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The economic impact of the commercialisation of publicly funded R&D in Australia

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Australia has improved its performance in commercialising publicly funded R&D significantly over the past five years - with both the pipeline of new companies and the success rate of these companies reaching ‘maturity’ increasing. However, this improvement has come off a low base of past performance and there is considerable scope for further improvements to be made.

The difference between continued performance improvement and a levelling off in performance could be worth around $20 billion per annum in additional turnover by technology-based Australian companies by 2020 (2002 dollars).

If Australia is to achieve maximum economic value from its innovation system a balance between policies supporting research and policies supporting commercialisation must be maintained. Also, given that the conversion of basic research into economically significant companies can often take ten to twenty years, policy makers need to have patience and provide long term policy consistency in relation to support for research and its commercialisation.

The context for this study

Australia’s multi-factor productivity growth has been particularly strong in the last decade or so, increasing at a rate significantly above the historical underlying growth rate. While innovation in products and processes has long played a crucial role in supporting the underlying rate of multi-factor productivity growth, macro and micro economic reforms implemented since the early 1980s, the widespread application of new IT tools as well as rising rates of innovation have all contributed to the productivity surge in Australia over the past decade.

Looking ahead, however, it is probably that if Australia is to sustain high rates of multi-factor productivity growth, it will need to leverage new sources of productivity improvement as the gains available from further structural economic reform become harder to achieve. Therefore, raising the underlying rate of innovation within the economy is emerging as crucial to underpinning economic growth and rising living standards in the future. This view is widely shared amongst OECD countries.

Over the last two decades there has been a gradual increase in policy interest in improving Australia’s commercialisation performance and actions have been taken in a number of areas. These are discussed in Chapter 3 and 4.

Particularly since 1998 and most notably in the Commonwealth Government's 2001 innovation statement *Backing Australia's Ability*, improving the environment for commercialisation has become a major pillar of innovation policy alongside investing in the research base and building linkages between the major elements on the national innovation system.

The public policy processes now underway in the lead up to what is being referred to as *Backing Australia's Ability 2* is considering the complete gamut of issues around science and innovation.

This study has been commissioned by the Australian Institute for Commercialisation to contribute to the debate on future science and innovation policies. The study is designed to throw light on the Australian experience with the direct commercialisation of publicly funded research in recent decades and analyses the potential for achieving a step change significant improvement in results in the future.

Our approach

In examining the commercialisation process and the value it can create in successful cases we have done a number of things. We have:

- looked at ten case studies of companies based on the commercialisation of research findings originating in Australian Universities and/or public research agencies. The case studies have been chosen to reflect the experience of high-growth technology-based companies in a range of areas of activity, to show the time periods that can be involved in going from minds to markets and to provide dimensions of the value such business can create and the contribution they can make to the economy.
- considered both the evolution of innovation policy settings in Australia and Australia's commercialisation performance over the past three decades – including a comparison of Australian performance with international best practice over this period.
- examined the current Australian commercialisation prospects associated with publicly funded R&D – including examination of how Australia now compares with international performance benchmarks in this area;
- considered the changes that have occurred within the Australian innovation system over the past five years that may significantly increase the future economic benefits from commercialisation;
- estimated the scale of economic benefits that could be realised by 2020 through a continued improvement in generating and growing technology-based companies in Australia; and
- finally, considered what needs to occur in the future if such increased economic benefits are to be fully realised.

Key Findings

The ten major findings of this study are that:

1. Australia has improved its performance in commercialising publicly funded R&D significantly over the past five years. Both the pipeline of new companies and the success rate of these companies reaching ‘maturity’ appears to be growing. Turnover of companies based on publicly funded research has grown from around $300 million (2002 dollars) in 1983 to over $1.5 billion (2002 dollars) in 2003. Most of this growth has come since 1998.

2. Prior to recent improvements, Australia performed poorly compared to international best practice. Now, while still not at best practice, we are closing the gap.

3. Currently we have 2-3 'star' performers, about 10 solid performers and then a large pool (a couple of hundred) of small companies based on publicly funded research.

4. Crucial to reaping future economic pay-offs from public investment in research is lifting the conversion rate of starters to solid and star performers.

5. Stars are based on cutting edge research, but the speed of their growth is influenced by the commercialisation environment. Solid performers can be based on good incremental research combined with a supportive commercialisation environment.

6. Investments in the innovation system made in recent years have not yet fully paid off. The time period for conversion of research into a mature company is often ten to twenty years.

7. The difference between continued commercialisation performance improvement and a levelling off in performance could be worth around $20 billion per annum in turnover and $18 billion per annum in exports (2002 dollars) by 2020.

8. Policy makers need to have take a long-term perspective in relation to support for the innovation system and provide consistency to the innovation environment.

9. To get maximum economic value from the innovation system you need a balance between policies supporting research and policies supporting commercialisation. We are getting closer to having the balance right than in the past.

10. Monitoring outcomes is currently quite limited and needs to be improved. Monitoring needs to occur on a consistent basis for a number of years and should allow comparisons with world best practice.

Chapter 1

Introduction

The importance of R&D commercialisation

The transition of developed countries towards becoming knowledge-based economies and societies has been thoroughly analysed in recent years – the OECD in particular has conducted a number of studies throwing light on different aspects of this development. The OECD has even proposed an indicator to measure the investments that are being made in knowledge – its creation, sharing and use – which aggregates investments in R&D, education and certain investments in software.

The emergence of the ICT and biotechnology/biomedical revolutions, each of which have been fundamentally influenced by discoveries about fundamental phenomenon in a range of research fields to which University researchers throughout the developed countries, but in the United States in particular, have contributed has focussed attention on the Universities and other centres of leading edge research as major sources for the development of new businesses and jobs growth.

The power of a virtuous cycle associated with breakthrough research, growth of new technology-based businesses enabled by specialist financial intermediaries such as venture capital providers and the development of clusters of related businesses has led to greater policy attention being given to the process by which ideas are transformed into businesses (i.e., the process of going from minds to markets).

Universities which have traditionally seen their role to be in research and teaching are taking on a third role in terms of the commercialisation of research findings and thereby are becoming even more important contributors to regional and national economies. Specialist research agencies are also being drawn into this process.

Governments that have traditionally invested in the higher education system because of their role in the creation of knowledge and the education of young people, are now looking to obtain a clear return on their investments and one of the potential channels for obtaining a return is through the commercialisation of research results.

As the Prime Minister said in his 2001 Federation Address and Launch of Backing Australia's Ability:

> "Yet, as fine as our achievements have been, the fruits of our ingenuity and inventiveness must be realised here in Australia. In an extremely competitive world of highly mobile capital and labour, it is all the more important that Australia has the right incentives and opportunities to translate Australian ideas into income and jobs at home for Australians."

The size of the economic benefits that could flow from a step change in Australia's performance in turning cutting edge research into commercial opportunities could be very large. For example, the June 2001 PMSEIC Report, *Commercialising Public Sector Research*, set out the goal of growing an extra 200-250 more Australian research-based companies over the next five years. The prize was claimed to be around an extra $20 billion in exports per annum.

This study is designed to throw light on the Australian experience with commercialisation in recent decades and to analyse the potential for achieving a step change significant improvement in results in the future.

Backing Australia's Ability and Beyond

While Australian governments have over a long time invested in the research base and technology transfer, especially in the fields of agriculture and resources, it is really only in quite recent times that both the Commonwealth and State governments have started to take a serious interest in, and become significant investors in, the process by which research findings are commercially applied.

The major statement by the Commonwealth government on innovation, *Backing Australia's Ability* (January 2001), not only provided for a significant additional investment in Australia's research base, but also provided funding for a number of programs relating directly to accelerating the commercial application of ideas. Notable elements were the Competitive Pre-Seed Fund for Universities and Public Research Agencies, the Biotechnology Innovation Fund and Commercialising Emerging Technologies (COMET) Program development of ICT incubators under the BITS Incubators program. These investments have been made in order to improve the prospects for cutting edge research to lead to the emergence of new businesses and business opportunities.

The public policy processes now underway in the lead up to what is being referred to as Backing Australia's Ability 2 is considering the complete gamut of issues around science and innovation.

This study is designed to provide a valuable input into these considerations focussed mainly on the commercialisation experience at both the level of the firm and the ecosystem which supports commercialisation.

There is no doubt that Australia has a highly developed scientific skills base and that publicly funded Australian R&D has generated a wide range of important scientific knowledge. However, it is also widely acknowledged that Australia has in the past been less effective at maximising the commercial returns potentially available from publicly funded R&D activity.

This study was commissioned by the Australian Institute for Commercialisation[1] to examine the extent of economic benefits that have been realised in Australia through the direct commercialisation of publicly funded R&D and to explore the potential for improved economic returns be generated in the future. This involves:

- consideration of past Australian commercialisation performance – looking back over a number of decades – including examination of a number of specific casse studies and then a more general examination of how Australian performance compares with international performance benchmarks;
- examination of the current Australian commercialisation prospects associated with publicly funded R&D – including examination of how Australia compares with international performance benchmarks;
- consideration of the recent changes that have occurred within the Australia innovation system that may alter future commercialisation success rates from previous success rates; and
- consideration of what needs to occur in the future for improved returns from the direct commercialisation of publicly funded R&D to be realised.

Defining direct commercialisation and public R&D funding

An important starting point for this study is to define what is meant by 'direct commercialisation' and to examine the extent of public funding for R&D that has occurred in Australia over the past two decades. These issues are addressed below.

Direct commercialisation

Commercialisation of R&D can occur in a number of different ways. Commercialisation is not restricted to the formation of new companies that utilise new intellectual property. In its broadest sense, commercialisation occurs wherever the R&D finds a route to use that generates economic returns.

At one end of the commercialisation spectrum, the use of publicly released research findings by an organisation or organisations to change their materials, products or processes is a form of commercialisation of the research. This is an instance of the commercialisation of research despite the fact that there may be no commercial interaction between the research performer and the subsequent research user.

[1] The Australian Institute for Commercialisation was opened in July 2002 with the objective of working with Australian research institutions and industry to maximise commercial returns from research and development expenditure.

In this study, however, we are seeking to identify the returns associated with a particular direct form of the commercialisation of research. In this study we wish to focus primarily on 'direct commercialisation' occurring through the activities of high-growth technology based companies whose activities are heavily based upon publicly funded research. These companies may be new spin-off companies from publicly funded research institutions or they may be privately formed companies that licensing or purchase publicly generated intellectual property. Therefore, in this study 'direct commercialisation' is defined as the commercialisation of R&D via:

- the formation of new spin-off companies (based on the IP generated through the publicly funded R&D) that then generate economic returns from the IP;
- the licensing (or outright purchase) of IP generated by the publicly funded R&D by a company that then generates economic returns from the IP.

When considering the economic impacts of this type of direct commercialisation, we need to include both the commercial returns captured by the research performing organisations and the economic impacts associated with the activities of the companies that have commercialised the research.

Both international studies and the findings of the 2002 Australian National Survey of Research Commercialisation[2] suggest that the benefits of commercialisation of public sector R&D captured by the institutions that performed the research may be of lesser economic significance than the activities of the companies that have commercialised the research.

Therefore, the major focus of this study is on the economic impacts associated with companies, such as Cochlear, ResMed and Radiata, that have successfully commercialised publicly funded R&D and now make a substantial economic contribution in terms of employment, value added and exports.

It is important to note that there are several other important avenues (the measurement of which is beyond the scope of this study) by which publicly funded research can be commercialised and generate economic benefits. Such avenues include the application of publicly funded basic knowledge by industry to improve products and production processes and the commercialisation of company conducted R&D which has been supported with public funding – whether via R&D grants or access to the R&D tax concession.

[2] ARC, CSIRO, NMHRC (2002), *National survey of research commercialisation: Year 2000*

Recent empirical evidence for the significance of the role of publicly funded basic knowledge in facilitating applied innovation was generated by a major study conducted by CHI research in 1997[3]. This study found that 73 percent of the science papers cited by US industry patents were generated by publicly funded research. This study also found that the strength of the linkage between patented technologies and contemporary public science is growing. A similar study undertaken to investigate the link between Australian patenting and basic science[4] has reported that there were 582 fractional citations of Australian authored papers in Australian invented US patents issued between 1990 and 1997. It also found that 95 per cent of these papers were authored in publicly funded research organisations.

The activities of the Rural Research and Development Corporations (RDCs) provide further evidence of the economic significance of non-direct commercialisation. In 2001-02 rural industries and the Government invested $209 and $196 million respectively in R&D managed through the RDCs[5]. A number of cost-benefit studies have found that strong economic benefits are associated with the R&D activities of the RDCs as improved production processes and new agricultural products are adopted as a result of R&D generated knowledge. However, in the context of this study into direct commercialisation, we do not include such benefits generated from RDCs in our measurement of direct commercialisation benefits. The application of research conducted by RDCs is somewhat analogous to the application of publicly available research findings by industry to improve products or production processes and as such can be seen as a form of indirect commercialisation of publicly funded R&D.

Similarly, a number of established Australian companies also generate economic outcomes via conducting R&D in partnership with publicly funded research institutions – especially through the CRC program – or through the receipt of R&D grants. However, measurement of such economic impacts are beyond the scope of this study which is focused primarily on the direct commercialisation impacts associated with new company formation.

Finally, it should be noted that commercialisation (both direct and indirect) of publicly funded R&D is by no means the only avenue through which social and economic benefits from publicly funded R&D can be captured. Socio-economic benefits may also be generated through avenues such as skills formation associated with R&D, improvements to policy making occurring due to improved knowledge regarding policy issues, improved access to international knowledge resulting from collaboration in multi-national research projects and returns through improved health and environmental outcomes generated by new knowledge in these fields.

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[3] CHI Research (1997), *The Increasing Linkage Between US Technology and Public Science*, Research Policy, Volume 26, Issue 3

[4] CHI Research (2000), *Inventing our future: The link between Australian patenting and basic science.*

[5] Department of Agriculture, Fisheries and Forestry Australia (2002), *Innovating Rural Australia*

Public R&D funding

Public R&D expenditure comes through a wide range of funding mechanisms – from University research block grants to R&D tax incentives for business. In looking at outcomes from publicly funded R&D however, analysis will be restricted to R&D that has been predominantly publicly funded. Therefore, the commercialisation outcomes associated with private R&D that has been partially subsidised through the R&D tax concession are not considered within this study.

Table 1.1 sets out overall Commonwealth support for R&D to be spent in 2003-2004. Excluding funding allocated to the general R&D tax concession, publicly funded R&D in budgeted at just under $5 billion for 2003-04 and represents 0.62 per cent of GDP.

Table 1.1

SUMMARY OF MAJOR COMMONWEALTH SCIENCE AND INNOVATION SUPPORT: 2003-04

Major Commonwealth Research Agencies	$M
Defence Science and Technology Organisation (DSTO)	355
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	568
Other R&D agencies	449
Sub Total	**1,372**
Science and Technology Support	
NH&MRC and other health	378
Cooperative Research Centres	202
Rural	202
Energy and environment	63
Other science support	43
Sub Total	**890**
Innovation Support	
IR&D tax concession	484
R&D START	162
Other innovation support	354
Sub Total	**1,006**
Higher Education Research	
Australian Research Council (ARC)	414
Other R&D support	1,744
Sub Total	**2,158**
Total Commonwealth Support	**5,426**
Total Commonwealth Support as a percentage of GDP	**0.68**

Source: Commonwealth Government Budget 2003-04, *Science and Innovation*, Table 1

However, it is important to note that in addition to Commonwealth support for R&D, State and Territory (and in some cases Local) Governments also provide significant funding in support of R&D. Over the past fifteen years, State/Territory and Local Government funding has represented around 17 per cent of total public funding for R&D. Table 1.2 sets out total Government (Commonwealth, State and Local) funding for R&D (in 2002 dollars) provided since 1988-89 and the share of GDP that this represented in each year.

Table 1.2

R&D EXPENDITURE BY SOURCE OF FUNDS

Year	Total government R&D funding (2002$million)	Government funding as a percentage of GDP
1988-89	3,634	0.66
1990-91	3,901	0.72
1992-93	4,128	0.76
1994-95	4,364	0.75
1996-97	4,610	0.76
1998-99	4,754	0.71
2000-01	5,155	0.71

Source: Unpublished ABS data drawn from publication category 8112.0, CPI index data and GDP data

Table 1.2 indicates that in real terms, public funding of R&D grew by an average of 3 per cent per annum over the period 1988-89 to 2000-01. Assuming that growth in funding from 1982-83 to 1987-88 and from 2000-01 to 2001-02 was of a similar real level, total public funding for R&D over the twenty year period from 1982-83 to 2001-02 was approximately $82 billion in 2002 dollars[6].

