



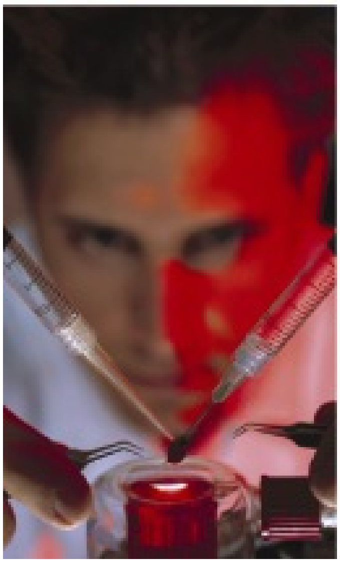

AVCC Submission to the Productivity Commission Research Study on Public Support for Science and Innovation

August 2006

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Australian Vice-Chancellors' Committee

the council of Australia's university presidents

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Foreword

The Australian Vice-Chancellors' Committee (AVCC) is the peak national representative body of Australia's university sector comprising the Vice-Chancellors of 38 Australian universities. Its charter is to advance higher education through voluntary, cooperative and coordinated action. It is non-partisan and exists exclusively for educational purposes, with its continuing aim to serve the best interests of the university sector through promoting higher education as an integral part of a growing national economy.

The AVCC is an active player in the determination and formulation of public policy, to advance higher education for those Australian and international students and staff who are involved in the higher education sector, and to the long term benefit of their individual communities, regions and nations.

The AVCC therefore welcomes the invitation from the Productivity Commission to provide input to its research study on the returns on public support for science and innovation, which was announced by the Treasurer, the Hon. Peter Costello MP and the Minister for Education, Science and Training, the Hon. Julie Bishop MP on 10 March 2006.

This AVCC submission is framed in three parts:

(i) an executive summary and recommendations, identifying the key themes and concerns for the AVCC and its members' universities of import to this Productivity Commission research study and recommending a range of strategies to maximise the return on both public and private investment in science and innovation;

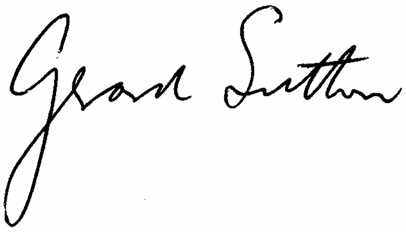
(ii) the AVCC's vision for Australia's university sector to the year 2020, particularly as it relates to issues under consideration by the Commission;

(iii) the AVCC's response on the broad issues raised by the Productivity Commission's Issues Paper (April 2006), and in other recent Australian Government publications that have a bearing on the issues under consideration by the Commission, in particular:

- the national benefits of increased public support for science and innovation, with particular emphasis on economic and social returns on investment; and
- how Australia can get the best value from that investment.

The submission is augmented by a number of case studies which illustrate the quality, relevance, nature and impact of university research and innovation, and linkages through research collaboration that have been supported in some or large part through vital public investment.

The AVCC looks forward to continuing its consultations with the Productivity Commission on this timely and important study.



Professor Gerard Sutton
AVCC President
August 2006

Executive Summary

Vigorous national science and innovation effort is critical to the strength and dynamism of Australia's economy and society. Bold public and private investment in its innovative people and institutions is critical if Australia is to keep up with the accelerating pace of growth of new knowledge and its application around the world. We should not limit our ambitions, but recognise, reward and build on our existing strengths – and develop new ones.

Unless Australia demonstrates its commitment to such efforts by increasing its investment in education and research, research training, positions and granting opportunities, and provides incentives for greater collaboration between educational disciplines and across sectors of the economy, we will soon lose our place in the global knowledge economy.

This study challenges the Commission to formulate recommendations that will ensure the maximum economic, social and environmental returns from public support for science and innovation within the framework of a cohesive and effectively resourced national innovation system.

In undertaking the present study, it is important that the Productivity Commission adopts a broad view of innovation rather than a narrow definition restricted to technological process and product innovation.

It is also important that the Commission adopts a broad focus on the definition of "productivity". There are many direct and indirect influences on productivity. While there may be a temptation to identify links between particular research in the basic sciences and the emergence of technological solutions to problems, the role of the social and behavioural sciences, the humanities, and other disciplines is vital to providing a complete picture of the impact of university scholarship on the national wealth, and welfare.

Australia's universities' vital role in science and innovation

Increased investment in higher education is necessary to underpin the quality of our diverse university system and meet the needs of students, employers and the community. The AVCC has articulated its vision for the year 2020 for Australian university education. In this vision, the AVCC sets out a number of important matters that need to be addressed if Australia is to be a strong and competitive knowledge-based economy in 2020.

The available data show that Australia's universities are strong performers, in spite of chronic underfunding. This is reflected in measures ranging from publications and citation statistics, to export earnings (Australia's fourth largest) and return on investment from government investment in research (eg. the Cooperative Research Centres Program). The medical and agricultural research undertaken in our universities is world-renowned and delivers major social, environmental and economic benefits to Australia. ABS data show that the impact of Australia's universities ranges across all sectors of the economy.

The national economic importance of Australian universities is reflected in revenues of $13 billion and employment (91,905 full time equivalent) in 2004[1]. In that year there were 3,031 foreign students undertaking postgraduate research degrees in science and engineering.[2] These students contribute to Australia's research output and will become part of Australia's international networks that are so important in keeping our research at the 'cutting edge.'

[1] DEST, 2004, Higher Education Finance and DEST, 2004, Higher Education Staff Statistics
[2] DEST, 2004, Higher Education Student Statistics

Australia's science and innovation system is effective and efficient in using the resources available to it. The quality of our universities is reflected in the strong national and international demand for Australian research graduates. Australia's two major funders of university research, the Australian Research Council and the National Health and Medical Research Council, both operate highly effective expert peer review competitive granting processes.

Australia's science and innovation system needs additional investment

Support for science and innovation in Australia needs to be increased if we are to maintain our living standards through strong and productive economic growth. By OECD country standards, Australia's Gross Expenditure on R&D (GERD) as a percentage of Gross Domestic Product (GDP) is low and government support for science and innovation as a percentage of GDP has been in decline since 1993-94. Australian Business investment in R&D (BERD) is also low and only 4.1 per cent of BERD is financed by government, compared with the OECD average of 7.2 per cent.[3] Business and university R&D have complementary roles — each stimulates the other. The weak business investment in R&D limits the opportunities for synergistic innovation and retards Australia's economic growth.

The AVCC believes that international comparisons of GERD and BERD are valid. Australia's low GERD and more specifically low BERD (compared to leading OECD countries) cannot be explained solely on the basis of our current industry structure. Further, the AVCC believes that Australia cannot rely on our current industry structure to maintain future living standards. Increased investment in R&D by both business and government is needed now. Countries such as Finland, Ireland, South Korea and Israel have demonstrated that strong investment in higher education and research can change national industry structures and generate strong economic growth in relatively short time frames. Australia should adopt a similar approach.

University research is delivering economic, social and environmental benefits

Australian university research is delivering real economic, social and environmental benefits through a wide range of activities including the training of graduates, research outcomes (including intellectual property and publications), consulting and contracting, and commercialisation of research (including start-up companies and technology licensing). University social and cultural contributions to Australian society also involve innovation and help to make Australia an attractive country in which to live and work.

The most important steps toward achieving the best value from public support for science and innovation in Australia are increased funding for infrastructure, longer time periods for some grants, provision of seed funding for start-up companies, resources to support commercialisation and community outreach/extension, and a stronger technology-focussed business sector with which universities can partner. There is a strong case for 'Third Stream' funding to facilitate the transfer of public knowledge and skills to other sectors and the broader community.

Other matters that are relevant to the effectiveness and efficiency of Australia's science and innovation system include:

- Australia's State and Territories play a valuable support role in Australia's national innovation system;
- science, innovation and related policies of other countries can impact on Australia, particularly in the demand for our graduate;
- Australia's National Research Priorities have been developed with extensive consultation and have an appropriate influence on research directions;

[3] OECD Main Science and Technology Indicators database, June 2006 (2003 data)

- reporting requirements on Australian universities are excessive and the recommendations of the AVCC's recent report on red tape should be implemented;
- excessive government interference in university affairs needs to be reduced; and
- inadequate funding remains the universities' main problem.

A series of case studies in Appendix A show a spectrum of fields of research and innovation impacting across the different sectors of the Australian economy. They demonstrate benefits over both short and longer time periods, and provide examples of cross-sectoral interactions.

Recommendations

The following recommendations are framed with the primary objective of maximising the economic, social and environmental returns from public support for science and innovation in Australia.

1. **That Australia develop a national innovation strategy encompassing all aspects of the nation's research and innovation.**

2. **That the national innovation strategy include:**

   (i) **a national commitment to a target for Australian investment in research and innovation: 2% of GDP by 2010, and 3% of GDP by 2020;**

   (ii) **a broad definition of innovation rather than a narrow definition restricted to technological process and product innovation;**

   (iii) **a broad definition of "productivity" that recognises the many direct and indirect influences on productivity, and the role and impact of the social and behavioural sciences, the humanities, and other disciplines in the university sector on the national wealth, and welfare.**

3. **That Government recognise that the benefits from university research, science and innovation flow across the economy and to the whole Australian community, and that there are strong economic arguments for government investment in higher education and research.**

4. **That Australia recognise the need to support a range of research and innovation, and do so by a number of different means. Allowing any single approach to dominate would inevitably result in a diminished overall research and capacity and a weaker national innovation system. The impact of research prioritisation should be restructured to recognise this fact.**

5. **That the peer review process for competitively funded research and innovation be retained within Australia to assure the international standing and quality of Australia's research grant funding system and proper accountability for the allocation of public funds.**

6. **That Australia reassess its investment in research study and training opportunities and redress the imbalance between the number of high quality students and the number and value of government-funded scholarships, in particular the Australian Postgraduate Awards (with Stipend) and the International Postgraduate Research Scholarships (IPRS).**

7. **That Government note the evidence that Australia's current investment in science and innovation lags well behind that of leading OECD countries and take positive action to correct the imbalance.**

8. **That Australia build on existing collaboration between universities, publicly funded research agencies and the private sector by developing new incentives for greater private sector participation in the national innovation system.**

9. That the Commonwealth Government create a specific program to enhance universities' capacity to use knowledge transfer to encourage wealth creation by business and communities and to address broader community social, health, and environmental challenges.

10. That Commonwealth, State and Territory Governments continue to work collaboratively and in consultation with the university sector in the development of effective legislative and regulatory frameworks that:

(i) balance external accountability with commercial risks; and

(ii) reduce the policy and funding impediments impacting on universities' capacity to contribute to the nation's economic, social and environmental development and prosperity.

1. The AVCC's 2020 Vision

Effective investment in higher education will underpin the international quality of our universities and ensure a diverse university system that is comparable to any in the world, able to meet the wide range of student, employer, employee and community needs. This is the broad premise of the AVCC's Vision 2020.

1.1 The AVCC's goals for Australia

Our 2020 vision for Australian university education has five defining features:

- all Australians will access post-school education or training, with more than 60% completing higher education, at least 10% at the postgraduate level, with choice across a diverse range of universities;

- research excellence will be found across the Australian university system, with a focus on key priority areas, extending basic knowledge, and innovative research and development. By 2020 Australian investment, from all sources, in research and development should be at 3% of Gross Domestic Product (GDP) - currently 1.6%.

- Australian educational exports will give Australia a pre-eminent place in global education – with a target of 20% of Australian students having an international experience during their time of study;

- Australia's universities will meet the needs of Australia's Indigenous peoples through education, research and community service comparable to the support provided to all Australians; and

- effective national investment in higher education will underpin the international quality of Australia's universities. By 2020 Australian investment, from all sources, in higher education should be at 2% of Gross Domestic Product (GDP) - currently 1.5%.

1.2 A national innovation strategy

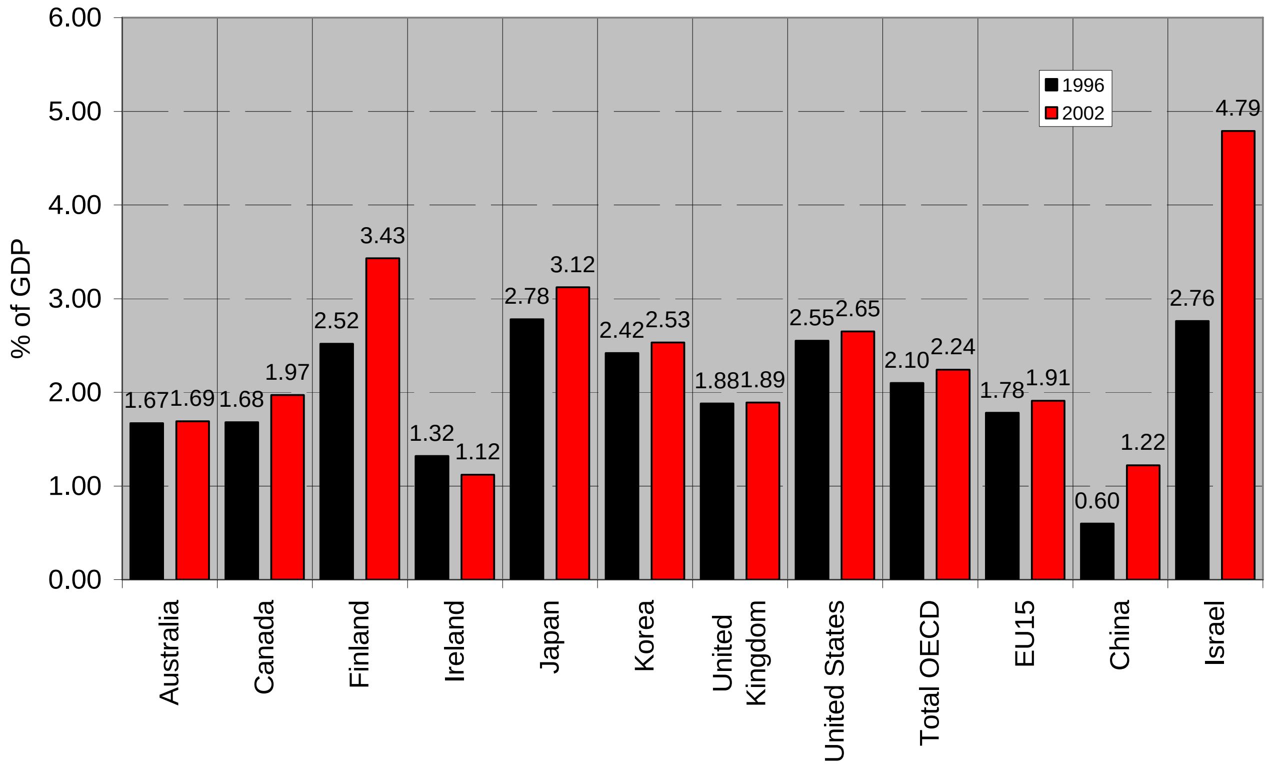
Australia's economic, social and environmental future depends on effective investment in research and innovation. Optimising such investment requires a national innovation strategy: one which sets clear goals, underpinned by sound policy and on-going investment, but which promotes flexibility in how its goals are to be achieved. It must also encompass collaboration between and among universities, publicly funded research agencies, the private sector and other research-active organisations for improved and cost-effective research and innovation linkages and outcomes.

As part of the national innovation strategy Australia needs to set a target for national investment in research and development (encompassing both public and private support) comparable to those set internationally. In *Beyond Backing Australia's Ability – The AVCC response*[4] the AVCC has proposed a target of 2% of GDP by 2010 and 3% by 2020 and provided detailed proposals for the key initiatives to begin to meet that target over coming years.

[4] *Beyond Backing Australia's Ability – The AVCC response,* AVCC, June 2004 - http://www.avcc.edu.au/documents/publications/policy/submissions/AVCC-Response-to-BAA2.pdf See also *Advancing Australia's Abilities: Foundations for the future of research in Australia*, AVCC, December 2003 - http://www.avcc.edu.au/documents/publications/policy/submissions/BAA2_AVCC_Statement_Dec03.pdf

The European Union (EU) has established a target of 3% of GDP to be spent on research and development (R&D) by 2010. In 2002 the 15 founding members of the EU, known as the EU-15, spent a combined average of 1.91% of GDP on R&D, up from 1.77% in 1996; the United States spent 2.65% of GDP; and Japan spent 3.12% of GDP.[5] While China's R&D expenditure as a percentage GDP was lower that Australia's in both 1997 and 2002, the growth in investment in R&D from 1997 to 2002 was over 50%. By contrast, in 2002-03 Australia spent only 1.69% of GDP on R&D. Further, Australia's R&D expenditure has remained fairly static, averaging 1.61% (range of 1.51% to 1.69%) from 1992-03 to 2002-03.

Figure 1: Gross Expenditure on R&D as % of GDP 1996 and 2002 (Selected Countries)



Source: OECD Main Science and Technology Indicators 2005

Note: Data for Israel do not include most R&D expenditure on defence

Private sector investment is crucial to successful national research and development. It is essential to achieving the AVCC's national research and development investment targets through new incentives for private sector investment in research and innovation. There needs to be greater emphasis on incentives for private sector investment in university research and training.

1.3 Progress against the AVCC's national investment targets for R&D

Since 2000 the Government has re-invested in Australia's university and research sector through:

- *The Virtuous Cycle: Working Together for Health and Medical Research*,
- *Backing Australia's Ability*, and
- *Backing Australia's Ability: Building Our Future Through Science and Innovation (BAA II)*.

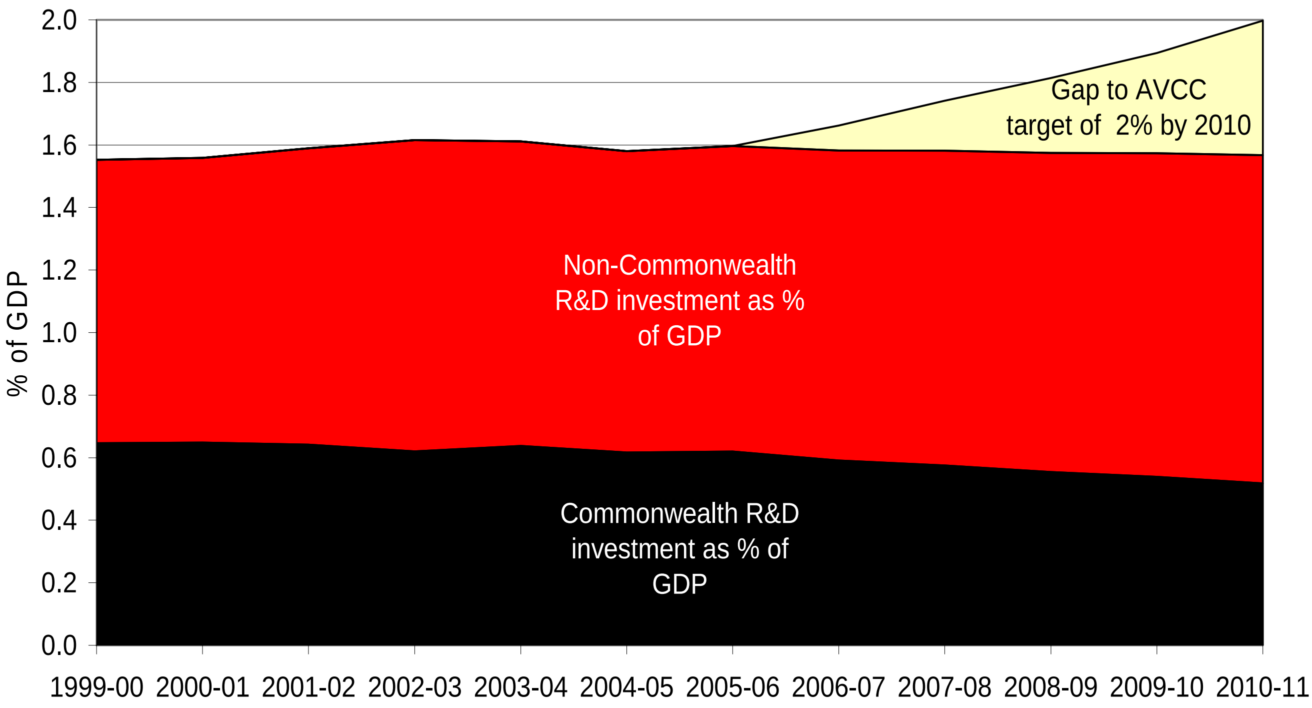
[5] OECD main science and technology indicator database, 2005

Structural change in university education has been funded through *Our Universities: Backing* Australia's *Future* and the new *Higher Education Support Act 2003*.

The AVCC welcomed the increase in funding provided in *Backing Australia's Ability I* and *II*. However, these reports allocate increases in funding to competitive funding schemes and each assumes an effective university research base and adds additional demands to this base. There has been virtually no increase in direct public investment in universities' core research capacity, placing at risk the quality of key university functions: the production of skilled graduates and new knowledge, in addition to linkages with industry and the commercialisation of research outcomes.

By identifying science and innovation as strategic priorities, the Australian Government has indeed recognised their critical importance to Australia's economic and social prosperity. However, Australia is likely to continue to fall behind our major international trading partners, allies and competitors without further investment, including re-investment in universities. This is illustrated in Figure 2 which shows the gap to the AVCC target of 2% investment in Australian R&D from all sources by 2010.

Figure 2: Estimated investment in Australian Research and Development



Source: DEST Finance Statistics and ABS National Accounts

Universities continue to respond to the government's policy, to reshape their research to focus more clearly on national needs and each university's research strengths. However, the missing element is increased investment in their underlying research capacity, targeted according to each university's relative research performance.

Building research capacity is a long-term endeavour, whereas capacity can be easily and rapidly lost and is extremely difficult and costly to recover. Investments made today may take many years before ultimate benefits are realised. Change to decrease current total levels of public support is inherently costly, in terms of the shorter term lost opportunity and longer-term loss of capacity. This is especially true today, where Australia must compete in a globalised, knowledge-based economy.

The common finding of a number of federal government research reviews conducted in 2003[6] is that increased investment in research and innovation is critical to Australia's economic, social and environmental future. However, there is the very real risk that with the commitments through these packages, the Government will consider that little more remains to be done.

The Government has an essential role to play through the provision of public investment and setting the framework in which universities work. For Australia's future we must move beyond the progress made to date. The primary areas of focus for the Australian Government need to be:

- significant additional investment in research and training;
- support for university core capacity; and
- an effective mechanism for regular adjustments to higher education funding which protects and maintains the existing value of the Government's investment in higher education.

Recommendation:

1. That Australia develop a national innovation strategy encompassing all aspects of the nation's research and innovation.

2. That the national innovation strategy include:

(i) a national commitment to a target for Australian investment in research and innovation: 2% of GDP by 2010, and 3% of GDP by 2020;

(ii) a broad definition of innovation rather than a narrow definition restricted to technological process and product innovation;

(iii) a broad definition of "productivity" that recognises the many direct and indirect influences on productivity, and the role and impact of the social and behavioural sciences, the humanities, and other disciplines in the university sector on the national wealth, and welfare.

[6] Federal Government Research Reviews and Evaluations – 2003:
The National Research Infrastructure Strategic Framework
Review of Closer Collaboration Between Universities and Major Publicly Funded Research Agencies
Evaluation of Knowledge and Innovation Reforms

2. University research – real impacts and outcomes

Definitions of innovation, such as those used in the OECD's Oslo Manual[7], focus upon technological product and process innovation. The Productivity Commission's Issues Paper endorses this general definition of innovation.

The objective when defining the concept of innovation is to help identify relevant phenomena, worthy of identification because they play or comprise a significant part in innovation processes. A narrow definition of innovation, restricted to technological process and product innovation, excludes core elements of innovation processes, especially those embodied in the social sciences and humanities.

Increased investment in higher education is necessary to underpin the quality of our diverse university system and meet the needs of students, employers and the community. The AVCC has articulated its vision for the year 2020 for Australian university education. In this vision, the AVCC sets out a number of important matters that need to be addressed if Australia is to be a strong and competitive knowledge-based economy in 2020.

