

# The role of science, research and technology in lifting Australian productivity

# 4

PROJECT

FINAL REPORT

AUSTRALIAN ACADEMY  
OF THE HUMANITIES  
AUSTRALIAN  
ACADEMY OF SCIENCE  
ACADEMY OF THE SOCIAL  
SCIENCES IN AUSTRALIA  
AUSTRALIAN ACADEMY  
OF TECHNOLOGICAL  
SCIENCES AND ENGINEERING

**ACOLA**



**AUSTRALIAN  
COUNCIL OF  
LEARNED  
ACADEMIES**

SECURING  
AUSTRALIA'S  
FUTURE

A three-year research program funded by the Australian Research Council and conducted by the four Learned Academies through the Australian Council of Learned Academies for PMSEIC, through the Office of the Chief Scientist. *Securing Australia's Future* delivers research-based evidence and findings to support policy development in areas of importance to Australia's future.

EXPERT  
WORKING  
GROUP

Dr John Bell FTSE (Chair)  
Dr Bob Frater AO FAA FTSE (Deputy)  
Leslie Butterfield  
Professor Stuart Cunningham FAHA  
Professor Mark Dodgson FASSA  
Professor Kevin Fox FASSA  
Professor Tom Spurling AM FTSE  
Professor Elizabeth Webster

© Australian Council of Learned Academies (ACOLA)

ISBN 978-0-9875798-3-6

This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of it may be reproduced by any process without written permission from the publisher. Requests and inquiries concerning reproduction rights should be directed to the publisher.

DATE OF PUBLICATION

June 2014

PUBLISHER

Australian Council of Learned Academies  
Level 1, 1 Bowen Crescent  
Melbourne Victoria 3004 Australia  
Telephone: +61 (0)3 98640923  
[www.acola.org.au](http://www.acola.org.au)

SUGGESTED CITATION

Bell, J, Frater, B, Butterfield, L, Cunningham, S, Dodgson, M, Fox, K, Spurling, T and Webster, E (2014). *The role of science, research and technology in lifting Australian productivity*. Report for the Australian Council of learned Academies, [www.acola.org.au](http://www.acola.org.au).

REPORT DESIGN

Lyrebird  
[joashley@live.com.au](mailto:joashley@live.com.au)

# The role of science, research and technology in lifting Australian productivity



Australian Academy of Science



ACADEMY OF THE SOCIAL SCIENCES  
IN AUSTRALIA



ACOLA is the interface of the four Learned Academies:

Australian Academy of the Humanities

Australian Academy of Science

Academy of the Social Sciences in Australia

Australian Academy of Technological  
Sciences and Engineering

**ACOLA**



**AUSTRALIAN  
COUNCIL OF  
LEARNED  
ACADEMIES**

# Australia's Learned Academies



## Australian Academy of the Humanities

The Australian Academy of the Humanities advances knowledge of, and the pursuit of excellence in, the humanities in Australia. Established by Royal Charter in 1969, the Academy is an independent organisation of more than 500 elected scholars who are leaders and experts in the humanities disciplines.

The Academy promotes the contribution of the humanities disciplines for public good and to the national research and innovation system, including their critical role in the interdisciplinary collaboration required to address societal challenges and opportunities.

The Academy supports the next generation of humanities researchers and teachers through its grants programme, and provides authoritative and independent advice to governments, industry, the media and the public on matters concerning the humanities.

[www.humanities.org.au](http://www.humanities.org.au)



Australian Academy of Science

## Australian Academy of Science

The Australian Academy of Science is a private organisation established by Royal Charter in 1954. It comprises ~450 of Australia's leading scientists, elected for outstanding contributions to the life sciences and physical sciences. The Academy recognises and fosters science excellence through awards to established and early career researchers, provides evidence-based advice to assist public policy development, organises scientific conferences, and publishes scientific books and journals. The Academy represents Australian science internationally, through its National Committees for Science, and fosters international scientific relations through exchanges, events and meetings. The Academy promotes public awareness of science and its school education programs support and inspire primary and secondary teachers to bring inquiry-based science into classrooms around Australia.

[www.science.org.au](http://www.science.org.au)

## Working Together – ACOLA

The Australian Council of Learned Academies (ACOLA) combines the strengths of the four Australian Learned Academies: Australian Academy of the Humanities, Australian Academy of Science, Academy of Social Sciences in Australia, and Australian Academy of Technological Sciences and Engineering.



ACADEMY OF THE SOCIAL SCIENCES  
IN AUSTRALIA

### Academy of Social Sciences in Australia

The Academy of the Social Sciences in Australia (ASSA) promotes excellence in the social sciences in Australia and in their contribution to public policy. It coordinates the promotion of research, teaching and advice in the social sciences, promote national and international scholarly cooperation across disciplines and sectors, comment on national needs and priorities in the social sciences and provide advice to government on issues of national importance.

Established in 1971, replacing its parent body the Social Science Research Council of Australia, itself founded in 1942, the academy is an independent, interdisciplinary body of elected Fellows. The Fellows are elected by their peers for their distinguished achievements and exceptional contributions made to the social sciences across 18 disciplines.

It is an autonomous, non-governmental organisation, devoted to the advancement of knowledge and research in the various social sciences.

[www.assa.edu.au](http://www.assa.edu.au)



### Australian Academy of Technological Sciences and Engineering

ATSE advocates for a future in which technological sciences and engineering and innovation contribute significantly to Australia's social, economic and environmental wellbeing. The Academy is empowered in its mission by some 800 Fellows drawn from industry, academia, research institutes and government, who represent the brightest and the best in technological sciences and engineering in Australia. Through engagement by our Fellows, the Academy provides robust, independent and trusted evidence-based advice on technological issues of national importance. We do this via activities including policy submissions, workshops, symposia, conferences parliamentary briefings, international exchanges and visits and the publication of scientific and technical reports. The Academy promotes science, and maths education via programs focusing on enquiry-based learning, teaching quality and career promotion. ATSE fosters national and international collaboration and encourages technology transfer for economic, social and environmental benefit.

[www.atse.org.au](http://www.atse.org.au)

By providing a forum that brings together great minds, broad perspectives and knowledge, ACOLA is the nexus for true interdisciplinary cooperation to develop integrated problem solving and cutting edge thinking on key issues for the benefit of Australia.

ACOLA receives Australian Government funding from the Australian Research Council and the Department of Education.

[www.acola.org.au](http://www.acola.org.au)

# Contents

List of figures	8
List of tables	9
List of boxes	9
Acronyms	10
Project aims	12
Executive summary	14
Key findings	22
Chapter 1: Introduction	26
1.1. Background	26
1.2. About this report	29
Chapter 2: Building Australia's future manufacturing industries	32
2.1. Australia's industrial future	34
2.2. International trends in manufacturing and services	41
2.3. Australian manufacturing firms responding to trends	49
2.4. Role of Government in supporting manufacturing	54
2.5. Conclusions	62
2.6. Findings	63
Chapter 3: Effective collaboration to improve Australian innovation and research impact	64
3.1. Collaboration between business and publicly funded researchers	66
3.2. Collaboration between businesses	82
3.3. Conclusions	89
3.4. Findings	90

Chapter 4: An innovative workforce to meet Australia’s future needs	92
4.1. Key issues for an innovative workforce	93
4.2. Building a broader science, research and technology base in Australia’s workforce	101
4.3. Future workforce needs of Australian industries	111
4.4. Conclusions	118
4.5. Findings	119
Chapter 5: The contribution of innovation to productivity and economic growth	120
5.1. Productivity growth: definition, importance and sources	122
5.2. Investment in knowledge capital and economic growth	127
5.3. R&D and other intangibles	130
5.4. Public R&D investment and productivity performance	131
5.5. Conclusions	134
5.6. Findings	134
Annex: Intangibles and the productivity decline	136
References	142
Expert working group	152
Acknowledgements	154
Evidence gathering	156
Appendices	162
Appendix 1: HASS-STEM skill mixing in innovative Australian firms	162

# List of figures

Figure 2.1: Manufacturing contributes disproportionately to exports, innovation and productivity growth	34	Figure 3.6: Australian firms have low levels of international collaboration	85
Figure 2.2: Industry contribution to Australian GDP, 1975-2013 percentage shares	35	Figure 4.1: Domestic IT undergraduate enrolments, by student status, and completions	94
Figure 2.3: Australian manufacturing by sub-sector, 1982-83 to 2012-13	35	Figure 4.2: Australian firms' performance in business management, compared to global best performers	99
Figure 2.4: Industry employment, 2011-2012	36	Figure 4.3: Human resources devoted to R&D in Australia, by occupation type	103
Figure 2.5: Business expenditure on R&D by sector, 2011-12	37	Figure 4.4: R&D personnel, per 1,000 employment, 2011	104
Figure 2.6: GVC participation index as a percentage share of gross exports, 2009	42	Figure 4.5: Employment in knowledge-intensive services as a percentage of total employment, 2011	104
Figure 2.7: The Boeing 787 Dreamliner manufactured around the world	45	Figure 4.6: Contributions of education completions and skilled migration to the supply of professional engineers in Australia	105
Figure 2.8: Investment in tangible and intangible capital as a proportion of GDP, 2006	47	Figure 4.7: International comparison of business expenditure on R&D, 2011	105
Figure 2.9: Average management performance in manufacturing	48	Figure 4.8: Proportion of research personnel in business, higher education, and government sectors	106
Figure 2.10: Venture capital investments as a percentage of GDP, 2012	52	Figure 4.9: Evolution of Australia's research workforce by sector, 1992-2011	106
Figure 2.11: Where crowdfunding fits on the funding lifecycle	53	Figure 4.10: Total males and females in selected engineering occupations	110
Figure 2.12: Direct government investment in business R&D and tax incentives for R&D, 2011	55	Figure 5.1: Labour productivity growth, real GDP per hour worked, annual average	123
Figure 2.13: Estimated Government investment in science, research and innovation 2012-13	56	Figure 5.2: Market sector cumulative multifactor productivity indexes	124
Figure 3.1: The multifaceted role of the university	66	Figure 5.3: R&D, innovation and productivity growth	126
Figure 3.2: Different models of collaboration, balancing short and long term with openness and protection	67	Figure 5.4: GERD as a proportion of GDP, Australia and OECD average, 1996-97 to 2012-13	129
Figure 3.3: Scope for collaboration	68	Figure 5.5: BERD as a proportion of GDP, Australia and OECD average, 1996-97 to 2012-13	129
Figure 3.4: Firms collaborating on innovation with higher education or public research institutions	73		
Figure 3.5: The role of intermediaries in the innovation system	76		