When comparing economic benefits generated from direct commercialisation of publicly funded R&D to the level of public funding for R&D, it is important to note that a significant share of public funding for R&D occurs in areas where the generation of commercialisation returns is (appropriately) neither an objective nor likely to occur. When public funding for R&D is broken down by socio-economic objective, it becomes clear that only around 50 per cent of public funding for R&D could reasonably be expected to generate some economic benefits via direct commercialisation of the R&D[7].

[6] It is important to note that Table 1.2 shows the sources of R&D funding rather than describing where this R&D is performed. For instance, some R&D conducted in the private sector is funded by the public sector while some R&D performed in public research institutions is funded by the private sector.

[7] In 2000-01, 42.2 per cent of all Commonwealth, State/Territory and Higher Education R&D expenditure (which together approximate total public funding for R&D) was defined as having economic development as its primary socio-economic objective. However, a significant proportion of heath oriented expenditure (which represents a further 18.6 per cent of Commonwealth, State/Territory and Higher Education R&D expenditure) could be reasonably expected to generate some commercialisation returns. Therefore, an expectation that around 50 per cent of public research expenditure could be reasonably expected to generate some commercialisation returns appears to be a defensible estimate.

Therefore in this report where we compare aggregate economic impacts realised from direct commercialisation of publicly funded R&D to public investment made in R&D, we only count 50 per cent of the level of total public R&D funding in this calculation, i.e. around $40 billion (2002 dollars) is the relevant portion of public funding for R&D over the twenty year period from 1982-83 to 2001-02 is appropriate.

The exclusion of 50 per cent of publicly funded R&D from the direct commercialisation rate of return calculations is in no way intended to suggest that potentially significant social and economic benefits are not associated with this publicly funded R&D. Rather, it simply reflects that the benefits associated with this portion of R&D funding are unlikely to occur through direct commercialisation of this R&D.

Chapter 2

Ten case studies of direct commercialisation of publicly funded R&D

Introduction

One way of gaining insight into the economic benefits that have been realised in Australia through the direct commercialisation, via company formation, of publicly funded research is to examine the experience of particular companies that have done precisely this and the economic value they have created.

The case studies have been chosen not only because of their intrinsic interest, but also because to include examples of both companies directly spun-off from publicly funded research institutions and privately founded technology based companies that have licensed IP generated by publicly funded R&D activities. The case studies highlight the processes by which publicly funded R&D has been directly commercialised and the economic value that can be associated with this process.

In the case studies the focus is on the wider economic impacts – in terms of employment, turnover and exports – associated with the activities of the commercialising companies, rather than on the commercial returns captured by publicly funded research institutions. Returns to publicly funded research institutions are considered in aggregate in Chapter 3 of this study.

The ten case studies do not represent a comprehensive profile of all direct commercialisation that has occurred in Australia over recent decades. Such a profile would require hundreds of case studies to be compiled. However, the fact that a small number of case studies are provided does not mean that the economic impacts associated with these case study companies represents a similarly small percentage of the total economic impacts associated with direct commercialisation of publicly funded R&D. This is because a small number of commercialisation events account for a significant share of total economic impacts relating to direct commercialisation of publicly funded R&D. For instance, within the ten case studies two, Cochlear and ResMed, account for the bulk of economic impact – whether impacts are measured in terms of employment, turnover, exports or market capitalisation. The implications, and issues raised, by the fact that a small percentage of all R&D direct commercialisation events tend to account for a large share of total economic outcomes are discussed in more detail later in this study.

In the case studies we examine both the overall economic impacts of the activities of the case study companies and the role that public funding of R&D has played in the development of these companies. Establishing the extent to which the economic impacts of these case study companies can be attributed to public funding is important when trying to establish the rate of return on public funding. However, the issues surrounding attribution of benefits is less important when considering the overall economic impacts of these companies (which is the main focus of this study), rather than the rate of return on public funding. Nevertheless, a discussion of this 'attribution of benefits' problem is included prior to the presentation of the case studies and in each of the case studies we have addressed this issue.

Issue of attribution of benefits

Calculating the degree to which public research funding is responsible for the economic impacts associated with companies that have commercialised this research require a somewhat complex assessment process that factors in the stage of project development at which public funding was provided and the relative importance of funding (from various sources) in generating outcomes.

To determine how responsible public research funding has been for the economic impacts of the case study companies examined below we therefore need to look at the specific financial histories of the case study companies and the point in the companies development when public funding made a contribution. Obviously, this represents only a very rudimentary solution to the attribution problem. However, we believe that it is a useful exercise as it provides for a reality check on claims relating to returns attributable to publicly funded R&D.

Returns to public R&D funded may tend to be significantly overstated if all the economic impacts of a company – such as Cochlear for instance – are attributed to public R&D funding even though many other sources of funding also made important contributions to the development of the company. In Cochlear's case for instance, charitable donations in particular were an important very early source of research funding. Similarly, at a later stage, funds raised via a public float of the company where important to funding its continued growth. To attribute all the economic impacts of Cochlear to public R&D funding would necessarily imply that no economic impacts can be attributed to such other sources of funding that have contributed to Cochlear's growth.

Direct Commercialisation case studies

The ten cases examined in this chapter are listed in Table 2.1. The table also shows the field of activity of the companies concerned and the source of the original technology upon which the companies are based.

As indicated above, all of the case studies are of companies whose foundation technologies were developed in Universities and/or the CSIRO.

Three of the case study companies are generally considered to be among the (all too short) list of outstanding technology-based companies developed in Australia. For example, the Chief Scientist in his submission to the recent House of Representatives Standing Committee on Science and Innovation Inquiry into Business Commitment to R&D in Australia stated that:

> "I want some 50,000 SMEs to grow from one to twenty employees to aspire to grow as have Cochlear, ResMed, Memtec and Radiata (the honour roll of Australian-born global companies….."

We have included Cochlear, ResMed and Radiata in the ten case studies below. Memtec, which was established in the early 1980s to commercialise continuous microfiltration technology developed at the University of New South Wales, was sold to a global company in 1997 at a time when its market capitalisation was US$300 million and has not been included in the case studies.

A number of the other case study companies examined below are more appropriately described as emerging companies which are at a comparatively early stage of their development and have not yet reached maturity.

Overall the case studies have been selected so as to cover a reasonably broad range of areas of activity and to highlight the role of public R&D funding at different stages of company development. Nevertheless, the case studies do tend to cluster in a relatively small number of areas such as medical devices, scientific equipment, biotechnology, pharmaceuticals and ICT.

Table 2.1

LIST OF CASE STUDY COMPANIES

Company	Established	Field of Activity	Key Sources of Original Technology
Cochlear	1981	Medical Devices	University of Melbourne
ResMed	1989	Medical Devices	University of Sydney
Ventracor	1995	Medical Devices	University of Technology Sydney, University of NSW
Radiata	1997	ICT	Macquarie University, CSIRO
IATIA	1999	Scientific Equipment	University of Melbourne
Amrad	1986	Pharmaceuticals	Four Melbourne based medical research institutes
Redfern Photonics	1998	ICT	Australian Photonics CRC
Biota Holdings	1985	Pharmaceuticals	CSIRO, Victorian College of Pharmacy, ANU
Proteome Systems	1999	Biotechnology	Macquarie University
GroPep	1988	Biotechnology	CSIRO, University of Adelaide

Cochlear Limited

With support from both the University of Melbourne and a number of Australian Research Council research grants, during the late 1970s Professor Clark at the University of Melbourne developed the prototype for the Cochlear implant for the profoundly deaf. Professor Clark began research into the feasibility of cochlear implants in 1967, and trailed the implant in 1978. Cochlear Limited was formed in the early 1980s to commercialise this technology. The company is now the world leader in hearing implant products, providing cochlear implants for children who are deaf and adults who have become deaf. Today, Cochlear Limited on of Australia's top 50 companies with a market capitalisation of over $1.9 billion.[8]

Cochlear employs over 700 people, 400 of them in Australia, with head office, manufacturing, and the majority of R&D remaining in Australia. They have regional offices in the USA, the UK, Belgium, Switzerland, Germany, Japan and Hong Kong.[9]

Cochlear's nucleus product range is available in more than 70 countries, with over 95 per cent of sales generated outside Australia. Since the first commercial implant 20 years ago, Cochlear's award-winning nuclear range has been implanted in nearly 40,000 people worldwide. Cochlear is the only publicly listed company in this industry and seeks to achieve strong ongoing growth of at least 20 per cent.[10]

Cochlear was formerly a business segment of Nucleus Limited, which itself was a wholly-owned subsidiary of Pacific Dunlop Limited. In 1995 Pacific Dunlop Limited decided to establish the hearing implant division as a separate listed company in order to facilitate the future growth and expansion of the company's activities and markets. This was achieved through a public float of the 50 million ordinary shares of Cochlear Limited on the Australian Stock Exchange at $2.50 per share. Priority access to the shares in Cochlear was given, under the public issue, to Pacific Dunlop shareholders, various research centres and technological institutes involved in hearing-impairment and implant research.[11]

Cochlear has been one of the major success stories on the Australian sharemarket over the last five years, experiencing enormous growth in revenue and operating profits and providing substantial share returns for investors over this period. The company's share price has increased from an initial issue price of $2.50 in December 1995 to a price of $33.30 in August 2003 (with a peak of $48 in December 2001).

Sales revenue for the year ending June 2002 for the company was A$255 million, an increase of 16 per cent over the previous year, and an increase of 56 per cent since 2000.

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[8] http://www.asx.com.au

[9] Cochlear Annual Report 2002, accessed from http://www.cochlear.com.au

[10] Cochlear Annual Report 2002, accessed from http://www.cochlear.com.au

[11] Online case studies, accessed from http://www.mcgraw-hill.com.au/mhhe/fin/peirson8e/stu/casestudy04.doc

A decade earlier Cochlear had sales of $40 million of which exports accounted for 95 per cent. The company's impressive results reflected strong system sales, which grew by 21 per cent in 2002.

The company maintains its technological lead by using its strong links with hospitals and research institutes around the world. Cochlear is a significant investor in R&D – its R&D expenditure was $37.7 million in 2002. R&D expenditure has grown significantly over recent years, increasing by 30 per cent between 1998 and 2002.[12] The company spends over 14 per cent of its sales revenue on R&D.

Profit after income tax in 2002 was $40.1 million, an increase of 29 per cent from 2001. The first half of 2002-03 has provided record half year profits, with system sales 22 per cent higher in December 2002 from December 2001. This resulted in $27 million profit after tax, an increase of 57 per cent from the previous year. Cochlear now holds a global market share in its product niche of 65-70 per cent.[13]

Summary of Cochlear's economic impacts

Approximately 400 employees in Australia and 300 employees off-shore.

Revenues exceed $250 million per annum.

Overseas sales of over $230 million per annum.

Extent of public R&D fundings' contribution to Cochlear's activities

The original research underpinning Cochlear was conducted with support from both the University of Melbourne and a number of Commonwealth research grants. It is important to note, however, that research conducted at the University of Melbourne and at the Bionic Ear Institute (founded in 1984) was also supported by significant charitable donations. In more recent times, Cochlear's R&D efforts have also benefited from public funded provided to the Bionic Ear Institute and, in 1999, the CRC for Cochlear Implant and Hearing Aid Innovation was established and will receive $14.2 million in public funding over a seven year period. Funding from public sources for research has been strategically important, coming as it did in the very early stages of work on the pathbreaking technology involved and subsequently being sustained over a considerable period.

[12] Cochlear Limited, *Annual Report 2002*, accessed from http://www.cochlear.com.au

[13] ASX Announcement/Media Release, accessed from http://www.asx.com.au

Over its history, as the case study indicates, Cochlear has received funding from a number of sources, including a $125 million revenue raising from its public listing in 1995. Given the extent to which charitable funding contributed to research work conducted in the late 1970s and early 1980s, and the extent to which private funding was raised in the 1980s and 1990s, it cannot be claimed that public funding was responsible for all or even most of the eventual economic impacts associated with Cochlear. However, even on a conservative basis it is reasonable to conclude that at least 20 per cent of the economic impacts generated by Cochlear are attributable to public R&D funding.

ResMed

Dr Peter Farrell formed the ResMed group of companies to commercialise technology developed by Dr Sullivan at the University of Sydney in the 1980s. This research was supported by both the University and through Australian Research Council research grants. Dr Sullivan and his colleagues invented a method of treatment of one a major forms of sleep disorder, Obstructive Sleep Apnoea (OSA). Left untreated, OSA can severely affect quality of life, health and mortality, and is strongly associated with hypertension, heart disease and stroke. The disease affects approximately 10 per cent of adult males in Australia.[14] Based on technology developed by Dr Sullivan, ResMed developed a range of masks that provide continuous positive airway pressure, thus treating the main cause of OSA.

ResMed has grown into an international success story, after starting in 1989 as ResCare Ltd, a company formed by Dr Farrell. ResCare raised $1.2 million from staff and private investors to begin production of devices for the treatment of OSA. Sales began in Australia in 1989, the USA later that same year and in Europe in 1990. Research and development undertaken by ResCare was supported by an IR&D Board grant of $150,000 in 1989 and an Austrade International Business Development Grant of $110,000 in 1990.[15] During these early years the company faced difficulties with attracting interest from potential financiers, primarily due to perceptions about its one product focus and a lack of understanding about OSA.

In June 1995 the company registered on the Nasdaq exchange as ResMed Inc, raising US$24 million.[16] In late 1999 the company transferred to the New York Stock Exchange and later co-listed on the Australian Stock Exchange. Subsequently, wholly owned subsidiaries have been formed (such as in the UK) or successful distributors have been acquired.

ResMed currently employs approximately 1,300 staff (over 400 of which are located in Australia). The company’s revenues exceeded $400 million in 2002-03. ResMed spends between 7 and 8 per cent of net revenue on R&D. At 30 June 2002, ResMed held 496 patents issued and pending for a range of technologies.

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[14] ResMed Corporate Fact Sheet, accessed from http://www.resmed.com.au

[15] http://www.atse.org.au/publications/focus/focus-barnes.htm.

[16] http://www.atse.org.au/publications/focus/focus-barnes.htm.

It has a current market capitalisation of A$1.9 billion on the Australian Stock Exchange and US$1.3 billion on the New York Stock Exchange.[17] As of June 2002, the company's compound annual growth rate was 36 per cent for revenue and 44 per cent for net income (using 1995 as a base).[18] The total size of the 'sleep industry', of which ResMed is the market leader, was valued at $1 billion in 2001 worldwide, and growing at 20 per cent per year. ResMed operates through direct offices in the United States, Australia, Germany, France, Sweden, the United Kingdom, New Zealand, Singapore, Malaysia, Japan, and through a network of distributors in more than 60 other countries. More than 95 per cent of ResMed products are exported.

Critical factors which influenced the success of ResMed include:

- *the research base* — Professor Sullivan's group has always led this field of research;
- *attracting the best overseas researchers through strong research credentials* — which enabled ResMed to access international markets;
- *establishing intellectual property* — the original patents enabled ResMed to keep potential competitors out of Australia for approximately five years. This was enough time to enable ResMed to start selling and establish an important base in the US.[19]

Summary of ResMed's economic impact

Approximately 400 Australian employees and 900 off-shore staff.

Revenues exceeded $400 million per annum for 2002-03.

Overseas sales of over $350 million per annum.

Extent of public R&D fundings' contribution to ResMed's activities

Prof Sullivan's initial research was conducted at the University of Sydney – and the original intellectual property was subsequently purchased from the University of Sydney by Baxter Centre for Medical Research (BCMR). Further research occurred in collaboration between BCMR and the University of NSW. In 1989 and 1990 further Government funding helped ResCare to continue product development. In 1997 ResMed received a $2.6 million R&D Start Grant.

ResCare (the fore-runner to ResMed founded in 1986) purchased the intellectual property developed through these research efforts for around $1 million and some continuing licence fees.

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17 http://www.nyse.com/cgi-bin/ny_quote?sym=RMD.

18 ResMed Corporate Fact Sheet, accessed from http://www.resmed.com

19 Australian Academy of Technological Sciences and Engineering (NSW Division), *Commercialising Innovation "The Second Step"* Workshop Proceedings Sydney – 10 May 2001, p. 26.

Between 1989 and the listing of ResMed in 1995 and number of further changes in the ownership structure of Rescare/ResMed occurred. In 1991 16% of the company was sold for around US$1 million and in 1993 Namura Jafco invested just over $1 million. By 1994 there were around 70 shareholders in ResCare. The 1995 listing of ResMed raised US$24 million and involved a 50 per cent dilution of shareholders' equity[20].

