia. Intrinsically determined investment in R&D is progressively falling further behind that of OECD nations, and significantly behind, in absolute terms, that of emerging economies such as China and India.

With regard to the structural issue, it is quite insufficient to argue that we have a level of R&D appropriate to our industry structure. While there is a commodity boom we prosper, though at the cost of a dramatically rising deficit in our balance of trade, as we are forced to import the necessary goods from countries that do operate in the knowledge-intensive sectors. When the cycle turns, our present industry structure may find us desperately uncompetitive. In these circumstances Australia's prosperity relative to the rest of the world will decline.

An examination of the relative economic performance of the US and the EU has revealed that 22 per cent of the US companies which were in the top 1000 (by market capitalisation) in 2000 had been created after 1980, compared with only 5 per cent in Europe.[9] Some 70 per cent of these new US companies were in the IT sector. Examination of the companies in the Industrial R&D Scoreboard[10] would indicate the Australian situation is far closer to (probably worse than) that of Europe than to the US.

The important conclusion is that countries that do not adequately support a substantial level of formation of new technology-based organisations in emerging high-growth industries will not gain a foothold in these industries, and their subsequent industry structure will be progressively skewed towards low knowledge-intensity.[11] A particular opportunity for Australia is the strong commitment of public funds to medical research, in which Australia has a well-deserved outstanding international reputation yet much more needs to be done to explore the possibility and means of generating a significant industrial capability based on this research capability.

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[9] EC Working Document, 2006

[10] Van Dyke, N, *R&D and Intellectual Property Scoreboard 2005,* Intellectual Property Research Institute of Australia, University of Melbourne, 2006

[11] Marceau, J et. al., *The High Road or the Low Road?,* Australian Business Foundation Limited, August 1997

To avoid this decline means adopting measures to encourage the formation of a strong Australian capability in the next generation of emerging knowledge-based industries. In embryonic form some of these industries already exist but rarely are they financially robust enough to afford the type of research outlays to allow them to grow rapidly and become world competitive. This is where publicly funded support for research becomes extremely valuable to help these new companies or existing companies to diversify into new areas.

Other countries have policies and programs to nurture infant industries and attract foreign investment in key technology areas. They all rely significantly on public investment. Appropriate mechanisms could be developed in Australia, particularly in supporting the development of new technology. Furthermore, because we don't have industrial strength in the knowledge-intensive areas, (for example, DaimlerChrysler invests millions of dollars a year in a substantial in-house Strategic Futures Group) we tend not to have the capacity to identify important areas of potential growth via the private sector. Our industrial structure requires that we provide this knowledge-intensive capacity.

Accordingly, the provision of this capacity rests crucially on the strength of public sector institutions and the breadth and depth of their relationship with industry. Despite the additional funding for research through the 'Backing Australia's Ability' program, the capability of Australian universities to play their central role in knowledge creation and distribution is being eroded by the failure to maintain adequate growth in their basic funding. Further, the evidence available suggests that a number of major public sector research organisations are somewhat in disarray about their roles and purpose, with a consequent decline in staff morale. It would appear that there has been a significant decline in public esteem in a number of these organisations, and they are less able to play a crucial role in transmitting appropriate knowledge throughout the Australian economy.

> ***Accordingly, there is a need to implement policies to strategically focus funding for R&D in PFRIs and to encourage further investment in business expenditure on R&D (BERD) in Australia in order to stimulate growth of the knowledge-based industries.***

As a result of the globalisation of knowledge production (see Attachment 1) there are a number of direct implications for government policy. For example:

- how to maintain, let alone increase, the attractiveness of Australia as a location to invest in R&D;
- future employment of the local R&D labour force; and
- how to access the offshore R&D capabilities to promote Australian innovation.

- ***Ensure that industry is the major driver for innovation***

Only 35 per cent of businesses in Australia are involved in innovation and expenditure on innovation is highly concentrated in a small number of businesses (see Attachment 2). Clearly, existing organisations are a major source of innovation in Australia.

> ***Accordingly, one major strategy to increase the level of innovation in Australia is to increase support and incentives provided to industry to undertake innovation**.*

Publicly-funded research, in support of industry collaboration, has provided an incentive for industry to increase its share of its funds to innovation and R&D. This, in part, has resulted in a sustained increase in BERD over the last decade after a dramatic decrease when the 150 per cent tax concession was lowered to 125 per cent. The position has improved since then because of the incentive for companies to match funds in many government linkage programs, through the introduction of 175 per cent premium tax concession and so on. The tax concession and the rebate programs are a form of public support for research as it is a tax foregone. Further initiatives to encourage industry to engage in R&D would be to raise the threshold for the tax rebate system from the present $1million research expenditure/ $5 million turnover threshold to say $2 million / $10 million and to provide additional funding for collaborative research grants.