# List of boxes

Figure 5.6: BERD as a percentage of GDP, 2011	130	Box 2.1: PCAST's recommended strategy for US advanced manufacturing	39
Figure 5.7: Australian Government investment on science and innovation 2012-13	132	Box 2.2: Textor Technologies and their role within multinational Kimberly-Clark	43
Figure 5.8: Australian Government support for research and innovation 1993-94 to 2012-13, 2011-12 \$ billion	133	Box 2.3: Botanical Resources Australia	43
Figure 5.9: Australian Government support for research and innovation 1993-94 to 2012-13, per cent of GDP	133	Box 2.4: Boeing	44
Figure A.1: Market sector real tangible and intangible investment, 2011-12 dollars, chain volume measures, \$ billion	137	Box 2.5: Flying Machine	46
Figure A.2: Shares of nominal total intangible investment, by asset type – per cent	138	Box 2.6: Orica Ltd	49
Figure A.3: Multifactor productivity, market sector, 1974-75 to 2012-13, Index 1974-75 = 100	138	Box 2.7: A W Bell	50
Figure A.4: Market sector MFP growth and public support for research agencies, higher education and business sector	139	Box 2.8: Nanosonics	52
		Box 2.9: Re-Time Pty Ltd	57
		Box 2.10: Small Business set-asides for R&D – a new approach for Australia?	58
		Box 2.11: The UK Technology Strategy Board	60
		Box 3.1: Examples of large-scale collaborations	72
		Box 3.2: Current measures to encourage collaboration	75
		Box 3.3: InnovationXchange	78
		Box 3.4: KTP Strategic Review – summary of main findings and conclusions	79
		Box 3.5: Imperial College mechanisms for engaging business	80
		Box 3.6: The Victorian Direct Manufacturing Technology Centre (VDMTC)	82
		Box 3.7: Important barriers to international collaboration on the part of SMEs	87
		Box 4.1: Cochlear HASS-STEM mixing case study	98
		Box 4.2: Initiatives to increase participation of women in STEM	111
		Box 4.3: Convergence of life sciences, physical sciences and engineering	116
		Box 4.4: Linking the developmental capacities of tertiary education to labour market demands	118
		Box 5.1: Sources of productivity growth	122
		Box 5.2: Connolly & Gustafsson 2013, Australian Productivity Growth: Trends and Determinants	125
		Box 5.3: Parham 2012, Australia's Productivity Growth Slump: Signs of Crisis, Adjustment or Both?	125
		Box 5.4: Measuring intangible capital	130

# List of tables

Table 2.1: Australian manufacturing by sub-sector contribution to GDP (2012-13)	35
Table 2.2: The number of crowdfund investing platforms in selected countries	54
Table 4.1: Summary of STEM qualifications in the Australian population, 2011	102
Table 4.2: Employment characteristics of people with STEM qualifications, by selected occupation groups, 2011	103
Table A.1: Estimates of nominal intangible investment in the Australian market sector	136

# Acronyms

ABF	Australian Business Foundation	CRCA	Cooperative Research Centres Association
ABS	Australian Bureau of Statistics	CRCs	Cooperative Research Centres
ACIP	Advisory Council on Intellectual Property	CSEF	Crowd Sourced Equity Funding
ACMA	Australian Communications and Media Authority	CSIRO	Commonwealth Scientific and Industrial Research Organisation
ACOLA	Australian Council of Learned Academies	CTD	Capability Technology Demonstrator
ADF	Australian Defence Force	CWL	Centre for Workplace Leadership
AiGroup	Australian Industry Group	DBI	Victorian Department of Business and Innovation
All	Australia India Institute	DEA	Danish Business Research Academy
AIMS	Australian Institute of Marine Science	DEST	Department of Education, Science and Training
APA	Australian Postgraduate Awards Scheme	DFAT	Department of Foreign Affairs and Trade
ARC	Australian Research Council	DIISR	Department of Innovation, Industry, Science and Research
ASIC	Australian Securities & Investments Commission	DIISRTE	Department of Industry, Innovation, Science, Research and Tertiary Education
ATSE	Australian Academy of Technological Sciences and Engineering	DITR	Department of Industry, Tourism and Resources
AusTrade	Australian Trade Commission	DMITRE	South Australian Department of Manufacturing, Industry, Trade, Resources and Energy
AVCAL	Australian Private Equity & Venture Capital Association Limited	DMTC	Defence Materials Technology Centre
AWPA	Australian Workforce and Productivity Agency	DNATF	Danish National Advanced Technology Foundation
BERD	Business Expenditure on Research and Development	DPMC	Department of Prime Minister and Cabinet
BDC	Business Development Bank of Canada	DSDBI	Victorian Department of State Development, Business and Innovation
BIAC	Business and Industry Advisory Committee to the OECD	DSTO	Defence Science and Technology Organisation
BIS	Department of Business, Innovation and Skills UK	EEF	EEF The Manufacturers' Organisation, UK
BRA	Botanical Resources Australia Pty Ltd	ERA	Excellence in Research Australia
CAESIE	Connecting Australian European Science and Innovation Excellence	ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
CAMC	Corporations and Markets Advisory Committee	ESS	Employer Skills Survey
CBR	Centre for Business Research	EU	European Union
CFI	Crowdfund investing	EU-15	15 Member States of the European Union
CIE	Centre for International Economics		
CIG	Commonwealth Industrial Gases		

EWG	Expert Working Group	PC	Productivity Commission
FDI	Foreign Direct Investment	PCAST	President's Council of Advisors on Science and Technology (US)
GAO	Government Accountability Office (US)	PISA	Programme for International Student Assessment
GE	General Electric	PoCP	Proof of Concept Programme
GERD	Government Expenditure on Research and Development	PwC	PricewaterhouseCoopers
GDP	Gross Domestic Product	R&D	Research and Development
GSCs	Global Supply Chains	RIBG	Research Infrastructure Block Grants scheme
GVCs	Global Value Chains	RTS	Research Training Scheme
HASS	Humanities, Arts and Social Sciences	SBIR	Small Business Innovation Research (US)
IAS	Institute of Advanced Studies, University of Western Australia	SEMATECH	Semiconductor Manufacturing Consortium
ICT	Information and Communications Technology	SERA	Survey of Employers who have Recently Advertised
IFS	International Foundation for Science	SKA	Square Kilometre Array
IGS	Institutional Grants Scheme	SMEs	Small and medium sized enterprises
IHGSC	International Human Genome Sequencing Consortium	SNA	System of National Accounts
InfoDev	Information for Development Program	SOL	Shortage Occupation List
IP	Intellectual Property	SRIBTs	Science, Research and Innovation Budget Tables
IPR	Intellectual Property Rights	STEM	Science, Technology, Engineering and Mathematics
IRU	Innovative Research Universities, Australia	STIUP	Small Technologies Industry Uptake Program
KTP	Knowledge Transfer Partnerships	STTR	Small Business Technology Transfer (US)
MACUK	Migration Advisory Committee (UK)	TAFE	Technical and Further Education
MBA	Master of Business Administration	TSB	Technology Strategy Board (UK)
MEP	Manufacturing Extension Partnership (US)	TTOs	Technology Transfer Offices (UK)
MFP	Multifactor productivity	UK	United Kingdom
MIT	Massachusetts Institute of Technology	UKCES	UK Commission for Employment and Skills
MRIs	Medical Research Institutes	UNCTAD	United Nations Conference on Trade and Development
MVP	Market Validation Program	USA	United States of America
NAS	National Academy of Sciences (US)	VDMTC	Victorian Direct Manufacturing Technology Centre
NHMRC	National Health and Medical Research Council	VET	Vocational Education and Training
NIST	National Institute of Standards and Technology (US)	WEF	World Economic Forum
OECD	Organisation for Economic Cooperation and Development	WTO	World Trade Organisation
PBBF	Performance Based Block Funding		



# Project aims

This project aimed to identify opportunities for applying knowledge and skills in science and research across a range of industries and sectors including private and public enterprises, and examine how to enhance innovation, creativity and productivity in the Australian workforce and business practices that will drive Australia's prosperity.

This project aimed to address issues including, but not limited to the following:

1. What are the attributes of an innovative workforce?
  - a. How do we generate increased awareness and acceptance of the value of a science degree in business and in industry?
  - b. How do we build a broader science, research and technology base in the workforce?



2. What are the future workforce needs of Australian industries?
3. What are the future manufacturing issues we need to address?
4. How can we maximise the translation of research and innovation into productivity?
5. How can we more effectively collaborate internationally to improve Australia's global reach and international impact in science, research and technology?

The above aims form the terms of reference for the project.