From this brief equity history of ResMed, it is clear that a number of investors made important and risky financial commitments during the early stages of ResCare/ResMed. However, it is fair to say that the public support involved in funding original research and the provision of additional support in 1989 and 1990 played a strategically important role in the development of the company. Similarly to the case of Cochlear, it is reasonable to conclude that around 20 per cent of the economic impacts generated by ResMed are attributable to public R&D funding.

Ventracor

Ventracor is a publicly listed company formed to develop and commercialise a rotary blood pump. The pump developed, known as the VentrAssist™, assists the blood pumping function of a failing heart, providing a long term alternative to transplantation.

The VentrAssist™ was initially developed by a group of researchers at the University of Technology (UTS) in Sydney and the University of New South Wales. In 1995, Dr John Wood approached Professor Vic Ramsden to develop a prototype rotary blood pump. They established the company Micrometrical Industries, which, in conjunction with UTS, later applied for and received an ARC Collaborative Grant of $80,000 per annum for 3 years, commencing in 1997, to get the research going. Micrometrical Industries provided matching funds. In 1999 the team received further ARC support through a $150,000 SPIRT grant. In 1998 the company also received an R&D Start grant. The company name was changed to Ventracor Limited in 2001.

The rotary heart pump is currently at the stage of human trials. As yet Ventracor has not turned a profit on the technology, though the market potential is estimated to be between US$7.5 and US$12 billion annually. It is estimated that in the US alone there are 81 million people suffering from various forms of cardiac disease, growing by 6.8 million per year.

Ventracor is listed on the Australian Stock Exchange, with a market capitalisation in late August 2003 of around $400 million, It was included in the S&P/ASX 200 on April 1st 2003. During 2001-02 the company issued 21.7 million shares with Australian and international investors, with the $17.2 million raised funding the commercialisation of the VentrAssist™. For the 2001-02 financial year the company made a loss of $8.5 million, reflecting their investment in the development of the VentrAssist™ towards full commercialisation. Total R&D spending for the company in 2001-02 was $6.39 million, an increase from $4.1 million on the previous year. In

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[20] Information drawn from discussions with ResMed staff

January 2003 Ventracor sold its e-health division to focus on the development of the VentrAssist™, raising $3.5 million. A further $2 million has been raised through employee share purchases.

On June 28th 2003 Ventracor and Alfred Hospital jointly announced that the VentrAssist mechanical heart-assist device had been implanted in a five-hour operation. The operation was part of a pilot trial at the hospital involving up to 10 patients. The trial will evaluate the safety of the VentrAssist device. A variety of left-ventricular assist devices are on the market, and other companies are also working on new-generation products that could compete with Ventracor's unit. Ventracor has planned to follow up the pilot trials in Australia with more extensive clinical trials in Europe and the US.

Summary of Ventracor's economic impacts

Approximately 80 employees in Australia.

Revenues for 2002 of around $2 million.

Extent of public R&D fundings' contribution to Ventracor's activities

The original research underpinning Ventracor was largely publicly funded, however the subsequent development work of Ventracor has been predominantly funded by equity raised through staff and public share issues. Given that Ventracor is currently in the relatively early stage of its development, public funding may at this point be seen to be as much as 50 per cent responsible for its economic impacts. However, as Ventracor grows and further funding is raised from private sources, it is highly likely that the share of it activities attributable to public funding will gradually diminish to levels of around 20 per cent or below.

Radiata

Radiata Communications was founded in 1997 by Dr David Skellern and Dr Neil Weste, to commercialise new chip technology for high-speed communications. This technology was initially developed at the CSIRO in conjunction with Macquarie University in 1992. The University had very complementary chip design expertise and some network and decoder knowledge needed to undertake the project.

Skellern and Weste developed groundbreaking chip technology for enabling very high-speed communication over wireless local area computer networks. At the time when the industry was getting used to wireless networks that could carry bits and bytes at 11 megabits per second (Mbps), Radiata had built a 'wireless engine' capable of sending data through at the air at 54Mbps. This new technology made it possible to run multiple channels of full motion video and other multimedia traffic between various mediums including PCs, hand-held computer, phones, television sets etc. The business market alone is expected to approach $US1 billion by 2005 as companies take up more flexible wireless networking solutions.[21]

After the company was incorporated, Skellern and Weste personally provided the initial funding. There was also a R&D Start grant and a development contract from an American company called MA/Com. Radiata's technology was developed by CSIRO and Macquarie University and was also assisted by ARC grants totalling $529,000 in funding between 1994 and 1999.

In late 2000 Radiata Communications was acquired by Cisco Systems for $US295 million. Cisco already owned an 11 per cent stake in the company after providing it with early stage funding in 1999.

Dr David Skellern is now Director of Wireless Technology in Cisco's networking business unit in Sydney.

There were a number of critical factors in the success of commercialisation for Radiata Communications:

- *matching the view of the future with the level of expertise* — there is no point in employing expertise in an areas that does not have a future. In Radiata's case, they knew they had world–class people and that they could create a world–class technology.
- *Preparedness and ability to adapt* — in the early stages Radiata believed that their European competitors had chosen some wrong technology. When new technology opportunities were made available (with the development of the internet) Radiata was quick to adapt;
- *Being part of the standards process* — which provides valuable marketing information and the opportunity to influence what is going on and to learn what other people and competitors are thinking;
- *The ability to continue during the middle years* — Radiata hung on during the middle years and the low point when they lost their major alliance and the market was difficult to identify; and
- *The incubating influence of CSIRO* — which provided physical space for the new company.[22]

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[21] National Office of the Information Economy, *ICT Success: Radiata*, accessed from http://www.noie.gov.au/projects/CaseStudies/ICT/ PDF/WEB%20radiata%20communications.pdf

[22] Australian Academy of Technological Sciences and Engineering (NSW Division), *Commercialising Innovation "The Second Step"* Workshop Proceedings Sydney – 10 May 2001, pp. 43.

Summary of Radiata's economic impacts

Apart from the value created by the sale of Radiata in 2000 for $US295 million, the recognition by one of the world's leading technology companies for a technology developed in Australia helped place Australia on the map as a place to conduct R&D in wireless technology.

Extent of public R&D fundings' contribution to Radiata's activities

Radiata had a relatively short time period between the original publicly funded research occurring and the company being sold to Cisco. Given that public funding was a significant source of funding for both the initial research at the CSIRO and Macquarie University and its subsequent development between 1994 and 1999, it would be reasonable to attribute at least 50 per cent of the economic impacts associated with Radiata to public R&D funding.

IATIA

IATIA is a company established to commercialise Quantitative Phase Microscopy (QPm) technology. This technology was developed by University of Melbourne physicist and ARC Federation Fellow, Professor Keith Nugent and his team. The technology enables a standard optical microscope to perform like a specialised phase microscope. It also allows, for the first time, quantitative measurements with a standard microscope. For example, a researcher studying cells in the normal, two-dimensional view, can now measure the volume of cells, thereby gaining access to three-dimensional information.[23] QPm was developed with the help of ARC funding of approximately $765,000. IATIA has also been supported by An R&D Start grant of $2 million in 2001[24].

IATIA was established in 1999 to commercialise QPm technology. QPi was the first product. The company was publicly listed in April 2002, with an initial share offer of 20 million shares (representing around 20 per cent of total equity) at a price $0.25. Prior to listing IATIA had raised around $4 million from staff and around $5 million from external investors[25]. Total funds raised by IATIA therefore now total around $14 million.

Since listing, IATIA has launched two new products, QPe and QPt. In 2002 the company had a market capitalisation of $30 million and 22 employees, all located Australia. IATIA has headquarters in Melbourne.[26]

IATIA operates two divisions to commercialise its proprietary technologies, IATIA Imaging and IATIA Instruments.

- IATIA Imaging has been granted a worldwide, exclusive licence from the University of Melbourne in relation to Quantitative Phase Imaging.

[23] National Survey of Commercialisation 2000.
[24] IATIA (2002) Prospectus
[25] Based on interview with IATIA staff
[26] IATIA *Annual Report 2002*, accessed from http://www.iatia.com.au

- IATIA Instruments develops and manufactures optical devices using its expertise in optical design and engineering. These products work in conjunction with the QPm technology.

IATIA reported a net loss in 2002 of $3.8 million, primarily due to costs associated with the public listing the company and research and development costs of advancing additional products towards commercialisation.

The company announced in May 2003 that it has entered into an agreement to have its phase imaging technology incorporated into a range of microscopes produced by Bio-Rad Asia Pacific, one of the world's leading manufacturers. The agreement provided Bio-Rad with a licence to incorporate QPm phase imaging software into every microscope sold in 17 counties within the Asia-Pacific region. The deal is expected to result in over a million dollars revenue for IATIA.

IATIA is currently refocusing its marketing efforts to potential industrial and defence applications — markets that could be worth billions of dollars around the world.

Summary of IATIA's economic impacts

22 employees in Australia.

Revenue for 2001 were around $250,000.

Extent of public R&D fundings' contribution to IATIA's activities

IATIA has had a very short time period between the original publicly funded research occurring and the company being listed. Given that public funding was a significant source of funding for both the initial research at the University of Melbourne and for ongoing product development through an R&D Start Grant, it would be reasonable to attribute at least 50 per cent of the economic impacts associated with IATIA to date to public funding. IATIA is clearly a company at the early stages of its development, but it is included here as a case study as it represents the type of technology commercialisation now occurring with increasing frequency in Australia.

Amrad Corporation Limited

Amrad Corporation Limited is a biotechnology research and development company based in Melbourne. Amrad's core business is the research and development of innovative medicines to treat human diseases. Amrad's in-house pharmaceutical R&D expertise is focussed on three key areas;

- infectious diseases
- neurological disease; and
- allergy and inflammation.[27]

[27] http://www.amrad.com.au

Formed in 1986, the founding shareholders of the company were four Melbourne medical research institutes and the Victorian State government which provided the seed capital. In 1996 Amrad listed on the ASX, raising $70 million.

There are approximately 56 employees working at Amrad, all located in Australia, many of whom have PhD qualifications. In addition, Amrad funds the activities of scientists at a number of medical research institutes, thereby enhancing the resources being applied to Amrad's pharmaceutical discoveries.

To increase the likelihood of successful innovative pharmaceutical product development, Amrad has deliberately focused its pharmaceutical R&D programs in therapeutic areas where there is unmet medical need and significant commercial opportunity. Amrad's compounds focus on treatments for chronic severe pain, infertility, cardiovascular disease. Neuromuscular disease and stroke.

In 2001-02 the company had total revenue of $12.9 million, significantly lower than the $68.5 million revenue from the previous year, though this included revenue from the sale of the consolidated entity's interest in Amrad Pharmaceuticals. In 2001-02 expenditure on research and development was $16.6 million, which is comparable to the $16.3 spent in 2000-01. In 2001-02 more than 50 per cent of research and development expenditure was incurred for three major projects in the development phase.[28] Amrad has 300 patent applications and granted patents, describing more than 30 inventions.

In December 2002 Amrad announced half year results indicating a 38 per cent improvement in revenue from the previous year.

On June 23 2003 Amrad announced a collaboration and Merck Sharp & Dohme (Australia) Pty Limited (MSD) in one of the largest biotechnology collaborations in Australian history, with a potential value of US$112 million plus royalties. MSD is the Australian subsidiary of one of the world's leading research-based pharmaceutical companies, Merck & Co., Inc. The agreement involves an exclusive licensing and multi-year research collaboration agreement. Based on the results of the collaboration, Merck will seek to develop drugs with therapeutic potential in areas such as asthma, other types of respiratory disease and oncology. Under the agreement with MSD, Amrad will receive an upfront payment of $US5 million. Total potential payments to Amrad by MSD based on the successful development of a human health product for all indications would amount to a total of $US112 million.[29]

Summary of Amrad's economic impacts

Amrad employs 56 staff in Australia.

Amrad's turnover was around $13 million in 2001-02.

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[28] Amrad Corporation Limited *Annual Report 2002* accessed from http://www.amrad.com.au

[29] http://www.amrad.com.au/AMRAD/News/News.asp?NID=106

Extent of public R&D fundings' contribution to Amrad's activities

Amrad is an example where public funding can be seen as very significant to the economic impacts associated with the company. Amrad was set up only through the considerable financial support provided by the Victorian Government (which in fact is still the largest shareholder - with a stake of over 15 per cent). It would be reasonable to attribute at least 50 per cent of the economic impacts of Amrad to public R&D funding support.

Redfern Photonics Pty Ltd

Redfern Photonics (a wholly owned subsidiary of Australian Photonics Pty Ltd which was set up by the Government in 1992) is an umbrella company that owns a number of subsidiary companies that are in the process of commercialising research emanating out of the Australian Photonics Co-operative Research Centre. It has raised over US$100 million from investors to support the development of both itself and its subsidiary companies.

Australia has a global reputation for quality world-leading intellectual property in the photonics sector. With a research staff of over 60 full-time equivalents, the Australian Photonics Cooperative Research Centre, is one of the largest photonics research operations in the world. It has over 230 members associated with its twenty-eight participants and co-ordinates over 90 per cent of Australia's research and development in optical fibre and photonic technology, in a joint venture between Australia's major universities and industry.

The photonics-related industry in Australia now turns over approximately $1.5 billion a year, or around 1.2 per cent of the world market, comprised of undersea cable manufacturing an the creation of optical components. Optical networking technology makes it possible to transmit large amounts of telecommunications traffic using light, or 'photons', instead of electrical signals.

Redfern Photonics was established in November 1998 — initially to invest in and commercialise Australian research and development outcomes in the photonics communications industry. Its interests are now much more international with portfolio companies having their headquarters in the USA, Germany and China as well as in Australia. Whilst from a technology perspective, it remains predominantly focused on photonics, it has diversified its interests beyond communications into industrial, sensing and defence industries. Redfern photonics' high profile investors include Deutsche Bank, GE equity and Citicorp, as well as the Australian Technology fund, Allen & Buckeridge and Macquarie Bank.

In mid-2001, Redfern Photonics had seven subsidiaries and investee companies employing more than 220 staff in Australia, the US and China. The group's complex structure reflects its mixed parentage, the volume of original photonics research springing from its members and the presence of an established optical networking industry in Australia. Notable Redfern companies include:

- *Indx* — the Redfern Photonics group of companies arose from funding the CRC raised from the sale of its first spin-off company, Indx, which was formed in 1995 to commercialise new technology. Redfern invested about $490,000 in Indx and the net profits well exceeded the factor of 10 when they sold it. The company was sold with six people; it now employs 250 people.
- *Fasten Photonics* — the money from selling Indx was used to fund Redfern Photonics and a number of companies, including Fasten Photonics in China in which Redfern has a 30 per cent equity.
- *Nufern Photonics* — formed as Redfern Fibres, Nufern is now based in Connecticut, USA, manufacturing optical fibre.
- *Redfern Broadband Networks* — a networking company, now based in San Francisco, with R&D undertaken at the Australian Technology Park in Sydney.

Summary of Redfern's economic impacts

As a unlisted holding company, full details of Redfern's economic impact are difficult to establish. However, Redfern's, providing some indicator of these impacts, former subsidiary Indx now employs 250 people, while Redfern Broadband employs over 60 staff in Australia.

Extent of public R&D fundings' contribution to Redfern's activities

Public funding support for photonics research, in particular through funding provided to the Australian Photonics CRC, has played an important role in the development of Redfern. Redfern Photonics itself was in fact established by the Government. However, it is also the case that more than US$100 million has subsequently be raised from private investors which in turn has supported the development of the Redfern group of companies. Given the large scale of private investment involved, it is appropriate to attribute around 25 per cent of the economic impacts associated with the Redfern group of companies to public R&D funding.

Biota Holdings Ltd

Biota is a biotechnology company engaged in the discovery of new human pharmaceuticals. A highly research intensive company, Biota's first product, Relenza, was developed in partnership with the CSIRO, Victorian College of Pharmacy and the ANU. Biota has received over $7.7 million in Commonwealth R&D grants, dating back to 1986/87 — the year after the company's formation.

The anti-influenza drug, Relenza, is the main product of the company. The drug was developed after scientists found that they could target an enzyme of the flu virus, going against what was the conventional wisdom at the time.

Biota started with a relatively small amount of money, $300,000, from Alan Woods and other entrepreneurs in August 1985.[30] Within a few months of this, the company was listed on the Second Board with $3 million raised.

Subsequently a number of private placements and rights issues were made:

- $4.8 million private placement in May 1992;
- $5.1 million rights issue in October 1992;
- $10.5 million private placement in May 1994;
- $6.8 million private placement in December 1995; and
- $21.8 million rights issues in November 1997.[31]

Options and employee options raised $22.4 million,[32] providing a means of smoothing out the availability of funds.