The AVCC's preferred definition of innovation is:

> *Innovation is the creation, exchange, evolution and application of new knowledge and ideas into marketable goods and services for the success of an organisation, the vitality of a nation's economy, and the advancement of society as a whole.*[8]

Measuring the economic, social and environmental impacts of public support for science and innovation is a difficult task. In spite of efforts from organisations such as the OECD[9] and ongoing progress with the development of economic impact indicators,[10] surprisingly little is known about the impact of science.[11]

> *'…it appears that most measures of the impact of science are concerned with the economic impact such as economic growth, productivity, profits, job creation, market share, spin-offs – and there are very few indicators as such that link science and technology directly to these economic pay-offs. Systematic measurements and indicators on impact on the social, cultural, political and organisational dimensions are almost totally absent from the literature.'*[12]

Beyond the metrics of commercialisation, there are relatively few existing metrics to help define short or longer-term impact; and these must be developed. Furthermore, attempts to move beyond economic dimensions tend to capture the indirect rather than the ultimate impact.

Godin and Dore define three challenges when measuring impact:

- One is to distinguish between output and impact (or outcome). 'While output is the direct result or product of science – production or mere volume of output as economists put it – impact is the effects that this output has on society and the economy.'[13]

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[7] Oslo Manual - http://www.oecd.org/dataoecd/35/61/2367580.pdf
[8] Modified from Amidon (1993) in 'An Exchange on Definitions of Innovation' from the Innovative Management Network, *The Innovation Journal* http://www.innovation.cc/discussion-papers/definition.htm
[9] see for example, OECD benchmarking and scoreboard reports and industry outlook reports (details in Appendix C).
[10] see for example 'The Economic Impact of UK higher education institutions' (details in Appendix C).
[11] Godin B and Dore C, 'Measuring he Impacts of Science: Beyond the Economic Dimension', p 5. http://www.csiic.ca/PDF/Godin_Dore_Impacts.pdf
[12] *Ibid*
[13] Godin and Dore *Op cit* page 8.

- Two is to identify specifically the transfer mechanisms by which science translates into impact.
- Three is to develop appropriate and reliable instruments and indicators.

Timing is another consideration when conducting impact assessments of public science and innovation. It is often argued that the impact of university research is long-term (and often indirect). This poses questions such as, 'When is a good time to measure impact?' 'How long should we wait?' 'For how long a period should we try to identify impacts?' There is substantial evidence that the timing of the evaluation effort significantly affects the results.[14]

Over time, simple input measures can provide some indication of the impact of public support (eg. the number of grants won by a particular university). Similarly, a surrogate measure for the impact of industry research conducted by a university is investment by industry over time, based upon the assumption that industry would not continue to invest in something that is not useful. However, these remain surrogate indicators since many other factors other than the extent of public expenditure on research over time determine research impact.

Indicators of academic and broad impact, with a factor of time, may include:

- research expenditure in an industry sector (% gross value production);
- publications and patents[15] in collaboration with business and international investigators (as a measure of engagement);
- citations;
- number and quality of graduates, particularly PhDs and Masters with research training;
- partner engagement;
- changes to Government policy due to research findings;
- levels of industry co-investment; and
- commercialisation income.

In terms of immediate impacts, researchers, for example, may be active collaborators nationally and internationally or disseminate research findings, methods and skills through participation in professional networks, associations or conferences. In addition, university graduates may take jobs where they can apply their skills and knowledge.

Of course university research is often close to application, directed at shorter-term problem solving, as in the case of contract research and consultancies, where work addresses a specific technical problem, industry need or highly topical issue. In such cases the impact may be short-term and difficult to assess at a later time, i.e. once the research findings have solved the problem. A good example of the latter is SIDS where the problem was raised, researched and solved relatively quickly (see SIDS mini case study in Appendix A).

The benefits of university science and innovation funding are often long-term in nature. The Allen Consulting Group's work for the CRC Association showed that even in a situation where benefits might have been expected to be realised quickly, the average lead-time is about eight years. For much basic research undertaken in Australia's universities, the time frame is even longer.

[14] Molas-Gallart *et al* 'Measuring Third Stream Activities' p 12 (details in Appendix C).
[15] Patents are a limited indicator — and only useful if they lead to an output where they may be captured in commercialisation income, but not when taken up but fail during development. In the latter circumstance companies still learn from the experience.

It is therefore important to take a holistic approach when assessing university activities to consider the total contribution of universities to society rather than relying on narrow indicators of commercialisation and/or linear models of innovation processes.

In relation to analytical and evaluation difficulties when assessing the market impact and economic development associated with technology transfer, Bozeman notes the following:

> *'While many of these evaluations have yielded quite positive results, there is an emerging consensus that university and federal laboratory technology transfer have only modest potential for creating new jobs or new businesses. …findings for universities suggest that businesses are created, economic wealth is generated, but these are not the chief benefits. …direct and tangible benefits are sporadic and not often realised quickly. At the same time, a stream of incremental benefits is realised over a long period of time and, in all likelihood, the partnerships contribute to a complex web of knowledge capital from which firms will ultimately benefit significantly, even if it is not possible to disentangle all the source of knowledge required for innovation and commercial success.'*[16]

2.1 Australian studies of the impact of science and innovation

The key source of data on Australian R&D and innovation impact is the Australia Bureau of Statistics and the AVCC is confident that the Productivity Commission is very familiar with this source. Other data is available from DEST (eg Selected Higher Education Student Statistics).

In relation to commercialisation of research, an international survey conducted by the (US) Association of University Technology Managers (AUTM) is a useful source. The Australia National Survey of Research Commercialisation (published by DEST) is also relevant although it contains some errors.

Citations of research are nearly always a measure of the significance and importance of a research publication. Citation data can be purchased from Thomson ISI in the USA. In Australia, Dr Linda Butler (ANU) is considered to be the leading expert and has access to the Thomson ISI data.

Some government programs collect annual data, most notably the CRC Program. Medical research data can be found in the Wills and Grant reports and a report on health research by Access Economics (see Appendix C).

An example of highly targeted, short-term university research with strong short-term impacts is that of the Tasmanian Institute of Agricultural Research and its predecessors which helped to establish the pyrethrum and essential oils industries in the state.

Australia's Rural Research and Development Corporations (RRDCs) have undertaken a number of studies to demonstrate accrued benefits (economic, social, environmental) and to demonstrate uptake of research in this sector, which may include changes in farming practice and regional development outcomes, plus influencing public policy in matters associated with their portfolios. The RRDCs have valuable links with Australia's universities.

AusIndustry has also commissioned detailed analyses of the economic benefit of investment across the programs that it administers. Both AusIndustry and the RRDC sector choose to invest in a significant amount of university research.

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[16] Bozeman B, (2000) Technology transfer and public policy: a review of research and theory', *Research Policy*, **29** 627-655, p 647.

2.2 The impact of higher education institutions in the UK

> *Higher education can impact on the economy in a very wide range of ways. Increasing attention is being paid to its contribution to the stock of human capital, with continuing analysis of both private and social rates of return to graduation. Higher education is also considered to have an important impact on the social and cultural environment and this in turn has an impact on the economic environment within which business operates. However higher education institutions are also independent business entities and the economic activity generated by institutional expenditure (the aspect of higher education's economic contribution which is most readily quantifiable) is substantial. The extensive scale of higher education institutional activity across the UK means that its impact can have macroeconomic significance.*[17]

The role of the British higher education sector in the creation and transfer of knowledge to the wider economy is widely recognised and regarded as having a pivotal role in ensuring economic competitiveness. Recent work defines this sector as higher education institutions as well as international students and visitors to such organisations.[18] The overall impact of the higher education sector includes:

- gross export earnings (direct international revenue and additional personal expenditure of international students and visitors);
- amount the higher education sector spent on goods and services produced in the UK;
- the combined valued of direct and secondary (or multiplier) effects for output, and
- the number of full time jobs throughout the economy.

2.3 Trends in impact assessment

The contribution of public research to industrial R&D is considerable and pervasive. Policy makers need to use new understandings of how the iterative relationship between public and industrial R&D differs across industry sectors, in addition to new understandings of which channels of access (or modes of knowledge transfer) are most important for industry when using public research.

An iterative relationship exists between public and industrial researchers where public research sometimes leads the development of new industrial innovations, and sometimes focuses on problems posed by prior industrial developments or customer feedback. Furthermore, large firms are more likely to use public research than small firms, with the exception that start-ups also make particular use of public research.

2.3.1 Sectoral differences

The pathways from publicly funded research to impact and the drivers of industry access to research, display significant sectoral differences. In some sectors public R&D is critical to industrial R&D, whereas public R&D also has an important affect upon industrial R&D across all sectors.

Cohen *et al* also found that the *uses* of public R&D tend to vary across industry sectors, with public research being used to address existing problems and needs at least as frequently as for identifying new research efforts and new products/projects.[19]

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[17] Kelly *et al* (2006) 'The economic impact of UK higher education institutions', A report for Universities UK, p 9. http://bookshop.universitiesuk.ac.uk/downloads/economicimpact 3.pdf

[18] Kelly et al *Op Cit*

[19] Cohen *et al Op cit*.

In some industry sectors, such as pharmaceuticals and biotechnology, for example, a strong linear relationship exists from a new idea or discovery in a university to new product development. In other manufacturing sectors (e.g. computing, automotive) firms access public research in response to ideas for new product innovation primarily derived from customers.

> *As soon as one accepts that innovation might occur differently in different disciplines, it becomes obvious that policy approaches that prescribe or merely expect a common approach … across all disciplines will be seriously flawed.*[20]

The critical policy lesson to derive from this kind of insight is that when designing policy to improve the impact of research, 'one size does not fit all'.

2.3.2 Human capital

The role of human capital is increasingly important in achieving effective and efficient pathways to impact. This is because personal, decentralised and longstanding channels of information flow between public research and industry are the most important.

Universities and publicly funded research agencies are the locus of the bulk of Australia's national research and innovation effort. As **Figure 3** illustrates, Australia has a greater proportion of its research and development workforce in the higher education sector than almost any other OECD country. This is due to a combination of factors, including the unique composition of Australia's innovation system, the nature and relatively small size of the Australian economy, and the ability of our universities and publicly-funded research agencies to meet the research needs of the private sector.

Backing Australia's Ability included incentives to increase private-sector investment in research and developments, and these incentives have had the desired effect, with major increase in investment after a long and steady decline.[21] But more needs to be done to sustain and build on this turnaround. Private sector investment in research and development remains low by international standards, as measured in terms of investment and human resources.[22]

Universities have welcomed this additional private sector investment as it helps secure and build on the research capabilities of universities and of the nation as a whole. Universities are attracting increasingly higher levels of business and industry funding with approximately 28% of the total research income of all Australian universities now derived from the private sector[23]

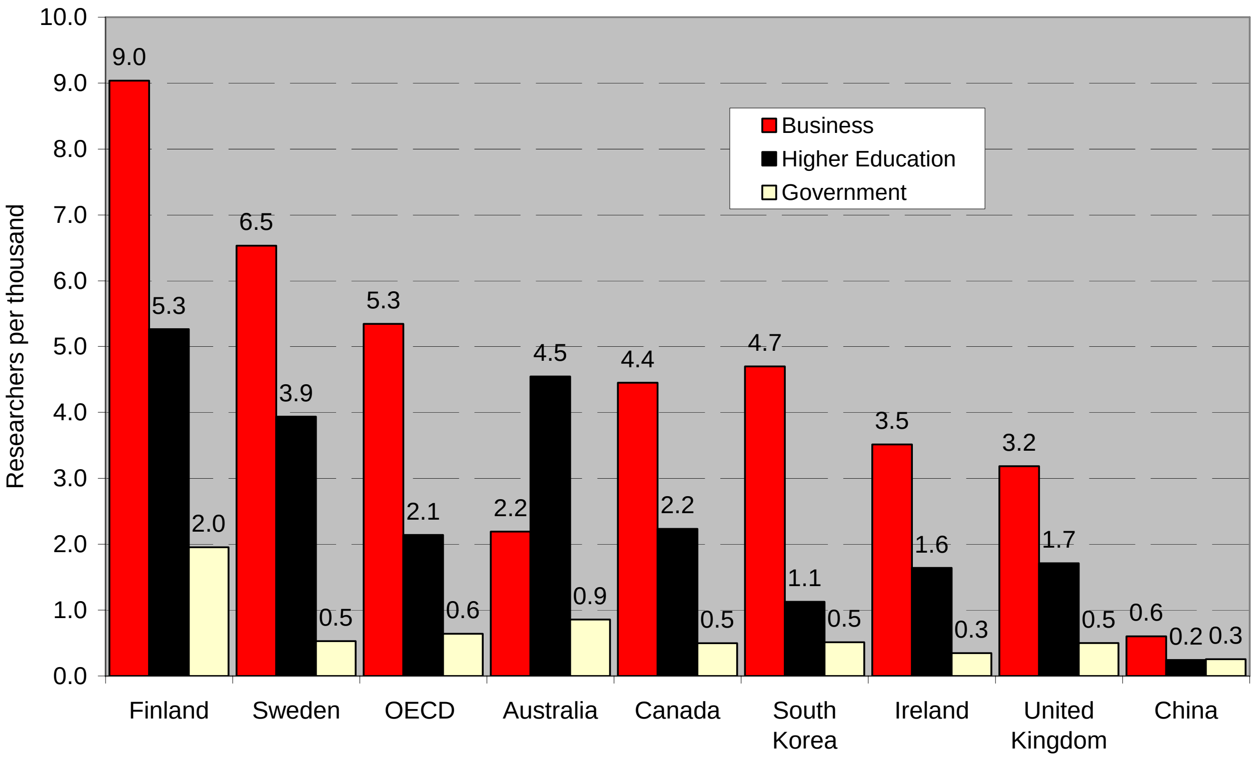
But notwithstanding this increase, private sector funding of research in universities only represents approximately 5.0% of total national expenditure on research and development in the higher education sector, and slightly less than 3.0% of all business expenditure on research and development.[24]

Universities and publicly-funded research agencies continue to provide the research capability essential to the strength of Australian business and industry, as demonstrated by the range of case studies in Appendix A. In the Australian context, they also represent a more economical means of meeting the research needs of business than the alternatives: the private sector duplicating research infrastructure and expertise which already exists in Australia's universities and publicly-funded research agencies, or paying for research and innovation to be done overseas.

[20] S Allott, 2006, *From Science to Growth,* accessed at www.hughes.cam.ac.uk/City_Lecture_060306.pdf
[21] ABS, Research and Experimental Development, Businesses, Australia (8104.0)
[22] Australian Government,(2003), *Mapping Australian Science and Innovation Report,* page 366
[23] DEST Higher Education Research Data Collection 2004
[24] ABS Yearbook Australia 2006 – Science and Innovation: Source of funds for expenditure on research and development (2002-03 data)

It is therefore sensible for business and industry to make use of the established university research workforce and infrastructure, since Australia's innovation capabilities lie chiefly in publicly-funded research in publicly-funded institutions.

Figure 3: Researchers employed per thousand full-time equivalent (2002 or closest available year) (selected countries)



Source: OECD Main Science and Technology Indications 2006

Public and personal channels of access to public research (such as publications, conferences, informal exchanges and consulting) have been shown to be the most important access channels, rather than for example, licenses or cooperative ventures.25

Even when university-industry cooperative ventures or technology licensing between public research institutions and industry support technology transfer in an immediate way, encouragement of such bridging mechanisms should not come at the expense of the other more important channels such as publications and conferences.

A review of technology transfer from universities and government highlights the role of scientific and technical human capital. University students are described as:

> *'…a means of technology transfer (through postgraduate job placements) and they often provide enduring links as the social glue holding together many faculty scientists and the companies they work with.'* [26]

This is where Australian universities have a vital role to play. High quality research graduates, whatever their discipline may be, can only be developed in high quality research environments and in the context of research projects of international quality.

[25] Cohen *et al Op cit*.
[26] Bozeman *Op cit.*

Recent initiatives to develop better impact indicators and measures of university activities are outlined in the following publications:

- *Measuring Third Stream Activities* (2002) – provides an analytical framework and comprehensive set of indicators that may assist in tracking and management of university Third Stream Activities.[27]
- *Measuring the Impacts of Science: Beyond the Economic Dimension* – provides a framework to access the contribution of science to society.[28]
- *The economic impact of UK higher education institutions* (2005) – as unlike other economic impact assessments, it includes secondary or 'knock-on' multiplier effects and expenditure by international students and international business and recreational visitors, in order to calculate an 'overall impact' of the higher education sector.[29]

Attention must be given to the development of sectorally appropriate training in various methods of knowledge transfer, especially for university post-graduates.

2.4 Significant outcomes

The 2003 Mapping Australian Science and Innovation undertaken by the Australian Government notes in Key Finding 2:

> *Australia has invested heavily in 'public good' research and evidence suggests that the commercial and non-commercial benefits from this investment have been considerable, although by their nature they are difficult to measure.*[30]

The knowledge produced by universities contributes also to the cultural, social and economic needs of the nation. This is a long-term benefit and its value has been noted by the former US Federal Reserve Chairman, Alan Greenspan:

> *What has made research universities so extraordinarily productive is their promotion of peer-reviewed scholarship and the value they place on creativity and risk-taking. Although some innovations move quickly from the development stage to applications, more often we cannot accurately predict which particular scientific advance, or synergy of advances, will ultimately prove valuable.*
>
> *What universities produce is highly valued in today's economy … The most significant challenge facing universities is the need to ensure that teaching and research continue to unleash the creative intellectual energy that drives the system forward. The challenge for institutions of higher education is to successfully blend the exposure to all aspects of human intellectual activity, especially artistic propensities and technical skills.*
>
> *Overwhelmingly, with the increasing scientific knowledge base, our universities are going to have to struggle to prevent the liberal arts curricula from being swamped by technology and science. It is crucial that that not happen.*[31]

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[27] SPRU (2002) op cit.
[28] Godin B and Dore C, op cit.
[29] Kelly et al (2005) op cit.
[30] Australian Government (2003) *Mapping Australian Science & Innovation, Main Report* page 5. www.dest.gov.au/mapping
[31] Greenspan A (undated) *Economy and change: investing in an educated future*, www.studyoverseas.com/business/greenspna.htm

The case studies at Appendix A illustrate these points.

In some cases, the benefits are diffuse and difficult to assess. For example, case studies best demonstrating economic benefits are FedSat (1); Inquirion (10); MiniFAB in manufacturing (11), the Lectopia (15); Trainz® end-user technology (16); Microdata and microsimulation at NATSEM (17); and the Higher Education Contribution Scheme (19).

Where the better examples of social gains can be demonstrated, the following case studies are provided: Recaldent® preventing and repairing tooth decay (2); RESMED sleep disorder management (3); the vaccine for the prevent of cervical cancer, Gardasil® (4); the research and subsequent screening program involving colorectal cancer (7); the influenza vaccine, Relenza™ (9); the spina bifida and folate research and the subsequent public health campaign (14); and the Triple P - Positive Parenting Program® (21).

However, there are also gains that have been made most prominently in the area of environmental research, and some of these are in areas such as technologies to balance pressure and liquid heating and cooling in the Quickstep process (6); maximising the return on investment in the legume industry by CLIMA (12); and the joint catchment reef research program (18).

To Greenspan's identification of rapidly increasing scientific knowledge as a threat to the liberal arts should be added a second threat: a preoccupation of government with the disciplines, approaches and mechanisms that are seen as having a direct influence on national economic development, without taking into account the vital contributions of the humanities and social sciences. This, regrettably, is reflected in the Commission's current terms of reference.

Data from the ABS demonstrates that universities contribute to business innovation across all sectors of the economy. In the last Innovation Survey, about 7.6 per cent of all Australian businesses attributed the source of ideas or information to universities and other higher education institutes (the electricity, gas and water supply sector reported a figure of 20.4 per cent). Universities were also significant recruitment sources for businesses seeking staff to develop or introduce new goods, services and processes.[32]

Insufficient attention is given to the role of the public sector in shaping demand and markets for technology. In Canada, for example, Dalpe et al (1992) found that 25 per cent of inventions were first applied in the public sector, suggesting that the public sector plays a significant role as first users of technological innovations.[33]

Increasing levels of support for R&D and innovation will provide Australia with an excellent economic and social return on investment, and result in both short and long-term benefits to Australia.

[32] ABS, 2003, *Innovation in Australian Business*, cat no 8158.0.
[33] Bozeman *Op cit* p 643.

2.5 Nature of university impacts

The national economic importance of Australia's university sector is reflected in its revenues ($13.024 billion in 2004)[34], and employment (91,905 staff (Full-Time Equivalent (FTE) in 2004).[35] Australia's universities also make strong economic, social and cultural contributions to the regions in which they are located. In addition to government support, the universities use student fees, philanthropic donations, contract payments and royalties to provide both private and public benefits.

Universities and their students purchase goods and services. These purchases have significant multiplier effects in the economy. One estimate[36] of the economic impact of Australia's universities concluded that expenditure by the universities and their students amounted to about $10.6 billion per annum, and estimated that university research contributed a further $2.2 billion to industry from spill-over impact. Australian universities also contribute to Australia's taxation revenues, to an extent that offsets about half of the Government's investment.

Australian university education also generates additional earnings over the lifetime of graduates, which can be estimated as the difference between average graduate and non-graduate income.

> *The most widely recognized gains from postsecondary education are the economic benefits that individual graduates receive in terms of greater lifetime income. But it isn't just the individuals who have gone to college who benefit; the larger society also gains. Not only do graduates pay more taxes on their typically higher incomes, but they also tend to have better health, rely less on government social programs, are less likely to be incarcerated, and are more likely to engage in civic activities. In fact, each type of benefit leads to others, producing a cascade of benefits from postsecondary education.*[37]

This differential leads to additional tax contributions by graduates, which has been modelled by the National Centre for Social and Economic Modelling at the University of Canberra to show that the rate of return to the Government for a Bachelor of Science is 9.9 per cent.[38]

2.6 Exports of Australian education services

Universities make the major contribution to Australia's education exports, which are currently Australia's fourth most important source of overseas earnings, amounting to $7.5 billion in 2005 (up nine per cent from the previous year).[39]

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[34] DEST Selected Higher Education Statistics, Finance 2004, Figure 2.1: Summary of 2004 HEP Operating Revenue, by Source, p 6.
http://www.dest.gov.au/NR/rdonlyres/FC5576B6-C249-4C16-BE17-91199CF47845/9697/finance_2004.pdf
[35] *ibid*.
[36] Australian Academy of Science, 2001, Submission to the Senate Employment, Workplace Relations, Small Business and Education References Committee – The capacity of public universities to meet Australia's higher education needs, April 2001.
[37] Cunningham A 'The Broader Societal Benefits of Higher Education,' for the Solutions for Our Future Project. http://www.solutionsforourfuture.org/site/DocServer/07.Social-Benefits.pdf?docID=102
[38] Dean R, 2002, 'Economic and Social Beneftis of Universities: Policy Implications' *Agenda, Volume 9, Number 3, 2002, pages 275-288, http://www.canberra.edu.au/vc-forum/AgenDean.pdf*
[39] The Hon M Vaile, 2006, *Trade 2006: A statement by the Deputy Prime Minister and Minister for Trade*, available at http://www.dfat.gov.au/trade/trade2006

Australian universities operate in a highly competitive international market and our education export earnings are utterly reliant on the quality and excellence of research and education. National and international students, researchers and academic staff are highly mobile. Thus, the standing and quality of our universities is highly influential upon choices to study or work in Australia.

Education and training of international students result in an increasing number of foreign business and government leaders who are well-disposed towards Australia. This helps to promote trade and foreign investment, as well as contributing to stable relations with countries in our region.

In 2004 there were 3,031 international students undertaking post-graduate research degrees in the natural and physical sciences, information technology and engineering. These students comprise about 6.4 per cent of all post-graduate research students at Australian universities and contribute to Australia's research output. [40]

Recommendation:

3. That Government recognise that the benefits from university research, science and innovation flow across the economy and to the whole Australian community, and that there are strong economic arguments for government investment in higher education and research.

[40] DEST, 2004, Selected Higher Education Student Statistics.