A business environment that is conducive to innovation depends on a wide range of policies that run the gambit of macro economic fundamentals (such as stable prices to competition policies) and to micro economic science and technology matters (such as incentives to private R&D and public procurement) and regulatory policies.[12]

- ***Encourage more collaboration between organisations and PFRIs***

Of the total expenditure on innovation and R&D in Australia in 2003 (Attachment 2), 31 per cent was on R&D (26 per cent was internal R&D and 5 per cent was acquired R&D). Furthermore, only 8 per cent of organisations had cooperation arrangements for their innovation activities, and of these about one-third had these arrangements with universities. Conversely, a fifth of those organisations in the top quintile, by innovation expenditure had collaborative arrangements for innovation with the 'science base'. Clearly, as more organisations become actively engaged in the innovation process they will naturally engage with the PFRIs, particularly if these institutions are prepared to actively market the services they can provide.

This low percentage of acquired R&D is consistent with the results from the UK study (Attachment 3) where only about 3 per cent of organisations had collaborative arrangements for innovation with the PFRIs. These observations are occurring at a time when there is a trend towards 'open innovation' as organisations (particularly those organisations that are actively engaged in innovation) increase their

[12] OECD *Science and Innovation Policy, Key Challenges and Opportunities*, Organisation for Economic Cooperation and Development, Paris 2004

collaboration and the use of external sources of innovation to enhance their internal capabilities and address uncertain economic conditions.[13]

Results from the UK study indicate that less than 2 per cent of organisations in Britain regarded the ‘science base’ as being of ‘high importance’ when sourcing information for their innovation activities. Further, as organisations increase their own commitments to innovation, there is a greater percentage of these organisations engaging with the 'science base' to support their innovation activities. Accordingly, the relatively small proportion of organisations that are actively involved in innovation will make greater use of the PFRIs. Conversely, the various linkage grant programs funded by various agencies in Australia are over subscribed with quality applications. Hence, the challenge is to get more organisations engaged with PFRIs as a way to support increased levels of innovation by organisations.

> ***Accordingly, there is a need to further develop policies and provide increased funding for R&D linkage projects between PFRIs and organisations undertaking innov*****ation.**

It is necessary, in view of the unmet demand, to increase the quantum of funding that is available for the various programs that support linkage with industry, such as the ARC Linkage Grant Program and the Co-operative Research Centre Program. In addition, increased support and incentives for PFRIs to align their activities with the innovation system could be provided by substantially increased funding for relevant programs; in the case of universities, this could be via the Institutional Grant Scheme, IGS. The IGS should be based, in part, on the quantum and quality of research supporting innovation in addition to the quantum and quality of academic research being undertaken. Increased funding for universities under such schemes as the IGS can be achieved by increased budget allocations and or by use of a small percentage of the Commonwealth operating grant to universities.

A very effective mechanism for organisations to collaborate with PFRIs and to become engaged with the innovation process is via access to human capital. Programs which might be considered include funding both recent graduates and advanced undergraduates for placement in those businesses that have a history of a low level of innovation but which have identified the need for them to become actively involved in the innovation process. It is appropriate that there be complementary funding provided by organisations and that participating universities actively support and are engaged with these new initiatives. Such programs will lead to greater collaboration between these organisations and the PFRIs and thereby further enhance the innovation system.

> ***Accordingly, there is a need to develop policies and to fund programs that enable organisations to both access relevant human capital skills and collaborate with PFRIs.***

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[13] OECD, *Science, Technology and Industry Outlook,* Organisation for Economic Cooperation and Development, 2004

There is a need to be cautious when expanding direct interactions between the PFRIs and industry at the expense of the indirect and longer-term interactions of the PFRIs; maintaining the core mission of PFRIs must also be considered. Interactions between publicly funded researchers and industry might however awaken an interest in research amongst some of those organisations with no history of investment in this area.

- ***Increase the capability to use knowledge generated elsewhere***

A frequently quoted statistic is that Australia generates only 2 per cent of the world's knowledge, so must seek the remaining 98 per cent overseas. Many countries, particularly in Europe, are making major investments to strengthen their access to international knowledge, through a variety of programs, such as: enabling students to move between universities in many countries during their degree studies (the Barcelona Agreement), supporting students to study abroad for a semester or year, international exchange programs, funding for researchers to participate in international research programs and funding for the interchange of personnel between PFRIs and industry. The same level of investment for similar programs does not exist in Australia.