Most recently, in June 2003 Biota announced a $2.5 million share issue, representing 7.5 per cent of total issued capital, to Babcock and Brown.

An important step in financing the development of Relenza, including the expensive process of drug approval, was identifying a partner, GlaxoSmithKline, or Glaxo, as it was in 1990. Glaxo took over all the expenses associated with the flu project, and the company was able to use its funds in other ways. Biota has raised approximately $75 million in its entire lifetime from public sources, by 2001 is had approximately $40 million of that in the bank, with the remainder spent over a 15 year period.

In hindsight, Biota may have benefited from diversity its portfolio more than it did in the early period. It is important, however, to note the embryonic stage in which the biotechnology sector was in the early 1990, with a corresponding lack of venture capital willing to invest in biotechnology ventures. Also important was the ability of Biota to survive the 1987 market crash, which saw many Second Board companies go out of business.

As the company grew, it faced issues with its corporate structure. The original company, Biota Scientific Management (BSM), owned the intellectual property from the CSIRO. The company that listed was Biota Holdings, a holding company which then owned 74 per cent of BSM, with private investors owning the remaining 26 per cent. This company structure caused problems, particularly when the company wanted to expand past the initial drug discovery to new drugs. In the end, the holding company had to buy out the majority shareholders at a substantial cost.

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[30] Australian Academy of Technological Sciences and Engineering (NSW Division), *Commercialising Innovation "The Second Step"* Workshop Proceedings Sydney – 10 May 2001, p. 54.

[31] Ibid.

[32] ibid.

Biota's share price has been hit significantly over the last two years, the company's share price fall from over $9 at its peak to around $0.70 (after bottoming out at around $0.35), Since 2000 revenue has fallen by 41 per cent. This fall is primarily due to a significant drop in the royalties received from sales of Relenza, which fell by 81 per cent from 2000 to 2002. This large fall was due to a lack of flu outbreaks in the northern hemisphere and significant competition from a rival US product. Total revenues have been supported by an increase in diagnostics sales revenue, rising by 71 per cent from 2000 to 2002.[33] Total revenue for 2001-02 were $9 million.

In 2001 the then CEO of Biota Holdings, Dr Hugh Niall, highlighted some lessons from the Biota experiences:

- the company was probably listed too early;
- it would have been more beneficial if the company was first listed in the US on the Nasdaq, rather than in Australia, given the ease of access to capital and the ability of the US markets to look further ahead when ascribing value; and
- the company should have branched out into new products earlier than it did.[34]

Summary of Biota's economic impacts

23 employees in Australia and 18 employees off-shore (Biota Inc).

2001-02 revenue of $9 million.

Extent of public R&D fundings' contribution to Radiata's activities

Since its inception Biota has raised a total of $75 million in private equity. In addition though it has received over $5 million in public R&D grants – some of this funding coming at a very early point in Biota's history. Also, the initial research that underpinned Biota's first product, Relenza, was developed in partnership with the CSIRO, Victorian College of Pharmacy and the ANU. It would be reasonable to attribute at least 20 per cent of the economic impacts of Biota to public R&D funding.

Proteome Systems Ltd

Proteome Systems Limited (PSL) is a private company established by Professor Keith Williams, commercialising technology developed at Macquarie University. The technology relates to manipulation of proteins amino acids. Proteomics enables proteins and enzymes to be analysed using high speed automated equipment. In addition to support from Macquarie University, the Australian Research Council provided $257,000 in funding in the mid to late 1990s.

[33] Biota Holdings, *Annual Report 2002*, accessed from http://www.biota.com.au

[34] Australian Academy of Technological Sciences and Engineering (NSW Division), *Commercialising Innovation "The Second Step"* Workshop Proceedings Sydney – 10 May 2001, p. 57.

PSL is recognised as a world innovator in the development of proteomic technologies. The technology has developed through work undertaken by Dr Williams and his team since 1984. Williams established the Macquarie University Centre for Analytical Biochemistry in 1992, and began working with corporations in Australia and overseas on scientific instrumentation. In 1995 Williams founded the Australian Protein Analysis Facility, the first major national facility for the analysis and characterisation of proteins. The facility developed instruments for protein sequencing, including automation.

In just four years of existence PSL has established itself as a player in the emerging 'post-genomic' phase of biotechnology, where companies are moving beyond genetic manipulation to engage directly with the core building blocks of life: proteins and their biochemical linkages. PSL's four main areas of activity are drug discovery for human disease, agricultural biotechnology, scientific instruments and consumables for proteomics technology, and protein databases and tools.

PSL was founded by six academics, lead by Dr Williams, all former Macquarie University research scientists. Since is inception PSL has built powerful partnerships with several overseas companies, including:

- Dow Agrosciences (USA), leading to research into plant proteins;
- Shimadu Corporation, a manufacturer of scientific instruments which has lead to the development of a patented product for protein identification;
- Sigma-Aldrich, a life science and high-technology company, which recently released, in conjunction with PSL a line of preparation kits for use in scientific and genomic research.[35]

A large number of computer-driven tools have also been developed at PSL that facilitate the identification of proteins from gene sequences.

PSL employs 125 staff in Sydney and Boston more than a quarter of whom are PhD graduates Their sites have more than 20,000 square feet of office, laboratory and manufacturing space. Turnover in the 2002-03 financial year is forecast to reach $15 million, up from $7.7 million in 2001-02, with the unlisted company valued at $400 million. The global market for the proteomics sector in 2000 was estimated at $US 1 billion, growing to nearly US$6 billion in 2005.

Summary of PSL's economic impacts

PSL employs around 110 people in Sydney and a further 15 in Boston.

Turnover is forecast at around $15 million for 2002-03.

[35] http://www.proteomesystems.com

Extent of public R&D fundings' contribution to PSL's activities

Public funding clearly played a very important role in supporting the work of Prof Williams that eventually resulted in the formation of PSL in 1999. Proteome Systems was started by 6 scientists who resigned from Macquarie University and established Proteome Systems (in January 1999) after failing to reach agreement with Macquarie University on the structure of the spin out. Therefore the university took no stake in Proteome Systems. Three other people acquired a small equity position at this time in the process of establishing the business.

In September 2000, PSL conducted a capital raising and sold 10 per cent of the business. Subsequently, PSL has had two more capital raisings and has in the process sold another 10 per cent of the business. The founders of the business still retain approximately 80 per cent of the equity in PSL. The major external investors in PSL are the Queensland Investment Corporation (8.5%), Biotech Capital (2.5%) and Itochu Corporation (1%). The remaining external equity holders are high net worth individuals.

Given that public funding underpinned the development of the IP on which PSL was formed, and given that little equity dilution has occurred to date, it would be reasonable to attribute up to fifty per cent of the economic impacts of PSL to date to public R&D funding.

GroPep Limited

GroPep is a spin-off company formed by CSIRO and the University of Adelaide in 1988 to commercialise research into novel growth factors.

In 1991 these to institutions expanded there research collaboration through the formation, with the Child Health Research institute and Dairy Research and Development Corporation, of the CRC for Tissue Growth and Repair. GroPep became the commercialisation arm of this CRC. In 1997 this CRC was renewed and Flinders University has also become a participant[36].

GroPep has also benefited from an R&D Start grant of $2.5 million awarded in December 2001 from research into the recombinant growth factor PV903[37].

GroPep now develops, manufacturers and commercialises biologically active proteins in four areas of the biotechnology industry, namely:

- cell culture;
- biotechnology reagents;
- drug development; and
- contract manufacturing

[36] Prime Minister's Science Engineering and Innovation Council (PMSEIC), (2001), *Commercialisation of Public Sector Research*, Paper for seventh meeting, 28 June 2001

[37] GroPep, *2002 Annual Report*

In 2000, GroPep entered a ten year commercial agreement with CSL Limited whereby GroPep develops and manufacturers growth factors which are then sold through CSL's wholly owned subsidiary JRH Biosciences.

Another significant partnership has been developed with ImmunoDiagnostics Systems in the UK for the joint development, manufacturer and marketing of assay kits.

GroPep was successfully listed on the ASX in 2000, raising $17.4 million in new capital through this listing[38].

As at August 2003 GroPep employed 83 people in Adelaide. Revenue in 2002-03 was almost $11 million[39] with over 70 per cent of sales revenue coming from exports.

Summary of GroPep's economic impacts

Employment of 83 staff in Australia.

Turnover of approximately $11 million in 2002-03.

Exports of approximately $7.5 million in 2002-03.

Extent of public R&D fundings' contribution to GroPep's activities

Public funding clearly played a very important role in the development of GroPep. The company, which was initially established due to publicly funded R&D, has been a long term participant in the CRC for Tissue Growth and Repair and in 2001 received a $2.5 million R&D Start grant. As at September 2002 the CSIRO remained the largest shareholder in GroPep with a 20.3 per cent equity stake while Luminis P/L (Flinders University commercialisation arm), the Child Health Research Institute and the dairy Research & Development Corporation together held a further 35.4 per cent stake in GroPep[40].

Notwithstanding the capital raised from private sector investors through its listing on the ASX, it would appear reasonable for the clear majority of the economic impacts associated with GroPep to be attributed to public R&D funding.

Key conclusions

In aggregate these ten case study companies have:

- around 1,500 employees in Australia;
- a total turnover of around $850 million per annum; and
- overseas sales of in excess of $700 million per annum.

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38 Ibid

39 GroPep, *Press Release 15th August 2003*

40 GroPep, *2002 Annual Report*

However, just two of the case study companies, Cochlear and ResMed, account for over 50 per cent of employment, over 75 per cent of turnover and 75 per cent of exports. While full data is lacking for the market capitalisation of the ten case study companies, Cochlear and ResMed both have a market capitalisation of approximately $2 billion. It is likely that they account for over 80 per cent of the market capitalisation of the ten case study companies.

The issue of the concentration of economic impacts in a small number of direct commercialisation examples is explored further in the later Chapters of this report.

When an attempt to attribute benefits to public funding is made, the economic impacts of these ten companies attributable to public R&D funding are closer to:

- Australian employment of around 400;
- turnover of around $170 million per annum; and
- overseas sales of around $160 million per annum.

When the economic impacts associated with specific companies such as ResMed are compared to the amount of public funding of R&D that contributed to its development, the rate of returns is high. In the case of ResMed, where public R&D funding contributed perhaps $5 million, if no attribution adjustment is made to economic impacts, the returns can be shown as:

- approximately 75 Australian jobs per million dollars invested;
- turnover of approximately $75 million per million dollars invested; and
- exports of approximately $70 million per million dollars invested.

This case highlights that the economic benefits from successful direct commercialisation can be very high compared to the cost of investment. However, as will be highlighted in Chapter 3, when compared to the total level of public R&D funding (that may be reasonably expected to generate some direct commercialisation returns), the level of total economic benefits generated through direct commercialisation have in the past been low in Australia.

Another important point to emerge from these ten case studies is that often considerable time lags are involved between the funding of basic research and the realisation of significant commercialisation benefits. While in the case of Radiata this time lag was relatively short, at around five years, in other cases, such as Cochlear and ResMed, a time lag of more than ten years was involved before significant economic impacts were realised. While part of these time lags were due to the nature of medical research and the lengthy testing processes required for medical products, these long lead times were also partly due to the limited commercialisation infrastructure in place in Australia during the early years of these companies development.

In contrast, the more recent examples of Radiata, Proteome Systems Limited and Redfern Photonics demonstrate that when commercialisation pathways are clearer and the supporting infrastructure (such as venture capital availability) is more developed, significant economic impacts can be generated in relatively short time frames.

Finally, the case studies considered also highlight that the largest commercialisation pay-offs in Australia have been associated with truly break-through science rather than with incremental improvements to existing knowledge. In the case of both Cochlear and ResMed, the scientific break-throughs involved essentially led to not only the creation of new products but the creation of new markets.

Chapter 3

Australian direct commercialisation performance – pre 1998

Introduction

The case studies presented in the previous chapter provide some of the highlights, at the individual firm level, associated with successful commercialisation processes. They are valuable for what they tell us about the growth cycle of new technology-based companies and the potential value that can be generated when things go right. Such companies are influenced by the environment facing 'commercialisers', though some of the companies established in the early 1980s may have succeeded in spite of the environment rather than with its help.

Our purpose in this chapter is to do three things:

- firstly, to consider the nature and richness of the policy environment provided by the Commonwealth Government to the commercialisation process divide into four periods – up to 1983, 1983-88, 1988-1993 and 1993-98;
- secondly, to consider the trend in the Universities and the publicly funded research agencies such as the CSIRO in the ways they handled commercialisation and the bodies established for the purpose; and
- thirdly, to consider indicators of Australia's direct commercialisation performance during the four periods identified.

Commonwealth Government Policies

Up to 1983 – Benign Neglect

This period can be characterised as one in which commercialisation was either not held to be a part of Commonwealth government responsibilities or one in which commercialisation was not really a priority activity.

Arguably the one Commonwealth Government program that came the closest to having an influence on prospects for commercialisation was the Australian Industrial Research and Development Incentives Scheme (AIRDIS) which provided Commencement and Project grants for companies undertaking R&D plus special Section 39 grants. Early stage companies receiving such grants were able to supplement their financial resources in such a way as to meet, at least in part, their need for "seed" capital.

The Espie Committee Report, *Developing High Technology Enterprises for Australia*, of 1983 with it critique of the environment in Australia facing technology-based start up companies drew attention, amongst other things, to the lack of venture capital available to start up companies in Australia and recommended the establishment of a Government scheme to fill a major gap in the capital market. The gap was not just a financial one but also a skills gap.

1983-88 – Awakening Interest

The need for the Commonwealth Government to take an initiative aimed at directly improving the situation for emerging technology-based companies was recognized following the Espie Report. The policy response was the introduction of the Management & Investment Companies (MIC) Scheme[41] which saw the establishment of a small number of MICs with financial support provided by way of a tax concession to enable them to provide early stage venture capital to technology-based companies.

Vision Systems Limited (see Box 3.1), is arguably the most significant success to emerge from the MIC program.

Box 3.1

VISION SYSTEMS LIMITED

Vision Systems Limited in its present form emerged in 1993 when Invetech and Vision Systems merged. Invetech and Vision Systems were established in 1987 and 1984 respectively and received significant funding from the MICs ($5 million in Invetech's case).

Vision Systems is a technology-based company that develops and markets a range of high-technology products and services. Its three core business segments are:

- contract engineering services;
- fire and security; and
- clinical diagnostics.

Vision Systems has had a number of successful collaborative research activities with public research institutions. For instance, it collaborated with the CSIRO to develop VESDA Laser plus smoke detection devices and with the DSTO to develop video based surveillance products and a Laser Airborne Depth Sounder business (subsequently sold to Tenix).

Vision Systems sales revenue has grown from $10 million ($2 million in exports) in 1993 to a running rate of annual sales of $140 million and exports of $120 million. R&D expenditure in 2002 exceeded $30 million. The company benefited significantly early in its life from the introduction of the 150% tax concession for R&D and was an active participant in a subset of the tax concession which facilitated R&D Syndication. This enabled a much accelerated product development program and led to $100's millions of exports.

The company is growing at a rate of over 30 per cent per annum and employs 770 staff globally. Market capitalisation has grown to close to $170 million.

Sources: Vision Systems Limited 2002 Annual Report; PMSEIC, (2001)

[41] The MIC program was in part modelled upon the US Small Business Investment Company (SBIC) scheme which commenced around 1960 and supported the growth of private investment companies through tax incentives and the ability to leverage private funds through borrowing up to four times their private capital base through the sale of Government guaranteed SBIC debentures.

Beyond the MIC scheme, the Grants for Industrial Research and Development (GIRD) Scheme which replaced AIRDIS plus the introduction of the 150 per cent R&D tax concession represented a significant additional injection of funding available to technology-based companies. While funding support was for R&D and not the commercialisation process as such, these schemes, by improving the financial position of the firms concerned, did contribute indirectly to the commercialisation process.

The third thing that was done in this period that potentially affected the commercialisation process of publicly funded research was the decision to require bodies like the CSIRO to generate 30 per cent of their revenues from external earnings. While the revenue target could be attained by other ways (notably contract research services), nevertheless, commercialisation did offer one route to meeting the target.

1988-1993 – Increasing Interest

The most significant initiative during this period was the introduction in 1990 of the Cooperative Research Centres (CRC) program which sought to encourage the development of research collaboration among the Universities and the CSIRO, provide a more user-oriented research environment for the training of researchers and to better connect the research providers to end users. As the succeeding rounds proceeded there was a trend to increase the contributions coming from non-government sources and to encourage greater efforts at commercialisation.