3. Australia's science and innovation system — effective and efficient

Innovation is thus the result of numerous interactions by a community of actors and institutions, which together form national innovation systems… Essentially they consist of the flows and relationships which exist among industry, government and academia in the development of science and technology. The interactions within this system influence the innovative performance of firms and economies.[41]

Universities play a vital role in Australia's innovation system. Clearly the performance of the higher education sector, in terms of efficiency and effectiveness has important implications for performance of the Australian innovation system as a whole. The consequences of a general decline in Government funding of higher education are reflected in greater class sizes, fewer technicians and staff salaries that are below industry and international levels.[42] This is largely caused by lack of full indexation of university funding. This threatens the future effectiveness and efficiency of universities.

3.1 Effective building of human capital

The development of human capital is a process that starts in early childhood. By the time students reach the age to enter university their interest in further education, and particularly in the fields of science and engineering, has already been shaped by their school education. For this reason, it is critically important that Australia provides a high quality school education that encourages inquisitive minds and an interest in science. The current lack of interest in key disciplines such as physics, mathematics and chemistry is a matter of concern. Australia's universities need well-prepared, competitive students who are motivated to expand the world's knowledge.

Achieving efficient and effective outcomes in higher education requires:

- sufficient resources to pay internationally competitive salaries to university researchers and staff;
- initiatives to address ageing of the present university workforce; and
- initiatives to encourage qualified academic staff to undertake research to underpin and complement their teaching.

It also requires:

- incentives for suitably qualified students to chose a SET-related degree;
- incentives for students to conduct post-graduate level study, especially in science, engineering and technology where fewer quality students are pursuing higher levels of study; and
- initiatives to encourage greater industry investment in research training.

Human capital is a crucial element of economic growth. All university graduates — social sciences and humanities as well as science, and engineering graduates — make a vital contribution to national innovation and productivity growth.

[41] OECD, *The Knowledge-Based Economy*, GD(96)102, p.16, Paris, 1996
[42] Commonwealth Government (2001) 'Universities in Crisis: report into the capacity of pubic universities to meet Australia's higher education needs', Senate Employment, Workplace Relations, Small Business and Education Committee.

Universities encourage creativity and provide their graduates with the ability to solve complex problems. They also provide transferable skills to equip Australian graduates for a labour market characterised by rapid changing requirements for capacities and skill sets. High quality graduates contribute to innovation across a range of sectors from banking to defence and not only in sectors with a scientific or technological orientation.

> University research provides Australia with access to the latest knowledge available. Graduates with research training play a key role in translating, adapting and adopting new technical advances from Australian and international sources. This helps to ensure that Australian business remains internationally competitive. Australian university researchers provide our nation with access to global knowledge networks — access which is essential if we are to achieve high levels of productivity and international competitiveness.

3.2 Effective contributors to innovation

Efficient and effective universities act as hubs of innovation, within the context of an innovation system. This is because they provide a number of innovation functions:

- repositories of innovative capacity - human capital, facilities, knowledge creation and transfer through research and teaching activities;
- knowledge creation – from highly targeted and applied to exploratory;
- knowledge transfer – from public domain, collaborative research, commercial activities, community engagement, informal networks, post-graduates etc, national and international, and
- production of graduates.

These functions are mutually reinforcing and overlap. They also vary according to each university's specialisation and locality. For example, individual universities have enhanced local innovative activities ranging, from wine making in Wagga, to marine science in Townsville, to national governance/public administration in Canberra.

Predicting what research will generate the highest net public benefits is not possible. For this reason it is important that public funding supports a range of different fields, types and stages of research. This is not to say that methods for predicting research outcomes, such as the setting of goals, foresight processes and effective project management cannot enhance chances of success. However, to be effective, university research requires a balance between the breadth and depth of its effort.

Australia needs *breadth* in order to identify challenges and opportunities as they arise and *depth*, in order to respond to such challenges. A balance between the two will ensure that we can, for example, take advantage of technologies from overseas to enhance the productivity of our society. For example, we no longer build computers in Australia, but our research strengths in information and communications technologies enables us to train graduates to be leading edge users of these important technologies. It also allows for Australian business to hire graduates with the ability to adopt and modify imported technologies, such that they might be best applied to meet business needs and support competitiveness.

There is very considerable risk that the value of the social and behavioural sciences and the humanities will be lost in the debate which will almost certainly (and understandably so) centre around the transfer of knowledge in the basic sciences to innovation and technological development. A perspective needs also to be included from the broader fields of scholarship found in the disciplines of the humanities and the social sciences, including the behavioural sciences, economics and management, history, literature and the arts, cultural and language studies.

Similarly, research developments in the professions of teaching and nursing need to be considered as they emphasise the relevance and importance of professional skills to national health and welfare. Research endeavours in these fields importantly contribute to national productivity.

Multi-disciplinary research augments the effectiveness of Australia's research effort because it helps to build both aspects of breadth and depth of research effort. For this reason, multi-disciplinary research must be specifically encouraged. Furthermore, multi-jurisdictional multi-disciplinary research teams are increasingly important for effective innovation. By this we mean research teams that are comprised of players from different sectors — private, public and not for profit.

It would be a mistake to focus only on Australia's current strengths. Funding current strengths alone will not enable the flexibility to recognise change when it occurs and capitalise on this to leap forward, rather than catching up with the game later. Mining and agriculture are currently important elements of the Australian economy. However, we must build upon the strengths of these sectors, by value adding with science and innovation, by for example, producing qualified graduates in developing technology services.

Increasing public support for research would increase effectiveness by enabling the expansion of numbers of and scale of collaborative/multi-disciplinary activity within the university system and among universities and other sectors of the economy.

Recommendation:

4. That Australia recognise the need to support a range of research and innovation, and do so by a number of different means. Allowing any single approach to dominate would inevitably result in a diminished overall research and capacity and a weaker national innovation system. The impact of research prioritisation should be restructured to recognise this fact.

3.3 An efficient funding system for research

University researchers operate in a competitive market. In order to obtain grants for their research they have to be able to demonstrate that they are across their field and able to propose new projects which are judged worthy of investment. In order to stay across their field, university researchers operate through formal and informal clusters and networks. Like firms, Australian researchers compete and cooperate with their competitors. For these reasons, our researchers are well able to identify emerging opportunities and to seek funding to explore these, to the national benefit.

As noted earlier, increased funding for university research has been delivered primarily in the form of competitive funding, through *Backing Australia's Ability* and *Backing Australia's Ability: Building Our Future through Science and Innovation*. The government sets the objectives for science and innovation funding, as well as the criteria to evaluate performance against such objectives. When a program is not achieving objectives, these are adjusted as necessary and in light of evaluation. Funding allocations to programs are generally based on assessed need and opportunity, influenced by historic factors and program evaluations.

Past success is appropriately taken into account in the Australian Research Council's (ARC) and the National Health and Medical Research Council's (NHMRC) peer review processes. It is considered alongside other factors including the quality and relevance of applications and the potential impact of research outcomes. Because of the long-term nature of research, much of the public funding for research over the next three years is already committed.

Some competitive research funding encourages collaboration with industry (eg CRCs) and publicly funded research organisations (such as CSIRO, DSTO and ANSTO).

Recent reviews of the ARC and NHMRC demonstrate that these programs are meeting their objectives.[43] The ARC funds discovery research that lays a foundation for new company formation, for example, see case studies involving Advanced Nanotechnology Ltd (13), The Australian Bionic Ear: Cochlear Ltd (5); and Hexima Ltd (8).

3.4 Peer review

Peer review is a process of subjecting an author's scholarly work or ideas to the scrutiny of others who are experts in the field. It is used by publishers and conference organisers to select papers for publication, and by funding agencies in order to award grants. Expert peer reviews may see flaws in arguments or provide suggestions on ways in which a paper might be improved. In the past, peer review has usually been an anonymous process, encouraging reviewers to be critical. Some journals now offer reviewers the option of anonymity.

Granting bodies, such as the ARC and the NHMRC, have established panels of reviewers both within Australia and overseas. The latter are important to ensure that Australian research grants meet international standards. However time spent reviewing papers is time away from productive research.

Peer review remains the best process for awarding research grants. While this can be time consuming for applicants and referees, it ensures that funding is determined by those best placed to judge the quality and merit proposals. Australian funding sources make frequent use of international referees to ensure that proposals are assessed by international standards.

Australian managers of research programs are well informed of international best practice in relation to benchmarking, performance criteria and reporting and have incorporated this in the design of Australian programs. Australian management of research is of a high quality.

Recommendation:

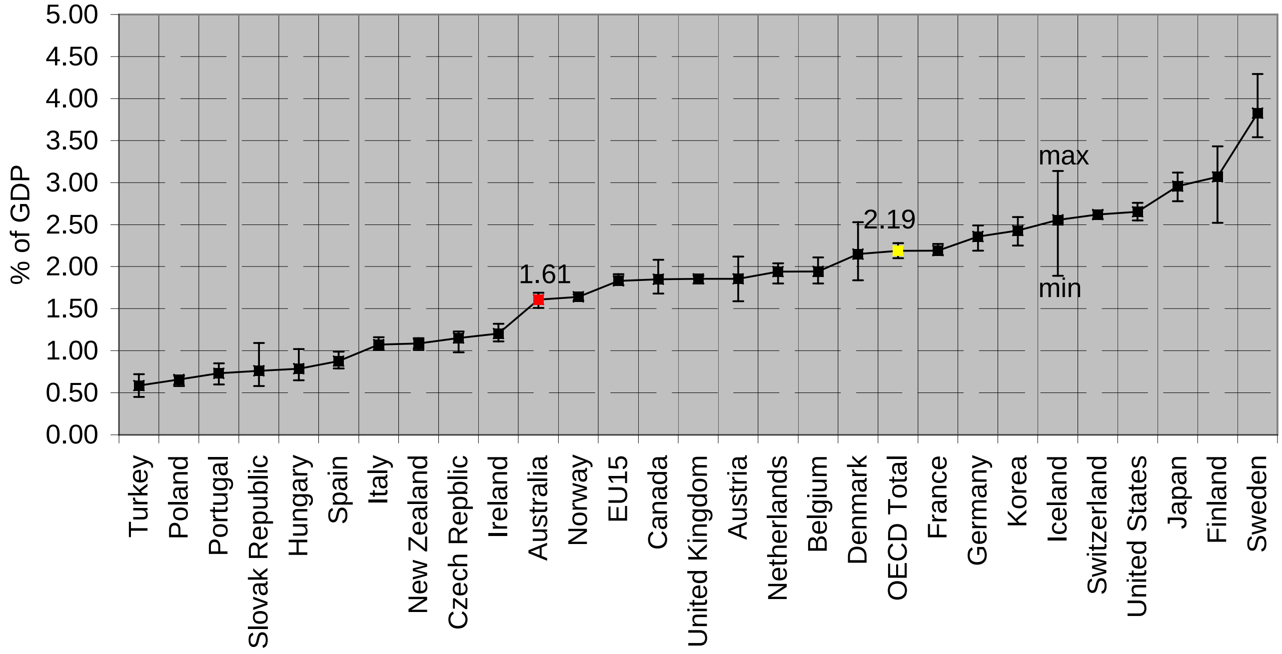
5. That the peer review process for competitively funded research and innovation be retained within Australia to assure the international standing and quality of Australia’s research grant funding system and proper accountability for the allocation of public funds.

[43] See also *Real results, real jobs:* The Australian Government’s Innovation Report 2004-05 available at http://backingaus.innovation.gov.au/reports/04_05/pdf/baa_innov_report.pdf

4. Support for science and innovation needs to be increased

4.1 Investment in Science and Innovation

Figure 4: Average Expenditure on R&D as a % of GDP 1996-2002 (selected countries) (with minimum and maximum range values)



Source: OECD Factbook 2006, p129

Support for science and innovation in Australia is not only low compared to many other countries, it has also remained fairly static for at least the last ten years. **Figure 4** graphically illustrates this point, showing a lack of responsiveness and other signals compared to other major competitor countries. A possible explanation for this stagnation could be Australia's heavy reliance on the resources sector as an export staple without at the same time providing a cohesive framework for public and private investment in knowledge-based R&D and innovation.

Table 2: DEST/ARC Research Training Awards (New Awards), 1996-2005

Year	Australian PG Awards (with Stipend)	Australian PG Awards (Industry)	International PG Research Scholarships	Research Fellowships	Total
1996	1,550	150	300	100	2,100
1997	1,605	205	300	112	2,222
1998	1,595	232	300	100	2,227
1999	1,550	288	300	100	2,238
2000	1,550	334	300	100	2,284
2001	1,550	350	300	100	2,300
2002	1,550	397	310	234	2,491
2003	1,550	461	330	236	2,577
2004	1,550	426	330	249	2,555
2005	1,550	389	330	243	2,512

Source: DEST Higher Education Triennium Funding Reports and ARC Annual Reports

Table 3: Research student enrolments 2001 to 2004

	2001		2002		2003		2004	
	Master's	Doctorate	Master's	Doctorate	Master's	Doctorate	Master's	Doctorate
Broad Field of Education								
Natural and Physical Sciences	1,100	5,965	1,081	6,553	1,074	6,884	978	7,317
Information Technology	210	771	301	1,000	347	1,134	298	1,359
Engineering and Related Technologies	1,023	2,906	1,228	3,374	1,195	3,699	1,294	3,985
Architecture and Building	234	384	267	425	264	468	252	472
Agriculture, Environmental and Related Studies	435	1,384	461	1,517	391	1,581	380	1,629
Health	1,027	4,052	1,216	4,663	1,138	4,976	1,121	5,218
Education	1,014	2,813	1,163	3,380	1,117	3,454	1,093	3,428
Management and Commerce	527	2,378	569	3,008	501	3,128	505	3,242
Society and Culture	2,314	7,667	2,499	8,958	2,347	9,164	2,231	9,531
Creative Arts	1,356	943	1,384	1,169	1,410	1,395	1,472	1,510
Total Number of Students	**9,240**	**29,263**	**10,169**	**34,040**	**9,784**	**35,875**	**9,624**	**37,685**

Source: DEST Student Statistics (various years)

The expenditure on R&D is reflected in the Government's investment in human capital through support for Australian students to obtain postgraduate research qualifications as the pathway to research and other high end careers. **Table 2** shows, however, that the number of the core Australian Postgraduate Awards (i.e. APAs with Stipend) has not increased since 1996, despite the increasing number of Australian students enrolled and completing higher degrees by research (**Table 3**). Further, while the number of APA (Industry) increased significantly between 1996 and 2004, in 2005 the number of new APA (I) decreased by approximately 9%.

Numbers of International Postgraduate Research Scholarships (IPRS) are low, with only a small increase in these since 2001. International postgraduates go on to research, policy and business leadership roles in their home countries, building networks of influence that facilitate business development by Australian companies in these countries. Increasing IPRS numbers needs to be on the agenda in terms of supporting future business development for Australian companies. This is also important in terms of growing the Australian R&D effort, given that filling APAs and APA(I)s during periods of full employment in Australia is difficult and there are growing numbers of international students emerging as the economies in Asia grow. Such an initiative would also increase Australia's earnings from education exports.

Recommendation:

6. That Australia reassess its investment in research study and training opportunities and redress the imbalance between the number of high quality students and the number and value of government-funded scholarships, in particular the Australian Postgraduate Awards (with Stipend) and the International Postgraduate Research Scholarships (IPRS).

4.2 National investment across sectors

The available data show that Australia's science and technology system is strong but not able to reach its full potential because of insufficient investment. Some key points arising from Department of Education, Science and Training (DEST) data [44] include:

Inputs

- Government Expenditure on R&D (GERD) as a percentage of GDP at around 1.69 per cent, is well below the OECD average of 2.25 per cent (Chart 2);
- Expenditure on tertiary education, at 1.6 per cent of GDP, is below the OECD average and well behind the leaders (USA, Canada and Korea) (Chart 4);
- Government support for science and innovation as a percentage of GDP has been in decline since 1993-94 (Chart 7);
- In the period 1994-2004 the annual average growth rate of government appropriations for R&D was only 3 per cent, placing Australia 15th in the OECD (Chart 11);
- Industry financing of GERD as a percentage of GDP is very low by OECD standards (Australia 0.83 per cent, OECD average 1.4 per cent, and Sweden, Finland and Japan in excess of 2 per cent) (Chart 38);
- Only 4.1 per cent of Business Expenditure on R&D (BERD) in Australia is financed by government, compared with the OECD average of 7.2 per cent (this does not include support through tax measures) (Chart 39);

Outputs – scientific

- Scientific output has increased over the years (Chart 67) and Australia's index of citation impact is at an all time high (Chart 68);
- In 2004, Australia accounted for 2.89 per cent of world research publications and ranked 9th among OECD countries (Chart 72);
- On a per capita basis, publications ranked close to the UK and well above the OECD average (Chart 73); and

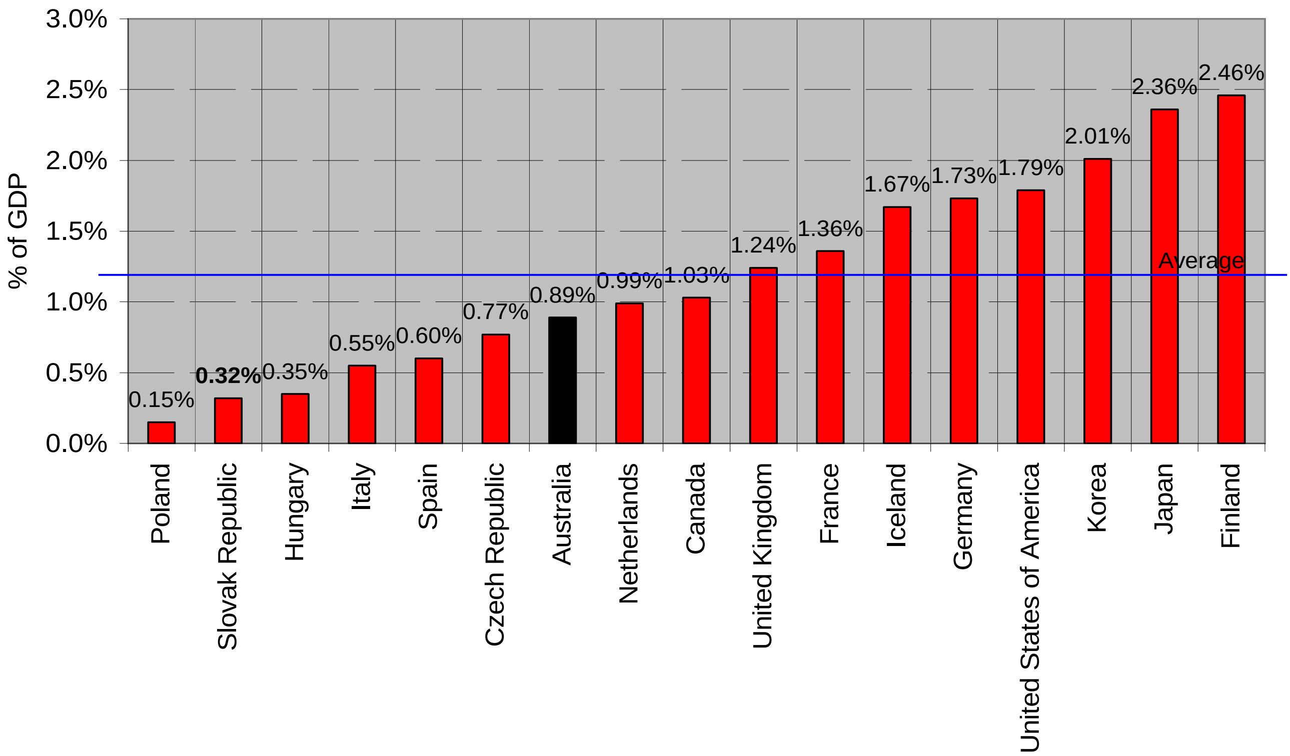
[44] *Australian Science and Technology at a Glance 2005*, Commonwealth of Australia, December 2005 – at http://www.dest.gov.au/sectors/science_innovation/publications_resources/profiles/australian_science_and_technology_at_a_glance_2005.htm

- Australian triadic patents (USA, Japan & Europe) have risen steadily since the mid 1980s (Chart 78).

What these points show is that there has been a continual under-investment by Australia in science, innovation, research and higher education particularly by Government. The performance measures noted above show that in terms of scientific citations and research publications, the Australian university sector is performing strongly, Sustaining and improving that performance requires a greater national commitment to retaining and rewarding the best and brightest of our research and innovators.

In the stronger OECD economies, the complementary nature of business and university R&D is particularly evident — one stimulates the other. By comparison, the weak Australian business investment in R&D and innovation limits research, and university research in particular, from achieving its full potential. At the same time, many companies around the world are changing the ways in which they undertake research and are making more use of university researchers. Our universities are well-placed to undertake research for firms. The ability of firms to commission such research would be enhanced by greater government support for business R&D.

Figure 6: Business Expenditure on R&D as % of GDP 2003-04 (selected countries)



Source: ABS Research and Experimental Development, Business Publication, (8104.0)

Long-term support is crucial to developing a vibrant and sustainable innovation platform in Australia. Public support is also crucial to developing new knowledge in areas that do not (or do not yet) have a commercial focus.

4.3 International comparisons

International comparisons of national science and education performance are standard practice and commonly based on work of experts at the OECD. For example, the OECD's work on R&D statistics spans more than four decades, with the development of standardised definitions and manuals (in particular the Frascati Manual).

A recent paper by staff of the Australian Treasury[45] implies that OECD R&D data are unreliable, and raises questions about the validity of international comparisons of GERD and BERD. While all statistics have their faults, R&D statistics are probably more reliable than the figures for GDP. For example, some elements of GDP such as the imputation for owner occupied dwellings are not robust.

GERD:GDP is one of the major statistical measures used to compare national efforts. This measure is so well accepted that some OECD governments have adopted GERD:GDP targets and measures to achieve those targets.

The AVCC supports the use of such targets and international comparisons to analyse Australia's performance. Furthermore, a detailed commentary of the approach of Davis and Tunny to this issue and their rejection of expenditure targets is provided in Appendix B. In particular the AVCC rejects their:

- Interpretation of OECD targets;
- Comments on industrial structure as a reason why Australia needs to invest less in BERD;
- Lack of attention given to the timeframe from an investment in research leading to economic growth;
- Notion that low Australian BERD is of little consequence for our economic performance, and
- Assessment of the relative generosity of Australian tax concession for industrial R&D.

Australia's BERD does not '*appear to be relatively low*' as suggested by Davis and Tunny – the undeniable fact is that Australia's GERD and BERD *are low* not only by OECD country standards, but also by the standards of newly industrialised countries. As Chart 1 of their paper shows, Australia's GERD and BERD are ranked 18th out of 30 countries. The fact that Australia's low BERD may be explained in part by Australia's current industrial structure is something that science and technology policy analysts have been aware of for many years. Australia cannot and should not rely on our current industry structure to maintain future living standards.

4.4 Advantages of a higher GERD:GDP

While a high GERD:GDP is not an end in itself, economies with a strong knowledge base can offer better quality jobs and a higher standard of living in the long-term. A strong GERD:GDP and innovative capacity underpins higher productivity, provides better-paid quality jobs, and a strong, productive, sustainable and competitive economy.

Australia's reliance upon commodity exports and the unusual structure of its business sector (low numbers large companies and large numbers of SMEs) makes its GERD:GDP ratio even more vital. Innovative capacity plays a critical role in adding value to the commodity base of Australia's exports and upon which our economy absolutely depends.

[45] G Davis and S Tunny, 2005, International comparisons of research and development, *Economic Roundup*, Spring 2005, Australian Treasury available at http://www.treasury.gov.au/documents/1042/HTML/docshell.asp?URL=07_International_RD.asp

For example, it:

- underpins the sustainability of the base – soils, feeds, climate modelling, pest control;
- continuously improves the quality of our exported agrifood products, tailored to particular markets – taste, shape, colour, packaging, transportability, durability, purity;
- increases productive capacity – extraction technology, companion crops, silviculture, etc;
- adds value to commodity products and processes – pelletisers, washers/scourers, etc; and
- supports a vibrant, knowledge based services sector.