There are significant opportunities to establish "Innovation Clusters" in Australia that focus on particular industry sectors and technologies. The purpose of these clusters is to link, via innovation / technology brokers, the knowledge base with appropriate organisations and PFRIs. It is important that PFRIs form part of the linkage to help interpret the sources of information and to translate it to specific organisations. This process will also help to develop collaborations between PFRIs and organisations that will be of long-term benefit to the process of innovation in organisations. There has been only limited support for such 'outreach' programs in Australia.

> ***Accordingly, there is a need to provide substantially increased funding to support 'outreach' programs, including the establishment of "Innovation Clusters".***

In recognition that there are multiple pathways for the adoption of research by industry, there has been recent debate about the prospect of Australia introducing a "third stream" or knowledge transfer" funding program to support such pathways. While the Academy is prepared to support such a concept, it is on the basis that such support is not at the expense of the introduction of "Innovation Clusters", and that any program funding is biased heavily towards those cases where industry/ end-user is clearly the driver of such pathways and where significant impact (or prospective impact) can be demonstrated.

- ***Stimulate the transition from the science base to the business sector***

Spin-offs and licence fees from publicly funded research can make a useful contribution to innovation, especially in the information technology and, increasingly, the biotechnology/medical technologies sectors.[14] Their indirect contribution to cultural change in PFRIs is even larger. There are numerous examples[15] of the need to improve the institutional frameworks (such as incubators and management of PFRIs and intellectual property) and to provide incentive structures (such as regulations governing researcher's mobility and the benefits from entrepreneurship) to ensure that there is more effective engagement between PFRIs and commercial organisations. Public seed capital to help early finance early-stage research (particularly at proof-of concept stage) when uncertainty is high and the projects too small for private venture capital has also proved useful, especially in countries where informal investors (such as business angels) cannot contribute much to filling the gap. There is also a case for public support and incentives to existing SMEs, especially in mature industries, to help them forge stronger links with the science sector.[16]

> ***Accordingly, governments need to support improvements in institutional frameworks and capabilities that will facilitate the transfer of knowledge from PFRIs to the business sector and to provide access to funding support for early-stage innovation by PFRIs.***

- ***Introduce flexibility in the innovation pipeline***

While Australia performs well in basic research, there is currently a void in the middle of the innovation pipeline. At the commercialisation end, good products and processes will be picked up by existing industry; for example, intellectual property in the ICT[17] and biotechnology areas is being further developed by the large companies.

While there are a number of very useful Government programs to facilitate the innovation process post invention, there are a number of restrictions place on the allocation of these assistance funds. There are examples[18] where organisations have found it difficult to access funds locally (because of the conditions attached to the grants) and they have been forced to go overseas to source funds to support the development phase.

> ***Accordingly, there is a need to review existing government programs that support innovation and implement greater flexibility in the allocation of such funds*.**

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[14] *The Economic Impact of the Commercialisation of Publicly Funded R&D in Australia*, A report prepared on behalf of the Australian Institute for Commercialisation by the Allen Consulting Group, September 2003

[15] Floyd, J M, *Converting an Idea into a Worldwide Business Commercialising Smelting Technology,* Metallurgical Transactions B, Vol. 36B, October 2005, pp557-575

[16] OECD *Science and Innovation Policy, Key Challenges and Opportunities*, Organisation for Economic Cooperation and Development, Paris 2004

[17] One such example is Radiata Communications Pty Ltd. Radiata was a publicly funded research spin-out that was the result of strong collaboration between CSIRO and Macquarie University. Radiata was the first company in the world to publicly demonstrate high transmission rates via wireless local area networks. Radiata was subsequently acquired by Cisco Systems. (This example is included in reference 14).

[18] Axon Instruments Pty Ltd. In 1985 Axon (an Australian company) submitted a small business innovation research (SBIR) grant to the US government to develop new technology, called an integrating patch clamp. The SBIR grant did not require any matching funding, nor were there any payback obligations or equity expectations.

An outcome of such a process will be the need to accept a higher level of risk in the allocation of funds. This increased risk must be considered from a portfolio perspective, recognising that while some projects may be assessed at a higher risk, they may have the potential to deliver significant returns.