Mention should also be made of R&D Syndication which enabled some emerging technology-based companies to access the capital needed to expand their R&D and to build their businesses.

While the MIC scheme was operating in this period the stock market crash of 1987 was a major set back to the MIC's and there was ongoing concern expressed about the lack of venture capital and in particular early stage venture capital.

In 1992 in response to concerns about the lack of early stage venture capital in Australia, expressed in the Block Report in 1991, *Bringing the Market to Bear on Research*, the Australian Technology Group (ATG) was established with a capital injection of $30 million from the Commonwealth Government to focus on taking equity in the early stages of development of Australian technology. The ATG was set up as a company in which the Commonwealth Government held almost 100 per cent of the shares.

Pooled Development Funds (PDFs) were also set up in 1992 to encourage long term equity investment and provide patient equity capital for growth oriented, small to medium sized enterprises. It provided concessional taxation treatment for investment companies established and registered as PDFs.

1993-98 – Heightening Interest

The CRC scheme was given a considerable impetus towards a much greater effort to be devoted to commercialisation. This was a focus of the Mercer-Stocker review of the program in 1997.

In order to improve the situation for venture capital in early 1997 the Government provided $130 million for the Innovation Investment Fund which saw 6 licensed IIFs established. In the Investing for Growth Statement later that year an additional $43 million was injected into the IIF scheme to enable additional funds to be created.

The 150 per cent R&D tax concession was replaced by the R&D Start program plus a 125 per cent R&D tax concession.

The establishment of the R&D Start program and its later expansion in the Investing for Growth statement at least indirectly contributed to an improved financing situation for the growth of technology-based companies. This was particularly the case with the R&D Start – Premium element which provides assistance up to an effective 72 per cent of the total project with support being repayable upon successful commercialisation through a royalty agreement or similar arrangement.

Box 3.2

SUMMARY OF THE GOVERNMENT POLICY SET SUPPORTING COMMERCIALISATION

UP TO 1983 • AIRDIS R&D Grants	**1983-88** • 150% R&D Tax Concession • Grants for Industrial Research and Development (GIRD) Scheme • MIC Scheme • CSIRO 30% External Earnings Target
1988-93 • Cooperative Research Centres • Australian Technology Group • Pooled Development Funds	**1993-1998** • R&D Start - Core grants element - R&D Start-Plus - R&D Start – Premium • 125% R&D Tax Concession • Cooperative Research Centres (expanded with greater commercialisation focus) • Innovation Investment Funds

Universities and Publicly Funded Research Agencies – Commercialisation Environment

The Australian Universities and then Institutes of Technology moved in the 1970s and 1980s to establish commercialisation arms. The University of New South Wales was notable for having established its body much earlier in 1959. In 1978 representatives of seven tertiary education institutions decided to form the Australian Tertiary Institutions Commercial Companies Association (ATICCA). By 1988 ATICCA's membership had grown to 46. More recently ATICCA has changed its name to Knowledge Commercialisation Australia.

The commercialisation arms generally had responsibility for technology transfer, consultancy, contract R&D and technology commercialisation. An example is Uniquest Limited, the commercialisation arm of the University of Queensland, whose main activities are:

- Consultancy;
- Testing and analysis;
- Expert witness;
- Technology commercialisation;
- Contract research and development; and
- Training services.

Box 3.3 below shows the date of establishment of a sample of University commercialisation bodies.

Box 3.3

UNIVERSITY COMMERCIALISATION BODIES – DATES ESTABLISHED

ANUTECH Pty Ltd (Australian National University) 1979

Insearch Limited (University of Technology, Sydney) 1976

Unisearch Ltd (University of New South Wales) 1959

UniQuest Limited (University of Queensland) 1984

Techsearch Inc (University of South Australia) 1971

Luminis Pty Ltd (Flinders University) 1984

Technisearch Ltd (RMIT) 1972

Montech Pty Ltd (Monash University) 1986

Cutin Consulting Services Ltd (Curtin University) 1971

UNITAS Consulting Ltd (University of Tasmania) 1992

Source: The Australian Research and Development Directory (1994), Hallmark Editions.

Most of these bodies had relatively small staff and budgets. When account is taken of responsibilities which are beyond the definition of commercialisation in this study, the resourcing of the commercialisation activities that are our focus is quite small.

Nevertheless, resourcing of the Universities commercialisation arms has increased over time. For example, UniQuest Limited had 18 staff in 1993. It now has over 60 staff.

The leading public sector research agency, the CSIRO, moved in the 1980s to establish its own specialist commercialisation arm, SIROTECH Limited. The body, which became operational in early 1984-85, by 1986 had a staff of 28. The body remained in place until the end of the 1992-93 finanical year, when the CSIRO Board decided that the organisation's commercialisation performance would be improved by placing responsibility for commercialisation with the line managers of divisions. Most recently the CSIRO has appointed an Executive Director with responsibility for business development and commercialisation.

Indicators of past direct commercialisation performance in Australia

Performance pre-1983

Very little information appears to be available regarding the commercialisation of publicly funded R&D in the period before 1983. The commercialisation of publicly funded R&D was clearly not a priority for publicly funded research organisations at that time. However, the Espie Report[42] does provide some interesting insights into the extent to which high technology enterprises developed in Australia prior to 1983.

This study investigated the number of independently owned Australian high technology companies that had been founded since 1960. The study found that only 255 independent technology intensive Australian companies founded since 1960 were in existence. Total sales of these companies in 1981-82 were $114.3 million (which equates to approximately $300 million in 2002 dollars) and they employed a total of 4,899 people in June 1982. Seven of these companies employed over 100 people while 125 of these companies employed less than 10 people.

The study also found that only five of the 255 companies had listed on the Sydney and Melbourne stock exchanges[43] and that together these companies accounted for 70 per cent of the total turnover of the 255 companies and 27 per cent of total employment for the 255 companies. Furthermore, the study identified only one company that could be categorised as having reached 'maturity'. It defined 'maturity' as having reached a cumulative breakeven point, having revenue in excess of $25 million per annum, gross assets in excess of $20 million and more than 300 employees.

[42] Australian Academy of Technological Sciences (1983), *Developing high technology enterprises for Australia*. This report is commonly referred to as the 'Espie Report'.

[43] It contrasted this outcome with the findings of a US study that between 1969 and 1974 alone 490 small US high technology companies 'went public'.

These 255 companies would in all likelihood encompass all of the new companies that were based on publicly funded R&D over that period. During the 1960 to 1982 period, public funding for R&D was in the order of $1 billion per annum in 2002 dollars[44]. Therefore, even if the economic impacts of the 255 high technology companies were heavily (say 50 per cent) based on publicly funded R&D it is fair to say that the return on investment – through the direct commercialisation of publicly funded R&D that occurred via new company formation – was extremely low during the period 1960 to 1983. The economic impacts of these 255 companies (if 50 per cent attributable to public funding) equate to approximately 0.1 jobs and annual turnover of $6,500 per million dollars of public R&D funding made over the 1960 to 1983 period (in 2002 dollars).

Comparison of Australian performance to that of the United States

The Espie Report set out findings from a number of US studies that indicate that in the pre-1983 period Australia's direct commercialisation performance was far behind that of the United States.

It quoted a US Commerce Technical Advisory Board report from 1976 that showed that between 1969 and 1974 alone, a total of 490 small US high-technology companies 'went public' compared to five such companies in Australia over the entire 1960 to 1983 period.

The Espie Report also detailed findings regarding the impacts of the US SBIC program. In 1981 a review of this program showed that over its first 21 years 40,000 companies received financing. It also found that in 1979 the program cost a total of US$4 million, but increased tax revenues received in 1979, as a result of the program's operation since 1960, totalled US$441 million.

Direct commercialisation performance between 1983 and 1998

Data relating to the direct commercialisation of publicly funded R&D in Australia over this fifteen year period is at best patchy. A number of studies have measured various elements of direct commercialisation performance over this period – however, there are no systematic and consistent measures of total performance in place relating to the period.

However, based on the limited data available, a number of conclusions can be drawn in relation to both the overall direct commercialisation performance during this period and to how this performance compares to pre-1983 levels. The available performance data for this period shows that:

- of the ten case studies set out in Chapter 2, six of these companies were formed during this period, and two (Cochlear and ResMed) had already reached 'maturity' by 1998. The performance of these six companies

[44] For instance, the Australian Science and Technology Council Report for the period 1 July 1980 to 30 June 1981 found that Commonwealth budget support for scientific, industrial and general research totalled $307 for that year, which equates to around $900 million in 2002 dollars. State/Territory support would likely have taken the overall level of public funding for R&D over the $1 billion (2002 dollars) mark.

alone represents an improvement on pre-1983 direct commercialisation activity;

- a 1997 report[45] into spin-offs by the CSIRO showed that between 1985 and 1995 42 spin-off companies were formed (1.3 for every US$100 million spent on R&D) and that 38 still survived in 1997 and 29 were still independent Australian companies. However, the study also showed that total employment associated with these 29 companies was only 270 and they had total turnover of only $60 million. Including all 38 companies gave employment figures of 400 and turnover of $110 million;

- the Management and Investment Companies Licensing Board 1987-88 Annual Report shows that by June 1988 the MICs had invested $144 million across 139 technology-based companies over the previous four years. This report also showed that the total value of venture capital funds in Australia had increased from almost zero in 1983 to around $500 million by June 1988. Australian Venture Capital Association Limited data suggests that between 1993 and 1998 a total of $1,231 million of venture capital was raised in Australia[46]. However, AVCAL data also shows that the total value of *early stage* venture capital funds formed in Australia between 1984 and 1996 was only $163.9 million[47];

- a 2002 study into spin-offs from CRCs[48] showed that pre 1998 only 4 direct research spin-off companies had been formed from CRCs;

- a survey conducted by ATICCA found that in 1998, 63 new licence and option agreements were negotiated with industry partners by Australian Universities and that total active agreements being managed by Australian Universities was 231. Between 1996 and 1998 46 spin-off or start-up companies were formed from tertiary institutions. Total licence and spin-off revenue received in 1998 by Australian Universities was $31 million[49]. (These figures are somewhat lower than those reported for Canadian universities in the mid 1990s - Industry Canada has reported[50] that Canadian universities held equity in 366 spin-off companies in 1997 and that the number of spin-off companies had doubled over the 1994 to 1997 period. As another point of comparison, Chalmers University in Sweden experienced, co-inciding with a general improvement in economic conditions in Sweden, a major take off in spin-off formation from around 1980, and during the mid 1980s was spinning-off approximately 50 companies per annum[51]); and

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45 CSIRO (1997), *Media Release*, 29th January 1997

46 AVCAL (2001), *2001 Yearbook: An Analysis of Australia Venture Capital*

47 Ibid

48 Yencken (2002), *CRCs and Spin-off Companies*

49 As cited in PMSEIC (2001), *Commercialisation of Public Sector Research*

50 Industry Canada (1999), *University research and the commercialization of intellectual property in Canada*

51 Department of Employment Education and Training (now DEST) (1993), *Creating Economic Growth Through Enterprise Generation and Industry Research Partnerships: the role of the post-secondary education sector*

- over the 1990s an average of 25 spin-off companies per annum were formed by, or in association with, public sector research agencies. It is claimed that CSIRO IP and expertise led to the launch of 50 companies over the 1983 to 1998 period. CSIRO estimates that these spin-offs has created over 1,000 jobs and had a combined annual turnover of $200 million by 1998[52].

Taken together, the performance data suggests that:

- the level of direct commercialisation of publicly funded R&D was certainly higher over the 1983 to 1998 period than in the preceding 20 years;
- the level of direct commercialisation activity was also accelerating during the mid to late 1990s compared to earlier performance; and
- the overall economic impacts associated with direct commercialisation during this fifteen year period were still quite low. Total company turnover appears very unlikely to have exceeded $1 billion in 1998, while total associated jobs in 1998 would not appear to be more than a couple of thousand.

Comparison of Australian performance to the United States

While Australia's performance in the area of technology-based high-growth companies was clearly beginning to improve over the 1983 to 1998 period, it still appears that it lagged considerably behind that of the United States over the same period.

A 1999 US study into the Small Business Innovation Research (SBIR) program[53] (see Box 3.4) looked at 50 companies funded through the National Science Foundation (NSF) SBIR program and its NSF predecessor program that started in 1977 (the NSF program represents 5% - or cumulative 1983-1996 around US$300 million spent - of total SBIR program budget). This study found that employment in these 50 companies had grown from 527 to 11,500 since receiving NSF SBIR funding, cumulative turnover attributable to NSF SBIR funded projects was US$9.1 billion, 34% of sales were exported and US$963 million in private follow on investment had been raised.

Even if the results from the NSF SBIR were twice as good as the overall SBIR average performance, the above findings would suggest that around 115,000 jobs were created in SBIR funding recipients between 1983 and 1996 and that associated turnover growth exceeded US$90 billion. Given that the US economy is approximately 19 times the size of the Australian economy[54], a similar level of performance in the Australian context would have seen turnover growth of US$4.7 billion over the period.

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[52] PMSEIC (2001), op cit.

[53] National Research Council (1999), *SBIR: Challenges and Opportunities*, Annex B – The SBIR Program and NSF SBIR Commercialisation Results.

[54] Based on PPP adjusted GDP statistics in the OECD's *Main Economic Indicators* publication

Box 3.4

SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM

The 1982 Act that created the SBIR indicated that the program had two purposes:

- to more effectively meet the R&D needs brought on by the utilization of small innovative firms; and
- to attract private capital to commercialise the results of Federal Research.

To meet these purposes the Act required Federal Agencies with R&D budgets in excess of US$100 million to set aside 0.2 per cent of their funds for SBIR. Over its first six years of operation the percentage set-aside increased to 1.25 per cent. The percentage set-aside was further lifted to 2.5 per cent in 1992. In 1998 SBIR funding totalled US$1.1 billion. Since the program's inception in 1983, SBIR has made over 45,000 awards, totalling US$8.4 billion in 1998 dollars.

The SBIR programs have three phases:

- Phase 1: A grant of US$100,000 to conduct a feasibility study of the potential of a technology.
- Phase 2: A much bigger grant of US$750,000 for extensive development and prototype development.
- Phase 3: Involves the attraction of private sector finance for further product development.

Source: National Research Council (1999), *SBIR: Challenges and Opportunities*

Key conclusions

The Commonwealth Government's interest in the commercialisation of public sector research and the growth of technology-based companies gradually built up over the period from 1983-1998. By 1998 there was a significantly better (and better funded) set of policies in place than was the case in 1983, but Australia's commercialisation policy set had still not reached world best practice standards.

There was also throughout the period an increasing interest demonstrated by the Universities and Public Sector Research Agencies in commercialising the research results produced in their organizations. The gradual growth in the membership of ATICCA (although membership levels have now stabilised) and the resources devoted to the member organizations by their home institutions were indicators of this interest. The size of the private venture capital market also began to increase significantly from the mid 1990s.

Actual direct commercialisation performance in terms of new technology-based business creation and to a lesser extent businesses achieving maturity rose from a very low base in 1983 to a considerably improved position at the end of the period. Despite the improvement in terms of absolute performance, Australia continued to lag well behind overseas best practice benchmarks.

Finally, Australia's performance in directly commercialising publicly funded research in terms of the value of the benefits generated to the economy while better by the end of the period was still not all that significant and well behind international best practice.

Chapter 4

Australian direct commercialisation performance – 1998 to 2003

Introduction

The level of interest in improving outcomes in the area of direct commercialisation of publicly funded R&D has increased dramatically in the past five years.

Our purpose in this chapter is to do two things:

- firstly, to consider the improvements to the policy environment provided by the Commonwealth Government to the commercialisation process that have been made over the past five years; and
- secondly, to consider the returns that are now being generated from the direct commercialisation of publicly funded R&D.

When analysing the returns from direct commercialisation over the past five years it is important to distinguish between the direct commercialisation benefits captured by publicly funded research institutions and the wider economic benefits associated with activities of new technology-based companies that commercialise the research. Australia's recent performance in these two areas is discussed in turn in this chapter. More focus is given to the later category of benefits given the higher potential economic impacts available in this area.

Commonwealth Government policies

1998 to 2003 – Commercialisation Centre Stage

The Commonwealth Government as part of its set of policies to enhance the prospects for the development of the Australian ICT sector put in place a significant program aimed at strengthening the prospects for the successful incubation of ICT technology-based start-ups. The Building on IT Strengths (BITS) incubator program provided over $70 million to establish an ICT incubator in each capital city. The $40 million Intelligent Island program subsequently provided $40 million for a range of measures to enhance the Tasmanian ICT sector, including establishment of an ICT incubator.