Relying on undifferentiated or non-value-added exports of commodities in the longer term is not sustainable. Commodities (especially in agriculture) tend to decline in price over the long-term. Australia has to export more tonnes of wheat each year to pay for the imports that we need to underpin Australia's economy and standard of living. In addition, the prices of Australia's mineral resources are subject to cyclical trends. Australia needs to employ an enhanced innovative capacity to diversify from its industry base and create new sources of foreign earnings.[46]

To this end, expenditure on university research and training ensures that Australian graduates have the high quality qualifications, capabilities and skills to be intelligent buyers, adopters and appliers of overseas technologies and use such a capability to stimulate further innovation. Adapting financial management software packages to Australian accounting standards and formulating prescription medicines to meet Australian requirements, are past examples of such practice.[47]

BERD is a key component of GERD, especially in Australia where levels of BERD are low. A higher level of BERD would provide Australia's universities with more opportunities for research cooperation and knowledge transfer. Findings from Cohen et al (2002)[48] suggest:

> *'...that both public research and industry product and process development progress through complex, intertwined processes, with public research sometimes driving industry R&D, but also providing knowledge that abets the progress of projects initiated due to information, needs and opportunities that originate from buyers, the firm's own manufacturing operations and other sources.'*

The authors also suspect that:

> *'…universities play this role not simply because they produce knowledge, but because… they are also repositories thereof.'*

OECD work indicates that there are correlations between BERD, technology-based exports and economic growth over the longer term. Countries with high BERD and high levels of technology-based industry have increased levels of economic growth (OECD, various years).

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[46] PMSEIC (2006), *Strengthening Australia's Position in the New World Order*, Working Group on Asia Report, June 2006, accessed at www.dest.gov.au/sectors/science_innovation/science_agencies_committees/prime_ministers_science_engineering_innovation_council/meetings/documents/PMSEIC_Working_Group_Report_pdf.htm

[47] A country's ability to absorb foreign technology is enhanced by investment in education and by investment in the country's own R&D (Scot, A. et al. (2001), *The Economic Returns to Basic Research and the Benefits of University-Industry Relationships: A literature review and update of findings* – Report for the Office of Science & Technology, available at www.sussex.ac.uk/spru/documents/review_for_ost_final.pdf

[48] M C Cohen, R R Nelson and J P Walsh, 2002, 'Links and Impacts: The Influence of Public Research on Industrial R&D', *Management Science*, **48**, 1.

4.5 Country comparisons

There are no perfect comparator countries, however it is suggested that the Productivity Commission examine the following list of countries that can be used for comparisons with Australia. These countries demonstrate what can be achieved when there is strong investment in education and university research.

- Canada has a similar economy (but a very large market across its southern border);
- The United Kingdom's national innovation system has certain similarities with Australia's but has a much larger population, a long established tradition of university research and is the leading native-English speaking research country in Europe;
- Ireland's increased investment in education from the late 1980s combined with tax incentives have resulted in strong economic growth, with Ireland being referred to as the "Celtic Tiger". The expansion of Ireland's higher education in this period has been described as enabling the economic acceleration of the 1990s.[49] By 1993, Ireland had the highest percentage of science and technical graduates in the 20 to 34 age group in the OECD;
- The Scandinavian countries (particularly Sweden and Finland) are small countries with high technology economies. In particular, Finland has adopted policies to diversify its economy away from wood-resources to technology-based sectors. The Finnish experience shows what can be achieved from long-term policies that shape research and education outcomes. Economic incentives, education and innovation have been the key elements of Finland's growth. 'Finland's innovation system has successfully converted R&D and educational capacity into industrial strengths.'[50]
- Israel has adopted aggressive policies to transfer technology from defence to civilian applications, and has provided generous support for research, venture capital and innovation Since 1990, Israel's economic growth has been powered by a strong influx of highly skilled migrants. More than 55 per cent had post-secondary education. By 2000, more than 9 of every 1000 Israelis were employed in high technology research and development, almost twice the concentration in the USA and Japan. The result has been strong industrial innovation and economic growth based on research, development and innovation;[51] and
- South Korea has recovered from a war in the 1950s to become a research and technology leader in Asia. Economic growth has been substantially driven by the adoption of foreign technology. Human capital is the key to such growth. While Korea's success was initially attributed to market-oriented reforms and an export-oriented growth strategy, equity and educational investments, and the supporting role of government have come to be seen as having played a significant role.[52]

Recommendation:

7. That Government note the evidence that Australia's current investment in science and innovation lags well behind that of leading OECD countries and take positive action to correct the imbalance.

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[49] Prof. James Burnham, 2003, "Why Ireland Boomed", *The Independent Review*, pp1086-1653.
[50] Dahlman, C J, Routti J and Ylä-Anttila (eds), 2005, "Finland as a Knowledge Economy: Elements of success and lessons learned — Overview", The International Bank for Reconstruction and Development/ The World Bank.
[51] L Sharaby, 2002, "Israel's Economic growth: Success without security", Middle East Review of International Affairs, pp 25-41.
[52] Prof Stephan Haggard, 1996, "Lessons from Successful Reformers: Korea and Taiwan", Economic Reform Today, No 2, 1996.

5. Acquiring value from public support for science and innovation

As innovation is a complex and often convoluted process, there is plenty of scope for impediments to impair the pathway from research through to ultimate public benefit. The types of impediments that the Productivity Commission may wish to investigate may include, for example:

- funding for infrastructure;
- lack of seed funding from government and early stage venture capital;
- lack of critical mass;
- departure of PhDs, and early and mid-career researchers, who may stay overseas during the most productive years of their career because of higher salaries, better infrastructure and overall support for R&D;
- lack of understanding among policy makers of the time course from discovery to application;
- the high level of resources required to complete a pathway from research to public benefit, in conjunction with the short time scale for funding; and
- impediments deriving from inter-group and inter-cultural dynamics, for example, at the interface between a university research group and its commercial partner or collaborator in industry.

5.1 Sectoral intersections

The federal government investment in R&D:

(i) provides research capability, training and capacity,

(ii) supports a fundamental research base, as well as the development of practical solutions to many problems facing society; and

(iii) encourages an often reluctant business community to invest in R&D.

Australia's BERD is low by OECD standards. While the mining industry, primary producers and innovation intensive sectors such as pharmaceuticals, have understood the value of investment in innovation, other sectors have not. As universities have unique research capacities it makes sense for firms to use them. However, firms operating in the knowledge economy must first have 'absorptive capacity' – the ability to assimilate and exploit new knowledge.

Publicly funded research is a source of strategic value for firms by improving capability — knowledge and research skills embodied in researchers and their networks, and variety — the creation of options for future development (a vital feature of flexible innovation systems).

> *By creating and maintaining variety, research maintains the diversity of science and technology options vital to a flexible innovation system faced with uncertain future demands and opportunities.*[53]

Universities can assist the private sector by:

- producing new scientific information;
- training skilled graduates;
- supporting new scientific networks and stimulating interaction;

[53] Godin and Dore *Op cit* p 2.

- expanding the capacity for problem solving;
- producing new instrumentation and methodologies/instrumentation;
- creating new firms;
- providing social knowledge, and
- access to unique facilities (held and developed at universities).[54]

The fact that universities and public research in general provide critical tangible and intangible benefits for the private sector highlights the importance of policies and programs to support university-industry interaction. As some sectors of the economy increasingly outsource R&D, there is scope for the role of universities as a research provider to increase. Two programs that support such interaction, the CRC Program and the ARC Linkage Program, have been found to be highly effective.

All Australian universities have arrangements in place to facilitate the commercialisation of research outcomes. The AVCC and BCA examined impediments in this area, some of which require Government action.[55] Unfortunately, in recent years there has been an over-emphasis on the creation of university start-up companies. While such companies attract attention, they are often under-capitalised, because of a shortage of early-stage (angel) investors and venture capital.

Large corporations and start-ups are the most common types of firms to engage with universities.[56] This is supported by ARC Linkage Program data. SMEs often lack the time and resources to become involved in research and commercialisation. Australia's universities could do more to help SMEs if provided with adequate resources.

Finally, it is very difficult to see how university research would crowd out private sector activity. Estimates presented in a report produced by the University of Sussex[57] indicated that there was no evidence of either 'crowding in' or 'crowding out'. Whether public funding of research in the higher education sector induces research investment from other sources ('crowding in') or a reduction in funding ('crowding out') requires robust modelling that assesses the direct and indirect effects influencing the various sources of funding.

Recommendation:

8. The Australia build on on existing collaboration between universities, publicly funded research agencies and the private sector by developing new incentives for greater private sector participation in the national innovation system.

[54] *Ibid* page 3.
[55] The Allen Consulting Group (2004) 'Building effective systems for the commercialisation of university research,' report for the AVCC and BCA.
[56] Bozeman, Op cit.
[57] Crespi, G. & Geuna, A. (2004) *The Productivity of Science*, Report prepared for the Office of Science and Technology, Department of Trade and Industry http://www.sussex.ac.uk/spru/documents/crespiost2.pdf

5.2 Improving the efficiency and effectiveness of linkages

Australia's universities are working to overcome barriers to the diffusion and transfer of knowledge. The lack of resources to undertake these activities is a significant issue. Government support for university efforts in this area would benefit the economy.[58]

A key barrier here has been a view that universities should be able to secure revenue through their own commercial enterprise, rather than providing universities with sufficient resources to facilitate processes of knowledge transfer to firms, whereby the market will ultimately deliver economic benefits. Resourcing 'Third Stream' activities to promote knowledge transfer has been recognised elsewhere as the most efficient and effective method of improving knowledge transfer and realising benefits.[59]

There is scope to improve collaboration between Australia's universities and other sectors. Other countries (in particular the UK) have addressed this issue with specific funding schemes.[60] These schemes recognise that, while such linkages may generate national benefits and benefits to other parties, universities may actually incur opportunity and commercialisation costs. Therefore, universities might not be attracted to pursue opportunities for linkages with other sectors.

Given the recognition of human activities in technology and knowledge transfer, more needs to be done to support this key mechanism for enhancing science and innovation outcomes.[61] In the US, for example, universities benefit from industry associations and 'technology supporters clubs' that are funded by companies, which bring business physically into a department and increase the flow of business representatives and entrepreneurs through university research departments.[62]

Australian universities would benefit from continued efforts to strengthen university-industry linkages, networks and relationships.

Recommendation:

9. That the Commonwealth Government create a specific program to enhance universities' capacity to use knowledge transfer to encourage wealth creation by business and communities and to address broader community social, health, and environmental challenges.[63]

5.3 Role of State and Territory Governments

State and Territory Governments play a valuable role in supporting Australia's national innovation system. State and Territory government funding is complementary to Australian Government funding and often provides essential infrastructure. Since the latter part of the 1990s, State and Territory Governments have become strategic investors in their science and innovation systems.[64] This represents a change in the long-standing practice of investing in only the elements of the research base necessary to support their direct responsibilities of resource development, public health and the environment.

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[58] See The Allen Consulting Group (2004) *Building Effective Systems for the Commercialisation of University Research*, report for the AVCC and BCA.
[59] Molas-Gallart *et al Op cit* (2002) op cit.
[60] Lambert R, (2003), *Lambert review of Business-University Collaboration*, report for HM Treasury www.lambertreview.org.uk.
[61] Bozeman *Op cit*, Lambert *Op cit* and Allot *Op cit.*
[62] Allott (2006) op cit.
[63] 2006 AVCC Budget Submission, *Funding Universities – Budgeting for the Future*, November 2005
[64] The Allen Consulting Group (2003) 'The Contribution of the States and Territories to Australia's Science and Innovation System.'

5.4 Impact of policy settings and actions of other countries

Currently, few impediments to science and innovation activities in Australian universities arise from the actions of other countries. Impediments that do exist are generally related to security issues (eg. rules that may limit the scope of application of some biotechnology and encryption research). However, the European decision to increase GERD to 3 per cent of GDP has the potential to adversely effect Australian SET.

As Europe increases its GERD it will need to recruit researchers from outside Europe. Australia has been identified as a possible source of science, engineering and technology (SET) personnel. Concurrently, the US continues to attract SET graduates from Australia to meet a long-standing shortfall. The consequences could be shortages of SET graduates in key discipline areas and difficulties in attracting leading researchers to Australia. This could diminish our talent pool and the scale of Australia's science and innovation endeavour.

The growth of SET in China and India has been the subject of a recent PMSEIC report.[65] Both are making massive investments in education and research. Their rapid progress threatens to reduce the attractiveness of Australia as a place to study and threatens the jobs of Australians in sectors where labour costs are significant. Australia needs investment in order to maintain and grow its competitiveness in light of these challenges.

5.5 Policy evaluation and public funding allocation

Nobel Laureates, or recipients of other distinctions, invitations to present keynote papers at conferences or to edit new books are all measures of the standing and quality of our universities. University research has societal and other impacts that are not captured by current measures, but need to be taken into account.

Some indicators of outcomes reflect the extent to which research has led to a change in practice, such as, a change in policy, public good, manufacturing practice etc. Often the **value** of the outcome is difficult to quantify; how, for example, does one value an Act of Parliament or a new government policy introducing a new social regimen (say new childcare support for working parents) that has resulted from economic research and modelling?[66]

Indicators of outcomes need to be used with caution. Many successful R&D outcomes will not translate into a patent or a new company. Rather they may improve a product, process or service, and thereby enhance or maintain competitiveness for existing businesses. Partial quantitative measures or indicators do not capture the latter kinds of outcomes.

Indicators of outcome vary across disciplines and therefore are not easy to categorise or aggregate. In the field of natural resource management, for example, a large degree of effort (in terms of time and dollars) is spent on so called 'extension activities', where relationships with end users aim to achieve a particular outcome.

[65] PMSEIC (2006) *Op cit*.
[66] The Allen Consulting Group (2004) 'Measuring the impact of publicly funded research', report to the Department of Education, Science and Training.
http://www.dest.gov.au/sectors/research_sector/publications_resources/profiles/measuring_the_impact_publicly_funded_research.htm

5.6 National Research Priorities

Australia's National Research Priorities (NRPs) were announced by the Prime Minister in late 2002 and were refined in 2003 to take greater account of the contributions of social sciences and humanities research. The NRPs apply across nearly all Australian Government programs, influencing the allocation of funds and the nature of applications. These Priorities were developed in 2002 and amended in 2003 through a process led by the then Chief Scientist, which involved extensive consultation. Any revision would be expected to follow a similar course. The process of determining Australia's current NRP took account of our strengths and opportunities.

National Research Priorities represent the view, at a point in time, on where limited resources should be invested. The advantage of such priorities is that they can focus additional effort in areas that are perceived to be important to Australia. The disadvantage is that they may result in the under-funding of emerging areas which could be important for the future. The NRPs are most relevant in relation to applied research. Australia needs to continue to support fundamental research which cannot be closely aligned with the NRP.

The AVCC considers that the NRP are satisfactory in their current form and would not want to see them more narrowly defined.

5.7 Reporting requirements and benchmarking

In *Room to Move, Room to Excel*[67], the AVCC has suggested a number of ways in which Commonwealth, State and Territory regulation of universities could be streamlined. These include a more effective and consistent approach across all Governments, with a focus on supporting universities to pursue their missions. Returns from additional tracking and analysis moderate when related to opportunity costs and the onerous nature of additional benchmarking.

The Commission's attention is drawn to the recent report on red tape *University Reporting Requirements Final Report* May 2006,[68] that highlights the burden and costs associated with Government reporting requirements.

The OECD working group, the National Experts on Science and Technology Indicators (NESTI), ensures that new indicators can be compared across countries. This group has worked for more than forty years to develop agreed statistical definitions and measures, including the Frascati and Canberra manuals. The work of the OECD in this area has been adopted by non-OECD countries and is well regarded. However international statistics are never perfect. On occasion, new measures are introduced but take time to appear in national surveys.

Benchmarks are not static; they are improved upon over time. Australia's major granting bodies (ARC and NHMRC) can demonstrate low benchmarks for their administrative overheads. However, this is the 'tip of the iceberg' in terms of total overheads. The burden of preparing and reviewing grant applications falls on researchers. For unsuccessful applications, this effort is not necessarily wasted. Lessons learned may result in future successful applications, or to seeking funds from other sources. However, very low success rates experienced in some government programs are an indicator of significant under-funding. This is of particular concern where a large proportion of quality applications narrowly miss out on funding.

[67] *Room to move, Room to Excel – Commonwealth and State regulation of universities,* The AVCC Response to *Building Better foundations*
http://www.avcc.edu.au/documents/publications/policy/submissions/Room-to-move.pdf
[68] Phillips KPA (2005) University Reporting requirements,- Final Report, report for the AVCC
http://www.avcc.edu.au/documents/publications/policy/submissions/ReportingRequirements14Feb06.pdf

5.8 Current and potential impediments

5.8.1 Impact on university autonomy: increased influence of external mechanisms and requirements

Funding problems of concern to the university sector include:

- inadequate funds to educate and train the numbers of qualified students who seek a university education;
- mismatches between research timeframes (which are long) and funding cycles (which can be annual; and
- uncertainty about funding due to late decisions/announcements by government. Faced such uncertainty, some researchers look for a job elsewhere.
- **Infrastructure problems** include:
- general inadequacy of funding for research infrastructure; and
- competitive funding schemes that do not meet the cost of the provision of infrastructure for research.

Policy problems faced by the universities include the following examples:

- excessive government interference in university affairs. Universities should be able to manage themselves without constant micromanagement from government (eg regulation of student enrolments and fees);
- excessive reporting requirements to government (see the red tape report);
- sudden shifts in government policy and funding levels, with universities given inadequate time to adjust;
- overly complex arrangements for research funding (e.g. the CRC program);
- lack of incentives for private sector engagement with universities. This could become more of a problem with the introduction of the RQF, if quality is seen as more important than impact;
- lack of funding for 'Third Stream' activities; and
- difficulty in obtaining early stage venture capital investment for start-ups.

The requirement to leverage some competitive grants is a problem for universities. This involves using significant core funds to obtain such grants. As a result, Australia's universities suffer a loss of flexibility in the use of core funds. Developing new research strengths in a university can be adversely effected by this problem. Australia's universities are struggling to provide basic core services. Student-to-staff ratios have been increasing and core funding is inadequate. The universities lack discretionary funds to access some programs and to take initiatives that might have high additionality.

At present there is a tendency in public policy to encourage collaborative research. Forcing partnerships that may be premature may not be beneficial to achieving mutually beneficial outcomes. This is seen in the AusIndustry criteria for evaluating applications for Commercial Ready funding, where there can be complications in commercialisation, IP ownership and management.

5.8.2 Research Quality Framework

The development and consequences of the proposed Research Quality Framework are matters that are being addressed through other mechanisms and forums.

5.8.3 Current policy and funding models

At the national level, coordination of research funding is managed through the Consultative Committee on Science and Technology (CCST). At the program level, the ARC and NHMRC consult on grant applications in areas of mutual interest. Most other government programs are free standing and require relatively little government coordination. The Commonwealth, State and Territory Advisory Council on Innovation (CSTACI) provides a forum for consultation between State, Territory and Australian governments on innovation matters.

The key point here is not whether there are too many programs, but rather that there is not enough funding to support the breadth and depth of university research activity.

The National Collaborative Research Infrastructure Strategy (NCRIS) avoids the political considerations sometimes associated with infrastructure investment and ensures that proposals are funded on their merits. The NCRIS process and outcomes to date are encouraging, but to realise the policy objectives of the Strategy, the scheme requires sustained additional funding.

Funding criteria for university research rest largely and appropriately on quality and relevance, regardless of field. How these are measured varies. However the basic approaches adopted are essentially similar and should remain so. For environmental and social research, community engagement is often an additional factor taken into account. Other factors may include partner financial contributions and project viability.

Recommendation:

10. That Commonwealth, State and Territory Governments continue to work collaboratively and in consultation with the university sector in the development of effective legislative and regulatory frameworks that:

(i) balance external accountability with commercial risks; and

(ii) reduce the policy and funding impediments impacting on universities' capacity to contribute to the nation's economic, social and environmental development and prosperity.

6. Concluding remarks: maximising the impact of public support for science and innovation

6.1 Fuelling innovation: the importance of research

Innovation is an essential driver of economic growth and development. Innovation necessarily reaches out to embrace many things: inventions, new ideas, or improvements in existing products and processes. It is not a breakthrough process: and it can involve gradual changes from measurements, to standards, and managerial practices.

Most innovation begins with research. Often, this research is – on first approach – well removed from the product or process or practice which benefits from it. This observation was made by two NHMRC funded Australian researchers in the early 1980s that led to the groundbreaking discovery of the causal link between peptic ulcer disease and the hitherto unknown Helicobacter pylori virus. The pioneering discovery by Professor Barry Marshall and Dr Robin Warren, for which they received the 2005 Noble Prize in Physiology or Medicine, established that the Helicobacter pylori virus is the cause of more than 90 per cent of duodenal ulcers and 80 per cent of gastric ulcers. Peptic ulcer disease can now be cured by a short regime of antibiotics and acid secretion inhibitors, eliminating the need for invasive or destructive medical procedures for many people, and resulting in very significant economic and social benefits worldwide. These benefits would not have been realised without the early, risk-taking fundamental research[69].

6.2 An effective national innovation system: the challenges

The Australian innovation system faces many challenges. Many of these challenges it shares with other nations, but not all. Those it shares are: competing claims for public investment; the increasing expense associated with fundamental research and development; intellectual property issues; and the question of how to increase private sector research and development.

Major challenges exist for Australia that are unique. These result from a reflection of the composition of the Australian innovation system, and of a combination of historical, economic and cultural factors that are subject to ongoing and widespread public debate. They include the need:

- to build an imaginative 'culture of innovation': one which encourages, supports and rewards genuine flexibility, creative problem-solving, and risk-taking;
- to raise Australian investment in research and innovation considerably, which would bring Australia into line with international trends;
- to ensure that public investment level is sufficiently high to meet Australia's research needs;
- to encourage industry and business to take up the challenge to be more collaborative (and hence innovative) by investing in research in Australian universities;
- to build up national research capacity so that universities and publicly funded research agencies can continue to provide the research and innovation base necessary for future economic and social development, and meet the growing level of industry demand for research; and
- to ensure a comprehensive research base such that Australia will be able to can focus on priority areas and demonstrated successes while retaining a broad capacity to meet future needs.

The need for effective public investment in science and innovation that ensures optimal economic, social and environment returns on that investment is well understood by Australia's major trading partners and competitors. In renewing Australia's commitment to a strong effective research and innovation base, Australia must set ambitious but achievable targets, and put in place a national innovation strategy to reach those goals.

[69] See 2005 Nobel Prize in Physiology or Medicine Press Release: http://nobelprize.org/nobel_prizes/medicine/laureates/2005/press.html

Appendix A – Case Studies

1. Australia's Federation Satellite (FedSat) – leveraging success in Space Science and Technology

Brief synopsis

In 1998, the CSIRO initiated the FedSat — a satellite developed with the aim of conducting space science and technology experiments for the Australian and international space community. The Cooperative Research Centre for Satellite Systems (CRCSS) was created. The CRCSS was a partnership of five universities, four commercial companies and two government agencies.

Timeframe

Although led by the CSIRO, FedSat drew on strong research and development contributions from Australian universities and international partners. The CRCSS developed a $20 million research satellite as a platform for contributing to the international effort in space science and technology with targeted outcomes of specific value to Australia. At the same time, this investment led to an increase in Australia's science and engineering capacity. Australia's scientists and engineers were trained in relevant research areas, such as satellite engineering. This increase in Australia's research capacity also improved Australia's opportunities to collaborate with space science and technology ventures in other countries. FedSat was launched in 2002.

Success factors

Although earth observation, communications and meteorology are the most prominent uses of space science in Australia, there are a number of other critical areas in which Australia has real strengths. These include space weather monitoring to protect satellite and ground assets from the effect of solar induced particles and radiation and the provision of navigation and positioning (including timing) signals for a variety of applications. Although Australia does not have the resources to develop comprehensive infrastructure in these areas, engagement in partnerships that allow access to other space services is significantly improved by contributions in our areas of demonstrated strength. In space applications, partnerships in one area can leverage a high return in other areas, and FedSat has enabled this leveraging to occur.

Barriers

The civilian space business relies heavily on government investment, traditionally through space agencies and other major space-oriented research organisations. In the absence of such an agency in Australia, the CRCSS was an innovative and successful experiment in government and private funding for specific space related activities.