There are a various examples of gaps and conflicts in the innovation system. One example of a conflict in the innovation system is provided by the Australian Government's intention to implement a Research Quality Framework (RQF) and link it to the distribution of research block funding to universities. The Academy has doubts about the value of such an approach but if it is to be implemented, is adamant that the system must consider Impact separate from, and equal to (for the purposes of funding distribution), measures of academic Quality. This Academy is most concerned that the importance of Impact has been substantially downgraded in the RQF Preferred Model; this issue still remains unresolved[19] and must be clarified. The Academy would prefer that the framework be retitled to "Research Quality and Impact Framework". Should there be a down grading of Impact, the research community in universities will rapidly adjust focus to give greater emphasis to Quality and less emphasis on Impact. This will produce major negative trends on the level of engagement by the research community with external stakeholders and the innovation system will suffer accordingly. [In addition, the teaching of engineering will suffer as academic staff (in engineering departments) focus more on academic outcomes; this will be reflected in hiring policies and staff will have less propensity to engage with industry and the quality of teaching to prepare students for professional life will decline]. As a result, the Australian community will receive less value for its investment in research, which is the direct opposite of what RQF is designed to achieve. The RQF model runs counter to other government policies and initiatives which are designed to encourage engagement between the research community and industry. Furthermore, if the RQF is introduced, it is essential that it be accompanied by a simultaneous increase in the block grant funding and that funding is provided to compensate for the additional administration costs that will be incurred. If this is not done then it can reasonably be argued that the large transactional/ administration costs that will be incurred with the RQF model will have the net effect of reducing the productivity, quality and impact of the national research system.

Innovation and R&D policy and funding programs are the responsibility of several departments such as Education & Science, Industry, Agriculture, Health, Environment, Communications and so on. It is important to maintain the spread and not to place these programs under a single umbrella as specific expertise is needed to respond to the requirements to the various industry sectors. Nevertheless, given this diversity of agencies, there are multiple opportunities for conflicts and gaps to be created in supporting the innovation system. In particular programs funded through agencies other than DITR may not always have an adequate focus on achieving commercial outcomes for the research investment. Many believe for instance that responsibility for CSIRO could be returned to the industry and Resources area.

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[19] Expert Advisory Group, *Final Advice on the Preferred Model,* DEST, Commonwealth of Australia, 2005

***Accordingly, there is a need to review the various programs that support public funding of science and innovation and to facilitate the elimination of gaps and conflicts in the innovation system in Australia*.**

- ***Increase the national investment in the skills required to prosper in a knowledge economy***

The researcher workforce in OECD countries continues to expand, driven mainly by investments in R&D and innovation in the business sector. Between 1991 and 2000, the number of researchers in OECD countries increased by 42 per cent. Although business is driving the overall demand for researchers, demand for researchers in the public sector, especially in universities, continues to expand. Large R&D–performing companies have downsized corporate laboratories and as a consequence have increased outsourcing. A growing share of business R&D spending and employment is found in small and medium size companies, in high technology start-ups and spin-offs and universities. The demand for tertiary-level graduates and science, engineering and technology (SET) personnel in particular, is expected to continue to grow in many OECD countries. On an international comparison, the number of Australian engineering graduates per million population lags most other OECD countries. Further, the aging of academic and research staff in PFRIs is expected to further increase the demand for young researchers. In the UK study (Attachment 3), lack of skilled staff was identified as an important factor inhibiting innovation.

The supply of human resources in SET depends strongly, but not solely, on new entrants into higher education. However, not all countries are making equal progress in generating a sufficient supply of SET graduates despite the general up skilling of the population. Science and engineering graduates represent just over one fifth of all graduates in OECD countries.[20]

> "Australia's productivity gains over the past two decades are well known. Less well recognised till now is the price that we have paid as a result of reduced funding of skills formation…the next wave of productivity gains will need to be founded on a new skills formation strategy."[21]

There are major concerns that an inadequate number of people with science, engineering and technology skills is likely to provide a brake on growth in Australia as opportunities in their own countries reduce the availability of skilled immigrants and enrolments in education in these areas remains static. A Science, Engineering and Technology (SET) Skills Audit by DEST (December 2005) pointed to a range of initiatives required to expand the participation in enabling studies in schools, the need to upgrade SET skills in teachers, the need to lift enrolments in all tertiary studies, the need to attract and retain skilled migrants and encouraging Australians overseas to return. The conclusions of this Audit are of concern and need to be

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[20] OECD *Science and Innovation Policy, Key Challenges and Opportunities*, Organisation for Economic Cooperation and Development, Paris 2004

[21] Senate Enquiry, Employment Workplace Relations and Education References Committee, *Bridging the Skills Divide*, Commonwealth of Australia, November 2003

followed up with policies to address the issues identified. In addition, it has been found that potential science and engineering students are poorly informed as to the employment opportunities that such qualifications can lead to and that this is proving to be a severe disincentive for students to enrol in science and engineering courses.