As Part of its Biotechnology Strategy, the Commonwealth Government also established a Biotechnology Innovation Fund (BIF) to provide seed capital to biotechnology-based start-ups.

In 2000 the Commonwealth Government in order to improve the prospects for commercialisation introduced the Commercialisation of Emerging Technologies (COMET) scheme.

A further boost to the commercialisation process was contained in *Backing Australia's Ability*. As well as providing additional funding for COMET and BIF, the Commonwealth Government also introduced a new Competitive Pre-Seed Fund for Universities and Public Sector Research Agencies. Under the program, four fund managers have been selected to invest more than $100 million in projects or companies spinning out from University or public sector research agencies. The Commonwealth Government contributed $72.7 million to these funds. The lack of pre-seed capital was a gap iddentified by a number of participants in the February 2000 Innovation Summit.

More recently actions have been taken through the taxation provisions to attract venture capital investments to Australia by the tax exempt US superannuation funds.

Taken together, these actions have improved the prospects for the successful commercialisation of public sector R&D.

Also influencing the potential for commercialising publicly-funded research is greater focus on ensuring that publicly funded research institutions have appropriate IP management practices in place — the ARC for instance has supported the development of best practice guidelines for management of IP.

State Government policies

Since the mid 1990s State and Territory Governments, reflecting the judgement that innovation is central to future growth and employment in the emerging knowledge economy, have become strategic investors in their science and innovation systems. This represents a step change beyond their longstanding practice of investing in elements of the research base necessary to support State and Territory government direct responsibilities in the areas of resource development, public health and the environment.

As State and Territory Government investments in science and innovation programs are designed ultimately to contribute to economic development, these governments investments in science and innovation have had a significant focus on improving pathways and support for the commercialisation of research. This has been done by way of business incubation support, technology commercialisation skills support and the provision of start-up grants and venture capital funding.

Recent examples of a number of State Governments' willingness to invest in elements of the commercialisation process include:

- the Victorian Government in its Science Technology and Innovation first generation innitiative, which had an alocation of $310 million, provided $20 million for a Technology Commercialisation Program. Its second generation STI initiative provides $30 million for Building Innovative Businesses;
- the Queensland Government established BioStart, a $6 million investment, designed to assist young start up companies by providing

early stage financing to get to the proof of concept stage. A $100 million BioCapital fund, administered by the Queensland Investment Corporation, has also been established to provide venture capital for biotechnology companies. Queensland also has The Innovation Start Up Scheme, which provides grants of up to $80,000, to promote innovation and commercialisation for early stage companies. Thus far, $2.7 million has been granted through this program;

- the South Australian Government has recently established a Bio Innovation SA Pre-seed Fund (with funding of $4.5 million over four years) administered by Bio Innovation SA (South Australia's key body for public/private partnerships in innovation). In the 2003-4 budget, the State Government allocated new funding towards a number of new initiatives to enhance science and innovation capabilities, these included the establishment of a Venture Capital Fund ($11.4 million over four years), to be managed by a Venture Capital Board; and
- the New South Wales Government, as part of its BioFirst Strategy, has introduced the BioBusiness program. This program provides funds and support to assist the growth of companies and the commercialisation of research outcomes for the global market. Support includes marketing, information forums, conferences and financial support for proof of concept. In 2003, the New South Wales Government provided $659,850 to seven NSW biotechnology companies under its Proof of Concept Program.

Universities and Publicly Funded Research Agencies – Commercialisation Environment

In 2001, ATICCA was renamed Knowledge Commercialisation Australasia (KCA). Membership of KCA includes universities, government research organisations and departments, medical research institutes, rural research and development corporations and TAFEs. There are also affiliate members from CRCs and industry. The objectives of KCA are to assist in the development and maintenance of skills associated with knowledge transfer from public sector organisations and to promote the activities of its members in government, industry and commercial forums.

A relatively recent development with the Universities which has important implications for their commercialisation activities is the establishment of early stage venture capital funds. A notable example is Uniseed Pty Ltd which was established in 2000 as a joint venture pre-seed and seed fund between UQ Holdings Ltd/UniQuest Pty Ltd and Melbourne University Private, the commercial arms of the University of Queensland and the University of Melbourne respectively. The fund was established with a capital of $20 million.

Commercialisation performance of public research institutions since 1998

Income to research institutions from licensing and start-up activity tend to be highly concentrated in both a relatively small percentage of institution and, to a small number of commercialisation events within these institutions. The license income generated by Universities in 2000 for instance was dominated by one commercialisation event, namely the revenue generated by the University of Melbourne relating to the listing of Melbourne IT. The average licence revenue (as a percentage of research expenditure) by the 23 Australian universities that received license revenue in 2000 was 3.1 per cent. However, only 3 of these 23 universities – Melbourne (19.2), New England (14.0) and Flinders (7.3) – actually generated licence revenue (as a percentage of research expenditure) over this average level. The mean level of licensing revenue for the 23 universities was a figure of 0.4 per cent[55].

The 2002 National Survey of Research Commercialisation[56] found that for every US$100 million spent by CSIR0 2.3 spin-off companies were formed, a 75 percent improvement on the rate reported between 1985 and 1995. This survey also showed that in 2000, 47 spin-off companies were formed from publicly funded research institutions in Australia. In regards to the performance of Australian Universities, of the 82 University initiated start-up companies operational at the end of 2000 32 were formed in that year. Even allowing for moderate attrition rates of start-up companies this suggests that the rate of start-up formation in 2000 was much higher than levels recorded in the past.

2002 study into spin-offs from CRCs[57] showed that between 1998 and 2000 23 direct research spin-off companies had been formed (7.7 per annum) from CRCs and that between 2001 and 2002 28 were formed (14 per annum). This performance is a marked improvement of the earlier performance, with the study also showing that pre 1998 only 4 direct research spin-off companies had been formed from CRCs.

Comparison of Australian performance to that of the USA and Canada

Key findings from the National Survey of Research Commercialisation were that in 2000, relative to the size of research expenditure:

- the rate of issuing of US patents to Australian institutions was 27 per cent that of the USA and 40 per cent that of Canada;
- execution of licences by institutions in Australia was 81 per cent of the rate in the USA and 63 per cent of the rate in Canada;

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55 Knowledge Commercialisation Australia (2003), *Forum and Fair of Ideas: Commercialisation Discussion Paper*

56 ARC, CSIRO, NMHRC (2002), op.cit

57 Yencken (2002), op.cit

- adjusted gross income from licences received by institutions in Australia was 70 per cent of that in the USA but was almost double the rate observed in Canada;
- the number of start-up companies formed by institutions in Australia exceeded the rate in the US by around 20 per cent but was less than half the rate observed in Canada.

Taken together, these findings suggest that while Australian commercialisation performance has narrowed the gap between its performance and the performance in Canada and the USA, a gap in performance does still exist. A key performance gap relates to US patenting (the number of US patents rather than total patents is perhaps the better measure of patents with high potential value). While 498 patents were issued to Australian institutions in 2000, only 115 were US patents.

As is the case in Australia, in the United States a relatively small number of research institutes account for the majority of all income generated from licensing and spin-off companies.

In 2000, the University of California system alone accounted for approximately 25 per cent of all University licensing income, generating US$261 million in that year. The largest five generators of licensing income in turn account for $571 million in revenue for that year, representing over 50 per cent of total licensing revenue received by all US Universities[58].

As is the case in Australia, a very small number of licenses account for a significant share of total licensing revenue generated in the US. Of the 781 licences generating income in the University of California system, only 10 generated over US$1 million in revenue in 2000.

However, unlike Australia, all but two of the 20 largest research universities in the United States generated license income (as a percentage of research expenditure) of over 3 per cent. Six universities generated income at a rate of over 10 percent, while the average for the top twenty licence income generating research universities was 9.2 per cent.

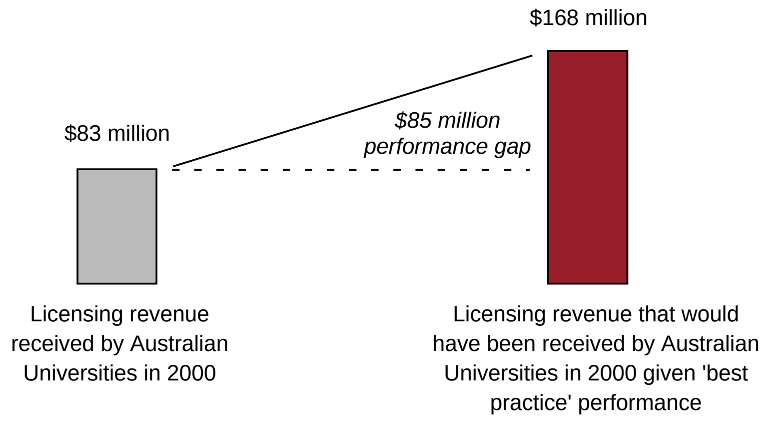
These figures suggest that while on average licence revenue generation in Australia is not too far behind the US university average (4.2 per cent), at the top end of performance the gap between leading US performers and leading Australian performers is in fact very significant. This lag in performance can perhaps be linked to the fact that most Australian Universities have only begun to seriously focus on commercialisation activities over the past ten years whereas some US institutions have been active in this area for a longer period.

Figure 4.1 below shows that if Australian universities had been performing at best practice levels in 2000, overall licensing revenues would have been around double those that actually were accrued in that year.

[58] Knowledge Commercialisation Australia (2003), op.cit

Figure 4.1

REACHING 'BEST PRACTICE' INVOLVES A DOUBLING OF UNIVERSITY LICENSING REVENUE



N.B. Figure assumes that 'best practice' would involve the top five performers in 2000 (in terms of licence revenue as a percentage of research expenditure) achieving a ratio of 15 per cent, the next five achieving a ratio of 5 per cent and the remaining 13 universities which generated licence income in 2000 achieving a ratio of 1.5 per cent.

Source: Knowledge Commercialisation Australia (2003), *Forum and Fair of Ideas: Commercialisation Discussion Paper*

The wider economic impacts from the direct commercialisation of publicly funded R&D

While more data is available in relation to recent direct commercialisation performance than was available for earlier periods it is still far from comprehensive. A key data problem is that while the National Survey of Research Commercialisation study tracked the commercialisation performance from an institutional perspective, data regarding the performance of the companies that have commercialised publicly funded research has not been collected. Therefore, in order to generate estimates of the overall economic impacts of direct commercialisation proxy data and 'rules of thumb' must be used. Available proxy data is set out below.

- The National Survey of Research Commercialisation study found that licensing income to Australian institutions was $99 million in 2000. Given that royalty rates may typically represent around 5 to 10 per cent of sales value[59], this suggests company revenue associated with these licences of around $1-2 billion in 2000.
- Data compiled from the case studies in Chapter 2 suggests that the largest two direct commercialisation successes had combined turnover in 2003 of $650 million while turnover of the other eight case study companies was around $250 million.
- AVCAL data[60] shows that from 1999 to 2001 total venture capital raised in Australia totalled around $3.5 billion and that in 2001 around 85 early stage investments were made. AVCAL data shows that total value of

[59] This is the royalty rate range used by CSIRO in CSIRO (2003), *CSIRO Research Commercialisation Report 2001-2002*.

[60] AVCAL (2001), op cit.

early stage VC funds formed between 1997 and 2001 was $2.7 billion compared to the $164 million raised between 1984 and 1996.

- 2001-02 IR&D Board annual report showed that 924 competitive grants were made to companies with turnover less than $5 million compared to a total number of 54 grants made in 1995-96.

Taken together, the above data suggests that over the past five years the economic impacts realised via the direct commercialisation of publicly funded R&D have increased considerably over the past five years. Based on the revenues of the case study companies and the level of licensing revenue that public research institutions are now receiving, total company revenues associated with direct commercialisation would appear to now be in the order of $2-3 billion per annum.

Estimate of overall economic impact in 2002

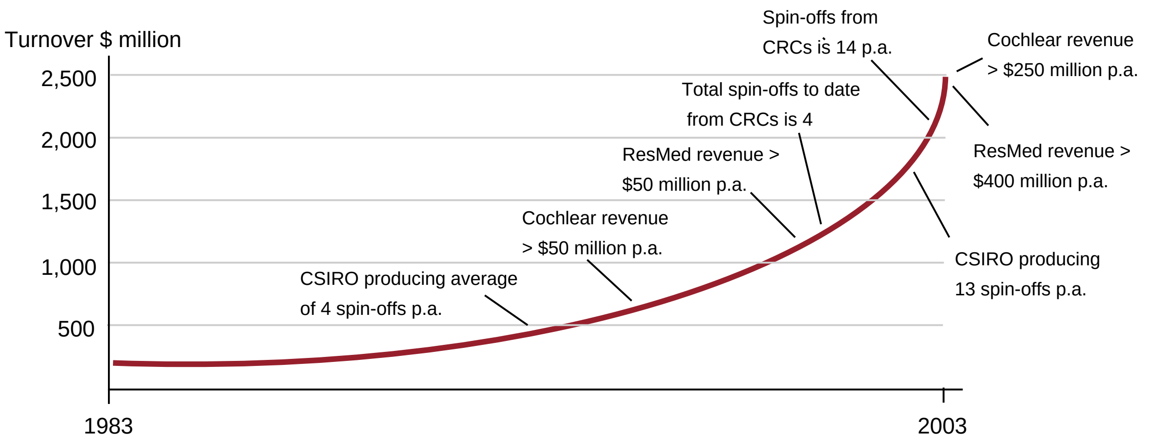
The total economic impacts associated with the direct commercialisation of publicly funded R&D appear to in the order of:

- 10,000 jobs in 2002 (assuming an average of four Australian jobs per $ million turnover);
- $2.5 billion per annum in revenue in 2002; and
- $2.0 billion in exports in 2002.

These figures represent a considerable improvement over earlier Australian performance levels. Figure 4.2 provides an indicative illustration of the increase over the past twenty years in the economic impacts (measured in terms of the turnover of companies based on publicly funded R&D) associated with the direct commercialisation of publicly funded R&D.

Figure 4.2

THE ECONOMIC IMPACTS OF DIRECT COMMERCIALISATION OF PUBLICLY FUNDED R&D



The above figure is based on an analysis of data from case studies, CSIRO studies, CRC studies, Espie Report data and data from the 2002 National Survey of Research Commercialisation

Given that the relevant amount of public R&D funding over past twenty years that has generated these returns was identified in Chapter 1 as being around $40 billion (in 2002 dollars), looking across the entire period from 1983 to 2003 the overall returns delivered through the direct commercialisation of publicly funded R&D are not particularly impressive.

However, as shown in Figure 4.2, performance has been on a sharply rising trend especially in the last five years. Over 60 per cent of total benefits from the twenty year period were actually realised in just the past five years and the signs are that benefits accrued will continue to rise in the future as the economic benefits associated with research funded over the past five to ten years would not yet be expected to have been fully realised.

Key conclusions

Direct commercialisation is a now emerging as a potentially significant avenue through which benefits from public R&D funding can be accrued in Australia. While Australian performance pre 1998 was very poor when compared to the US and Canada, in recent years considerable catch up has been occurring. However, returns currently being realised still trail best practice levels.

The National Survey of Research Commercialisation indicated that while overall Australian performance may still lag somewhat behind international best practice in the area of generating commercialisation revenue. However, even if Australian institutions reached best practice levels, the total level of commercialisation revenue would remain small relative to research expenditures. While improving commercialisation practices could perhaps in total double revenues captured by the research performing organisations, it is unlikely that revenues to these institutions would be able to be increased much further.

Given this, in assessing the commercialisation returns associated with publicly funded R&D, it would not appear that high overall economic impacts are likely to be found in the area of revenues accruing to research performing institutions. Even at world best practice levels, total returns to institutions are unlikely to represent more than 5 or 10 per cent of total public research expenditure. It is therefore likely that the major economic impacts that Australia could realise in the future through the direct commercialisation of publicly funded R&D will be associated with the activities of companies that have successfully commercialised publicly funded R&D. The spin-out of research intensive companies in turn creates a virtuous cycle as these companies grow and re-invest in collaborative research projects with publicly funded research institutions.

The case studies in Chapter 2 highlighted that the pay-offs from commercialisation in successful cases can be very high (e.g. Cochlear and ResMed). However, the number of such ‘star’ performers has been very low. The number of ‘solid’ performers generated has also been quite limited and hence the overall return on total public R&D funding through commercialisation has been low.

Currently we have 2-3 'star' performers, about 10 solid performers and a large pool (a couple of hundred) of small companies based on publicly funded research. Crucial to reaping future economic pay-offs from public investment in research will be lifting the conversion rate of starters to solid and star performers.