Benefits

FedSat contributes a a magnetic field measuring instrument for monitoring space weather effects that have the potential to disrupt satellite services or even damage satellites. The data from this instrument is provided to international agencies through the Australian Government's Ionospheric Prediction Service. Data from this instrument has been shared to obtain access to other instrument data from other agencies, the combination of which has led to new discoveries that inform our understanding of space weather. Data from this instrument (coupled with data from another GPS instrument on FedSat) was used by the Japanese space agency to determine the cause of the failure of the $1 billion earth observation satellite (ADEOS2) and has led to design improvements for the protection of future satellites.

A number of new spacecraft tracking facilities have been established. Although NASA operates a tracking station for its mission outside Canberra, few commercial facilities exist in Australia. Through the FedSat project, a ground station has been established at Mawson Lakes in South Australia which is now owned by UniSA. This ground station has the capability to track many civilian space missions, and its unique position in the Southern hemisphere has the potential to lead to new opportunities for both mission support and data acquisition. Direct data acquisition allows early researcher and commercial access to valuable data.

The high profile of the FedSat project in the international space community has allowed Australian researchers to participate in international fora relating to space science and technology. For example, Australia hosted the Asia Pacific Regional Space Agencies Forum in 2004 and was a major participant at the 2005 session in Japan. The benefits acquired from this profile have been involvement in major regional activities, including participation and leadership in the Asian Disaster Monitoring project initiated by the Japanese space agency. Australian access to a variety of space imagery and data for disaster management will be facilitated by involvement in projects such as this, and would have been unlikely had not FedSat leveraged participation through the international space community.

While commercialisation of space technology is a long process (particularly in relation to space-borne instruments which require demonstrated heritage), some progress has been made in introducing standards for remote messaging from space (through the ADAM payload). The ADAM payload has been adopted as a regional standard and has flown on other nations' spacecrafts or is planned for future missions. Business opportunities to develop ground terminal equipment arise from the deployment of space technology, and standardisation is an early start to this process. More immediate returns have been inspired by parallel projects in satellite communications technology, and early stage demonstration of efficient satellite communications networks that may be suitable for rural and remote communications have been trialled.

The importance of FedSat as a national asset was demonstrated by the fact that when the CRCSS closed in December 2005, the Department of Defence took responsibility and ownership of FedSat in order to ensure that its data and payloads continued to be available for scientific research and development. This reinforces the value of FedSat and the resulting scientific and technological outcomes for the end-user communities.

Commercial return on investment from civilian space activities is hard to quantify – many countries take it as a given that investment in space is both necessary and desirable for a variety of public benefits. The environmental and societal benefits that Australia derives from having access to space assets amounts to billions, both in direct impact on daily life and in the mitigation it affords from natural and human-made disasters. The relatively small public investment in space made through the FedSat program continues to leverage direct and indirect returns that would not have been possible without the critical mass and focus afforded by the partnerships formed through the CRCSS.

Supporting documentation

http://www.crcss.csiro.au/fedsat/default.htm

2. Recaldent™ Pty Ltd – new technology for prevention and repair of tooth decay

Brief synopsis

Recaldent™, also known as casein phosphopeptide amorphous calcium phosphate (CPP-ACP), is a new technology that has the potential to prevent and repair tooth decay. The development of this product was based on the investigation of the bacteria that is responsible for dental caries and periodontitis, and the identification of the molecular processes that allow the repair of early tooth decay without invasive processes.

Timeframe

Over a decade of research occurred leading to the development and release of the product.

Success factors

Professor Eric Reynolds was awarded the 2005 Victoria Prize for his work on the molecular basis for dental caries and periodontitis. The research changed the practice of preventive dentistry by tackling oral diseases and disorders that cost Australians around $3 billion a year in treatment. To date, the research has resulted in 16 patents and five license agreements with major international companies. In the last ten years Professor Reynolds has attracted $42 million of research funding for oral health science from government agencies and industry. He has established the Victorian Centre for Oral Health Science and the CRC for Oral Health Science which are internationally recognised research centres focusing on major oral diseases.

Benefits

This technology, derived from cow's milk, can:

- repair early tooth decay;
- prevent tooth enamel loss from decay and erosive foods;
- correct injuries from fluorosis or over bleaching of teeth;
- desensitize teeth;
- protect oral soft tissues.

There are significant health and social benefits that can arise from applications of the technology. Products based on CPP-ACP technology are used in dental practices in Australia, Japan, Asia and Europe. Recaldent™ has been incorporated into a range of professional dental products such as gels, pastes and rinses, as well as foods such as chewing gum. These products generate over $200 million in sales annually. Pfizer, the global pharmaceutical giant, now sells chewing gum containing the product in the US, Japan and Europe.

Recaldent™ Pty Ltd, which is a Victorian company, manufactures over 50 tonnes of Recaldent™ a year, which generates many millions of dollars worth of exports for Victoria.

Supporting documentation

http://www.business.vic.gov.au/BUSVIC/STANDARD/1001/PC_61054.html

3. ResMed — development, manufacture and marketing of products for management of sleep disorders

Brief synopsis

ResMed is a leading developer, manufacturer and marketer of products for the screening, treatment and long-term management of sleep-disordered breathing (SDB) and other respiratory disorders. SDB encompasses a range of respiratory disorders, which range in severity from obstructed sleep apnea (OSA) to snoring. OSA occurs when someone's airway temporarily collapses during sleep, preventing or restricting breathing for up to ten seconds or more. Such events can occur several hundred times a night, and severely disrupt sleep. Untreated OSA can severely affect quality of life, health and mortality. While SDB affects around 20 per cent of the adult population, making it as widespread as diabetes or asthma, awareness of the condition is low. ResMed estimates that around 90 per cent of people who have OSA remain undiagnosed and untreated.

Clinical research shows that OSA is linked strongly to a range of serious diseases such as stroke, heart failure, hypertension, diabetes, obesity and coronary heart disease. Other links include preeclampsia in pregnant women, attention deficit disorder in children and an increased risk of workplace accidents. Positive airway pressure is a proven and popular way to treat OSA, and is widely accepted across the globe as being highly effective. This treatment involves wearing a mask or nasal pillow system connected to a small portable airflow generator that delivers air at positive pressure. The air pressure acts like a splint to keep the airway open.

Timeframe

Developed **in 1981** by Professor Colin Sullivan and colleagues at the University of Sydney, nasal continuous positive airway pressure (CPAP) provided the first successful noninvasive treatment of OSA. When ResMed was formed **in 1989,** its primary purpose was to commercialise a device for treating OSA. **Since 1989**, ResMed has maintained its focus on SDB, which is gaining greater public and physician awareness. Operations have grown dramatically through the introduction of a number of highly innovative product lines.

Success factors

- ResMed invests approximately 6 per cent of its revenue back into research and product development, as a result of which expenditure on research and development continues to grow every year.
- ResMed's team is focused on developing innovative therapies that increase patient comfort and convenience while improving health at the same time.

Benefits

ResMed is committed to increasing education and awareness of the serious health consequences of untreated SDB among both the general public and physicians. ResMed has established Foundations in both Australia and the United States and are funding a public relations program (together with other industry participants) in several countries to publicise the dangers of undiagnosed SDB.

Supporting documentation

http://resmed.co.uk/portal/site/ResMedUK/index.jsp?vgnReset=1&epi_menuItemID=865067b275ef2bf3602453976c2001ca&vgnChId=022a27e4bd475010VgnVCMServerc60210ac____

4. Gardasil™ – Human Papilloma Virus vaccine for the prevention of cervical cancer

Brief synopsis

GARDASIL™ is the world's first vaccine to prevent cancer. It protects women against four strains of the human papillomavirus virus (HPV) – types 16 and 18, which account for about 70 per cent of cervical cancer cases (the second most common cause of cancer death in women) and types 6 and 11, which account for about 90 per cent of genital wart cases.

The vaccine was developed at The University of Queensland (UQ) Faculty of Health Sciences, Centre for Immunology and Cancer Research by 2006 Australian of the Year, Professor Ian Frazer and the late Dr Jian Zhou. The pair discovered the basis of the HPV vaccine in the late 1980s, when they developed recombinant virus-like particles which could be used to train the body to fight the virus. Professor Frazer had concentrated on HPV because it was known to cause genital herpes and had links to cancer.

Timeframe

From the late 1980s, and ongoing.

Success factors

- The long-term commitment to the underlying research: Professor Frazer began research work on the vaccine almost two decades ago, starting out as just "me and the broom cupboard" and building up the Centre for Immunology and Cancer Research to a position where it attracts around $3 million per annum in grants and supports 50 scientists[70].
- Timely patenting of the ground breaking HPV technology by UniQuest **in 1990** after Professor Frazer approached UniQuest with the disclosure to ensure the intellectual property was protected before he published the research at a conference.
- Industry funding for developing the vaccine provided by the Commonwealth Serum Laboratories (CSL) Limited. **In 1991,** CSL funded a research and development collaboration which included an option to license the vaccine technology via UniQuest, leading to licensing **in 1995** and commercial release **in 2006** by licensees, CSL Limited and Merck & Co., Inc (USA).
- Successful, subsequent cross-licensing: **in 2005** CSL and Merck entered into a cross licensing agreement with GlaxoSmithKline (GSK) in relation to a competitive HPV vaccine being developed by GSK. Under the licensing arrangements, royalty payments from the sale of both the Merck and GSK vaccines will be made to UQ.

Benefits

Health and social

- Cervical cancer is one of the few cancers known to be caused by a virus.
- Worldwide, cervical cancer is the second most common cause of cancer death in women.

[70] UQ website: http://www.uq.edu.au/research/index.html?page=4229&pid=0

- Most HPV infections clear up naturally. However, some high-risk types of HPV, if unrecognised and untreated, can lead to cervical cancer. In addition, certain low-risk types of HPV cause genital warts.
- Each year in Australia, 100,000 women have a pap smear test (that detects a cervical abnormality) requiring a medical follow up. In the United States, an estimated 4.7 million Pap results are abnormal, of which at least 3 million are caused by HPV.

To help make the vaccine accessible in developing countries, Professor Frazer is working with the Gates Foundation and is a consultant to the World Health Organisation's Expanded Vaccine Initiative. In addition, Merck will be introducing a differential pricing structure to help ensure the vaccine is available at a cheaper price in developing countries.

Financial

UniQuest licensed the HPV technology to CSL in 1995, and CSL subsequently on-licensed the HPV technology to Merck & Co, Inc, retaining the rights to market the HPV vaccine in Australia and New Zealand. Merck subsequently funded the successful Phase II and Phase III clinical trials of the vaccine, enabling its commercial release in 2006.

The vaccine was approved by the US Food and Drug Administration in June 2006 following the successful completion of Phase III clinical trials in 2005, and will be commercially released later this year. Industry projections of sales range from $1-4 billion per year, and the product is expected to be a “blockbuster”.

On 29 June 2006, Merck & Co. announced[71] that the U.S. Center for Disease Control and Prevention's Advisory Committee on Immunization Practices (ACIP) voted unanimously to recommend that girls and women 11 to 26 years old be vaccinated with GARDASIL™ to prevent cervical cancer, precancerous and low-grade lesions, and genital warts caused by human papillomavirus (HPV) types 6, 11, 16 and 18. The Committee has recommended that GARDASIL™ be administered to 11- and 12- year-old females and to females aged 13 to 26 who have not previously been vaccinated, and that nine- and 10-year-old females can be vaccinated with GARDASIL™ at the discretion of their physicians. The ACIP stated that Pap and HPV screening prior to vaccination are not necessary. The ACIP also recommended that females can receive GARDASIL™ regardless of whether they have or previously had an abnormal Pap test, a positive HPV test or genital warts.

“It's a great privilege to be recognised by Australia as the 2006 Australian of the Year. But it's an even greater privilege to be able to do something tangible for the health of Australian women, and for women throughout the world.” Professor Ian Frazer

Supporting documentation

http://www.gardasil.com

[71] Merck & Co. website: http://www.merck.com/newsroom/press_releases/product/2006_0629.html

5. Cochlear Ltd – The Australian Bionic Ear – a world first

Brief synopsis

The Australian Bionic Ear (cochlear implant) is the result of pioneering research commenced by Professor Graeme Clark in the late 1960s at the University of Melbourne's Department of Otolaryngology, when he began researching the possibility of an electronic, implantable hearing device. Professor Clark's vision for such a device was spurred by witnessing from childhood his deaf father's desire for a greater connection to others. He returned to research, leaving a career as an ear, nose and throat specialist, to pursue this goal.

The Australian Bionic Ear has now been implanted in over 60,000 severely or profoundly deaf children and adults in more than 120 countries. It is considered by many the first major advance in helping profoundly deaf children to communicate in the last 200 years since signing was established at the Paris Deaf School.

Timeframe: from the late 1960s and ongoing

1978: The prototype multiple-electrode Bionic Ear was implanted in the first adult at The Royal Victorian Eye and Ear Hospital. Professor Clark and his team discovered how to analyse the complex speech signal and present it as electrical stimulation to the hearing nerve so that speech could be understood. In addition, they were successful in engineering a speech processor small enough for the patient to wear.

1981: Cochlear Limited's global headquarters established in Sydney.

1982: The Cochlea Implant Clinic (CIC) was established at the Royal Victorian Eye and Ear Hospital in Melbourne, where the first device for clinical trial world-wide was implanted the same year. The CIC is a joint University of Melbourne and hospital clinic, the team is made up of ENT surgeons and clinicians (audiologists & speech pathologists) offering specialist medical, audiological and speech pathology services to people with significant hearing impairments.

1984: Professor Clark founded The Bionic Ear Institute, an independent, non-profit, medical research organisation (that continues to partner with Cochlear Limited).

1985: The international trial established that it was safe and effective, and it was approved by the US Food and Drug Administration (FDA), the first multiple-electrode Bionic Ear to be approved by any world regulatory body.

In 1985 also, the team implanted the first child with a multiple-electrode Bionic Ear. This Bionic Ear was developed industrially by Cochlear Limited in co-operation with The University of Melbourne and The Bionic Ear Institute. This was the start of a world-wide trial for the Bionic Ear and its use in young children.

1990: The FDA approved the Bionic Ear as safe and effective for use in children born deaf or developing hearing early in life by the FDA. It has also been approved by the Chinese and other world regulatory bodies.

December 1995: Cochlear Limited was first listed on the Australian Stock Exchange.

Success factors

- Professor Clark's and the research team's dedication and long-term commitment to the fundamental research that led to its safe and effective clinical application and the development of the Bionic Ear.

- In the early R&D stage in particular, donations from the general public and the help of clubs such as Rotary, Lions and Apex were invaluable.
- In 1981, the partnership of Nucleus, an Australian medical device group, Cochlear Ltd and the Australian Government (with support of public interest grant ($5m)) helped the development of the product to market, now known as the Nucleus multi-channel cochlear implant.
- Over the late 1980s to 1990s, public support included funding through an Australian Research Council Special Research Centre, National Health and Medical Research Council grants for biological science, and CRC funding (1992 and 1999 funding rounds).
- Cochlear Limited's ethos and approach, including:
  - corporate goals encompassing customer focus, organisational performance, and shareholder value – and strategic thinking that has leveraged innovation into a very successful business;
  - provision of technology upgrades without additional surgery or implant replacement; and
  - collaboration with a worldwide community of leading scientists in 70 countries, with global research and development conducted at the company's facilities in Australia, Belgium and the United States.

Barriers

At the time of early development in the late 1960s, scientists said that a successful Bionic Ear or cochlear implant was not possible in the foreseeable future, nor was there support from deaf communities. This made it difficult to secure competitive research grant funding.

Benefits

"It's not just voices that sound good, it's all the other sounds like birds, a knock on the door, a car going past, and the dog barking, it's fabulous." User aged 38[72]

Together, Professor Clark and Cochlear Ltd continue to explore new avenues in technology and deliver first-to-market high quality innovations that help the deaf hear with more clarity and ease and provide.

Cochlear Limited continues to grow:

- from an initial share price of $2.50 in 1995 to approximately $53.00 in July 2006;
- current export earning of approximately $350m per year;
- by 2005: Asia Pacific – 16,300 recipients, 260 Nucleus clinics; USA – 27,000 recipients, 500 Nucleus clinics; Europe – 21,000 recipients, 260 Nucleus clinics.

The CIC is involved in pioneering research into outcomes and management of cochlear implant recipients. Surgical techniques and research studies are constantly being developed to keep the CIC standards at the forefront of the cochlear implant field.

Supporting documentation

The Bionic Ear: http://www.bionicear.org/bei/AboutHistory.htm
Cochlear Limited: http://www.cochlear.com.au/
Financial history: http://www.cochlear.com.au/Corp/Investor/189.asp
ASX listing:
http://www.asx.com.au/asx/research/CompanyInfoSearchResults.jsp?searchBy=asxCode&allinfo=on&asxCode=COH&companyName=&principalActivity=&industryGroup=NO#chart

[72] Recipient Information: http://www.bionicear.org/mhg/cicwhatrecipientssay.html

6. Quickstep Process – technologies to balance pressure and liquid heating and cooling

Brief synopsis

Quickstep, or more specifically, the Quickstep Process, is a range of unique and patented technologies involving carbon fibres that can be used in the out-of-autoclave manufacture of advanced composite materials using balanced pressure and liquid heating and cooling. The initial process producing high quality moulded composites was developed by a Western Australian company called Quickstep Technologies Pty Ltd in conjunction with CSIRO.

Deakin University provided a significant proportion of the underpinning research that supported Quickstep to move from start-up phase to a public listing.

The Quickstep Process has applications in the aerospace and automotive industries where strength and weight are critical, as well as in many other industries seeking to replace metals with composites. Carbon fibre composites have been used to shape aircraft panels and Formula One racing cars for many years, but material costs have kept the technology out of reach of mass manufacturing. Now the researchers are unlocking ways to move these materials out of aircraft hangars and into the family garage.

The engineering research team is led by Dr Bronwyn Fox of Deakin University's Faculty of Engineering, a chemistry graduate whose doctorate is in aerospace composites. The team includes engineers and researchers from Quickstep, Holden Special Vehicles (HSV), and the Victorian Centre for Advanced Materials Manufacturing (VCAMM), which includes several universities.

Timeframe

From January 2004 to the present.

Success factors

- Deakin University had a broad skill set in the area of smart materials that enabled it to take a unique systems approach to improving the conceptual Quickstep Process that had been invented by an industry partner. This approach involved a broad range of disciplines including mechanical engineering, materials science and many others.
- This systems approach was instrumental in the industry partner's decision to move its research operations from Western Australia to Deakin University in Victoria.
- Effective collaboration between and among researchers, engineers and technicians in the public and private sectors and in the development of the associated business partnerships continues to underpin Quickstep Process's development and marketability.

Barriers

The use of balanced pressure and liquid heating and cooling for the manufacture of advanced composite materials, rather than auto-claving, was an entirely new idea that was contrary to conventional wisdom. As a result, there were several challenges in relation to process and perception that needed to be overcome.

Benefits

Reduced costs to industry in terms of capital expenditure, tooling and operational expenses, as well as providing a lightweight alternative to metals such as steel and titanium. This has the potential to provide Australian industry with a significant competitive advantage in high value manufacturing, such as aerospace.

Dr Fox's team is currently refining the technology; and it is thought that 'composite cars' could be on the road within five years. The successful development of composite car panels with a completely smooth surface finish promises significantly lighter vehicles, helping to reduce emissions and cut fuel costs. The composite car panels also have the potential to slash conventional manufacturing costs. Fast-tracked production times and the second-generation materials now in development could cut the cost of automotive parts by 50 per cent.

Supporting documentation

http://www.deakin.edu.au/scitech/et/profiles/staff.php

http://www.quickstep.com.au/index.php

7. Colorectal Cancer Screening Program – overcoming behavioural barriers to screening, and increasing lifespans and productivity

Brief synopsis

Colorectal cancer is the second most common cancer in Australia, affecting nearly 13,000 persons per year. Of the cancers where the evidence supports a national screening program, it is the only one where there has not been a screening program available for the whole community, until now. The National Colorectal Cancer Screening Program will adopt a process that is modelled on the research and service program developed by Professor Graeme Young in Adelaide — a simple test that detects faecal occult blood (FOBT). He was able to identify a more successful approach to screening the population with this new technology, doubling population screening rates to almost 50 per cent. The national screening program also incorporates aspects of his research looking at behavioural strategies that help overcome barriers to screening.

Timeframe

The timeframe from the beginning of the research activity to the application within the national screening program has been more than two decades. Basic research **in the late 1980s and early 1990s** in the laboratory and with human subjects led to an increase in knowledge and understanding of the nature of bleeding from cancers and pre-cancer lesions (adenomas). From here, Professor Young identified how occult bleeding might be used as an effective early warning sign to detect curable lesions. This research led to the development of a screening test that was selective for bleeding from the large bowel only. Further research showed how the new technology translated into more effective action — as screening became easier for individuals, and as behavioural barriers were overcome, screening rates improved.

Success factors

- Professor Young's demonstrated expertise and leadership skills have been critical to the development of the National Colorectal Screening Program. His communication skills have also enabled him to:
  - achieve consensus among his peers for an evidence-based approach to prevention;
  - work successfully with local and federal politicians;
  - interact effectively with a wide variety of media;
  - successful relationships with relevant public bodies, advocacy groups and other stakeholders; and
  - popularity as a speaker at public forums.
- The venture received funding of about $12 million from a number of sources, including grants from NIH, NHMRC, state cancer councils, ARC, Wellcome Trust and industry grants.
- Effective partnerships with research and clinical colleagues, research organisations and industry partners enabled the development of a truly multidisciplinary approach to solving the problem of screening for colorectal cancer. Key partnerships include:
  - clinical researchers at Flinders Medical Centre, Repatriation General Hospital and Royal Melbourne Hospital to allow access to patients and translation of laboratory research to the clinical setting;
  - CSIRO P-Health Flagship and CSIRO Divisions Molecular and Health Technologies (CMHT) and Mathematical and Information Sciences (CMIS); and

– Enterix Pty Ltd, an Australian/US medical diagnostic company committed to development of diagnostics for colorectal cancer screening.

Barriers

Some of the barriers to success included the fact that it was difficult to obtain funding for research and development in the early stages. In relation to this, it was also difficult to establish 'proof of concept'. There was a lack of an integrated, whole-of-government support for colorectal cancer screening. This needs to include Medicare funding for screening tests, and national integration of health data. There was also perceived to be a limited understanding by government agencies and the community of the long timeframes, ethical, behavioural and logistical issues associated with 'proving' the efficacy of population-based cancer screening.

Benefits

Social

The social impacts of improving life for those with colorectal cancer are significant, retaining productivity and increasing life spans. The approaches and technologies being applied for colorectal cancer screening can be applied to other cancers in future as robust screening tests and markers are developed.

Financial

Estimated spending on colorectal cancer in Australia rose 44 per cent between 1993-94 and 2000-01 to $235m and continues to rise (Source: CSIRO). As with other cancers, most of the funds for cancer care are spent in the final stages of the disease and very little (less than 10 per cent) on prevention and early detection strategies. Development and widespread use of effective screening tests for early stage colorectal cancer will have enormous impact on the financial and personal burden of the disease. If colorectal adenomas can be detected early and removed, it is estimated that more than 50 per cent of colorectal cancer cases could be prevented.

Supporting Documentation

hsttp://www.cancerscreening.gov.au/bowel/bcaust/about_fobt.htm

8. Hexima Ltd — research and innovative technology for biological enhancement and protection of crops

Brief synopsis

Hexima is a plant biotechnology company established as an unlisted public company in 1998 based on core intellectual property developed at the University of Melbourne and La Trobe University. The goal of the company is to be a world-class provider of innovative technologies for the biological enhancement and protection of crops. The intellectual property portfolio of the company is the result of major research projects that have been conducted for more than a decade.