> ***Hence, to support increased levels of innovation it is essential that there is a significantly increased number of graduates in science, engineering and technology. Accordingly, much greater resources need to be provided for the teaching and curricula development of science and technology subjects in primary and secondary schools and the promotion of career opportunities.***

One of the most important challenges facing countries is the waning interest in science amongst young people. However, no single policy measure can address the underlying causes which are many and varied. Indeed, government, universities and business as well as individuals and society, must play a role in shaping values and perceptions of science and technology.[22]

- ***Review national research priorities***

Given the limited resources there is an urgent need for Australia to focus on a limited number of research areas that are key to Australia's future economic, social and environmental development. There is too much diversity in the various research priorities established by governments and some PFRIs. There is a need to have clearly defined research priorities for Australia (while providing latitude for emerging areas of research to be supported). These priorities need to be supplemented by the identification of key research areas that need to be addressed.

> ***There is a need to review the operation and effectiveness of the current research priority system.***

- ***The role of PMSEIC***

It has been noted previously in this submission that there is need for greater coordination and oversight of the innovation agenda. Australia lacks a capacity to undertake important strategic studies in science and innovation such as were previously carried out by the former Australian Science and Technology Council (ASTEC). The Prime Minister's Science, Engineering and Innovation Council (PMSEIC) plays an important role in high level coordination and information exchange but it needs to be underpinned by a capacity for independent studies such as might be carried out by the learned Academies (possibly through their joint mechanism, the National Academies Forum (NAF), or a reconstituted version of ASTEC).

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[22] OECD *Science and Innovation Policy, Key Challenges and Opportunities*, Organisation for Economic Cooperation and Development, Paris 2004

It is recommended that PMSEIC ensure that mechanisms are implemented to achieve the coordinated development of policies and strategies related to innovation.

Coordination of various agenda issues is required, including:

- Long-term strategic directions for science and innovation;
- Harmonisation of the various policy settings and programs that support science and innovation;
- Research priorities;
- Develop of critical mass in both research and infrastructure capabilities consistent with the research priorities;
- Expanding the level of innovation in industry;
- Expanding the engagement of PFRIs with the innovation process;
- Creating an enhanced culture of innovation in both PFRIs and industry; and
- Provide coordinated support to facilitate commercialisation of research in PFRIs.

As noted above, there is also a need to explore mechanisms whereby the Academies can further contribute to the Australian science and innovation system.

Attachment 1

The Central Context of Innovation – the Global Knowledge Economy

> "There is one certainty: the long-term trend towards a knowledge-based economy continues, driven by the growing globalisation of knowledge".[23]
>
> "In a knowledge economy the production, distribution and use of knowledge is the main driver of growth, wealth creation and employment across all industries".[24]

Available statistics support these claims:

- **Investment in knowledge exceeds investment in capital goods**: investment in knowledge (R&D, education and software) is 9 per cent of GDP in OECD countries, compared with 7 per cent for machinery and equipment.
- **Investment in knowledge generation is growing at 5 per cent per year** in the OECD nations.
- **Knowledge workers now constitute the largest category of employment**: professional and technical workers constitute over 35 per cent of employment in Australia.
- **Intellectual property is a major generator of economic activity**: the number of patents doubled in the past decade, to 450,000 pa, and many knowledge intensive companies generate greater profits from trade in intellectual property than in sales of goods and services.
- **The ICT sector now is responsible for 10 per cent of global business value added.**

Three rules of the global knowledge economy have been proposed:

i) What determines economic performance is not so much knowledge creation as the knowledge distribution power of a country, company or culture;[25]

ii) What counts is knowledge of how to develop new knowledge, how to locate and acquire knowledge generated elsewhere, how to recognise connections between different pieces of knowledge, how to embody knowledge in goods and services – these are the challenge for the modern manager and policy-maker;[26] and

iii) Knowledge is being transformed from an intellectual pursuit to a commodity in the global capitalist system. This leads to inevitable pressures for increased efficiency, productivity, outcomes and ownership, of knowledge.[27]

These rules and statistics provide the basis for a submission on 'Returns on Public Support for Science and Innovation'.