Based on the case studies examined in Chapter 2 it appears that the ‘stars’ are based on cutting edge research, but the speed of their growth is influenced by the commercialisation environment. Solid performers, however, can be based on good incremental research combined with a supportive commercialisation environment.

Investments in the innovation system made in recent years have not yet fully paid off. The case study analysis also indicated that the time period for conversion of research into a mature company is often ten to twenty years – however, it would appear that having supportive commercialisation infrastructure in place can act to shorten time lags.

The June 2001 PMSEIC report, *Commercialising Public Sector Research*, set out the goal of growing an extra 200-250 more Australian research-based companies over the next five years. It also set out that the prize for such success could be around an extra $20 billion in exports per annum. Consideration of the economic impacts associated (not adjusted for degree of attribution) with a such companies to date highlights the scale of this task. In the past twenty years only a few companies have emerged from public R&D that now have exports of over $100 million per annum. Total exports from such companies are unlikely to currently exceed $2 billion per annum. To reach the goal set out in the PMSEIC report requires increasing our performance in this area by around a factor of ten. Chapter 5 considers the prospects for this occurring.

Chapter 5

Outlook for future direct commercialisation performance – 2003 to 2020

Introduction

The purpose of this chapter is to consider the potential economic impacts that may be realised from direct commercialisation over the period out to 2020. In making this assessment we consider both:

- trends in relation to the size of the pipeline of Australian companies at the early stage of the direct commercialisation process; and
- trends in relation to the success rate of these companies growing to reach maturity.

Once these trends have been considered, it is then possible to consider the scale of economic impacts that may be generated by continued endeavours to improve Australia's direct commercialisation performance.

It is very difficult, however, to isolate the economic impacts of the direct commercialisation publicly funded R&D from the economic impacts associated with all high-growth technology-based companies. This is because almost all high-growth technology-based companies are linked to, and benefit from, publicly funded R&D to some extent. Some companies have very direct links to publicly funded R&D, e.g. they were formed as spin-offs from public research organisations. For other companies, the links may be less direct, e.g. companies that form research partnership with public research organisations (including through CRCs), companies that rely on skills developed due to publicly funded R&D, and so on. Yet another group of companies benefit from other types of public support for R&D, e.g. companies that receive public R&D grants assistance and R&D tax concessions.

As highlighted in Box 5.1, Mincom provides an examples of a high-growth technology-based company that, while its formation was not due to publicly funded research, has benefited from public support for R&D.

Box 5.1

MINCOM LIMITED

Mincom Limited is a leading global information technology partner for asset–intensive industries including mining, oil, gas, utilities, transportation, government and defence. As one of Australia's largest software developers, Mincom is an example of a company that focused on niche market, maintaining a leadership position for more than two decades.

A strong focus on research and development helped Mincom become the dominant global software and services player in the mining industry, which it then used to establish a leadership position in other vertical markets. The company's growth was driven by a strong emphasis on research, with an average expenditure on research and development of 15 per cent of revenue.

Mincom is an unlisted public company. Colonial First State Private Equity and Caterpillar are the only major institutional shareholders, with a 19.5 per cent and 11.45 per cent ownership, respectively. The remaining shareholders are primarily current or former employees.

Founded in 1979, Mincom is based in Brisbane, Queensland. Mincom's annual revenues were A$207.8 million (year ending 30 June, 2002). They now have around 1,200 employees in 18 offices in 12 countries covering Australia, North America, South America, Southeast Asia, Africa, and Europe. The company generates exports in excess of $100 million per annum. While Mincom remains an unlisted public company, it has been able to fund growth through both profits and through funding received from a number of Government research (R&D Start) and export (EMDG) grants.

Sources: National Office of the Information Economy, *Mincom Case Study*; Mincom Annual Reports

Keycorp (see Box 5.2) provides another example of a high-growth technology-based company that has, while not being based on research conducted at public research institution, benefited significant from public R&D funding.

Box 5.2

KEYCORP LIMITED

Keycorp Limited is a global provider of secure electronic transaction solutions: from smartcards and point-of-service payment terminals to network carriage and payment engines. Keycorp provides the infrastructure that facilitates secure electronic transactions via a physical network or the Internet. The company's high transaction network solutions provide high-speed. Flexible and robust transaction carriage services. Keycorp's e-commerce platform delivers secure and truly end-to-end online transaction processing interfacing services like IVR (integrated voice response), call centres, mall, telephone or fax ordering and Internet based transactions.

Keycorp has developed this technology with the assistance of the Commonwealth Government, which provided funding of $300,000 in 1985 and $337,000 in 1988 for the development of two key initial products. It was the development of these products that allowed the company to list on the stock market in 1987. Keycorp Canada is a wholly own subsidiary of Keycorp Limited. Keycorp also received a significant Commonwealth R&D grant in 1999, contributing towards its Privacy host e-commerce project.

Keycorp's initial stock market listing raised $1.2 million in 1987, and subsequently it raised a total of $13 million through a research syndication vehicle.

In February 2003 Keycorp announced a profit of $1.1 million for the half year ending 31 December, with revenue of $52.3 million. Keycorp is forecasting a similar result for the second half of 2003, with revenues between $50 million and $60 million.

Sources: Keycorp annual reports; DISR, *Case Studies on Innovative Australian Firms*

In this chapter, therefore, we look at the total performance of Australian high-growth technology-based companies – rather than only performance associated with companies they were based on the direct commercialisation of University and/or public sector agency research results.

We consider past performance and then make forward performance estimates under two different future performance scenarios – a high performance scenario that assumes that past rates of improvement continue and a lower performance scenario that assumes performance improvement levels off. This analysis indicates that the economic impact gap between continuing improvement the performance of technology-based high-growth companies and resting upon our laurels is large.

Caveat in relation the calculations in this chapter

The calculations made in this chapter – in relation to the growth in the pipeline of technology-based high-growth companies, the relative success of such companies in reaching maturity and the overall economic impacts that may result from such companies activities – should all be treated as indicative estimates only.

The data available on which to make these calculations is far from comprehensive and hence a number of data proxies and 'rules of thumb' have been used in making the calculations. For this reason, the calculations below are not precise, but rather are intended to provide a reasonable 'ball-park' estimate of the past and potential future performance of high-growth technology-based companies in Australia.

In the analysis below, particular reliance has been placed on IR&D Board statistics. This is because they provide a reasonably common basis for time series comparison and that they can be seen as a proxy for the overall number of technology-based high-growth companies in Australia. Obviously there are significant limitations to this data. Some double counting may be involved across programs and also undercounting may occur due to not including the number of unsuccessful applicants in calculations.

However, a number of other statistics point to very similar trends as those suggested by the IR&D Board data. For instance, there was almost no spin-off activity for universities and public research institutions prior to the 1980s. Only a small number of tertiary institutions had established commercialisation offices before 1980.

Between 1985 and 1995 the number of spin off companies formed by the CSIRO was 1.3 per US$100 million spent where it was 2.3 per US$100 million by 2000. Similarly, prior to 1998 only 4 spin off companies had come out of CRCs whereas in 2001 and 2002 it was 14 per annum.

The level of early stage venture capital being invested has also increased dramatically in the late 1990s. Between 1984 and 1996 the total value of early stage venture capital funds raised was $164 million while between 1997 and 2001 the value of early stage venture capital funds formed was $2.7 billion. In 2001 around 85 early stage investment were made.

All of the available data, while not comprehensive or precise, does point to the same key conclusions, namely, that Australian performance in relation to high-growth technology-based companies has begun to improve significantly in recent years off a very low past level of performance and that, not withstanding recent improvements, there is still considerable room for further improvement to be made.

Growth in the pipeline of Australian companies at the early stage of the direct commercialisation process

Over the past twenty years the number of companies in Australia that can be described as high-growth technology-based companies appears to have increased by 600-700 per cent. This translates to an net[61] annual average increase in the pool of such companies of around 60 per annum.

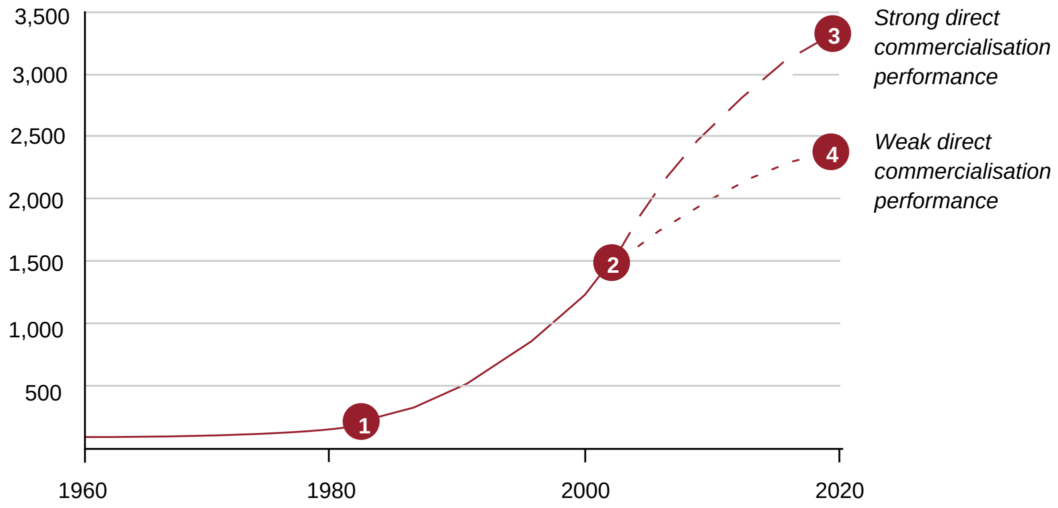
However, performance in this area was not steady across the 1983 to 2002 period, with the rate of new high-growth technology-based company formation accelerating throughout the period. Early stage venture capital investment levels have particularly increased during the past five years, as have the rates of spin-off company formation by Universities and public research agencies. It would therefore be reasonable to assume that the current net rate of new high-growth technology-based company formation is around 100 per annum. Indeed, based on analysis of the rate at which new companies are being generated out of public research institutions, it would appear that Australia is now approaching best practice levels in this area.

Therefore, in the figure below, a continuation of this current rate of pool growth is seen as representing strong performance. By contrast, weak performance in defined as a halving of the current net rate of growth of this pool of companies over the period to 2020.

[61] The net rate of growth of the pool of technology-based high-growth companies is the number of new companies minus the number of existing companies ceasing to operate.

Figure 5.1

NUMBER OF TECHNOLOGY-BASED HIGH-GROWTH COMPANIES IN AUSTRALIA



Data point 1: *Total of 255 companies in existence*. Espie Report identified 255 companies formed since 1960 were in existence.

Data point 2: *Total of ~1,500 companies in existence*. In 2001-02 around 1,100 companies with turnover less than $50 million received IR&D board assistance (excluding those accessing the tax concession). A total of around 1,960 companies with turnover less than $50 million accessed the tax concession. Perhaps an in between figure of around 1,500 would therefore be a reasonable estimate of the number of truly technology-based high-growth companies in Australia in 2001-02.

Data point 3: *Total of ~ 3,300 companies in existence*. Assumes that total company 'pool' growth rate (now around 100 new companies per annum) continues to 2020. Therefore approximately an extra 1,800 companies are added to pool by 2020.

Data point 4: *Total of ~ 2,400 companies in existence*. Assumes growth rate in the total company 'pool' falls back to 50 new companies added to pool each year out to 2020.

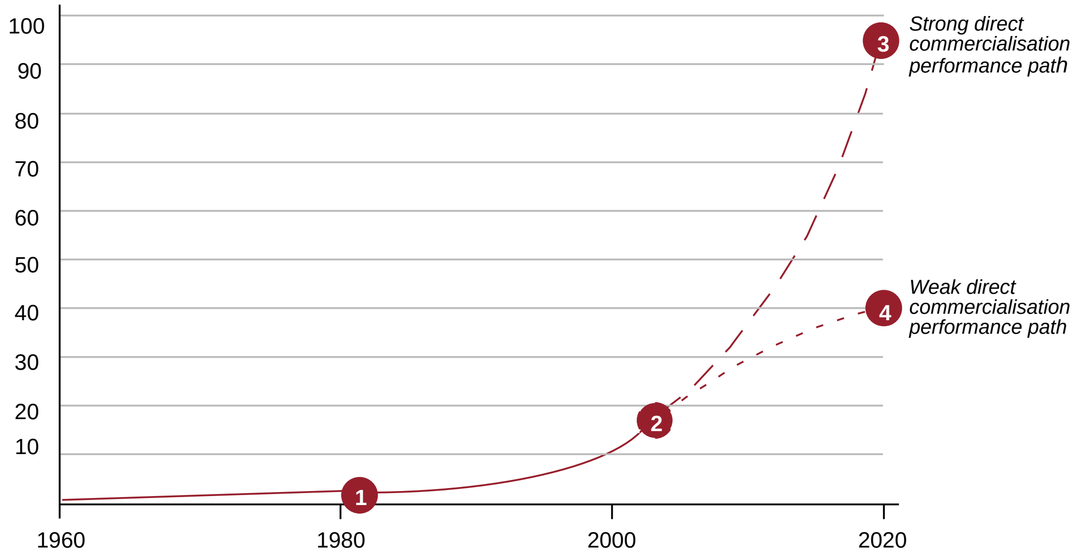
Improvement in the success rate of these companies growing to reach maturity

In addition to strong growth over the past twenty years in the number of high-growth technology-based companies being created in Australia, available evidence also suggests that the rate of success of these companies in reaching maturity (defined here as having revenues in 2002 of more than $50 million per annum) is also now increasing.

As Figure 5.2 illustrates, the 'conversion rate' seems to have moved from around one in two-hundred-and-fifty to about one in one-hundred over the past twenty years. Continuation of this rate of improvement (strong performance) would see the conversion rate reach around one in forty by 2020.

Figure 5.2

NUMBER OF TECHNOLOGY-BASED HIGH-GROWTH COMPANIES IN AUSTRALIA REACHING MATURITY



Data point 1: Total mature companies =1. In 1982 only one technology-based high-growth company identified in AATS report as having revenues higher than $50 million in 2002 dollars.

Data point 2: Total mature companies ~15. From ten case studies alone we can see three companies that reached maturity (ResMed, Cochlear and Radiata). Other Australian high-growth technology-based companies that have reached 'maturity' include the likes of CSL, Mincom, Keycorp, Vision Systems, and Memtec. The total number of companies now also approaching maturity appears to be considerable as 166 companies receiving R&D Start grants in 2001-02 had annual revenues between $5 and 50 million. 26 companies receiving R&D Start Grants that year had revenues over $50 million (however, not all of these companies would be defined as having been a technology-based high-growth companies at some point since 1983 – some may have been formed and matured much earlier while other may be primarily resource based companies for instance). From this information a number of around 15 companies is reasonable.

Data point 3: Total mature companies ~95. Success rate in reaching maturity from 1960 to 1982 was 1 in 255. From 1983 to 2002 it was probably closer to 1 in 100. Assuming success rate climbs to 1 in 40 for the period out to 2020 (i.e. follows same improvement rate as in the past 20 years) and given pipeline now around 1500 companies (and around 100 new high potential start ups are entering the pipeline per annum) this success rate would suggest that around 80 new companies should reach maturity by 2020 (in addition to the 15 that were already mature by 2002)

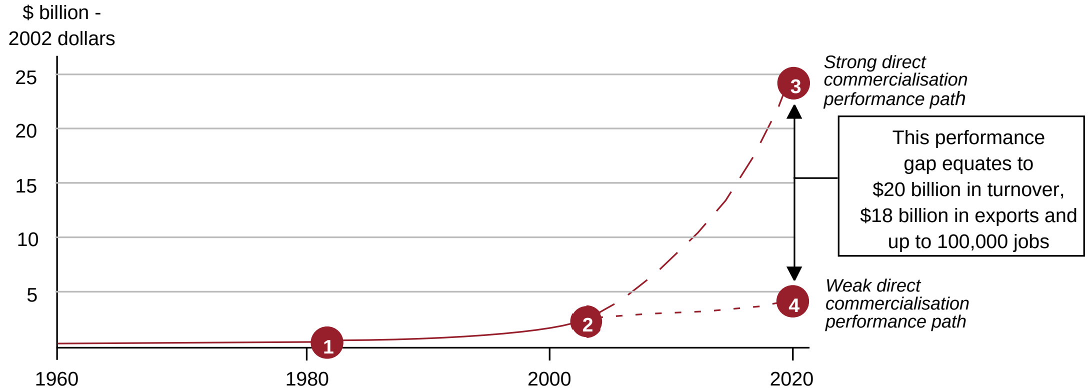
Data point 4: Total mature companies ~40. Conversely if you assume that success rate stagnates at 1 in 100 and that the pipeline only grows by 50 companies per annum then you would expect only around 25 new companies to reach maturity by 2020 (in addition to the 15 that were already mature by 2002).