The primary piece of intellectual property is based on a novel gene that confers insect resistance to crops. The gene (NaPI) was discovered by “accident” during a fundamental research program aimed at understanding the molecular basis of pollen recognition in flowering plants. This was funded by an ARC Special Research Centre at the University of Melbourne that was headed by Professor Adrienne Clarke. Subsequent basic research on the gene and the insecticidal properties was conducted at La Trobe University using ARC funding granted to Professor Marilyn Anderson. This basic research suggested the NaPI gene had potential commercial application for protection of plants against insect attack. Commercial funding was initially sought in 1995 when the patent entered the International phase and patent costs began to escalate. PIVOT industries were the first commercial partner. Over the last 5 years commercial development has been funded by Hexima.

Hexima was restructured in 2001 after the core Intellectual Property Portfolio was secured from the University of Melbourne. It is currently owned and funded by a series of private investors and is governed by a board of directors with extensive commercial experience.

The company has just completed the first two years of field trials with transgenic cotton and has developed links with International Companies to commercialise the technology.

Timeframe

1981:	ARC Special Research Centre established
1989:	NaPI gene discovered.
1992:	First patent lodged
1995:	Commercial funding from PIVOT
1998:	Hexima Ltd established
1999-01:	START grant
2000:	First GM plants expressing NaPI
2001:	Hexima restructured
2003:	Institutional Biosafety Committee (IBC) established and Office of the Gene technology Regulator (OGTR) applications lodged
2004-05:	R&D START grant
2004-05:	First field trial
2005-06:	Second field trial

Success factors

- The three founding scientists; Professor Adrienne Clarke, Professor Marilyn Anderson, Dr. Robyn Heath have continued to be highly involved in the research as well as management of the company, and many of the scientists involved in the project are internationally renowned.
- The intellectual property portfolio is tightly managed, and advice is sought from patent attorneys in Australia and the United States.
- Hexima has a relatively low cost structure, as research is contracted to groups at the University of Melbourne (cotton transformation and field trials) and La Trobe University (gene discovery and function).
- Funds from investors are leveraged by competitive government grants.

Barriers

One of the barriers in the transition from basic to applied research is caused by a difficulty in finding a source of funds for patenting and legal costs. Commercial partners do not like dealing with Universities because they are often too slow at preparing contracts or intellectual property agreements or have unrealistic expectations of the value of the research. On the other hand, once an inventor establishes a company and becomes a director or shareholder, they are not eligible for funds through the ARC linkage scheme. Additionally, small companies cannot get insurance for their directors or the members of their IBC, however, funding for small companies is always tight, and so talented staff have 12 month contracts and lack security.

Requirements in Australia are often more stringent and expensive than in competing countries (e.g. USA). The OGTR requirements are particularly demanding. Finding time and resources to deal with multiple regulatory agencies can be a challenge. At the same time, establishing commercial relationships with international companies that have access to relevant markets can be challenging.

9. Relenza™ — preventing and treating influenza — global economic and social benefits

Brief synopsis

The project that ultimately discovered the drug to prevent and treat influenza — Relenza™ — began with basic research that determined the cause of influenza, and the nature and structure of the virus responsible. This was followed by the application of elaborate chemistry which identified the three dimensional structure of the molecules on the influenza virus that are responsible for the infectious nature of influenza — neuraminidase (N) and haemagglutinin (H). The reason for interest in influenza stems from the fact that it is caused by a virus that can change in character. The N and H components are known to vary from time to time, which gives rise to the possibility of devastating international pandemics. Even if the changes are only minor, significant disease can occur in susceptible people, and as a result, many deaths are likely. Therefore, research was conducted into developing ways to inhibit one or both of the key determinants of influenza's infectivity. This research was conducted at the Faculty of Pharmacy at Monash University. The financial backing of Biota Holdings Ltd, a world-leading antiviral drug development company based in Melbourne, was critical. It resulted in a much faster pathway to market for a drug that is a very effective inhibitor of N, and which went on to be marketed by GlaxoSmithKline (GSK) as Relenza™.

In 1996 the quality and positive impact of the underlying research to discovery was recognised with the awarding of the Australia Prize to Professor Mark von Itzstein, who was then at Monash University, Dr Peter Colman, who was then at CSIRO, and Dr Graham Laver who was then at the Australian National University.[73]

Timeframe

From initial research to discovery to involvement of Biota took several decades, beginning **in 1978** at the Australian National University and culminating in the synthesis of zanamivir at Monash University **in 1992**. Towards the concluding stages, CSIRO was a central player in the analytical chemistry/biology that elucidated the structures of N and H. It was only when a drug to block H or N was being sought that industrial funding became available, which is when Biota greatly facilitated the research. Finally, **in 1999,** Relenza™ was launched onto the world market by GSK.

Success factors

- The substantial investment by Biota without which the project was likely to have taken many more years to complete.
- The undoubted skill of key scientists at CSIRO, Monash University and the ANU.
- The highly sophisticated equipment that made possible the elucidation of the structures of H and N. Previously, crystallography equipment with the required resolution was unavailable.

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[73] The Australia Prize (the predecessor to the Prime Minister's Prize for Science) was an annual international award (1990-1999), aimed at a worldwide audience for an outstanding specific achievement in a selected area of science and technology promoting human welfare. Of the 28 recipients, 18 were Australian, demonstrating Australia's strong international standing in many scientific fields.
https://sciencegrants.dest.gov.au/SciencePrize/Pages/PreviousPrizeWinners.aspx

Barriers

Several barriers had to be overcome ranging from technical difficulties associated with characterising keys aspects of the virus, to the very large amount of funding required to develop the drug candidate, and the even larger amount of money required to get the drug onto the world market. A key barrier at the scientific level was the complete absence of a suitable animal model for human influenza — it was not possible to undertake any of the research utilising laboratory animals.

Benefits[74]:

Relenza's phase III clinical trials showed:

- a positive effect both on shortening duration of illness and reducing severity of symptoms;
- a reduction of up to 2 days in alleviation of flu symptoms;
- a 61 per cent reduction in antibiotic usage and a 70 per cent reduction in complications in 'high risk' groups; and
- that the drug is safe and easy to use.

Relenza™ is already on the world market. Millions of doses have been sold, and it has been reported that a small number of lives have been saved and a significantly large number of people have been spared the debilitating effects of full-blown influenza.

Zanamivir, the drug that ultimately became Relenza™, was licensed by Biota to GSK. In return, there are royalties to various parties, including Monash University and to the inventors of the drug. Some royalties have already been paid because Relenza™ is an approved pharmaceutical product in many parts of the world. The payment of those royalties has been in line with an agreed formula which is based on international sales of the product. Sales to date have been modest but still amount to millions of dollars world-wide. The advent of avian influenza and the resultant stockpiling of both Relenza™ and a competing product called Tamiflu have resulted in a very substantial increase sales of both products in virtually all parts of the world.

The product is now approved in over 50 countries for therapeutic use and in eight countries for prevention. The major markets where the product has been approved for therapeutic use are the U.S., the European Union and Japan. Reimbursement coverage is in place for a significant portion of the market in the U.S. and Japan, and for high-risk groups in the U.K. These three markets represent approximately 85 per cent of the world pharmaceutical market.

Public awareness of influenza is continually growing because of the marketing efforts of companies with anti-influenza drugs and publicity associated with vaccine companies. Biota should benefit from this increased focus on the health threat posed by the ever-changing influenza virus.

Sir Gustav Nossal, Chairman of the Australia Prize selection committee in 1996, said the discovery of the anti-influenza drug had re-instated Australia on the world science map. 'It not only gives us prestige but also a drug with great commercial potential that will be developed by an Australian company. A big portion of the economic benefit will be reaped by Australia'.[75]

Supporting documentation

http://vcp.monash.edu.au/125/stories/relenza.html; http://www.biota.com.au/products/relenza.html

[74] See also Biota website: http://www.biota.com.au/products/relenza.html

[75] See: https://sciencegrants.dest.gov.au/SciencePrize/Pages/Doc.aspx?name=previous_winners/Aust1996Colman.htm

10. Inquirion Pty Ltd — software developed to manage very large databases

Brief synopsis

TeraText is a suite of software products that allows storage and retrieval of text-based information in very large databases. RMIT researcher, Ron Sacks-Davis developed new techniques to manage Very Large Databases (VLDB) using indexing systems which allow efficient searching and retrieval of data. The research was funded by the Australian Research Council. As research continued, the software matured into a development phase and the funding base shifted from government research grants to commercial development grants. Agreements with a number of software companies followed in which development funds were granted in return for a share of license revenue for products being developed. These agreements along with license revenues allowed the group to become self-funding. The final phase involved creation of a spin-off company (InQuirion Pty Ltd) and a research and development funding agreement with a US-based Fortune 500 company (Science Applications International Corporation) which eventually purchased the company and the IP outright. The company now has 25 employees and clients include the Australian Tax Office; the Australian Research Council; the Australian Department of Defence; the National Library of Australia; the Tasmanian, New Zealand and Canadian legislatures and a number of defence organisations in the US.

Timeframe

Initial research began in **1982** and ARC funding has been secured from soon after that **until the late 1990s**. Commercial funding began around this time with partnerships with Australian companies and continued until the company was formed in **2001**. Revenue then was from software sales, applications development and an R&D agreement with Science Applications International Corporation through which the company was able to enter the US market.

Success factors

- The ARC funding was a critical success factor because the initial research was driven by ideas rather than products, and was therefore not attractive to commercial interests despite its long term potential.
- The involvement of commercial companies (e.g., Ferntree Computing and Aspect Computing) in the development stages. Apart from the funding base it provided, the direct interaction with commercial users helped direct the research into more effectively dealing with the issues needed to improve productivity for clients.
- The backing of RMIT: many commercial companies felt more comfortable investing in a small group when it had the backing of a larger parent such as RMIT.
- Seeking and finding a partner in the US allowed entry into the US market without a significant investment of RMIT's funds. This allowed growth for the business along with new client requirements which allowed further development of the software.
- The granting of equity in the company to the developers of the software (i.e., the researchers responsible) when the company was established in 2001. This was important because it kept together a key group of software researchers and developers which made the growth of the business sustainable. The IT industry is very mobile, but staff have resisted many efforts to poach them over several years. In this industry, it is most unusual for a group to have remained together for so long, especially a group of such high quality as this one.

- The productivity of the group has been excellent, the profitability of the business has been high and this is why SAIC was willing to purchase it. The purchase was contingent upon key staff remaining with the company to ensure that it continued to grow and prosper. Having equity in the business prior to the sale meant that these staff were fully committed to the venture and were keen to stay on to see it prosper.

Barriers

Conducting commercial work inside a university is difficult because of the regulatory framework which exists. Hiring staff, approving and signing contracts, taking equity in commercial ventures are all regulated in a way which gives outside companies an advantage in terms of responsiveness and commercial flexibility.

However, having a research group winning significant amounts of DEST reportable research revenue is attractive to a university and once the company is sold all of this lost. There appears to be no incentive to genuinely spin off a company based on university IP and have it succeed on its own in the marketplace. In the case of InQuirion, the next stage of its development requires significant investment and it was sensible to have this investment made by commercial interests rather than with university funds. The purchase price will be used to re-invest in research at RMIT so that we may be able to create another successful case study but there is no direct incentive from Government to wean such companies into the marketplace.

Benefits

A working business has been established which employs 25 staff in Melbourne and which exports products overseas. At the time of sale, company turnover exceeded $4 million and this will grow in the future.

The software has been used extensively by defence agencies here and in the US for many years and its usefulness underlies its success in the market.

Supporting Documentation

The InQuirion website is at www.teratext.com.au. It includes links to client organisations: Tasmanian Legislature, Macquarie Dictionary, British Columbia Archives and the Australian Tax Office.

11. MiniFAB Pty Ltd – a new model for commercialisation and development of a new manufacturing industry

Brief synopsis

MiniFAB (Aust) Pty Ltd is a Melbourne-based business which provides an open access, polymer-centred, micromachining and packaging facility. Such a facility is critical for the Australian manufacturing industry to develop the commercial potential of locally held IP in the nano, micro and biotechnology fields, particularly relating to devices.

MiniFAB offers customised manufacturing and advanced product development, exploiting leading edge polymer microfabrication. Its business is the design, fabrication and integration of polymer microengineered systems, to address industry/market needs, based on research outputs. It has also provided incubator space for companies developing in this area.

The successful establishment of the company is built on the collaboration of its three partners - Swinburne University of Technology, the building company, Wilkore, and Caribbean Park, the business park where MiniFAB and Wilkore are co-located.

Swinburne's research activities and expertise in the nano, micro and biotechnology fields from the late 1990s have been (and continue to be) integral to the company's development and operations, with Swinburne researchers, technicians and research students actively involved with the company on site.

Timeframe

From the late 1990s, and ongoing.

Success factors

- The knowledge and expertise of Swinburne staff and students, providing ongoing, high-level academic support to the R&D projects: research and technology diffusion activities assure industrial relevance at the cutting edge of innovation.
- Swinburne's research concentration in emerging and niche areas: its understanding of customer requirements; appreciation of world-wide market competition; capacity to capture future technology trends; and recognition of time-to-market constraints.
- Swinburne's Industry-Based Learning Program, enabling students in the field to undertake paid employment in industry as part of their course. For MiniFab, this includes students testing products in a manufacturing environment.
- The provision of a free 5-year lease to MiniFAB by Caribbean Park, the use of Swinburne's sophisticated equipment, and the fitout provided by Wilkore, have enabled MiniFAB to commence operations on a 'bootstrapping' basis.
- Australian Government support through the CRC for Microtechnology in which Swinburne was a partner, and through which 25 postgraduate students were supported (this CRC has not been renewed).
- Victorian State Government funding under the Science, Technology and Innovation (STI) Round 3 in 2005 to establish the Small Technologies Cluster (STC), promoted by MiniFAB. This will indirectly help MiniFAB to consolidate its business.
- The support and interest of an enthusiastic industry community, where the need exists.

Barriers

The lack of investment in building the very specialised skills in micro, nano and related technologies is a significant barrier to the development of new business in this important field.

While MiniFAB's success has been recognised (by government and others) this has not been backed by direct investment, significantly inhibiting the company's potential for growth.

The lack of government support for research and research training in this field (in particular the non-renewal of the CRC for Microtechnology) further inhibits the development of new skills, building upon recent R&D efforts, and commercialisation of the results.

Benefits

In less than five years, MiniFAB has begun to generate significant commercial revenue, and provides a ready vehicle for the ongoing commercialisation of specific research outcomes.

There are currently 15 companies operating from the MiniFAB building, providing the base for a new manufacturing industry in Victoria – and for Australia. Detailed financial information is not yet available for MiniFAB itself and this grouping, but the company, its staff and partners are collectively building a significant world profile in this emerging industry. For example, MiniFAB and the STC are organising the Commercialisation of Micro and Nano Technology Systems International Conference (COMS2007) to be held in Melbourne.

The company has the potential to generate further businesses within the MiniFAB framework, be they set up by students and/or staff, or through other microtechnology businesses which may access MinFAB's facilities, for example, to trial prototypes or develop and market products.

Supporting documentation

www.minifab.com.au

12. Centre for Legumes in Mediterranean Agriculture (CLIMA) — maximising the return on investment for the legume industry

Brief synopsis

CLIMA is a Research Alliance between The University of Western Australia, the Department of Agriculture and Food Western Australia, CSIRO and Murdoch University. Formed in July 2000, the Centre continues the collaboration begun in 1992 under the Australian Government's Cooperative Research Centre (CRC) Program. The objective of the partner institutions is to create a research environment for the legume industries where the returns from the substantial investment in R&D made by the State and Australian Governments, Universities, CSIRO, external funding bodies and industry groups could be maximised for the benefit of primary producers, industry and the community, through efficient co-operation and co-ordination of research and development.

Timeframe

From 1992 to the present time, benefits have continually flowed from the research done under the CLIMA umbrella. Many of these are listed under "Benefits" below and in supporting document 1.

Success factors

- CLIMA makes efficient use of research resources by sharing major facilities and equipment and through effective collaboration of teams of top researchers from a variety of organisations including two universities.
- Within the CRC phase the main sources of funding were the core funding from the Commonwealth Government's CRC Program, cash and in-kind contributions from the partners and industry funding from GRDC, RIRDC, GRC-WA and ACIAR.
- A strategic plan (*supporting document 2*) for CLIMA beyond CRC funding was developed through an industry workshop held in August 2001, and adopted in July 2002. As part of this plan CLIMA has significantly increased the amount and the diversity of its external funding sources. In 2005-06, research funding is being received from external sources including GRDC, ARC, RIRDC, ACIAR, AusAID, and FRDC and from private investors, such as Council of Grain Growers Organisation (COGGO), CBH.
- CLIMA has a large Industry Advisory Group (19 members) with an independent Chair which provides feed back on legume industry needs and emerging issues. An additional advantage of the large group is the profile it provides for CLIMA with its key clients groups.

Barriers

The withdrawal of CRC funding in 2000, the lack of significant core funding since 2000, the lack of industry partners willing to fund research that does not produce immediate outcomes, the short-term nature of most project funding, and the uncertainty of CLIMA's future whilst the position of a new alliance "Agricultural Research Western Australia" is being determined.

Benefits

CLIMA was a successful CRC which fulfilled the objectives of the CRC Program and demonstrated the benefits of research co-operation to its partners and the industry beyond the CRC phase.

The large number of co-authored publications (1,300) is testimony to CLIMA's collaborative research effort between different institutions.

CLIMA has been a key player in the development and release of a significant number of innovations such as crop and pasture varieties (>25 varieties) as well as knowledge products. There are clear indications that a majority of these products are already showing economically and environmentally important roles in the Australian farming systems.

Between 1992 and 2006, CLIMA had over 85 full-time PhD students, most of whom were co-supervised by non-university staff. As of 2006 there were 55 PhDs awarded.

CLIMA was committed to high quality collaborative research and education and has established national and international links (more than 10 organisations) that will provide a long-lasting flow of benefits to the agricultural industry in Australia.

CLIMA attracted 4.5 dollars for every CRC dollar invested by the Commonwealth. It attracted 1.7 dollars from competitive research grants per dollar of CRC invested. Industry contributed about 23.5 million dollars in cash through the funding of various projects and the partners contributed about 38.9 million dollars in in-kind contributions and 0.85 million dollars in cash contributions.

The financial benefits of the Centre to the University arise from CLIMA's reputation as a reliable, high quality research provider to Commonwealth R&D corporations (ARC, GRDC, RIRDC, AWI) and to other investors in R&D (currently ACIAR and COGGO). In 2005-06 the CLIMA research budget from these sources was estimated to be $5.0 million.

CLIMA is the only Centre in Australia thriving after the termination of CRC phase with its original partners for such a long period of time.

Supporting documentation

1. An Evaluation of the Scientific, Educational and Economic Impact of the Cooperative Research Centre for Legumes in Mediterranean Agriculture 1992 to 2000.

2. Centre for Legumes in Mediterranean Agriculture Strategic Plan. July 2002.

3. CLIMA Biennial Research reports 2002-03 and 2003-04.

13. Advanced Nanotechnology Ltd – competing globally

Brief synopsis/overview

Advanced Nanotechnology Ltd is an innovator and manufacturer of advanced nano-materials, employing over employs over 30 staff and with its own manufacturing site in Perth, Western Australia. The company manufactures and sells a number of high quality nanopowders and dispersions which have applications in various markets. The first product is *ZinClear®* which is a transparent nano-particle dispersion of zinc oxide for UV protection in cosmetics and personal care products. *Alusion®* is a platelet form of aluminium oxide specially formulated for the cosmetics market and used to provide a soft-focus effect. *An entirely different product is a nanoparticle cerium oxide dispersion* supplied exclusively to Oxonica plc, a UK company, and used as a fuel additive for diesel engines which Oxonica states improves fuel efficiency and promotes cleaner burning. The company's broad based proprietary technology and multiple product applications provide strong growth prospects.

Timeframe

The original research work on the mechano-chemical process to produce nano-particles was pioneered by Professor Paul McCormick and his team at the University of Western Australia's (UWA) Research Centre for Advanced Mineral and Materials Processing. **In 1997** Advanced Nanotechnology Ltd (Advanced Nano) was formed (originally named Advanced Powder Technology Pty Ltd). UWA funded a business planning and market-assessment study in return for equity in the company. The intellectual property of the manufacturing process is protected through three key patents which have international status. Further patent applications covering products and applications have been made. **In May 2000**, Advanced Nano and Samsung Corning established a JV to develop the MCP™ technology at production scale. Samsung Corning invested $6 million for a 50% share in the JV and a further $1.5 million for a 10% shareholding in Advanced Nano. **In April 2001** a $2.8 million AusIndustry Start Grant was obtained. **In 2002**, the Office of Industry & Innovation at UWA assisted the company with an additional $2M through introduction to a local investor in the form of a convertible note. In the meantime, the company has successfully pursued the development of its distribution channels for its growing portfolio of products and further refined its R&D work.

In 2004, the Company raised approximately $4m as pre-listing capital to fund activities and to convert previous noteholders to shareholders. **In January 2005**, the joint venture with Samsung Corning was concluded, with both partners now co-owning the MCP nanopowder manufacturing technology.

In February 2005 Advanced Nanotechnology listed on the Australian Stock Exchange (ASX). The capital raising was over-subscribed, raising $9.5 million. The company has a strong board and is poised for further success and growth in 2005 and beyond. The UWA continues as the major share-holder with just under 30% of the issued capital, including shares held on behalf of the original inventors of the technology.

Success factors

- The company's success is due largely to the quality of the fundamental research work funded by ARC grants which led to the intellectual property, which in turn formed the basis of the patented technology and the ability to build successful commercial products from this technology.
- Advanced Nano's competitive advantage stems from a number of areas including superior nanopowder and product quality; the use of industry standard raw materials and equipment; strong intellectual property position providing barriers to entry by competitors; and a history of innovation and new product development.

- To leverage the MCP™ technology into high value products, Advanced Nano has developed processes to evenly disperse the nanoparticles into carrier media which are then used in downstream processing. This means the nanoparticles are usually sold to manufacturers in a dispersion. The ability to make high quality true nano dispersions is critical to the nanopowder market, as even minor levels of agglomeration can severely affect the properties of many final products. Advanced Nano has developed proprietary downstream processing techniques which allow the MCP™ nanopowders to be dispersed into a wide range of materials.

Barriers

At the outset, patent costs proved to be impediments. Other challenges and concerns included the finding of good commercially-savvy people to work in the enterprise; selling new products from the remoteness of Western Australia when over 85 per cent of sales are for overseas; and the high cost base of WA/Australia for manufacturing and sourcing of raw materials.

Benefits

The company has experienced strong revenue growth since commercialisation of its technology commenced in late 2002. FY2003 - $347,207; FY2004 - $862,865; FY2005 - $1,502,512; FY2006 (9 months only) - $2,083,449 (note, the full year sales to customers will be released to the ASX prior to the end of July).

Today over 85% of the company's sales are to overseas markets and customers, including the US and the UK: Advanced Nano has established a strong network of international distributors which it believes is critical to achieving growth in the sales of all of its products. The company currently has the following distribution arrangements in place:

Australasia:	Seil Chemicals, Korea - *ZinClear*® and *Alusion*®; Marubeni, Japan - *ZinClear*®, *Alusion*®, and *NanoZ*® Lipont, Taiwan - *ZinClear*® TR Chemicals, Australia - *NanoZ*®
America:	American Nanotechnology, USA - *ZinClear*® Elevations, USA - *Alusion*®
Europe:	Provital, Spain - *ZinClear*® and *Alusion*® Provital, France - *ZinClear*® and *Alusion*® Castelli, Italy - *Alusion*® Cornelius Group, United Kingdom - *NanoZ*®

Key advantages of the MCP™ technology include:

- *Small discrete particles*. MCP™ produces nanoparticles with a low level of agglomeration (the particles do not clump together), satisfying quality requirements for applications that require such low levels of particle agglomeration;
- *Narrow size distribution*. The MCP™ technology inherently produces nanoparticles with a narrow size distribution. This means the nanoparticles are all approximately the same size, an important attribute required for many applications;
- *Size and shape control*. A key attribute of the MCP™ technology is that it allows control of particle size, to meet customers' particle size requirements. By controlling surface chemistry it is also possible to produce particles with well defined shapes, such as rods or plates; and
- *Cost*. The MCP™ technology utilises standard industrial process equipment and standard industrial chemicals, which the Company expects will provide a relatively low cost base for its high quality products.