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[23] OECD, *Science, Technology and Industry: Scoreboard 2005*, Organisation for Economic Cooperation and Development September 2005

[24] OECD*, Science and Innovation Policy: Key Challenges and Opportunities*, Organisation for Economic Cooperation and Development, Paris 2004

[25] *Ibid*

[26] *Ibid*

[27] Professor Ron Johnston FTSE, http://www.aciic.org.au, 2004

Globalisation of R&D/ Knowledge Production

Until 2000, the extent of globalisation of R&D was relatively modest. Most multi-national corporations conducted the majority of their R&D close to corporate headquarters. The exceptions were where local markets had sufficiently specific conditions to require local R&D capability; for example, the US IT companies setting up R&D in Europe, or where the goal was to gain access to particular world-leading expertise (for example, Sony at Stanford).

However, with the dramatic growth in advanced R&D capability in emerging countries with a markedly lower wage structures, notably China and India, there is a significant move by many companies to outsource R&D. In the 10 years from 1993, China's expenditure on R&D has grown from 25 billion Yuan to 130 billion Yuan. Investment in R&D by the multi-national companies operating in China has now reached 10 per cent of turnover (ACIIC China database).

There are a number of direct implications for government policy. For example:

- how to maintain, let alone increase, the attractiveness of Australia as a location to invest in R&D;
- future employment of the local R&D labour force; and
- how to access the offshore R&D capabilities to promote Australian innovation.

Attachment 2

Patterns of Innovation in Australian Businesses 2003

Background

The report entitled *Patterns of Innovation in Australian Businesses, 2003*[28] represents the first consolidated analysis of innovation across Australian businesses as part of a collaboration between the Department of Industry, Tourism and resources (DITR) and the Australian Bureau of Statistics (ABS). The research is based on micro-level data from the ABS Innovation in Australian Business 2003 survey, which covers businesses with 5 or more employees in most industries.

Main Features

The survey provides detailed information on innovation in Australian businesses. The aim of this study is to provide a broad overview of the main patterns of innovation in Australian businesses, the general characteristics of innovators and an analysis of expenditure on innovation. It shows that:

- Innovation is occurring across the economy. 35 per cent of Australian businesses undertook one or more forms of innovation activity (introduced new goods and/or services, operational and/or organisational/managerial processes). These types of innovation are not confined to particular sectors in the economy as it is wide in scope. Industries that may be regarded as less likely to innovate, such as electricity, gas and water supply, have very similar proportions of innovating businesses to those in communications services, which are frequently regarded as the cutting edge of modern innovation.
- Only 9 per cent of goods or service innovators are engaged in 'new to the world' activities. For most goods or service innovating businesses the highest degree of novelty is 'new to the business' (56 per cent). Very few businesses are introducing 'new to the world' operational processes (3 per cent), and 75 per cent of these innovators are focusing on 'new to the business' activities. This strong emphasis on 'new to the business' innovation occurs in nearly every industry across the economy. Australia is not unique in this respect as this strong emphasis on 'new to the business' innovation appears to be a general characteristic of innovation at the global level. It should be noted that 'new to the business' product and process innovation are forms of diffusion that have powerful economic impacts over the long term.

[28] Trewin, D and Paterson, M, *Patterns of Innovation in Australian Businesses 2003*, Australian Bureau of Statistics, Canberra 2006

- More than half (53 per cent) of goods or service innovating businesses generate less than 10 per cent of their turnover from new goods or services, while just 10 per cent generate more than 50 per cent of their turnover from new innovations. This result is found in most industries as the majority of goods or service innovating businesses report that less than 10 per cent of their turnover is attributed to new goods or services. The proportion of businesses innovating increases with employment size, from 28 per cent in businesses with '5-9' employees to over 60 per cent in businesses with '250 plus' employees.
- Foreign ownership appears to be associated with a higher rate of innovation. In terms of innovation novelty, businesses with more than 50 per cent foreign ownership have more than double the proportion of 'new to the world' goods or services than the other categories. The variation between ownership categories is less marked for operational process novelty. The relationship between the age of the business and innovation activity appears to be unclear. Although there is some variation across the categories used in the analysis, the degree of innovation novelty does not suggest any particular association.
- Innovation expenditure is not primarily based on R&D, as it involves high levels of non-R&D expenditure. Non-R&D expenditure on innovation represents 69 per cent of innovators' expenditure on innovation. Overall, innovating businesses expenditure on R&D represented 0.7 per cent ($5,800.6 million) of total business expenditure whereas non-R&D innovation expenditures represented 1.7 per cent ($13,123.4 million). Only 31 per cent of innovating businesses report R&D expenditure. These results demonstrate that innovation inputs are much broader than R&D.
- Not all types of innovation require the same commitment of financial resources. Although the proportion of businesses reporting operational and organisational/management process innovation is higher than goods or service innovation (23 per cent, 21 per cent and 17 per cent respectively), these process innovations do not require substantial expenditure in comparison with goods or service innovation.
- The relationship between business size and expenditure on innovation and R&D is not straightforward. While a greater proportion of large businesses innovate compared with small businesses, the expenditure ratio (measured as the ratio of innovation and R&D expenditure to total business expenditure) does not follow this pattern. Small businesses with 5 to 9 employees have an innovation and R&D expenditure ratio that is similar to large businesses with 250 or more employees, but these results do not take into account the uneven distribution of expenditure within firm size categories.
- There is wide variation between the proportion of businesses innovating and the intensity of expenditure reported across industry. This suggests that in some industries the nature or extent of the innovation they are undertaking requires relatively less financial investment.