The potential economic pay off of improved direct commercialisation performance

Figure 5.3 below sets out the significant potential economic pay-off associated with continuing to improve direct commercialisation performance in Australia.

Figure 5.3

TURNOVER OF TECHNOLOGY-BASED HIGH-GROWTH COMPANIES IN AUSTRALIA



Data point 1: Total turnover of ~$300 million per annum. Total turnover of technology-based high-growth companies was $300 million in 2002 dollars based on AATS report.

Data point 2: Total turnover of ~$1.5 billion per annum. Total turnover of only 10 identified case study companies in 2002 was around $900 million. If the $100 million royalty stream from licensing going to public research institution in 2000 represents 10 percent of turnover generated from the technologies under licence, of associated companies then total turnover from these technologies would be expected to be around $1 billion per annum. This 10 per cent royalty rate figure may in fact be lower which would imply a higher figure for total associated turnover. If the average turnover of the 166 companies with revenue between $5 and 50 million receiving R&D Start grants in 2001-02 was $10 million then a total revenue figure of $1.66 billion would be generated. Overall a figure of $1.5 billion seems a reasonable estimate.

Data point 3: Total turnover of ~$24 billion per annum. Assuming a total number of mature companies of 100 this implies total revenue of in excess of $5,000 million. However, the mature case study companies considered had average revenues of $150 million per annum – however this figure is skewed by inclusion of ResMed and Cochlear. Also, assuming that mature companies represent two thirds of total turnover and that there were 15 mature companies in 2002 when total turnover was $1,500 million, this implies an overall average turnover per mature company of $67 million. Under a higher growth scenario though, it would be reasonable to assume that as well as the success rate improving by 2.5 times the average size of mature companies could also improve by 2.5 times. Therefore if you assume the average size of the 95 mature companies in 2020 is $167 million turnover (and hence $150 million in exports per annum given the high export orientation of such companies) and that mature companies represent two-thirds of total revenues of all the technology-based high-growth companies in Australia, this suggests a total revenue figure of around $24,000 billion per annum in 2002 dollars and exports of around $21.5 billion.

Data point 4: Total turnover of ~$4.0 billion per annum. Assuming a total number of mature companies of 40 with average revenue of $67 million (as average size will not grow given that the success rate hasn't grown in this scenario) and that they represent two-thirds of total revenue this suggests a total revenue figure of around $4 billion per annum and exports of around $3.5 billion.

Achieving the 'strong performance' outcome requires:

- a continuation of current growth rate in the pool of high-growth technology-based companies;
- a continuation of recent improvements in the 'conversion rate' of new companies into mature companies; and
- alongside this, an increase in the average size of these successful companies.

Conversely, 'weak performance' outcomes would result from:

- a halving in the current growth rate in the pool of high-growth technology-based companies;
- no further improvement in the 'conversion rate' of new companies into mature companies; and
- alongside this, no real growth in the average size of these successful companies.

As the above figure indicates, the gap between achieving these 'strong' rather than 'weak' future direct commercialisation outcomes is economically very significant. The difference in the turnover and exports (associated with high-growth technology-based companies in Australia) under the two difference performance paths are estimated at $20 billion and $18 billion respectively (in 2002 dollars) by the year 2020.

Key conclusions

All the available data, while not comprehensive or precise, points to the same key conclusions – namely, that, while Australian performance in relation to high-growth technology-based companies has begun to improve significantly in recent years off a very low past level of performance, there is still considerable room for further improvement to be made.

The number of companies recently entering the commercialisation pipeline is very high compared to earlier periods and Australian performance in this area is catching up to Canada and the United States.

There are also some early indicators that the success rates for companies in this pipeline reaching 'maturity' are also improving on past levels.

This upturn in performance, particularly in relation to the number of new start-up companies entering the growth cycle, co-incided with the introduction since 1997 of a range of Government programs targeting the environment for commercialisation in Australia.

Consideration of the time lags associated with converting research into mature companies suggests that it is too soon yet to see the large economic pay-offs that may result from this recent improvement in performance regarding activity at the early stage of the commercialisation cycle. However, analysis of US experience suggests that the pay-offs accruing over the next five to ten years and beyond should be high.

For such a high performance scenario to be achieved, improving the success rates of high-growth technology-based companies is crucial – perhaps even more so than increasing the rate of such companies being created.

If support for the commercialisation infrastructure is withdrawn, there is reason to believe that recent rates of performance improvement in this area will not be sustained and that a return to relatively low performance levels could occur. While there are still problems within the commercialisation system to be addressed – such as IP management issues, limited outcomes monitoring, continued weakness in entrepreneurial skills base and culture, lack of critical mass in commercialisation entities operated by publicly funded research institutions and still relatively low levels of business R&D – there is little doubt that the policy decisions taken over the past five years have dramatically improved the quality of the commercialisation infrastructure in Australia. However, if we are to fully capitalise on public investment in research and development, more and faster growing technology-based companies are still needed.

The challenge now is for Australia to continue the rate of recent improvement so that major economic benefits can be realised over the next two decades. The key requirements for achieving such an improved future direct commercialisation performance are considered in Chapter 6.

Chapter 6

Key requirements for improved future direct commercialisation performance

Where does Australia now stand?

Over the last two decades there has been a gradual increase in policy interest in improving Australia's commercialisation performance and actions have been taken in a number of areas. These are discussed in Chapter 3 and 4.

Particularly since 1998 and most notably in the Commonwealth Government's 2001 innovation statement *Backing Australia's Ability*, improving the environment for commercialisation has become a major pillar of innovation policy alongside investing in the research base and building linkages between the major elements on the national innovation system.

Australia has gradually improved its performance from the very low level of commercialisation that took place in the 1980s, resulting in greater economic value creation occuring through the building new businesses.

In his appearance before the House of Representatives Standing Committee on Science and Innovation, the Chief Scientist summarised recent progress in the following way:

> "…we are on track for the sort of target that I had proposed to the Prime Minister's Science, Engineering and Innovation Council a year or so ago of creating 250 start-up companies from our public investment in R&D within five years, with an expectation that this will add $20 billion per annum…to our exports…[This] is telling us that we are now getting the settings more right than we have in the past."
>
> Dr Robin Batterham, As quoted in *Riding the Innovation Wave*, House of Representatives Standing Committee on Science and innovation

There has also been an improvement in Australia's position in the international league table as an innovative economy. A recent study by Gans and Stern[62] argues that over the last two decades Australia has been transformed from a classical "imitator" to a "second-tier" innovation economy. However, Australia has not yet lifted itself to the level of performance achieved by "first-tier" innovator nations.

This suggests that the investments in the innovation system that have been made in the last five years or so have not yet fully paid off. While this is to an extent a question of the time required to turns ideas into marketable products, services and processes, it also reflects the need to sustain the investment process for a considerable period of time.

[62] Gans, J. and Stern, S., (2003), *Assessing Australia's Innovative Capacity in the 21st Century*

What could be the gains of achieving first-tier innovator nation status?

A notable characteristic of "first-tier" innovator nations is that they posses a well developed set of commercialisation intermediaries, such as venture capital providers, people skilled in growing emerging, technology-based businesses and development oriented policies around the use of IP generated originally in the Universities and Public Sector Research Agencies. The presence of such intermediaries together with appropriate incentives enables the market to be brought to bear on taking ideas to the market.

With these enabling conditions in place we would expect to see a number of things develop.

First, we would expect to see strengthened growth in the population of small, emerging technology-based businesses. While growth in the population of such businesses has been growing over time in Australia the potential exists for this to be further strengthened.

Second, we would expect to observe an increasing proportion of the population of small, technology-based businesses breaking through to become "emerging globals". Australia has over the last two decades produced some companies that have achieved such a breakthrough – Cochlear and ResMed being the outstanding examples. These companies illustrate the potential upside in terms of value creation that such businesses can contribute to the economy.

Third, we would expect as a result of the increased population of technology-based businesses and the greater proportion of them that are able to become "emerging globals" that the aggregate impact of technology-based companies emerging from the commercialisation process in terms of contribution to economic value, well paid jobs and exports will be highly significant. Such companies have the potential to be an important source of dynamism for the Australian economy in coming decades adding diversification to the Australian economic activity portfolio.

Fourth, success in achieving recognition for Australia as becoming a "first-tier" innovator nation will assist the process of attracting innovation intensive activities of the leading research-based multinational companies to Australia. It will also assist the position of Australia in attracting and retaining highly qualified researchers and innovators in all areas of activity.

Finally, it is likely that a virtuous cycle will be established in which greater investment in the generation of ideas, will directly lead to the creation of greater value and jobs for the economy which in turn will increase Australia's capacity to invest in the generation of ideas. Achieving a self sustaining virtuous cycle like this will be vital to increasing living standards in Australia in the 21st Century.

What needs to be done?

The process of going from minds to markets can be relatively short in some areas – there are examples in ICT where this has been so – but in general it does appear that the more usual situation is that considerable periods of time must be allowed for the process to be worked through. Building successful businesses that can succeed in global markets when these are based on things other than technology as such generally requires a good deal of time. The same is true of most technology-based businesses especially when these are based on "breakthrough" technologies addressing markets that may not have been previously developed.

A consequence of the extended time period in going from minds to markets is that successful policies will need to be consistently applied over considerable periods of time if they are to have their full effect. As Gans and Stern point out, patience by policy makers is required. Cutting off successful programs prematurely is likely to result in poorer outcomes than would otherwise be the case.

While not always true, especially for incremental improvements in technology, nevertheless there is a germ of truth in the old rule of thumb for the relationship between research, development and commercialisation, in terms of the dimension of the investment required, is in the ratio 1:10:100. This suggests that first-tier innovator nations (those that are good at both incremental and breakthrough innovation) are likely to be those that are willing to devote the required proportion of resources to not just the R&D stage but also to commercialisation. The successful SBIR scheme of the US Federal government requires federal research bodies to set aside a certain proportion of their funding to assist the process of smaller companies taking ideas to the market. Given Australia's more challenging situation there is a case for ensuring commercialisation support is provided to a higher proportion of research funding than is the case in the US.

Experience shows that developing technology-based businesses is not just a question of ensuring that sufficient pre-seed and later stage venture capital is provided, but also that there are sufficient people possessing the range of skills needed to grow technology-based businesses. Commonwealth and State/Territory governments have sought to address the skill needs but more needs to be done.

IP is in many ways the mainspring of technology-based innovation. The Bayh-Dole Act of 1980 which took a very IP utilization positive approach to Universities and other research agencies receiving US Federal Government funding, has generally been recognized as an important element in the success achieved in technology-based innovation in the US. The Commonwealth Government has already identified IP policies of the Universities as an important issue for improving commercialisation performance.

The Australian research-based universities have all formed technology transfer and commercialisation related bodies. Some of these bodies seem to below optimal operating size and as noted by the Chief Scientist there may be a case for consolidation into a relatively small number of well resourced bodies able to address the needs of the Universities more effectively.

While a good deal of effort has been devoted to improving the linkages in the national innovation system – the CRC system and the ARC linkage grants program are a direct response to this issue – a case can be made that more should be done on the demand side. One option that would be worth considering would be to restructure the 125 per cent R&D tax concession to strengthen incentives for collaboration between businesses and the Universities and the Public Sector Research Agencies.

Finally, commercialisation outcomes have only recently begun to be measured in Australia unlike the situation in the US where the AUTM has long experience in performance measurement. Measurement is necessary both to assist understanding of the way value is being created through commercialisation and to benchmark Australia's performance against international comparators. The ongoing comprehensive measurement of commercialisation performance would be an appropriate role for the Australian Institute for Commercialisation for which it would need to be appropriately resourced.

Appendix One

References

Advisory Council on Science and Technology (Canada) (1999), *Public Investments in University Research: Reaping the Benefits*

Allen Consulting Group (1997), *Winning Companies and Jobs: How High Growth and Knowledge Intensive Industries Create Jobs. A report for the Australian Business Foundation*

Australian Academy of Technological Sciences (1983), *Developing high technology enterprises for Australia*

Australian Academy of Technological Sciences and Engineering (NSW Division), *Commercialising Innovation "The Second Step"* Workshop Proceedings Sydney – 10 May 2001

Australian Bureau of Statistics (ABS) (2003), Unpublished data drawn from publication category 8112.0, CPI index data and GDP data

Australian Centre for Innovation, Howard Partners, Carisgold, (2003), *Best Practice Processes for University Research Commercialisation*

Australian Research Council (ARC), (2001), *Mapping the Nature and Extent of Business – University Interaction in Australia*

ARC, CSIRO, NHMRC, (2002), *National Survey of Research Commercialisation: Year 2000*

Australian Science and Technology Council (1981), *Annual report for the period 1 July 1980 to 30 June 1981*

Australian Venture Capital Association Limited (2001), *2001 Yearbook: An Analysis of Australia Venture Capital*

Block, R., (1991), *Bringing the Market to Bear on Research*, Task Force on Commmercialisation of Research

Centre for International Economics, (2001), *Assessing the Contribution of CSIRO: CSIRO pricing review*

Chief Scientist, (2000), *The Chance to Change*

CHI Research, (2000), *Periodic Newsletter, Vol. VIII, No.1, July 2000*

Commonwealth Government (2001), *Backing Australia's Ability*

Commonwealth Government Budget 2003-04, *Science and Innovation*: *Table 1*

CSIRO (1997), *Media Release*, 29th January 1997

CSIRO (2003), *CSIRO Research Commercialisation Report 2001-2002*.

Department of Agriculture, Fisheries and Forestry Australia (2002), *Innovating Rural Australia*

Department of Employment Education and Training (1993), *Creating Economic Growth Through Enterprise Generation and Industry Research Partnerships: the role of the post-secondary education sector*

Department of Industry Science and Resources (2000), *Science and Technology Budget Statement 2000-01*

Erskinomics Consulting Pty Ltd (2003), *Critical Factors in Successful R&D: An International Comparison*

Gans, J. and Stern, S., (2003), *Assessing Australia's Innovative Capacity in the 21st Century*

House of Representatives Standing Committee on Science and Innovation (2003), *Riding the Innovation Wave: The Case for Increasing Business Investment in R&D*

Howard, J., (1997), *Investing for Growth. The Howard Government's Plan for Australian Industry.*

Howard, J., (2001), *Federation Address and Launch of "Backing Australia's Ability", Transcript.*

Industry Canada (1999), *University research and the commercialization of intellectual property in Canada*

Industry Research and Development Board (IR&D Board) (1996), *Annual Report: 1995-96*

IR&D Board (2002), *Annual Report: 2001-02*

Innovation Summit Implementation Group (2000), *Innovation – Unlocking the Future*

Kemp, D., (then) Minister for Education, Training and Youth Affairs, (1999) *Knowledge and Innovation: A Policy Statement on Research and Research Training*

Knowledge Commercialisation Australia (2003), *Forum and Fair of Ideas: Commercialisation Discussion Paper*

Management and Investment Companies Licensing Board (1988), *Annual Report 1987-88*

Mercer, D. and Stocker, J., (1998), *Review of Greater Commercialisation and Self Funding in the Cooperative Research Centres Programme*

Narin, F., Hamilton, K., Olivastro, D., (1997), *The Increasing Linkage Between US Technology and Public Science*, Research Policy, Volume 26, Issue 3

Narin, F., Albert, M., Kroll, P., Hicks, D., (2000), *Inventing Our future: The Link Between Australian Patenting and Basic Science*

National Research Council (1999), *SBIR: Challenges and Opportunities*, Annex B – The SBIR Program and NSF SBIR Commercialisation Results

OECD, (2001), *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*, STI Working Paper 2001/3

Prime Minister's Science Engineering and Innovation Council (PMSEIC), (2001), *Commercialisation of Public Sector Research*, Paper for seventh meeting, 28 June 2001

University of Melbourne, (2001), *R&D and Intellectual Property Scoreboard 2001: Benchmarking Innovation in Australian Enterprises*

Wills, P.J., (1998), *The Virtuous Cycle: Working together for health and medical research*, Health and medical research strategic review discussion document, December 1998

Wing, P, (1993), This Gown for Hire. A History of the Australian Tertiary Institutions Commercial Companies Association.

Yencken, J., (2002), *CRCs and Spin-off Companies: Findings from a Survey by the Cooperative Research Centres Association Inc*