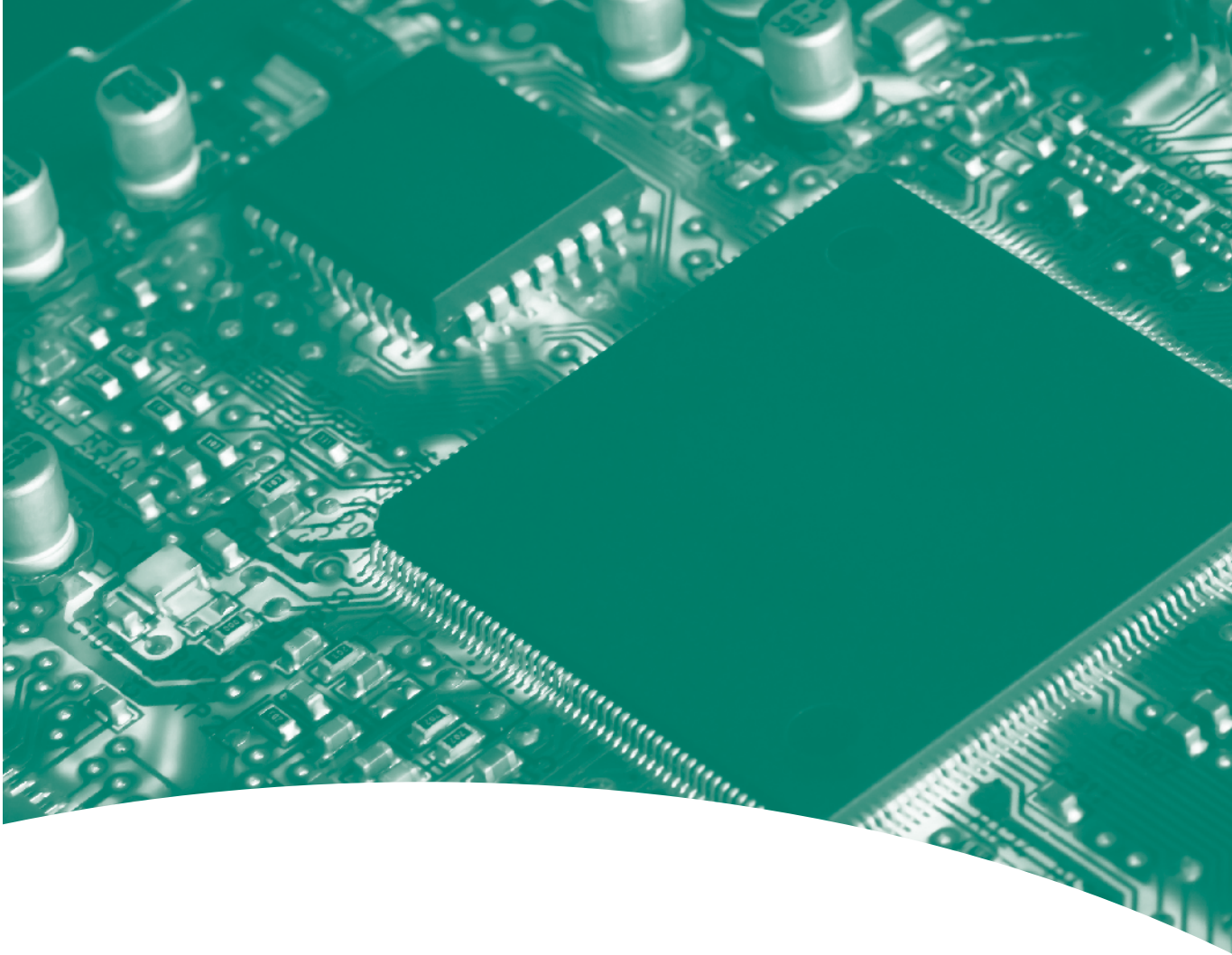
# Executive summary

## **Lifting productivity growth is the key to Australia's prosperity**

Productivity is critical for Australia's prosperity, economic growth, and social wellbeing. Lifting productivity growth is a critical priority for Australia. Innovation is a key driver of productivity growth. This report examines how investment in and application of science, research and technology can enhance creativity and innovation to lift productivity in Australia.

This report has three major conclusions:

- Building Australia's future industries will depend on adopting technological innovation to develop high-value products and services for a global market.
- Improving collaboration in Australia, between businesses and between business and publicly funded research, will significantly enhance innovation. International collaboration is also critically important. Both domestic and international collaboration improves the productivity and competitiveness of Australian technology-based firms.
- An innovative workforce that combines technical and non-technical disciplines, and enables good business management, is essential to underpin the competitive advantage of Australian industries and realise opportunities to lift productivity.



## Innovation is vital to Australia's future manufacturing industries

**Manufacturing plays an important role in Australia's economy.** It accounts for around 7 per cent of GDP (\$104 billion), 11 per cent of employment, 25 per cent of business R&D and 34 per cent of merchandise exports. However, there are many challenges facing Australia's manufacturing sector. In recent decades there has been a decline in the contribution of manufacturing to Australia's gross domestic product (GDP), employment share and productivity, while the contribution of the services sector to GDP has increased.

**There is no longer a clear delineation between the manufacturing and services sectors.** Firms are increasingly offering services integrated with a manufactured product. This is enabled by an Internet-connected world, where innovations are frequently tied to a service component.

**Advanced manufacturing technologies provide opportunities for Australia.** Advanced manufacturing builds new industrial sectors and creates high quality jobs. Technological advances, such as 3D printing and bio-manufacturing, are opening up opportunities for the growth of high-tech manufacturing industries and services, especially where these are linked into global value chains.

**Advanced manufacturing** involves the innovative application of technologies, processes and methods to product design and production. A number of leading OECD countries including the USA, Canada, Korea and Germany have adopted targeted measures to assist firms in this area.

**To compete in a global market, Australian firms need to understand international trends in manufacturing.** Where firms are not leaders in their field (e.g. through the performance of R&D), they need to be ‘fast followers’ through the adoption of technologies from overseas. To be competitive, firms need to invest in new knowledge and practices, in order to benefit from emerging opportunities. Becoming an early adopter of technology and fostering advanced manufacturing techniques allows greater output and efficiency, enhancing a firm’s share of the market. The low level of international engagement by Australian firms makes it difficult for them to access new, high-technology, niche sectors.

**Global value chains provide the ability to share knowledge, processes and skills.** Global value chains involve the creation, production and delivery of product, spread between a number of companies across the world. Global value chains can initiate longer term collaborations. They can make an important contribution to productivity and firm growth. However, Australian firms are generally not well linked to global value chains compared to firms in other OECD countries.

**Information and communications technology (ICT) infrastructure is critical to the operation of effective global value chains.** A high-speed open-access broadband network has the potential to drive economic growth and lift productivity by reducing business costs.

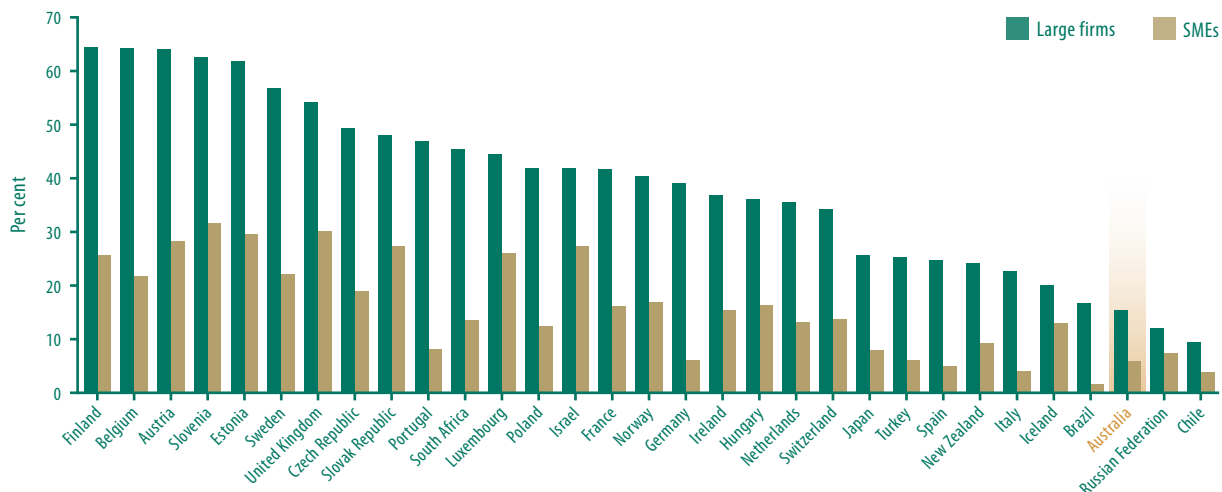
**Manufacturing in Australia is dominated by small to medium enterprises.** SMEs make up more than 90 per cent of all firms in this sector and most do not operate on a global scale. They have strong innovative potential but are faced with several barriers to growth, such as: a lack of funds; risk; and a lack of access to infrastructure, processes and knowledge networks.

**Facilitating the creation and growth of innovative firms of all sizes is essential to build Australia’s future industries.** This requires access to venture capital and new measures such as crowd sourced equity funding. However, the lack of venture capital in Australia, in comparison with other leading OECD countries, can cause some start-up companies with innovations to fail or to move overseas.

Moving overseas can be to Australia’s disadvantage, particularly if it takes place before a company has established an Australian base.

**Australia can learn from international best practice in providing support to SMEs.** Examples of successful measures include the US Small Business Innovation Research (SBIR) Program and Manufacturing Extension Partnership, the Danish Funding Agency for Technology and Innovation, and the UK Knowledge Transfer Partnerships. Long-term stability is a key factor in the success of these assistance programs, for example the SBIR program has been in operation for over thirty years.

### Australian firms have low levels of international collaboration

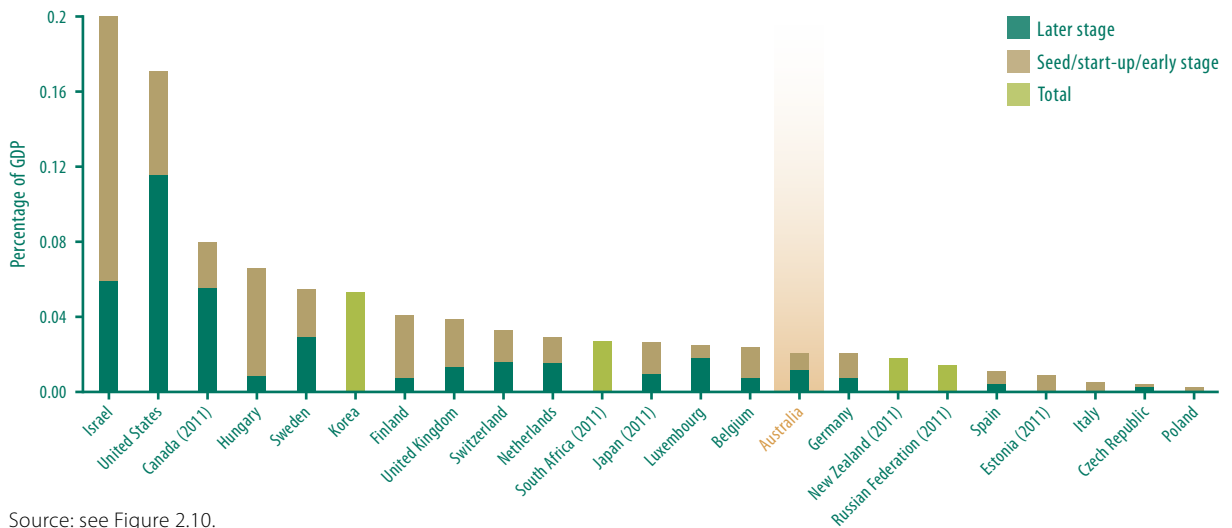


Source: For notes and source see Figure 3.6.

Unlike most other OECD countries, Australia has a history of frequent changes to assistance measures. This makes it difficult for business to plan for and have confidence in government assistance. The Commonwealth Government has a few examples of well-designed measures to assist firms (e.g. the Researchers in Business Program), however they are fragmented, lack scale and continuity. In contrast, Canada's Industrial Research Assistance Program has been in operation since 1965, albeit with some minor adjustments over the years. Its budget in 2012 was more than \$A250 million.