Supporting documentation

www.advancednanotechnology.com

14. Spina Bifida and Folate Research — and subsequent, ongoing preventive health campaign

Telethon Institute for Child Health Research, an affiliated institution of The University of Western Australia

Brief synopsis

The project involved fundamental research identifying a link between maternal folate consumption and rate of neural tube defects, including spina bifida. The study found that women who consumed high levels of dietary folate were less likely to have babies with neural tube defects, independent of other factors. No other nutrient was found to cause this effect.

The fundamental research provided the basis for a public health campaign to inform doctors, nurses, pharmacists and women of childbearing age of the link between increased folate consumption and reduced rates of spina bifida. The campaign raised awareness significantly in the target group of women of childbearing age. The research project in isolation would have had had little or no impact on public health without an effective health promotion and publicity campaign. The researchers who discovered the link between spina bifida and folate consumption also drove the public health campaign to apply the findings to prevention.

Timeframe

The initial research on the link between folate and spina bifida began as a PhD project by Carol Bower supervised by Fiona Stanley **in 1983**. The discovery of the link was published **in 1989**. **In 1992** the Institute for Child Health Research sought and received funding from a number of government bodies and in-kind support from media organisations and students. **By 1995** there had been an increased awareness of the issue and the health benefits could begin to be calculated.

Success factors

- The high quality of the fundamental research provided the foundation for the public health campaign.
- Effective campaigning by Professor Fiona Stanley and her team secured the necessary funding to deliver a public awareness campaign. By means of an evaluation of the publicity campaign, the research team conducted a survey of women of childbearing age, doctors and pharmacists prior to the commencement of the campaign and then half yearly after that until March 1995. The survey results found that awareness of the folate/NTD link increased from 8.2 per cent in September 1992 to 67.5 per cent in March 1995 among women of child-bearing age, and that the number of general practitioners who would as a matter of practice offer folate supplements to women planning pregnancy increased from 15 per cent to 70 per cent over the same period.
- The commitment to an ongoing public aware campaign to demonstrate economic and social benefits of dietary folate. In 1995 the Health Department assumed management of the folate publicity campaign completely, with key Telethon Institute research staff continuing in an advisory capacity. Manufacturers of folate supplements noticed a marked increase in sales of folate tablets over the period of the publicity campaign, particularly in Western Australia. Bread and cereal manufacturers began adding folate to their products in 1996, and the mandatory fortification of flour for bread making with folate has now become a matter of national interest.

Barriers

One of the barriers to success was that no private company stood to gain from innocation and commercialisation, and that the benefits were essentially of a public good kind. AAs a result, obtaining support for a public health awareness campaign was a challenge. Most of the support for funding the folate message to expectant mothers in 1992 came from the Health Department of Western Australia.

Benefits

The increase in awareness led to a reduction in the rate of neural tube defects from an average of 2 per 1000 pregnancies (before) to a rate of 1.4 per 1000 pregnancies (afterwards). With around 25 000 babies born in WA each year, this means that as a result of the folate research and the subsequent promotion campaign, approximately 15 babies are saved each year from developing neural tube defects.

This represents a substantial health gain with associated benefits in reduced cost for health delivery and social support services. A study funded by the Western Australian Government covering the benefits to WA up to 2002 identified a net present value to WA alone of $21.6 million for the research and the campaign (benefit-cost ratio of 16.6) on the basis of a reduction of medical expenditure associated with treating spina bifida, reduction in expenditure on special education, improved productivity in the workforce and a reduced welfare burden.

The implications and benefit of the research are spread more widely than that. There is evidence to suggest that the increase in folate intake among expectant women because of the NTD link may also be linked with a reduction in other birth defects and leukaemia.

There are substantial health benefits with consequential reduction in health care services and costs. These include:

- reduced direct medical costs;
- reduced ancillary costs related to disability;
- reduced educational costs with fewer requirements for special schooling;
- improved future employment prospects;
- improved opportunities for future income earning;
- reduced potential social security and welfare costs; and
- reduced social costs such as abortions, stillbirths and neonatal deaths due to neural tube defects.

It is estimated that up until 2024 in WA alone, the folate research and subsequent public health initiatives will result in 124 fewer infants dying of neural tube defects and 53 fewer people living with spina bifida.

Supporting documentation

Centre for International Economics, *Child Health Research: Estimating the contribution of ICHR* prepared for the Telethon Institute for Child Health Research, 31 March 2004. For electronic copy contact John Finlay-Jones johnfj@ichr.uwa.edu.au Assistant Director of the Telethon Institute for Child Health Research.

Bower C, Stanley FJ. Dietary folate as a risk factor for neural-tube defects: evidence from a case–control study in Western Australia. *Med J Aust* 1989; 150: 613-619. This publication was 8th on the list of the 10 most cited articles in the Medical Journal of Australia (*MJA 2004; 181: 9-12)*

15. Lectopia – an on-line learning platform showcasing university IT innovation

Brief synopsis

Lectopia is a leading lecture capture and delivery system for universities wishing to make lectures available on-line, developed at the University of Western Australia (UWA) within the Arts Faculty's Multi Media Centre.

The UWA's commitment to develop flexible modes of teaching and learning and equity of access, together with UWA's expansion into rural areas (Albany and Geraldton) required a novel approach to course delivery. With no commercial system able to satisfy UWA's demanding requirements, the only option was for the University to develop its own cost effective solution.

Lectopia has proven its suitability for large scale implementation, with high reliability and massive scaleability, and has been and continues to be successfully marketed within Australia and overseas.

Timeframe

Lectopia commenced as an internally-funded development project **in 1998**. Deployed **in 1999** at UWA, Lectopia was overwhelmingly well received by staff and students.

Soon after the formation of UWA's Office of Industry and Innovation **in 2001**, the commercial potential of Lectopia was first recognised. **Since 2002**, when the first licence agreement was signed with the University of Melbourne, the following universities have licensed the system from UWA:

2002: The University of Melbourne
2003: Curtin University of Technology, Murdoch University and University of Wollongong
2004: The University of New South Wales and Macquarie University
2005: Deakin University, University of Tasmania, The University of Newcastle and Swinburne University of Technology
2006: The University of Auckland

In 2005 Duke University, North Carolina, became the first US university to carry out a large scale trial of Lectopia. The Duke trial generated significant interest within not only the US university sector, but also from Apple Computer Inc. The increasing number of installation requests from both US and UK universities in particular will result in a significant international roll-out of Lectopia **from 2007 on**, via a third party organisation.

Success factors

Factors that contributed to the success of the venture include:

- UWA's passion and commitment to delivering "excellence" in teaching and learning;
- The University's provision of a modest level of seed funding (less than $50,000) to support the development team in 1998;
- effective collaboration between UWA's Multi Media Centre and Office of Industry and Innovation in Lectopia's ongoing development and marketing; and
- Lectopia's global marketability: its effective capturing and streaming of content, especially via podcasting, and competitive licensing costs.

A key factor in Duke University choosing Lectopia over other contenders was the ability of Lectopia to capture and stream content to students via the Apple iPod. With the increasing popularity of podcasting in the education sector as a means for distributing audio content to students, establishing podcasting as a feature of the iLecture System has been essential.

Barriers

Limited internal resources meant that the Multi Media Centre staff had to fit the development and implementation in amongst their other duties. This extended the development timeframe and meant that a significant amount of work was conducted “out of hours”.

Benefits

Lectopia was licensed to Australian universities more as a technology transfer project rather than a “money earner.” Nevertheless, with the modest seed funding provided by UWA (less than $50 000) it has generated almost $500 000 in licence fees to date, with approximately 30% of Australia’s universities as licensees. Looking to the future, Lectopia also has significant potential in the US and UK: UWA’s approach in these markets will be to appoint appropriate resellers before year end 2006.

From an educational and social perspective, many students at Australian universities now have ‘on-demand’ access to high quality course content, captured by Lectopia and delivered over the web. With the majority of students working part time, Lectopia augments the classroom delivery and enhances the overall student experience.

In 2002 the University of Western Australia was the recipient of an Australian Award for University Teaching (AAUT) for its Innovative and Practical Approach to the Provision of Educational Services to the Local and/or Regional Community.

Supporting documentation

www.lectopia.uwa.edu.au

16. Trainz – end user, business and university collaboration in development of online games

Brief synopsis

The Australian-based gaming company, Auran Technologies, established in 1995, has pioneered the idea of involving their fans in developing the successful online game, *Trainz.* As one of Australia's oldest and largest game studios Auran, has a team of international experienced developers, quality programmers and artists and operates from world-class facilities in Brisbane. The company has won numerous technology awards.

In 1997 University of Queensland PhD student, John Banks approached Auran Technologies as a prospective partner in the field of interaction design.

Gaming companies have always needed to combine creative business with the technical aspects of gaming. Including fans as co-creators of the game in on-line forums and the development of prototypes adds a further humanities dimension to the generic cross-sectoral collaboration inherent in the games industry.

The games industry is a very research intensive industry, technically sophisticated, with rapid innovation cycles in content creation: as an industry one of the strongest claimants to R&D at its base than any other non-science area with humanities and the creative arts leading the innovation pathway.

Big changes in the online games industry are not driven by technology, but by consumer and community shifts: active and interactive demands. Gaming fans have a strong ‘do-it-yourself’ cultural ethos: Auran is successfully leveraging this into Auran’s own production processes.

Timeframe

Five to seven years and ongoing (new version approximately even 12-18 months) - iterative process.

Success factors

- The underlying research, supported by Auran being prepared to spend time and money on options to make it work and to rethink their processes and the role of their staff, to more effectively incorporate end-user creative practices and innovation.
- Auran’s success in winning merit-based funding through the R&D Start Program and the Export Development Marketing Grants Program
- *Trainz* is a product that Auran has continued to update and market successfully worldwide
- The product builds in expectation that end users will contribute to future versions (artwork, models, endusers)
- While the games industry in Australia is going through difficult times, Auran Technologies has managed to maintain its intellectual property and market share by focusing on massive multiplayer online games—the area of growth and innovation globally. Fan-created content, in the form of extensions to gaming software, is on the increase.

Barriers

- Very high risk, volatile, blue sky business sector ("the long tail" – there are only a small number of very successful products that sustain their market beyond one release)
- Developing relationships with gaming fans and meeting their needs can be difficult for corporations, particularly when the game is under construction.
  - IP value sourced from users not producers – some challenges around ownership and who uses
  - Ad hoc fan networks
  - Challenging management issues for producers (fan voluntary labour; increased risks)
- Rapidly rising costs of production especially content:

Benefits

- Strengthening and ongoing university-business collaboration:
  - Auran was a core partner in the Australasian Centre for Interactive Design (now a private company)
  - major spinoff from creative R&D (winning government and private funding to become a CRC (2002 round): $70m over 7 years ($8m industry and university; 12.5 federal, rest in kind)
- Spin-off businesses established by contributing end users – add on products
- Leading edge new business models
- Outsourcing content strategy for lowering costs
- The good return on investment for Auran:
  - 90% of games releases are for one edition
  - Trainz has a record of ongoing sustainable sales and in top 5% of games sold worldwide
  - the Trainz Railroad Simulator has more than 100,000 registered users and dominates the niche train simulator market.
  - Self-publication of *Trainz:* (net return increased) low cost, high return (even if volume low compared to some other games in the industry
- Auran is rapidly expanding as a games publisher in the Australian, New Zealand and Asian games markets. With a strong distribution connection Auran currently provides on average four quality titles a month to the Australian, New Zealand and Asian games markets. Having connections with leading publishers and developers such as Irrational Games, JoWooD Productions, 1C Company, Techland, Paradox, Monte Cristo, Cyanide Studios, Stardock, Whiptail Interactive and many more, Auran is aiming to be the publisher of choice for independent game developers.

Supplementary documentation

http://www.auran.com/

17. NATSEM – microdata and microsimulation modelling to enhance social, economic and business decision-making

Brief synopsis

The National Centre for Social and Economic Modelling (NATSEM) is a research centre associated with the University of Canberra, which has developed a national and international reputation through specialising in the use of microdata and microsimulation modelling to address ongoing and emerging research agendas that are aimed at contributing to social, economic and business decision making. Since its establishment, NATSEM has developed a range of state-of-the-art microsimulation products that can be purchased off the shelf or tailored to particular requirements. The NATSEM models are 'bottom-up', commencing with individual records of real (but unidentifiable) Australians. This base provides tremendous flexibility, as results can be derived for small subgroups of the population or for all of Australia.

Timeframe

NATSEM was established in 1993. Any NATSEM commissioned work varies in timeframes according to client requirements and funding agency's timeframes.

Success factors

NATSEM supports its activities through research grants, commissioned research and longer term contracts for model maintenance and development. The major advantage of microsimulation models for social and economic policy analysis is that they produce results which can be analysed at the individual level. Thus, the distributional impact of a policy measure across different types of families or different geographical regions can be assessed. At the same time, estimates of the aggregate outcomes can still be derived easily, by summing the individual results. It is these features which led a recent exhaustive review of microsimulation in the United States to conclude that no other type of model can match microsimulation in its potential for flexible, fine-grained analysis of proposed policy changes.[76]

NATSEM has linkages with the Australian Government departments of Family and Community Services, and Education, Science and Training. Its diverse clientele also includes the Business Council of Australia, The Australian newspaper, the Department of Immigration and Multicultural and Indigenous Affairs, the Smith Family, Business Review Weekly and the Department of Employment and Workplace Relations.

Barriers

Until relatively recently, the enormous cost of the computing resources required and the lack of appropriate microdata had made their development and use for policy formation in Australia of questionable value. Only with the development of increasingly powerful computer hardware and the greater availability of individual unit record data has microsimulation modelling become a cost-effective and accessible option.[77]

[76] Citro, C.F. and E.A. Hanushek (eds) (1991), *The Uses of Microsimulation Modelling*, vol. 1, *Review and Recommendations*, p. 115, National Academy Press, Washington, D.C.

[77] Harding, A. (1993), *Lifetime Income Distribution and Redistribution: applications of a microsimulation model*, Contributions to Economic Analysis, Vol 221, p.1, Amsterdam, North Holland

Benefits

- **STINMOD** — NATSEM's static micro-simulation model of the Australian tax and transfer systems; provides information on the financial impact of government policy on individuals and families within Australia; DYNAMOD simulates these individuals and families through time and makes projections of future wealth.

- **APPSIM (Australian Population and Policy Simulator)** — a five-year ARC Linkage Grant project, 'Assessing the Social and Fiscal Policy Implications of an Ageing Population' involving collaboration between NATSEM, the University of Canberra, two international researchers and 13 industry partners. Its aim is to develop a model that will give the Commonwealth Government the capacity to assess the future distributional and revenue consequences of changes in tax and outlay programs.

- **Adding Regional Dimensions to Modelling** — a three year ARC Linkage Project seeking to develop new models for analysis of the spatial effects of policy, socio-demographic and economic changes at the regional level. NATSEM is partnering with the Australian Bureau of Statistics (ABS), the ACT Chief Minister's Department, the New South Wales Premier's Department, the Queensland Department of Premier and Cabinet, the Queensland Treasury and the Victorian Department of Sustainability and Environment, and in collaboration with the University of Liverpool (UK) Department of Geography.

- **Regional Housing Modelling** — two regional housing projects funded by the Australian Housing and Urban Research Institute (AHURI) covering issues such as the regional impact of Commonwealth Rent Assistance and baseline small area projections of the demand for housing assistance.

- **Aged Care Modelling** — ongoing work being supported in part by a two-year ARC Linkage Grant ($188 000) for a project on the care needs, costs and the capacity for self-provision: detailed regional projections for older Australians to 2020. NATSEM's project partners are the Office for an Ageing Australia in the federal Department of Health and Ageing and the NSW Department of Ageing, Disability and Home Care.

- **Using Enhanced NSW Hospitals Data and the Private Health Insurance Model** — supported by an ARC Strategic Partnership with Industry Research and Training Grant. This model will be used in conjunction with the Hospitals Projection Model to estimate private and public hospital usage and expenditures under different policy settings.

- **A New Model of the Australian PBS** — supported by an ARC Linkage Grant, this model will, for the first time, be able to forecast not only the expenditure associated with the current and future use of PBS-subsided medicines and with a range of policy scenarios, but also the health out-comes gained from such medicines.

Supporting documentation

http://www.natsem.canberra.edu.au/

18. The Catchment to Reef Joint Research Program – new tools for mitigation and monitoring of water quality and ecosystem health

Brief synopsis

The problem of water quality from catchment to the Great Barrier Reef is widely recognised as one of Australia's most pressing and challenging environmental issues. The Catchment to Reef Joint Research Program (2003-2006) has undertaken research on the impact of agriculture and other land based activities on the Wet Tropics and the Great Barrier Reef lagoon. It has and developed a suite of tools and strategies to enable land managers to mitigate the effects of human activities on water quality. The project has been be spearheaded jointly by the Cairns-based Rainforest CRC and the Townsville-based CRC for Reef Research, led by Professor Richard Pearson of James Cook University.

An essential component of the Catchment to Reef Program relates to converting the outputs of each task into tools that can be adopted by land users and managers across the catchment. Tools are tailored for, and communicated to, different uses throughout the community from school groups, to farmer and management agencies. While the research has taken place on selected catchments and inshore areas in the Wet Tropics region, outcomes from the program are applicable across all the Great Barrier Reef Catchments

Timeframe

The project commenced in 2003 with a budget of $5 million over three years. It is anticipated that with the closure of the Rainforest CRC and CRC for Reef Research in late September 2006, the activities of the Catchment to Reef program will be further developed under a Water Quality research theme within the new, Australian Government-funded Marine and Tropical Science Research Facility (MTSRF).

Success factors

- The track records of the Rainforest CRC and the CRC for Reef Research contributed significantly to the successful bid for funding for this specific program. The project linked the two CRCs in the development of successful management practices for the two most economically important and popular World Heritage Areas in Australia.
- The research has enabled successful collaborations with the following organisations:
  - the Rainforest CRC;
  - CRC for Reef Research;
  - Coastal CRC;
  - CRC Savannah;
  - Australian Institute of Marine Science;
  - Wet Tropics Management Authority;
  - Great Barrier Reef Marine Park Authority;
  - National Resource Management Board;
  - Queensland Department of Natural Resources;
  - Mines and Water;
  - CSIRO;
  - Griffith University; and
  - James Cook University.

Benefits

The Catchment to Reef research will fill gaps in the knowledge of the effect that farming practices have had on the Great Barrier Reef. Importantly, the research will provide the Australian Government with effective tools and guidelines — built on a sound scientific basis — for monitoring the status and trends of water quality entering the Great Barrier Reef World Heritage Area. This is particularly in relation to cases where excesses of nutrients, sediments and other contaminants into nearby coastal waters and the Great Barrier Reef lagoon impacts the viability and condition of these ecosystems and the industries that depend on them.

It will also identify alternative ways to measure the health of catchments and inshore reefs, and provide farmers and land managers with guidelines to help reduce loss of sediment and nutrients into waterways. The program has contributed to capacity building through its support of a number of postgraduate research and honours studies in relevant fields.

The findings of the Catchment to Reef research are being delivered in a range of media, such as an interactive DVD and accompanying synthesis booklet, technical reports and monitoring manuals, international and national forums and consultations. The range of products aims to cater for different interests and end users — from individual farmers and community-based organisations to researchers and management agencies.

Supporting documentation

http://www.rainforest-crc.jcu.edu.au/latestNews/C2RNews.pdf

19. Higher Education Contribution Scheme (HECS) — income contingent loans — a world first in higher education financing policy

Brief synopsis

The introduction of Australia's Higher Education Contribution Scheme (HECS) in 1987 was one of the major policy changes to higher education in Australia. HECS was introduced to address the increasing demand for higher education services without directly financing the demand from tax revenue. HECS is based on a broadly based income contingent loans policy for the payment of higher education charges.

Timeframe

From 1987, and ongoing.

As part of the review of Australia's higher education system conducted in 2002 by the Australian Government, changes occurred from January 2005 to HECS and the Postgraduate Education Loan Scheme (PELS). What were known as HECS places are now called Commonwealth supported places. While HECS remains, higher education providers determine the amount of student contribution (or HECS) for these places, within ranges set by the Australian Government.

Success factors

- HECS can be seen as a watershed in terms of the relationship between economic theory and education policy. The three key factors are the underwriting of risk by government, the HECS repayments by students dependent on the level of their income, and the simplicity of its administration, with HECS repayments collected through the Australian Tax Office.
- HECS has assisted the creation of educational opportunities for those who cannot afford to pay upfront fees. The system that is in place today continues to support the deferred payment arrangements and discount for upfront payments that were part of this original HECS scheme, however, they are now terms HECS-HELP assistance.

Barriers

While not considered barriers to HECS per se, there were initial concerns regarding the potential level of financial risk for the government, as the lending agent and the effect that HECS might have on access to higher education by students from disadvantaged backgrounds.

Benefits[78]

As noted by Chapman in June 2005, HECS has raised, and continues to raise, considerable revenue for the higher education sector. In administrative terms it has proved to be very cost-effective.[79]

[78] Chapman, B (June 2005), 'Income Contingent Loans for Higher Education: International Reform', Discussion Paper No 491, Centre for Economic Policy Research, The Australian National University
[79] Chapman, B and Ryan, C (May 2002), 'Income-Contingent Financing of Student Charges for Higher Education: Assessing the Australian Innovation', Discussion Paper No. 449, Centres for Economic Research, The Australian National University

Evaluations of the scheme suggest there is no evidence that either the introduction of HECS or any subsequent changes to the scheme have had any significant effects on the socio-economic profile of the higher education student cohort. Evidence suggests that participation increases are evident across all family wealth backgrounds.

The success of HECS over more than 16 years of the Australian Income Contingent Loan (ICL) model has been the impetus for the adoption and adaptation of the Australian ICL model in a number of other countries — most recently in Thailand for both university and vocational education students.

Supporting documentation (see also footnote references)

http://www.avcc.edu.au/documents/publications/stats/History-of-HECS-April2006.xls

20. Sudden Infant Death Syndrome (SIDS) — discovery of the link between cot death and the prone sleeping position

Brief synopsis

A review of the data on disease distribution in Tasmania in the 1980s showed that Sudden Infant Death Syndrome (SIDS) had an annual rate in Tasmania twice the national average. In 1988, with the impetus of financial assistance from the Australian Rotary Health Fund, the first full data collection for a cohort study was initiated by the Menzies Research Institute at the University of Tasmania. This was a significant endeavour involving measurements each year in 1500 infants and their mothers on three occasions in the first three months after birth.

In late 1990 evidence was accumulating from case-control studies that the prone sleeping position might be a major cause of SIDS, but the research was retrospective, creating concerns that recall bias might explain the findings. UTas had the only prospective data in the world and was able to show that the association was equally strong prospectively, ruling out recall bias.[1] A number of countries, including Australia, launched campaigns to encourage parents not to place babies on their stomachs in the cot, with astonishing results — the death rate from SIDS in Australia fell from 507 in 1990 to 139 in 1998, with similar falls in a number of other countries.[2]

While the Menzies Research Institute's work was not the only important contribution to the understanding of this major cause of SIDS, it provided an important piece of evidence needed for solving the puzzle. In 1993, the Institute's team explained why the prone sleeping position seemed to exert a different effect in winter than summer and a different effect across countries.[3] In 1995, the team provided evidence that showed clearly that the fall in deaths could only be attributed to the changes in prevalence of the prone sleeping position.[4] The death rate from SIDS fell so rapidly after the prone sleeping position campaign that, by late 1991, it was clear there would eventually be insufficient cases occurring annually in Tasmania for epidemiological research (when the SIDS program started there had been an average of 27 cases a year for an extended period, and by 1998 there were only three).

The Institute's major new strategy is to follow the TIHS cohort, now numbering 11 000 infants and children, to search for links between early life exposures and later disease such as asthma and the development in childhood of risk factors for cardiovascular disease and diabetes.