    - The total expenditure on innovation and R&D in Australia during 2002-2003 was $18,920 million. Of the 31 per cent expenditure on R&D ($5,800 million), 26 per cent was internal R&D ($4,886 million) and only 5 per cent ($914 million) was acquired R&D. The expenditure on goods or service innovation by innovating businesses represents the largest proportion in expenditure on R&D (namely 46 per cent of expenditure or $8,766 million).
- Expenditure on R&D and goods or service innovation by innovators varied markedly across industries.
- Although innovation is widespread across industry, expenditure is highly concentrated in a small number of businesses. This pattern is evident across all business size classes and industries. The conclusion that can be drawn from these data is that innovation and R&D expenditure intensity is strongly focused on a small proportion of the business population.

Attachment 3

Sourcing Science – the Use by Industry of the 'Science Base' for Innovation

The following observations are given in a paper entitled *Sourcing Science – the Use by Industry of the Science Base for Innovation; Evidence from the UK's Innovation Survey,*[29] and is drawn from the UK's version of the 3rd European Community Innovation Survey (CIS-3). This survey was used to investigate the contribution that the public 'science base' – that is universities and publicly funded research institutes – makes to innovation in organisations. Use is made of CIS-3 data to investigate both the *direct* and *indirect* links between the 'science base' and innovation in organisations.

Background

In recent years, the economic contribution of the 'science base' has come under increasing scrutiny. Science budgets have often been cut precisely because they could be reduced without an immediate and noticeable impact on the economy. Throughout the 1980's and 1990's universities came under increasing financial pressure, largely because of the massive expansion in student numbers which has not been matched by increased funding and in real terms funding per student has declined by some 50 per cent. The government is also beginning to increase, in real terms, expenditure on higher education. But as a price for this increased funding the government expects reform and one aspect of this reform is that universities and the 'science base' more generally, increase their links with industry.

Level of Innovation

The survey results indicate that overall 46 per cent of production activity organisations and 41 per cent of service organisations were categorised as being engaged in innovation activities.[30]

The UK survey results indicate that the majority of organisations that did engage in innovation activities do not appear to have made large commitments to innovation. Half of those that declared expenditure on activities in 2000 spent no more than £1,000 per employee on these activities. By contrast, the average expenditure amongst the top quintile was about 10 times that. This 'demand side' problem – if indeed it is a problem – has been identified before. Coombes and Metcalfe,[31] for example, observed that "the real problem with the sub-optimal utilisation of the UK's 'science base' for commercial ends lies not with the universities, but with private organisations in the UK who still underspend on R&D and innovation, and therefore have under developed capability and ambition with respect to innovation as a competitive weapon".

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[29] Tether, B S & Swann, G M P, *Sourcing Science – The Use by Industry of the Science Base for Innovation*; Evidence from the UK's Innovation Survey, Version 1.2, 8 August 2003

[30] Stockdale B, *UK Innovation Survey, 2001,* UK Government Department of Trade and Industry, London, 2002

[31] Coombes R & Metcalfe S, *Universities, the Science Base and the Innovation Performance of the UK*, CRIC Briefing Paper number 5, CRIC, University of Manchester 2000

Use of the 'science base'

Combined, about 19 per cent or production and 14 per cent of service organisations claimed to have used the 'science base' as a source of information for innovation, but only about 1 per cent and 1.5 per cent respectively claimed the 'science base' was a source of information of 'high importance' for their innovation activities. Certainly relative to other sources, such as sources within the firm, suppliers and customers, the 'science base' was not widely engaged and was perceived as being relatively unimportant.