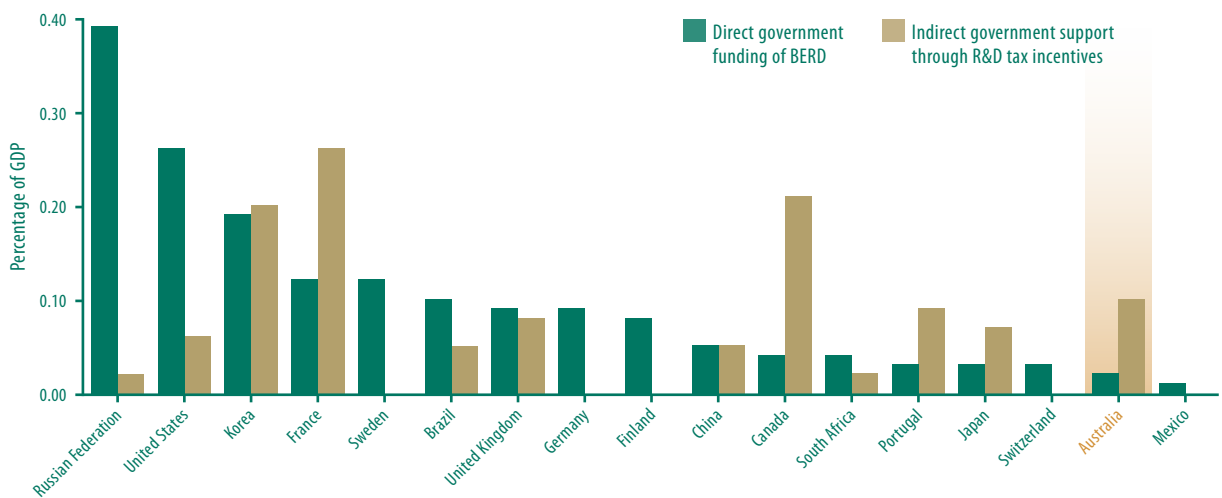
In comparison to other leading countries, direct government support for Australian business R&D is very low. By working together and adopting some of these measures, Commonwealth and State governments could build innovative capability, enhance economic growth and improve productivity. Providing appropriate assistance to Australian SMEs will enable them to grow into globally competitive multi-national enterprises (MNEs). MNEs play an important role in supporting a strong, innovative and diversified industry base.

### Venture capital investments as a percentage of GDP 2012 (US\$ current prices)



Source: see Figure 2.10.

### Direct government investment in business R&D and tax incentives for R&D, 2011



Source: see Figure 2.12.

## Effective collaboration is critical to improve Australian innovation and research impact

**Collaboration between firms and researchers can increase innovation in many ways.** Examples include promoting awareness of innovative opportunities as well as facilitating the adoption of new technologies, approaches and ideas. Collaboration has significant benefits for boosting business competitiveness and enhancing the impact of publicly funded research.

**There are many forms of collaboration.** It can occur through strategic alliances, joint ventures and R&D consortia. Collaboration can occur both nationally and internationally, in vertical arrangements within supply or value chains, and in horizontal structures involving parties engaged in similar activities. Collaboration between businesses (both SMEs and large firms) and publicly funded research organisations is an important driver of innovation and the translation of research into economic and social benefits. International scientific collaboration is increasingly necessary to address global challenges.

**Collaboration can provide businesses, particularly SMEs, with opportunities to boost their productivity.** Because we cannot be leaders in many technologies, Australian businesses must be early adopters of innovations developed elsewhere. International collaboration can help businesses to access new markets and networks.

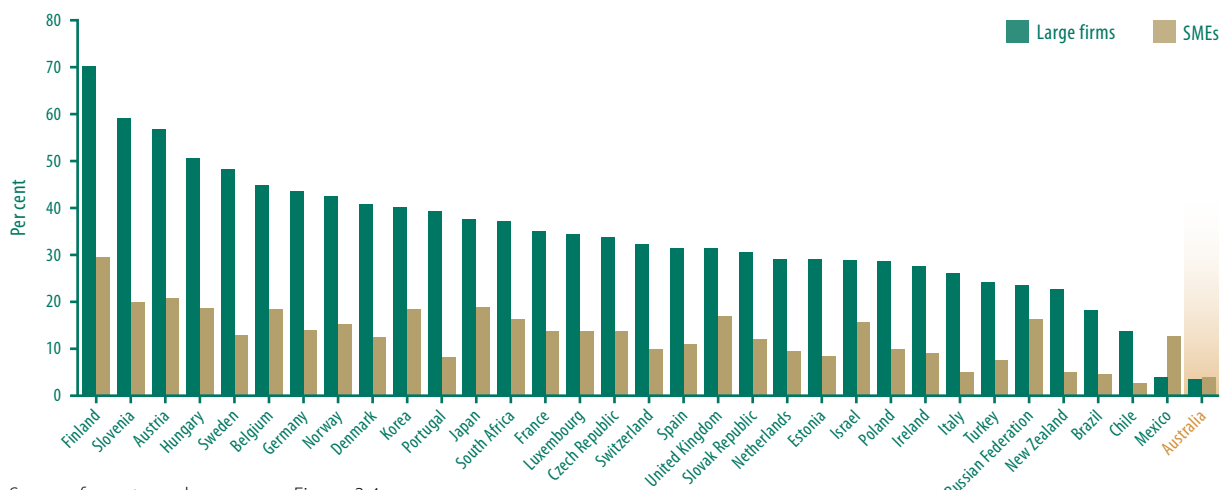
Through collaboration, firms can mobilise additional resources and access expertise needed to tackle complex issues and projects. This facilitates learning, capability development and an ability to deal with risk and uncertainty. The capacity to attract collaborators and work effectively with them is central to the ability of organisations to create, capture, and deliver value, and hence their continuing survival and development.

**The key drivers of innovation are firm size, formalised planning and investment in employee skills, especially managerial.** Putting this another way: well-managed firms are more innovative. A study commissioned for this project highlighted the existence of a number of virtuous cycles between productivity, internationalisation and innovation. It demonstrated that there is a cyclical relationship between innovation and collaboration where collaboration improves the innovativeness of firms and innovation also supports further collaboration.

Despite the many recognised benefits of collaboration, evidence suggests that Australian businesses collaborate less than their OECD counterparts. This is the case for both national and international collaboration. Australia has not made effective use of collaboration between businesses and publicly funded research organisations to build innovative capability.

The low levels of networking and collaboration remain a significant shortcoming in the Australian innovation system, which is a problem for

### Firms collaborating on innovation with higher education or public research institutions



Source: for note and source see Figure 3.4.

Australia because so much of our research effort takes place in the public sector.

**There are fundamental systemic barriers to collaboration between businesses and research organisations.** For example, there are: some

barriers (e.g. Excellence in Research Australia); few incentives for researchers to collaborate with business; financial barriers for SMEs to becoming involved in collaboration; mismatches in the timing horizons of potential partners; low levels of technically-skilled employees in Australian firms to interact with public sector researchers; and a paucity of collaborative management skills. The level of government support in Australia for international collaboration is declining at a time when its significance is increasing.

**There are opportunities to learn from good practice approaches to improve collaboration.**

Evidence from both Australia and overseas suggests there is value in utilising procurement policies and innovation intermediaries of various types. With the right incentives research organisations, especially universities, could become more strategic in developing partnerships and more effective in their incentivisation and management.

**Broadening the criteria by which government evaluates research organisation collaboration performance** would more accurately capture the breadth of their engagement activities. Greater dividends from collaboration, and making better use of public investment in research, would improve innovation, research management and productivity in Australia.

## Australia needs an innovative workforce

**An innovation-capable workforce is critical to the goal of increasing productivity.** There has been a shift in developed economies towards greater requirements for business acumen and interpersonal skills, driving increased levels of education. Many of the fastest growing occupations and emerging industries require STEM skills and knowledge, as well as general business skills.

**Urgent efforts are needed to improve language, literacy and numeracy skills.** This will enable the skill deepening and increased participation that the Australian economy needs. The Australian Workforce and Productivity Agency's 2013 National Workforce Development Strategy provides a roadmap to develop Australia as a knowledge intensive economy, supporting productivity growth through cutting-edge innovation. Increasing participation will require greater participation in tertiary education from less advantaged sectors of the population.

**Innovation involves more than technical skills.** It also needs people who understand systems, cultures and the way society uses and adopts new ideas. Much has been made of the importance of having people in knowledge-based enterprises who have both depth and breadth. Innovation needs depth of disciplinary and/or technological expertise. However, this expertise needs to be allied with the ability to effectively and efficiently integrate various knowledge bases and skill sets and deploy skills such as team building and emotional intelligence. Social sciences and the humanities make a significant contribution to innovation and productivity improvement.

Another way to understand the importance of this combination of depth and breadth is by seeing it as the intersection of science, technology, engineering and mathematics (STEM) and humanities, arts and social sciences (HASS) disciplinary inputs in knowledge-based firms.

**Innovation management is becoming increasingly important to enable firms to adapt to new challenges.** The quality of business management is critical. The concept of management, and particularly innovation management, covers a wide area incorporating governance, leadership, culture, finance, skills and strategy, new product and service developments and intellectual property management. Some, but not all, of these require or benefit from formal STEM education. However, evidence suggests that Australia's business management performance is well behind the leading countries.

**Business management in Australian firms falls well short of best-practice.** Given the importance of business management for business growth and competitiveness, lifting business management performance in Australia is an important objective for government, business and industry organisations.

**Entrepreneurial skills are needed to encourage and enable graduates to set up new business enterprises,** particularly those with strong technical backgrounds. This could be facilitated by entrepreneurial training at secondary and tertiary education stages.

**There is a positive association between investment in training and firm performance.** This is particularly so where training forms part of a business or wider human resource management strategy. Effective workplace training is also an important aspect of a firm's response to potential skills shortages.

## Research and innovation make important contributions to productivity and economic growth

There is widespread agreement in the literature that research and innovation are major driving forces behind long-term productivity and economic growth. However, productivity has a number of components that are difficult to measure. This makes analysis a more complex task. Some of the commentary in the media on single-year multifactor productivity figures is superficial.