Timeframe

The initial research was undertaken over nine years from 1987 to 1995. Significant milestones:

1988: Tasmanian Infant Health Survey (TIHS) began (prospective study on SIDS)

1991: prospective evidence confirmed importance of prone sleeping position as a cause of SIDS[80]

1992: evidence that SIDS death rate was falling after a national campaign on infant sleeping position

1993: research helped to explain how prone position interacts with other factors to increase risk [81]

1995: first follow-up of TIHS cohort on early life influences on childhood diseases showed that the major decline in SIDS deaths from 1991 onwards is the result of changes in infant sleeping position[82]

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[80] Lancet, 1991; 337: 1244-1247
[81] New England Journal of Medicine, 1993; 329: 377-382
[82] Journal of the American Medical Association, 1995; 273: 783-789

Success factors

- Funding from the NHMRC, the Australian Rotary Health Research Fund, and from donations from the Tasmanian community.
- Expertise, in particular Professor Terry Dwyer who led the research and Professor Anne-Louise Ponsonby (a PhD student at the time).

Barriers

The Menzies Research Institute had some difficulty recruiting the expertise needed to carry out the study, especially in the areas of epidemiology and biostatistics. It seemed that Australian academics were either not interested in living in Tasmania, or were not confident their careers would flourish there. This problem was compensated for when Anne-Louise Ponsonby enrolled at Menzies as a PhD student. The Institute also used its international network to recruit Michael Jones, a young Master of Science graduate from Oxford (referred by Sir Richard Doll) and Laura Gibbons, from the University of Massachusetts.

Benefits

The social and economic benefits from the Institute's SIDS research are considerable. The death rate from SIDS in Australia fell from 507 in 1990 to 139 in 1998. Follow up work in 1997-2000 on the Tasmanian Infant Health Survey cohort into childhood has provided important evidence about early life determinants of risk for osteoporosis, blood pressure and asthma[83].

The Institute's work on SIDS prevention and infant sleeping bedding and asthma has been cited by various international health advice policy groups, including the American Academy of Pediatrics. Its scientists have provided national policy advice to the Department of Health and Aged Care in relation to indoor environment, infant bedding and asthma. In 2005, the Institute contributed, by invitation, to the World Health Organisation's position document on the principles and methods for assessing autoimmunity associated with exposure to chemicals of exposure to chemicals and autoimmunity.

This success has also established the Menzies Research Institute as one which, in its special location, could have a significant impact on international medical science and the national and international economic and social benefits that can flow from investment in such endeavours.

Supporting documentation

1. Dwyer T, Ponsonby AL, Newman NM, Gibbons LE. Prospective cohort study of prone sleeping position and sudden infant death syndrome. *Lancet* 1991; 337: 1244-1247.

2. Australian Bureau of Statistics. Deaths, Australia, 1990, 1998. Canberra: ABS, 1998. (Catalogue no. 3302.0/3303.0.)

3. Ponsonby AL, Dwyer T, Gibbons LE, et al. Factors potentiating the risk of SIDS associated with the prone position. *N Engl J Medicine* 1993; 329: 377-382.

4. Dwyer T, Ponsonby AL, Blizzard CL, et al. The contribution of changes in the prevalence of prone sleeping position to the decline in SIDS in Tasmania. *JAMA* 1995; 273: 783-789.

[83] The Journal of Clinical Endocrinology and Metabolism. 1998; 83: 4274-4279; Journal of Bone and Mineral Research,1999; 14: 146-151; British Medical Journal,1999; 319: 1325-1329; *Thorax*: An international journal of respiratory medicine,1999; 54: 664-669

21. Triple P – Positive Parenting Program®

Brief synopsis

Triple P – Positive Parenting Program ® – was developed in Australia by Professor Matt Sanders and his colleagues from the Parenting and Family Support Centre in the School of Psychology at The University of Queensland (UQ).

The program is a unique, multi-level model of family intervention that promotes good communication and strong relationships between parents and children. The program's multi-level framework aims to tailor information, advice and professional support to the needs of individual families. It recognises that parents have differing needs and desires regarding the type, intensity and mode of assistance they may require.

Professor Sanders began developing Triple P in 1979 when he commenced his PhD on the value of good parenting and its positive effect on child behaviour.

In 1992, Professor Sanders moved from the Department of Psychiatry to the Psychology Department. Over the next four years, Professor Sanders established the Parent and Family Support Centre (PFSC) to develop the Triple P model. He raised funds through grant applications and lobbying Australian state and federal governments.

By 2000, it became clear that UQ was no longer capable of handling the volume of Triple P training and publications, as well as the marketing required to support the program's growth.

UniQuest and UQ decided to license the Triple P publishing and distribution rights to Families International Publishing Pty Ltd. The licensing arrangement was put in place in 2001 and shortly afterwards Families International Publishing changed its name to Triple P International Pty Ltd and turned the business over to marketing the Triple P program.

Timeframe

From 1979, and ongoing.

Success factors

- The long-term commitment and dedication of Professor Matt Sanders, the key inventor
- Professor Sanders's success securing funding from Australian federal and state governments to support the underlying clinical and empirical research.
- Triple P's credibility as one of the only evidence-based parenting programs available worldwide: the program is based on contemporary knowledge, has been well tested in international research and has been found useful by many parents
- the financial support of Queensland Health, Victorian Department of Human Services, Health Department of Western Australia, the National Health and Medical Research Council, and the School of Psychology and Department of Psychiatry at The University of Queensland who have contributed to the development of Triple P over time.

Benefits

Through the combined efforts of Triple P International, UniQuest and UQ, Triple P now has a presence in 12 countries. Triple P International employs 14 staff and, most importantly, more than one million families internationally have been able to access its benefits.

The PFSC research activities establish the scientific basis of all aspects of Triple P intervention and dissemination, including rigorous evaluation of new program variants. The PFSC collaborates with research groups around the world, remains informed of research developments elsewhere, and disseminates research findings from current PFSC projects internationally. This process ensures that Triple P continues to evolve, responds to data about the impact of the intervention and incorporates new knowledge about how to best assist families.

The PFSC also contributes to policy development that may affect the family. This is achieved by consultation with government ministers and policy advisers, and by dissemination of research findings. PFSC staff members are active in national and state professional associations, serving on editorial boards for journals, grant review committees and policy forming bodies.

The PFSC also operates the Child and Family Psychology Clinic, a demonstration community service and training facility for practitioners and postgraduate students. This clinic offers both individual and group programs for parents at the PFSC as well as seminars and group programs run in community organisations, kindergartens, schools and private sector organisations.

The PFSC's media liaison helps to inform the public about psychological and social issues. Staff members frequently comment on topics of general community interest, and the activities of the centre have been the subject of many current affairs programs, newspaper and magazine articles.

Supporting documentation

Triple P – Positive Parenting Program:	www.triplep.net
Parent and Family Support Centre, UQ:	http://www.pfsc.uq.edu.au/

Appendix B - Comment on paper by Davis and Tunny

Davis and Tunny list GERD:GDP targets for the EU and for seven OECD countries and criticise these targets on the basis that, by definition, some OECD countries have to be below the OECD average. This is hardly a valid criticism of such targets. It should be noted that only two of the eight country targets listed in the paper have been specified with reference to the OECD average. That meeting those targets is unlikely to be achieved by increasing business R&D intensities within the existing industry structure is hardly surprising. That R&D alone is not sufficient to drive innovation is well recognised. However such observations do nothing to allay concerns about the current level of Australia's R&D performance, especially at a time when other countries are making efforts to increase their R&D performance.

Davis and Tunny's approach to this issue is flawed. Many of Australia's industry sectors are small because of Australia's historic lack of support for innovation. If Australia was achieving similar levels to the USA and Japan in these sectors, they would be much larger elements of the Australian economy. This interaction between sectoral BERD intensity and sectoral strength is a 'chicken and egg' issue and the use of an OECD database for these calculations is logically inconsistent with the suggestion that GERD figures are unreliable.[84]

What the Davis and Tunny paper shows is that if the high technology sectors of the Australian economy were to undertake BERD at US intensities, their component of Australian BERD:GDP would actually double (from 0.33 to 0.61 per cent), which most policy makers would see as a desirable outcome. The fact that it would not result in overall Australian BERD:GDP reaching US levels is irrelevant, given the significant differences in the economies and policy frameworks of the two countries. Countries such as Israel and Finland demonstrate how national R&D policies and other related measures can change industrial structures. As a result, both of these countries have created high technology sectors that did not exist in their economies ten to fifteen years ago.

Policy measures to encourage R&D, whether they are direct or indirect, have to be looked at together to assess the overall impact of government measures on BERD. Australia's current BERD is the outcome of number of factors applied over a range of timeframes. There is therefore no reason for the current level of direct support to correlate with an outcome influenced by such a range of factors. Some 14 countries in the David and Tunny paper are shown as offering more generous direct support for BERD than Australia.

Davis and Tunny's claim that the relationship between R&D and more direct measures of innovation does not appear to be strong and stable across countries is based on a flawed analysis of the percentage of businesses engaged in innovation, compared with BERD intensities. The percentage of businesses engaged in innovation tells us nothing about the size distribution of these businesses. A country where small businesses dominate innovation will have quite a different BERD outcome to one where larger businesses are the main innovators. Attempting to relate the percentage of innovating businesses to GERD is also not appropriate for similar reasons.

Australia's BERD does not "*appear to be relatively low*" as suggested by Davis and Tunny – the undeniable fact is that Australia's GERD and BERD *are low* not only by OECD country standards, but also by the standards of newly industrialised countries. As Chart 1 of their paper shows, Australia's GERD and BERD are ranked 18th out of 30 countries. The fact that Australia's low BERD may be explained in part by Australia's current industrial structure is something that science and technology policy analysts have been aware of for many years. Australia cannot and should not rely on our current industry structure to maintain future living standards.

[84] The sectoral classifications of R&D make this use of the database problematic (consider the difficulties in classifying BHP Billiton's R&D between mining, manufacturing and services).

(ii) Differing levels of public support

The levels of public support in other countries may be lower than current support in Australia because past investment in science and innovation has resulted in GDP increasing faster than Government support. Countries that currently have low levels of BERD:GDP are more likely to provide higher levels of support in order to address this problem.

There are many factors other than public support that influence national GERD, BERD and GDP. However public support for science and innovation is an essential component. It would be surprising if Australia's 1.6 per cent of GDP spent on R&D could be closely correlated with GDP itself (i.e. 100 per cent) even allowing for time lags in the realisation of returns on R&D investment.

Assessing the relative generosity of the tax system towards R&D has been examined in a number of papers.[85] An index developed to measure this 'generosity' is sometimes quoted as showing that Australia's tax treatment of R&D is generous by OECD standards. Unfortunately this index has a number of deficiencies. It does not take into account:

- ***The availability of a measure***. It is not possible for a single measure of 'generosity' to take account of a range of different circumstances around the issue of availability:
  - Some tax measures are available only to companies with revenue below a cap. For example, Australia's R&D rebate is available only to companies with a turnover below $1 million.
  - Other measures are available only in certain narrow circumstances. For example Australia's 175 per cent deduction is only available to companies which meet certain criteria for increases in R&D. Companies are unlikely to be able to continue to increase their levels of R&D over an extended period, and their ability to claim the 175 per cent deduction is therefore time limited.
  - The availability of some tax measures is limited by legislation. Items that can be counted as R&D in some countries are not eligible in other countries.

- ***Administrative overheads***. Tax measures are intended to be administratively simple. ***However*** some countries, including Australia, have implemented notification and accounting requirements which have the effect of significantly reducing the value of the tax relief.

- ***Uncertainty.*** Uncertainty over the continued availability of a tax measure and constant changes to the rules governing eligibility have the effect of reducing the incentive effect of a tax measure. Countries where uncertainty has been an issue have experienced difficulties in observing additionality from tax measures to encourage investment in R&D.

- ***Timing of benefits***. Benefits that are paid to companies as a result of tax measure to encourage R&D are unlikely to encourage additional investment.

- ***New companies***. New companies that are not yet profitable are not able to benefit from tax measures to encourage R&D. Some countries have addressed this issue, but the reality is that tax measures are most useful to larger companies.

Thus the index may suggest a level of generosity that is somewhat misleading.

[85] See for example, Warda J (2001) 'Measuring the value of R&D tax treatment in OECD countries', *OECD STI Review*, no. 27, pp185-211.

Appendix C - Relevant Australian and international reports

The documents listed below variously identify the significant economic and social returns from public and private investment in research and innovation; the growing importance of policy and funding frameworks that provide internationally competitive levels of public support and incentives for greater private investment, and the enhanced productivity that is gained through effective and efficient collaboration among and between the different sectors of the national innovation system.

Reference and URL	Comment
The Allen Consulting Group (2004) 'Building effective systems for the commercialisation of university research', report for the Business Council of Australia & the Australian Vice-Chancellors' Committee www.avcc.edu.au/documents/publications/policy/submissions/BCA-AVCC%20Report_Final.pdf	• This report examines issues and barriers to the commercialisation of university research.
The Virtuous Cycle Working together for health and medical research: Health and Medical Research Strategic Review December 1998 (the Wills Report). Summary at www.health.gov.au/internet/wcms/publishing.nsf/content/hmrsr.htm/$FILE/summary_document.pdf	• Federal Government accepted Wills Report recommendations for increase in government support for medical research, to provide increased benefits.
Australian Government (2004) *Sustaining the Virtuous Cycle: for a healthy, competitive Australia,* the Final Report of the Investment Review of Health and Medical Research Committee, Commonwealth of Australia (the Grant Report). Summary at www.researchaustralia.com.au/files/IRHMR_Executive_Summary.pdf	• Confirmed that additional funding recommended by Wills is generating economic and social benefits. (Federal Budget 2006-07 – further significant investment in health and medical research)
Metrics for Research Commercialisation, A Report to the Coordination Committee on Science and Technology, 15 April 2005 (focussed on Publicly Funded Research Organisations (PFRAs). www.dest.gov.au/NR/rdonlyres/E3170A75-79D5-4737955E-BE41714948E8/5637/FinalMoCReport15April2005.pdf	• Current metrics for commercialisation of publicly funded research require expansion to capture broader understanding of commercial and economic benefits of research commercialisation. • Three primary recommendations: adoption of a new holistic definition of research commercialisation; that 14 metrics covering IP, contracts & Consultancies, and skills development & transfer be the basis of future data collection; and a strategy for research commercialisation metrics be developed.
The Allen Consulting Group (2004) 'Measuring the impact of publicly funded research', report for the Department of Education, Science and Training. www.dest.gov.au/sectors/research_sector/publications_resources/profiles/measuring_the_impact_publicly_funded_research.htm	• Attempts to capture the range of indicators necessary to measure both quality and diffusion of publicly funded research
The Allen Consulting Group (2003), 'The ARC's implementation of government decisions from *Knowledge and Innovation* and *Backing Australia's Ability*', report for the ARC www.arc.gov.au/publications/arc_publications.htm	• An independent review of the ARC's success in implementing government decisions which have increased and diversified funding for university research.
Access Economics (2003), *Exceptional Returns: The Value of Investing in Health R&D report to the Australian Society for Medical Research* www.researchaustralia.com.au/files/Access_Economics_Exceptional_Returns.pdf	• Investment in health R&D surpasses every other source of rising living standards in our time. • Three key issues remain following Willis Review — State & Territory and local governments need to match Commonwealth effort, reverse erosion of basic research and capital investment in public sector during 1990s, and boost to Health R&D relative to GDP warranted.

The Allen Consulting Group (2005), 'The Economic Impact of Cooperative Research Centres in Australia: Delivering Benefits for Australia', report for the CRC Association, Inc. www.crca.asn.au/activities/ 2005/CRCAEconomicImpactFinalReport.pdf	• An analysis of the economic impact of 25 successful CRC projects using general equilibrium modelling. • This report demonstrates that Australia has received an excellent return on our investment in CRCs.
Commonwealth of Australia (2003), *Mapping Australian Science & Innovation* www.dest.gov.au/sectors/research_sector/policies_issues_reviews/reviews/previous_reviews/mapping_australias_science_innovation_system/default.htm	• Mapping of Australian science and innovation activities cross the public and private sectors. • Identified strengths, weaknesses and complementarities in science and innovation. • Focussed on — performance & global standing, capacity to innovate, state of research infrastructure, human capital, strength of national & international linkages, and investment and support.
Howard Partners (2003), Evaluation of the Cooperative Research Centres Programme, report to DEST, July 2003. www.howardpartners.com.au/publications/crc-report.pdf	• Most recent program review of the CRC programme. • CRCs most successful in environment and minerals sectors where a history of 'match between the technology-push from the research base and the demand-pull from potential research users' exists.
The Australian Vice Chancellors' Committee (2004), *Achieving the vision for Australia's universities: Making Backing Australia's Future and Backing Australia's Ability work.* www.avcc.edu.au/documents/ publications/Achieving-the-Vision.pdf	In the context of the Federal Budget 2005-2006, and to ensure the ongoing effectiveness of the Commonwealth Government's packages, *Backing Australia's Future* (teaching and learning) and *Backing Australia's Ability* (research and innovation), the AVCC argued (and continues to argue) for: • increased investment in universities to maintain the real value of Government funding to universities and ensure opportunity and fair access to university for Australian students; • effective investment in research and innovation underpinned by a national innovation strategy; and • removal of intrusive red-tape based on a workable balance between university autonomy and proper accountability.
Association of University Technology Managers (AUTM) (2004), FY 2004 Licensing Survey. Summary available at www.autm.net/events/File/FY04 Licensing Survey/04AUTM-USLicSrvy-public.pdf	232 US & Canadian organisations reported 635 new products introduced in 2004 & 462 start-up companies launched. Individuals (not institutions) funded nearly 50 per cent of all start-ups.
OECD (2004), *Benchmarking Industry-Science Relationships,* OECD www1.oecd.org/publications/e-book/9202051E.PDF	• Intensity and quality of industry-science relationships play an increasing role in determining returns on investment in research, in terms of competitiveness, growth, job creation, quality of life and ability of countries to attract or retain qualified labour. • Highlights six areas for policy action, including greater priority to basic and long-term mission-oriented research, and matching supply and demand of scientific knowledge.
OECD, *OECD Science, Technology and Industry Scoreboard*, OECD 2003 edition. www.oecd.org/document/21/0,2340,en_2649_33703_16683413_1_1_1_1,00.html	• The 6th in a biannual series on latest internationally comparable data on the knowledge-based economy. • Themes include growth in the knowledge base of OECD countries, the information economy, global integration of economic activity, and productivity and economic structure.
OECD, *OECD Science Technology and Industry Outlook*, OECD 2004 edition www.oecd.org/document/60/0,2340,en_2649_33703_33995839_1_1_1_1,00.html	• The 5th in a biannual series provides overview of trends, prospects and policy directions in SET and industry across OECD, with an emphasis on innovation. • Chapters examine the role of public/private partnerships in stimulating innovation, and global challenges related to the supply of human resources for science and technology.

King, D.A., (2004) 'The scientific impact of nations', *Nature* vol430, 15 July 2004 www.ost.gov.uk/about_ost/Nature_Article_15_July_FINAL.pdf	• Measures output & outcomes from research investment over 10 years, to measure quality of research on national scales. • Stark disparity between the first (USA, EU15) and second divisions in scientific impact. • 15 of the top 20 universities are in the USA and four in the UK.
Measuring Third Stream Activities – Final Report to the Russell Group of Universities from the Science and Technology Policy Research Unit, University of Sussex, April 2002. www.sussex.ac.uk/spru/documents/final_russell_report.pdf	• Third stream activities: generation, use, application & exploitation of knowledge and other university capabilities outside academic environments. • Provides an analytical framework and comprehensive set of indicators to assist the tracking and management of university third stream activities (i.e. external & commercial activities).
US National Research Council (2005), *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* fermat.nap.edu/catalog/11463.html?onpi_newsdoc10122005	• Concern that SET building blocks of US economic leadership are eroding at a time when many other nations are gathering strength. • Two key challenges: creating high-quality jobs and responding to need for clean, affordable and reliable energy. • Four recommendations: K-12 education (10,000 teachers), research (Sowing the Seeds), higher education (Best & Brightest), and economic policy (Incentives for Innovation).
Allott, S. (2006) *From Science to Growth – What exactly is the mechanism by which scientific research turns into economic growth?* Hughes Hall Cambridge University 2006 City Lecture. www.hughes.cam.ac.uk/City_Lecture_060306.pdf	• 'People Centric' policy approach – argues for more investment in people when using science to promote economic growth • One size does not fit all – innovation and the manner in which industry accesses research differs across disciplines, therefore a common policy approach across disciplines will be flawed • Highlights importance of PhD graduates in the business – university interface
Lambert R. (2003) 'Lambert review of Business-University Collaboration', report for HM Treasury www.lambertreview.org.uk	• Argues that while much good collaborative work, more to be done. • Most effective knowledge transfer involves human interaction, suggests ways to unite business & university people. • Need for government to support university departments & development agencies in roles to improve business-university links, negotiations over IP, and market signals between employers & students.
Centre for International Economics (2002) 'CRC for sustainable Production Forestry Economic evaluation of R&D portfolio'	• Results indicate substantial benefits valued at many times project costs. • The partnerships and cooperative links formed between CRC researchers and industry is of major benefit to forest products industry (resulting in rapid adoption of research findings by companies). • In absence of CRC, uptake by industry expected to be far less.
Scot, A. *et al.* (2001) *The Economic Returns to Basic Research and the Benefits of University-Industry Relationships: A literature review and update of findings* – Report for the Office of Science & Technology www.sussex.ac.uk/spru/documents/review_for_ost_final.pdf	• Rejects 'linear' / intuitive approaches to rates of return, focus on complex relationships between research & innovation, science & technology • Most studies find substantial rates of return on investment (20-25%) • benefits significantly higher than narrow calculations of rates of return • benefits include enhancing capabilities in economy – creating & maintaining variety, SET options for flexible innovation systems facing uncertain demands & opportunities.

Guellec, D and van Pottelsberghe, B, 2003, "The Impact of Public R&D Expenditure on Business R&D", *Economics of Innovation and New Technology*, **12**, 225-243, available at http://ideas.repec.org/a/taf/ecinnt/v12y2003i3p225-243.html	Direct government funding has a positive effect on business financed R&D.
Kelly U et al (2005) 'The economic impact of UK higher education institutions', A report for Universities UK. bookshop.universitiesuk.ac.uk/downloads/economicimpact 3.pdf	• New evidence of impact of higher education institutions as independent business entities (additional to increasing stock of human capital). • Confirms growing economic importance of sector (in 20003/04 income £16.87 billion, gross export earnings £3.6 billion, employed 1.2% total workforce, wider impact over £45 billion of output) including role of international students. • Direct economic importance of sector expected to grow in future.
Strengthening Australia's Position in the New World Order, Working Group Report to PMSEIC, June 2006 http://www.dest.gov.au/sectors/science_innovation/science_agencies_committees/prime_ministers_science_engineering_innovation_council/meetings/fifteenth_meeting.htm	The Report recommends a three-pronged strategy: – capture the opportunities emerging for Australian science and innovation; – enhance our science and technology linkages with China and India; – strengthen our science and innovation foundations for competitiveness.
Pathways to Technological Innovation, House of Representatives Standing Committee on Science and Innovation, June 2006 http://www.aph.gov.au/house/committee/scin/pathways/subs.htm	• Identifies a range of areas where key stakeholders will be able to provide constructive input to ongoing development of Australia's innovation and commercialisation policy framework. • Recommends that the Business Industry Higher Education Collaboration Council examine and develop the business case for Third Stream funding.
Australia's Universities: Building our Future in the World, A White Paper on Higher Education, Research and Innovation, The Hon. Jenny Macklin, Shadow Minister for Education, Training, Science, and Research http://www.alp.org.au/download/now/060721_white_paper___australias_universities___building_our_future_in_the_world.pdf	• Major Australian Labor Party policy paper outlining the ALP's strategies to build skills, infrastructure and productivity through a cohesive innovation strategy underpinned by public and private support.
Science and Innovation - Big Science. Big Picture., The Hon. Julie Bishop, Minister for Education, Science and Training, Address to the Sydney Institute, 19 July 2006 http://www.dest.gov.au/Ministers/Media/Bishop/2006/07/b011240706.asp	• Acknowledges the need to strengthen the foundations of our competitiveness, and build a prosperous future for this nation on a broad front as part of a new, forward looking vision for science, higher education and research in Australia, encompassing. global engagement; quality research; world class infrastructure; competitive skills; connected industries and communities.