The results indicate that as organisations increase their own commitments to innovation they become more interested in directly engaging the 'science base' with their innovation activities. While the proportion of organisations with high levels of innovation regarded the universities and the 'science base' as sources of information of 'high importance' for their innovation activities is small, it would appear that one fundamental reason why relatively few organisations make use of the 'science base' as a source of information for innovation, is that relatively few organisations make substantial commitments to innovation.

Collaboration

Overall, only 8 per cent of organisations had cooperation arrangements for their innovation activities. Of these, about one-third had these arrangements with universities, while just 13 per cent had such arrangements with government research organisations. Amongst organisations with cooperative arrangements for innovation, suppliers (57 per cent) and customers (50 per cent) were, unsurprisingly, the most widely engaged types of innovation partner. Amongst the production activity organisations, a fifth of those in the top quintile by innovation expenditures, had collaborative arrangements for innovation with the 'science base', whilst 14 per cent of service organisations in the top quintile of service organisations with innovation expenditures, had these arrangements. Unfortunately, the CIS-3 does not ask how important these collaborations were for these organisations' activities.

Indirect links

It is important to appreciate that the 'science base' also makes indirect and non immediate contributions to innovation in organisations, contributions that are easily overlooked. The most obvious indirect contribution is through the education of graduates who are then employed in organisations to apply the knowledge or skills that they have acquired at university. Other indirect contributions follow from the circulation of information or knowledge in the economy. In short, other sources of information or knowledge such as other enterprises (including competitors, customers, suppliers, and so on), regulations, standards, and the trade and technical press, may draw directly on the 'science base', and at least some of this information will then reach other organisations through indirect links.

Impediments to Innovation

The survey results show that the principal impediments to innovation were economic factors, such as the perceived excessive economic risk of innovation, the direct cost of innovation, and the cost and availability of finance for innovation. By contrast, access to information on technology was amongst the least widely cited inhibiting factors, being identified as an impediment of some importance by 60 per cent of production and half the service organisations, but this factor was identified as being 'high importance' by just 14 per cent and 6 per cent of these organisations respectively. A lack of qualified personnel was a more widely identified factor than the lack of access to technological information, but was less likely identified than the economic factors discussed above. Only a small proportion of organisations claimed not to have innovated because of factors hampering innovation.

Broadening engagement

Clearly based on the foregoing information, it is desirable to increase the interaction between the 'science base' and business. Given that there is a 'demand side' problem with innovation, governments must find mechanisms to encourage innovation by businesses – for example, tax credits for R&D expenditure. However, a further issue is whether the 'science base' has the capacity or the institutional arrangements to deal with increased demand.

Some issues surrounding a possible broadening of the interaction between the 'science base' and business are noted below:

- In the UK, less than 1 in 5 businesses tap into skills and knowledge. Clearly there is room for improvement but what level of engagement would constitute success?
- Need to be careful in the selection of performance indicators as universities have shown themselves to be adept as meeting performance indicators. For example if a performance indicator is the number of spin off companies, this could be to the detriment that many technologies might have been better commercialised through licensing agreements.
- There are certainly areas in which the 'science base' can work closely with industry and where those interactions are appropriate and mutually beneficial. (For example, work placement schemes.) However, there is a danger that the opportunity costs to the core mission of the 'science base' must be considered before there is a head long march to expand the interactions between industry and the 'science base'. There is a need to be cautious about expanding direct interactions at the expense of the indirect and longer term interactions of the 'science base'.

- It is vital that the universities and the 'science base' continue to undertake independent and long term research, most of which will be remote from the current needs of industry. There are two issues here. There is a need to undertake basic research, which is exactly the sort of research that industry will not fund because of the uncertainties involved and because of the difficulties of appropriating the returns to new discoveries. In addition, there is a need to undertake independent science that serves the public interest. R&D is undertaken by organisations in their own private interests which do not necessarily coincide with the public interests of society.
- The conceptualisation of universities as 'engines of economic growth', or as hubs of the knowledge economy is worrying. Some of the US's largest and most technology intensive organisations are beginning to worry aloud that increasing industrial support for research [in US universities] is disrupting, distorting, and damaging the underlying educational and research missions of the university, retarding advances in basic science that underlies these organisations' long term future.[32]

[32] Florida, R, *The Role of the University: Leveraging Talent not Technology*, in Tiech, A, Nelson, S D, McEnaney, C, and Lita, S J (editors) AAAS Science and Technology Policy Yearbook, American Association for the Advancement of Science, Washington DC 2000