**Australia's productivity grew during the mid-1990s as a result of the adoption of ICT and microeconomic reform.** Since that time, productivity growth has declined. Sources of productivity growth include: changes in the quality and quantity of labour and other inputs; diffusion of ideas; technological improvements; sources of new knowledge; changes in efficiency; changes in the functioning of markets; returns to scale; and changes in incentives.

**There is a wide dispersion in the productivity performance of Australia's 'market sectors'.** Overall, multi-factor productivity for these sectors

has grown by 16 per cent in the period 1989-90 to 2012-13. However, mining was 35 per cent less productive in 2012-13 than in 1989-90, largely explained by extensive capital investment without a corresponding increase in output. On the other hand the agriculture, forestry and fishing sector improved its productivity by 72 per cent over the same period, partly due to investment in research and uptake of new technology.

While there are many possible influences on productivity, the literature shows that innovation makes an important contribution to increasing productivity. Productivity benefits from research and successful innovations are not fully absorbed by the innovating organisations or firms, but rather they diffuse through the rest of the economy leading to positive externalities in growth and the productivity performance of the other users. Spill-over benefits occur when the benefits flow to parties other than those involved in the research, such as the users of new products derived from the research.

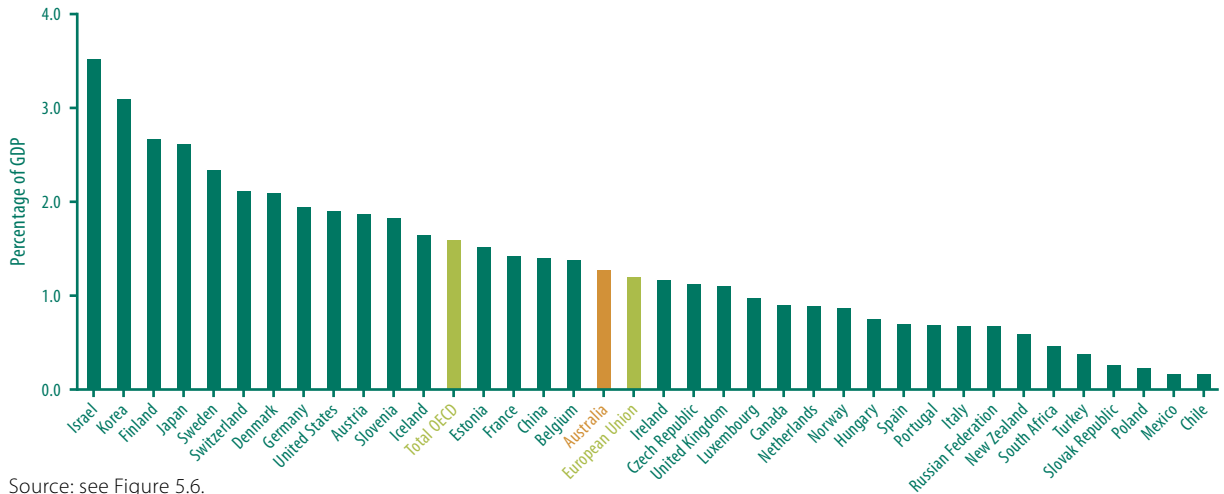
OECD work has found that a one per cent increase in business research and development (R&D) could be expected to generate a long run increase in productivity of 0.11 per cent and a similar increase in public research would increase productivity by 0.28 per cent. R&D is a major contributor to knowledge capital and an important element of innovation. There is a broad range of other business sector knowledge capital and other intangible assets that can significantly affect productivity. Examples include product design, market development and organisational capability.

**Increasing levels of R&D in the medium-term to at least the OECD average would be an appropriate immediate policy objective.**

Australia's gross expenditure on R&D (GERD) has been growing in recent years and is starting to approach the OECD average. Australian business expenditure on R&D (BERD) has also been approaching the OECD average, however, it still lags well behind leading OECD countries.

Research undertaken for this project suggests that direct public sector R&D expenditure by government research agencies, the Australian Research Council and the universities has strong spill-over benefits with positive impacts

## BERD as a percentage of GDP, 2011



Source: see Figure 5.6.

on productivity. Public support for R&D has a number of channels, both direct and indirect. A study undertaken for this project has shown Australian evidence of this for the first time, consistent with international findings.

While Australia's system of National Accounts has capitalised some intangibles (computer software, artistic originals, mineral exploration and, more recently, R&D), some other countries are yet to adopt this approach, making it difficult to compare productivity performance between countries.

## There is an urgent need for action

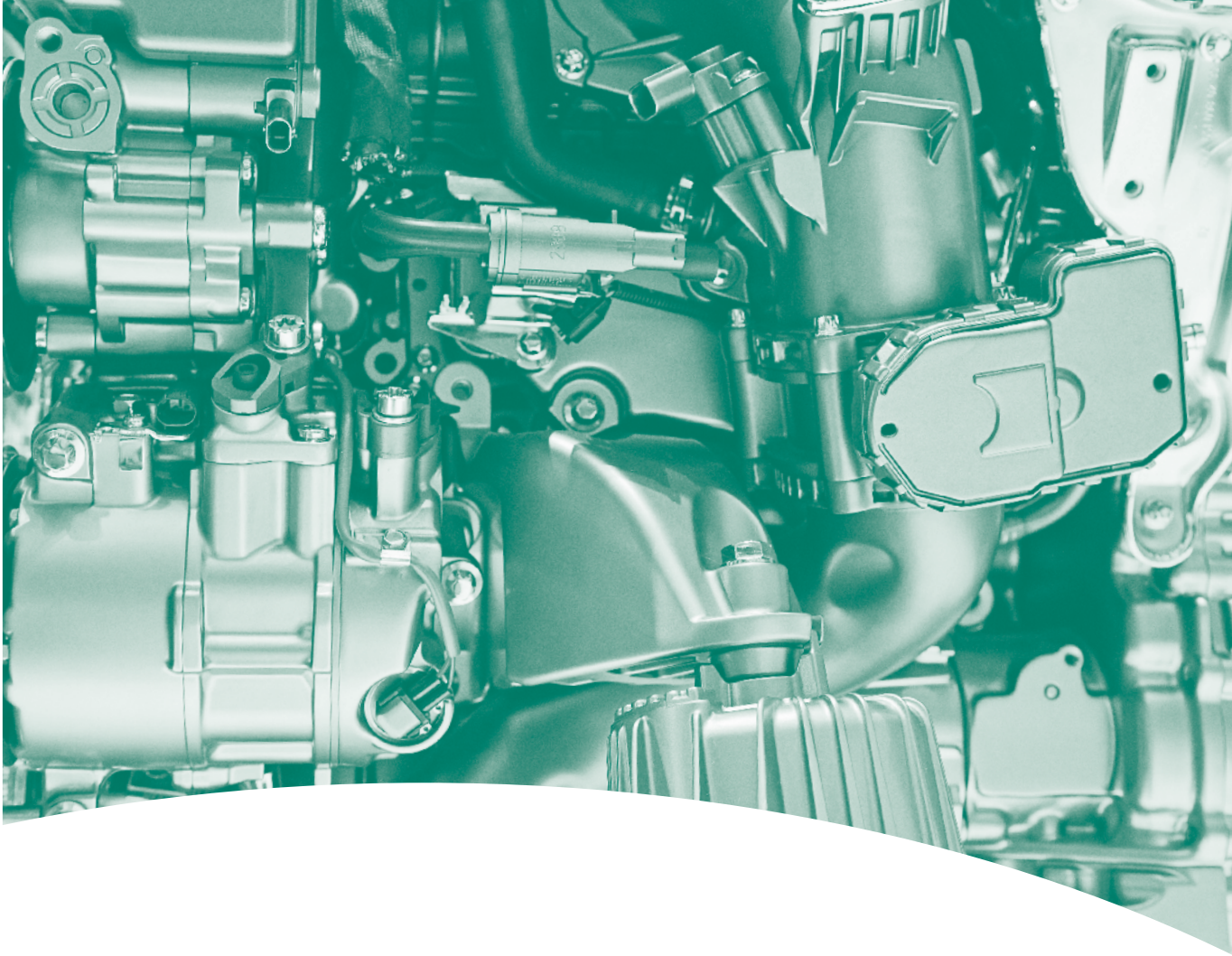
This report finds that there is an urgent need for Australia to increase innovation to lift productivity and build future industries. Time is not on our side. In the past ten years, other countries have moved ahead of us. Addressing the findings of this report will help to reposition Australia as a competitive economy based on a highly productive innovation system.



# Key findings

## Chapter 2: Building Australia's future manufacturing industries

- 2.1 Some areas of Australia's innovation system are underperforming. These need urgent attention if Australia is to avoid being left behind international competitors.
- 2.2 The future of much of Australian manufacturing in many areas depends on enhanced interconnection with services.
- 2.3 Advanced manufacturing has been recognised by leading OECD countries as an important source of economic growth and quality jobs. Australia needs to build on existing initiatives such as the Advanced Manufacturing CRC and expand its efforts in this area.
- 2.4 Businesses find continual change to government assistance programs confusing. More stability is needed and unnecessary changes should be avoided.
- 2.5 New approaches to promoting the creation and growth of new firms, including small business 'set-asides', crowd-sourced equity funding and support for innovation intermediaries, are worthy of serious consideration.



- 2.6 Australian firms need to adopt better management practices, improve their access to information on business opportunities and develop greater agility in order to be internationally competitive and, where appropriate, early adopters of new technologies.
- 2.7 Difficulties in raising capital continue to be a major barrier to firm growth. New measures are needed to assist start-ups, such as crowd funding, tax concessions for investors in start-up companies and reform of the tax treatment of employee share options.
- 2.8 SBIR-type procurement schemes, used successfully in many OECD countries and in place in Victoria and South Australia, could be adopted by the Commonwealth Government.
- 2.9 High-speed broadband communications are a vital element of industry competitiveness in the 21<sup>st</sup> Century. Australia needs to catch up to the leading OECD countries in this regard.

## Chapter 3: Effective collaboration to improve Australian innovation and impact

- 3.1 Collaboration plays an important role in innovation, but is under-recognised by government. The level of Australian collaboration, both nationally and internationally, is low by OECD standards. This limits our ability to capitalise on research investments and access knowledge from overseas.
- 3.2 Current measures to encourage collaboration between firms and researchers are inadequate. New approaches are needed. Examples of successful measures used in other countries include:
- Enhanced incentives and rewards, and removal of disincentives for public sector researchers to engage with business;
  - Additional funding for collaborative activities, including voucher schemes to encourage SMEs to collaborate with research organisations; and increased funding for the Researchers in Business Program;
  - Encouragement of dynamic clusters integrating small and large firms, research organisations and government.
- 3.3 Innovation intermediary organisations operating outside government but with government support are an effective way of assisting SMEs to develop collaboration with other businesses and with research organisations.
- 3.4 Australia should take a strategic approach to research collaboration with other countries, supporting activity in areas of mutual interest, particularly with those countries with which Australia has science and technology agreements.

## Chapter 4: An innovative workforce to meet Australia's future needs

- 4.1 Long-term market demand for STEM skills is difficult to predict – many of today's STEM jobs did not exist a decade ago, as illustrated by the convergence between the life sciences, physical sciences and engineering.
- 4.2 The best way to ensure that supply meets demand is to improve the quality and currency of information available to students when they make career choices and throughout their education. By preparing students for life-long learning, the education system will help to meet evolving workforce needs. Government has an important role to play in this regard.
- 4.3 Productivity improvements driven by innovation rely on a mix of STEM and HASS skills, together with an understanding of innovation systems.
- 4.4 Government, universities and industry organisations should work together to improve entrepreneurship and business management skills, including the ability to manage innovation.
- 4.5 STEM training needs to encourage entrepreneurship and the development of management skills both at university and VET levels. Education providers need to engage with business to gain a better understanding of trends in STEM skill needs.
- 4.6 Providing work experience for university students as part of their training is a way of increasing the awareness of the benefits of STEM skills on the part of employers. Programs such as Researchers in Business are also valuable in this regard.

## Chapter 5: The contribution of innovation to productivity and economic growth

- 5.1 There is strong evidence that research, science and technology contribute positively to productivity.
- 5.2 Measuring research and innovation by focusing only on those assets which are currently capitalised in the System of National Accounts distorts analysis of growth in capital services and consequently, productivity. Different countries have capitalised intangibles to different degrees, making international comparisons difficult.
- 5.3 Private sector knowledge capital is a source of positive benefits (spill-overs) to productivity. This implies that innovative activity has broad benefits that diffuse throughout the economy.
- 5.4 Public sector R&D expenditure by Australian government research agencies, the Australian Research Council and the universities has strong spill-over benefits and is an important source of gains in productivity.
- 5.5 Increasing levels of R&D in the medium-term to at least the OECD average would be an appropriate policy objective.
- 5.6 More comprehensive and better-linked databases are needed to inform science, research and innovation policy analysis in Australia. There is also a case for the establishment of sustained, independent research effort in this area.



# Introduction

## 1.1. Background

This report examines how the application of skills and research enhance innovation, creativity and productivity in Australia and contribute to economic growth. It also identifies measures to improve Australia's innovation capability and performance, especially in small and medium sized enterprises (SMEs). The report focuses on the impact of innovation on productivity and economic growth, recognising that science, research and technology are major components of innovation and contribute to Australia's prosperity in many ways.

The report reviews contributions to innovation from science, technology, engineering and mathematics (STEM) as well as from the humanities, arts and social sciences (HASS). The use of the term innovation in this report covers both technological and non-technological innovation.

Case studies are used to show how firms combine STEM and HASS skills to gain competitive advantage. Business management skills are identified as critical to achieving growth through innovation. These issues are examined as part of a broader analysis of the features of an innovative workforce to meet Australia's future needs.



Factors influencing Australia's industrial future are examined, with a particular focus on current and emerging global trends in manufacturing. The interconnection of manufacturing with the services sector, and the opportunities of advanced manufacturing are also explored. The report presents case studies to show how firms have adopted new technologies and adapted their business models to lift competitiveness, access new markets and respond to global trends. Collaboration between businesses and between publicly funded research organisations and businesses is analysed to show how it can be used to improve the translation of Australia's research into economic outcomes.

### **Building future industries**

Technological advances can transform business practices and lift competitiveness. For example, information and communications technology

(ICT) has been shown to be a major factor in productivity gains experienced towards the end of the 20<sup>th</sup> century (Oliner, *et al.* 2007; Kretschmer 2012). Firms in Australia's manufacturing sector that adopted ICT have secured productivity gains and competitive advantage. Technology is driving rapid transformation in the manufacturing sector, with the emergence of new techniques and processes such as additive manufacturing that have the potential to lift productivity and enable the establishment of new industries.

Early adoption of new technology can provide productivity gains to position Australian firms ahead of their international competitors. To stay competitive, firms need to be continuously innovating. Science, research and technology make a critical contribution to such competitiveness. Research and development (R&D) leads to the creation of new knowledge. This is used by firms to increase the efficiency with which

inputs to production are translated into outputs in the form of new goods and services.

Thus R&D is a key driver of increases in productivity over the longer term. A key macro-economic study by Guellec and van Pottelsberghe de la Potterie (2001) found that there is a relationship between increases in R&D and productivity growth. Subsequent Australian studies have confirmed this finding. R&D is an important input to innovation. Australia has a strong research base underpinned by some world leading research organisations such as CSIRO and supported by strong national research infrastructure. While ranked highly on scientific publications, Australia performs poorly in translating research results into innovative products and services.

Enabling the creation and growth of innovative firms, particularly SMEs, is critically important for national productivity. SMEs are a significant component of Australia's economy, accounting for more than a third of gross domestic product (GDP) and almost half of private sector industry employment in Australia. Facilitating the growth of SMEs should therefore be a priority.

## Innovation can lift productivity growth

Economic studies in Australia and overseas consistently find that the level of innovation is an important factor in driving productivity growth (e.g. Hall 2010; Mairesse 2010; Mohnen 2001). Productivity growth is also influenced by many other factors, including public infrastructure, workplace relations, regulation and legislation, and the availability of a skilled workforce.

Innovation contributes to productivity growth by lowering the cost of production or by improving the quality of goods and services. Innovation can also involve improvements in areas such as management and marketing. Productivity gains arising from innovation are captured not only by innovating firms but also by the users of their products and services. Furthermore, new-to-the-firm innovation is as important as new-to-the-world innovation. Australia's low performance in this area is an indication of a weakness in Australia's innovation system.

The Global Index of Innovation ranks Australia at just 19<sup>th</sup> overall. While Australia ranks well on some measures, there are some important categories in which we need to do better. In relation to technology outputs Australia is ranked 46<sup>th</sup> and in knowledge diffusion, high tech exports and communication technology exports ranked 77<sup>th</sup> (Dutta and Lanvin 2013). This demonstrates the gap in translation of the outputs from research into economic outcomes that benefit Australia.

## Linking business with research

Collaboration with publicly funded researchers can help firms to access new technologies, ideas and markets. However, there are fundamental barriers to business collaboration with researchers. Australia's levels of collaboration are low by OECD standards.

An econometric analysis of 8,000 Australian firms has found that innovating firms that also collaborated had a productivity level that was 31 per cent higher, and firms that innovated using ideas that were sourced from research organisations had a productivity level that was 34 per cent higher. Introducing an innovation led to a 24 per cent rise in a firm's productivity (Palangkaraya, *et al.* 2014).

There is scope to increase the dividend from our investment in public sector research through new policy measures, or by expanding successful existing measures. New incentives that reward researchers for collaborating with business and encourage mobility between business and research organisations are needed. Geographic proximity of firms in related businesses, including competitors, can generate "productivity spillovers". For example networks and clusters can help to provide opportunities for businesses to work together and to jointly engage with research organisations.

Innovation intermediaries, preferably operating outside government but with government support, provide an effective means of creating networks and stimulating collaborations. Examples include technology brokers, incubators, accelerators and clusters. Intermediaries can make use of vouchers and other government schemes to encourage collaboration.

## A skilled workforce is needed

A skilled and productive workforce is critical to economic growth. Skilled labour is one of the key contributors to productivity gains through innovation. Skilled personnel recruited by firms bring with them the knowledge to improve processes, or adopt new processes to lift firm productivity. Technology-based industries require STEM skills to innovate and compete. However innovation involves more than technical skills, it also needs people who understand systems, cultures and the way society uses and adopts new ideas. Innovative firms develop strategies to mix STEM skills with HASS skills for competitive advantage.

Skilled labour needs to be flexible and to continue to acquire new skills. Preparing students for life-long learning is a key requirement to meet evolving workforce needs. Absorptive capacity for innovation, problem solving capabilities, creativity, and adaptability are critical attributes for innovative business. The adoption of new technology is creating new jobs and demanding new skill sets. Business needs graduates with problem-solving skills and adaptive capacity.

Australia faces some potential shortfalls in skills and an ageing population. Offsetting this population ageing, there is an increasing trend to remain in the workforce for longer. More skilled workers are going to be needed in areas of future industry growth, including clean energy, natural resources management, advanced manufacturing, digital and services sectors.

Businesses face a number of challenges, from disruptive technologies, globalisation and changing market structures. Innovation in the way that firms do business can address these challenges and help to raise firm productivity. There is a clear link between the quality of management and firm productivity. Innovation management is critical for corporate competitiveness, enabling business to deal with disruption and access new emerging markets.

## Lifting productivity growth is critically important

Productivity improvement is critical to sustaining long-term economic growth. It is essential

for Australia's national competitiveness and prosperity. This report has focused on drivers of productivity such as investment in research and innovation, adoption of technology from overseas, skills development, and design and organisational improvements. These all have the potential to create more efficient services and production processes and more effective workplace organisations. This can also result in opening up new markets.

Over recent decades, productivity growth has played a key part in the growth of the Australian economy, with a particularly notable role during the mid-1990s. This is attributed to the uptake of ICT and to micro-economic reform. However more recently, productivity in Australia has been declining. Over the period 2003-04 to 2011-12 market sector multifactor productivity declined by 4.5 per cent. At the same time, Australia's competitiveness and innovation capacity, as measured by global rankings, has fallen. Given the importance of productivity in determining living standards, periods of declining productivity should be of significant public policy concern.

There is some urgency in the need to lift Australia's productivity. Australia recently dropped from the top 20 competitive countries for the first time, to 21<sup>st</sup> out of 148 in the World Economic Forum's Global Competitiveness Index 2013-14 (Schwab & Sala-i-Martin 2013). The WEF report states that more needs to change for Australian industries to strongly compete globally.

## 1.2. About this report

The Expert Working Group has undertaken a review of existing literature, building on work from Australia and internationally. Consultants have been commissioned to undertake original research addressing some aspects of the project aims. The Expert Working Group has also had strong international engagement, including with key innovation experts. The Expert Working Group provided two Interim Reports to ACOLA during the course of the project.

A total of nine workshops were held around Australia to seek input from key stakeholders in Adelaide, Brisbane, Canberra, Melbourne, Perth

and Sydney. Each workshop drew between thirty and fifty participants, including senior representatives from industry, academia, research organisations, and government. In all, more than 160 people attended these sessions. In addition, a workshop was convened to focus specifically on management challenges for businesses. A second workshop held in collaboration with the Australian Academy of Technological Sciences and Engineering (ATSE), examined the translation of research into economic benefits for Australia. For further details, see the Section on Evidence Gathering.

This report provides an analysis of the ways in which science, research and technology can lift Australia's productivity in four chapters:

- Chapter 2: Building future manufacturing industries

This chapter examines key issues for realising future manufacturing opportunities in Australia by looking at current and emerging trends. It discusses international best practice for building innovation capacity in SMEs and analyses government support programs in Australia and how they assist these firms. The chapter highlights the interconnection between manufacturing and services sectors, and uses case studies of several Australian firms that have been agile and responsive to changing environments and which, through changing their business models, are now competitive players in manufacturing.

- Chapter 3: Effective collaboration to improve Australian innovation and impact

This chapter examines how collaboration can lift innovation. It is in two sections: 1. Collaboration between business and publicly funded researchers; 2. Collaboration between businesses. Each section discusses the nature and importance of collaboration; Australia's performance in collaboration and

current policy approaches; constraints to collaboration; good practices that stimulate collaboration and overcome its barriers; and highlights opportunities for Australia to improve its performance. The chapter draws attention to Australia's low levels of collaboration in comparison to other OECD countries.

- Chapter 4: An innovative workforce to meet Australia's future needs

This chapter examines the attributes of an innovative workforce. It highlights the intersection and combination of STEM with HASS disciplines in Australian knowledge-based enterprises. The chapter discusses the way in which innovative Australian companies mix depth of disciplinary knowledge, such as technological expertise, with breadth of knowledge, such as communication skills and the ability to effectively integrate a range of skill sets to achieve business competitiveness. It also reviews the evidence on the future workforce needs of technology-based Australian industries; and on building a broader science, research and technology base in the workforce.

- Chapter 5: The contribution of research and innovation to productivity and economic growth

This chapter examines the contribution of research and innovation to productivity and economic growth at both industry sector-wide and firm levels. The relationships between research, innovation, industry productivity and economic growth are analysed in detail and defined quantitatively, with a focus on assessing the impact of publicly financed R&D on productivity. The chapter discusses business sector knowledge capital and other intangible assets that can affect productivity.



# 2

## Building Australia's future manufacturing industries

### Summary

- Manufacturing plays an important role in Australia's economy.
- There is no longer a clear delineation between manufacturing and services sectors.
- Advanced manufacturing technologies provide opportunities for Australia.
- To compete in a global market, Australian firms need to understand international trends in manufacturing.
- Global value chains provide the ability to share knowledge, processes and skills.
- Information and communications technology (ICT) infrastructure is critical to the operation of effective global value chains.



- Manufacturing in Australia is dominated by small to medium enterprises.
- Facilitating the creation and growth of innovative firms of all sizes is essential to build Australia's future industries.
- Australia can learn from international best practice in providing support to SMEs.
- Unlike most other OECD countries, Australia has a history of frequent changes to assistance measures. This makes it difficult for business to plan for and have confidence in government support.
- In comparison to other leading countries, direct government support for Australian business R&D is very low.
- Innovation is vital to Australia's future manufacturing industries.

## 2.1. Australia's industrial future

Australia's industrial future rests largely on adopting technological innovation to develop high-value goods and services for a global market. Advanced manufacturing technologies are transforming the global landscape, and the delineation between services and manufacturing is increasingly blurred. To succeed in an increasingly connected global market, Australian firms must be fast adopters of new technologies to lift productivity in existing businesses and grow new high technology, high-value industries. Manufacturing makes important contributions to exports, trade, research and development (R&D) and productivity (Figure 2.1). A major study by the McKinsey Global Institute (2012) found that:

*"manufacturing continues to matter a great deal to both developing and advanced economies. ... It is a diverse sector ... that is evolving to include more service activities and to use more service inputs. ... The future of manufacturing is unfolding in an environment of far greater risk and uncertainty than before the Great Recession. ... To win in this environment, companies and governments need new analytical rigour and foresight, new capabilities, and the conviction to act."*

(McKinsey Global Institute 2012)

The links between manufacturing and services mean that R&D in manufacturing drives innovation across the whole economy. In reverse, innovation in services can also drive growth in manufacturing. Productivity levels of innovating firms in Australia have been found to be 24 per cent higher than non-innovating

firms (Palangkaraya, *et al.* 2014). As the McKinsey Global Institute has shown, manufacturing makes a larger contribution to exports, innovation and productivity growth than might be expected.

### 2.1.1 Manufacturing is important to the Australian economy

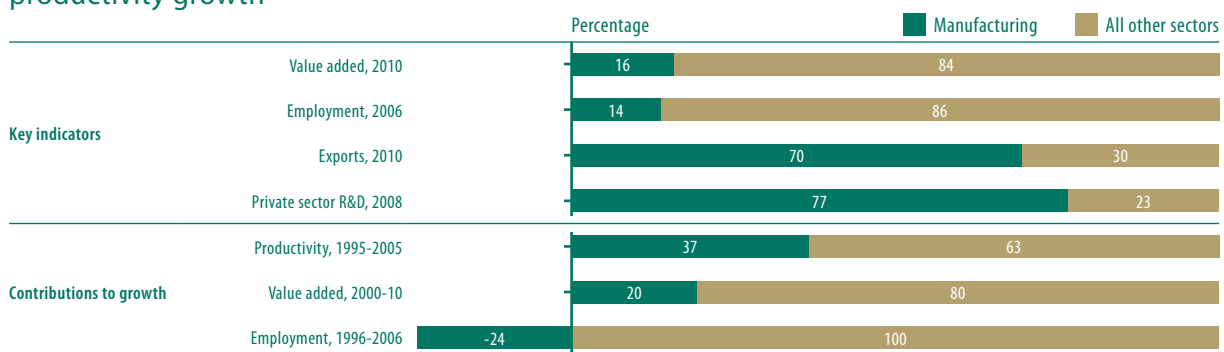
Manufacturing is an important sector of Australia's economy, providing large direct and indirect contributions to employment, investment and national output. Manufacturing plays an important role in underpinning Australia's exports. It is increasingly interconnected with the services sector. These sectors have wide-spread links across the economy as suppliers to, and purchasers from businesses (DIISRTE 2012a).

Technological advances are driving transformational changes in the manufacturing sector (such as the emergence of new additive manufacturing techniques) that have the potential to lift productivity in existing firms and enable the establishment of new high-tech firms in niche industries. To realise these opportunities, Australian firms must adopt new technologies and be able to exploit business opportunities.

#### Contribution of manufacturing to Australia's economy

Manufacturing promotes innovation, productivity and trade (McKinsey Global Institute 2012). It creates a multiplier effect in the Australian economy where, according to one study, every dollar invested in manufacturing generates \$1.74 in other sectors (Roos 2012).

Figure 2.1: Manufacturing contributes disproportionately to exports, innovation and productivity growth



Source: McKinsey Global Institute 2012, p. 3.

However, the manufacturing sector's contribution to Australia's gross domestic product (GDP) has been in decline for decades. Manufacturing accounted for approximately 25 per cent of GDP in the late 1950s-1960s but has recently fallen to around 7 per cent. In contrast, the contribution of services to GDP has been steadily increasing (Figure 2.2).

Between 2000 and 2010, manufacturing had the largest fall in industry share of contribution to Australia's GDP (ABS 2012a).

Total industry value added contribution for manufacturing in 2011-12 was approximately 10 per cent of GDP. Figure 2.3 shows how this contribution was distributed between sub-sectors.

Table 2.1 shows the contributions of manufacturing subsectors to Australian GDP in 2012-13. In that year, they totalled around \$104 billion.

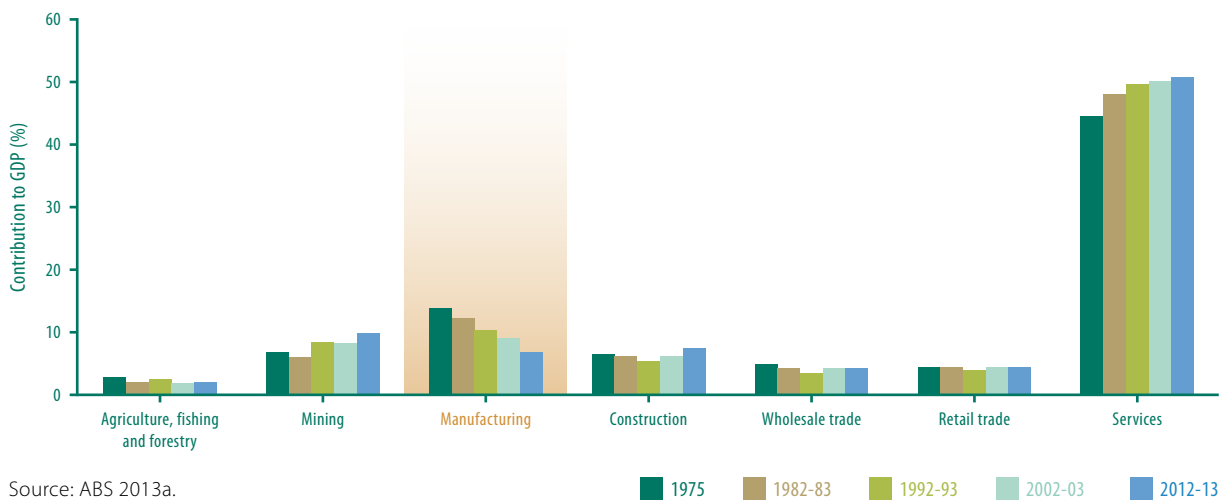
**Table 2.1: Australian manufacturing by sub-sector contribution to GDP (2012-13)**

Sub-sector	\$ billion
Food, beverage and tobacco	24.38
Machinery and equipment	21.76
Petroleum, coal and chemical	19.23
Metal products	16.94
Wood and paper products	6.47
Non-metallic mineral products	5.50
Textile, clothing and other	5.25
Printing and recorded media	4.15
TOTAL	103.71

Source: ABS 2013a.

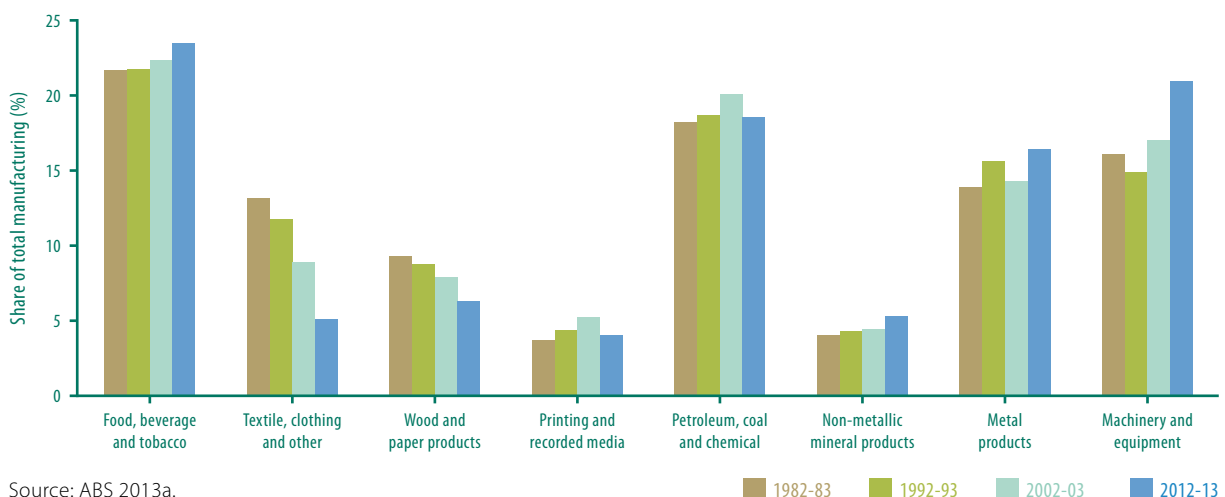
Some manufacturing sub-sectors have real capacity to grow. There is a need to understand what the strengths of these emerging sectors

**Figure 2.2: Industry contribution to Australian GDP, 1975-2013 percentage shares**



Source: ABS 2013a.

**Figure 2.3: Australian manufacturing by sub-sector, 1982-83 to 2012-13**



Source: ABS 2013a.

are and to ensure that they are strategically supported. This will be largely dependent on the leadership of the private sector. In particular, food processing and medical supply sectors are expected to become key growth sectors in the future (Deloitte 2013a).

### Exports

Manufacturing accounted for approximately 34 per cent of the value of Australia's merchandise exports in 2010-11 (\$84 billion); 4.5 per cent was attributable to the export of medicinal and pharmaceutical products, approximately 2 per cent to scientific instruments and approximately 6 per cent to the export of machinery not including road vehicles (ABS 2012a). Australia's share of world manufactured exports declined between 1996 and 2012. Other advanced economies experienced similar declines, while there was an increased share in the case of China and other Asian countries (Atkin & Connolly 2013). Australia lags behind most OECD countries by having a low share of high and medium-level technology in manufacturing exports, with our manufacturing ranked 30<sup>th</sup> in the OECD (DIISRTE 2012b).

### Employment

Manufacturing remains a significant contributor to employment in Australia, with nearly one million people currently employed within the sector. However over the period 2003-13 there was a decline in employment in the manufacturing sector of around 11 per cent (ABS 2013b).

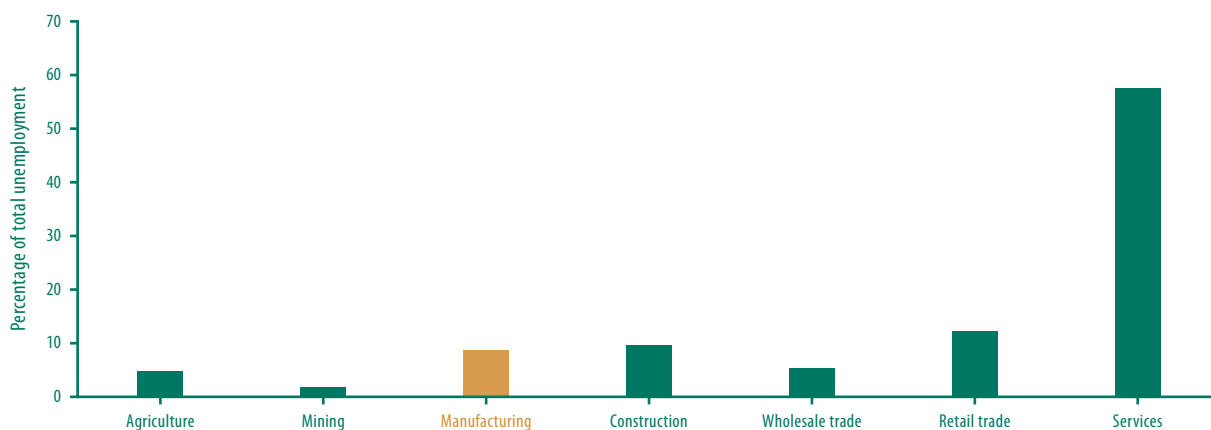
Despite the rapid increase in mining sector employment during the commodity boom, the manufacturing sector contribution to total employment is almost five times that of the mining sector – 8.6 per cent and 1.8 per cent respectively, as shown in Figure 2.4. Currently, manufacturing is the fourth largest employing sector in Australia. The mining boom impacted the competitiveness of Australia's manufacturing industry due to the effect on the value of the Australian dollar (Minifie, *et al.* 2013).

### Business expenditure in R&D in Australia's manufacturing sector

Nearly a quarter of Australia's total business expenditure on research and development (BERD) in 2011-12 was in the manufacturing sector (Figure 2.5). This is lower than the OECD average. In the previous year, manufacturing in Australia accounted for more than one quarter of all BERD, representing an investment of around \$4.8 billion. In contrast, Germany, Slovenia, Finland and Sweden devoted 75 per cent or more of BERD to manufacturing.

The level of capital investment in Australian manufacturing declined around the time of the global financial crisis (Productivity Commission 2013). This suggests an under-investment in manufacturing in Australia that could disadvantage Australia's innovative capacity. Increasing our capacity for innovation could encourage increased uptake of new technologies by local manufacturers, leading to enhanced innovation and productivity, particularly as Australia lags behind most OECD countries in this area.

Figure 2.4: Industry employment, 2011-2012



Source: ABS 2013c; ABS 2013d.

Note: Percentages were calculated for selected industries, 10,727 total.

## SMEs are a large part of Australia's manufacturing sector

Small and medium sized enterprises are the major employers in most nations and an important source of new products and services. The performance of SMEs plays a key role in the health of many economies (Temperley, *et al.* 2004). SMEs account for nearly half of Australia's private sector employment. Improvements in productivity will largely depend on the collective performance of many individual firms (Koźluk & Zipperer 2013).

Australia's manufacturing sector is largely composed of many SMEs, with 80 per cent having less than 20 employees. However SMEs contributed only one third of manufacturing industry value added (AWPA 2013a). Clearly, lifting the productivity of our manufacturing SMEs would greatly enhance the overall productivity of the economy.

### 2.1.2. The importance of expanding advanced manufacturing

Manufacturing continues to evolve, with traditional, labour-intensive, mechanical processes being replaced by more sophisticated technology-based processes. This is termed 'advanced manufacturing'. Advanced manufacturing is a family of activities that depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or make use of cutting edge materials and emerging capabilities, enabled by the physical and biological sciences.

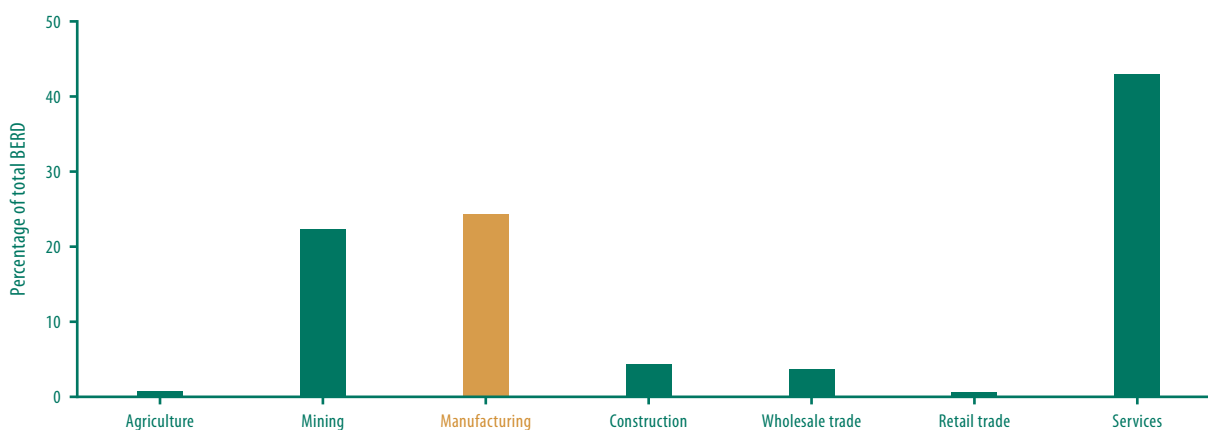
Advanced manufacturing involves both new ways to make existing products and entirely new products based on emerging technologies. Many countries are adopting policies to foster advanced manufacturing.

### USA

In a *Report to the President on ensuring American leadership in advanced manufacturing*, the President's Council of Advisors on Science and Technology (PCAST 2011) observed that other nations are investing heavily in advanced manufacturing and related innovation systems. They also observed that:

- Advanced manufacturing has the potential to create and retain high-quality jobs.
- The long-term ability of the USA to innovate and compete in the global economy greatly benefits from co-location of manufacturing and manufacturing-related R&D activities in that country. The loss of these activities will undermine US capacity to invent, innovate, and compete in global markets.
- A strong advanced manufacturing sector is essential to US national security.
- The USA lags behind competitor nations in providing the business environment and skilled workforce needed for advanced manufacturing.
- US federal investments in new technologies, shared infrastructure, and design tools have been crucial to the birth and growth of major new industries.

Figure 2.5: Business expenditure on R&D by sector, 2011-12



Source: ABS 2013e.

- Individual companies cannot justify the investment required to fully develop many important new technologies or to create the full infrastructure to support advanced manufacturing. Private investment must be complemented by public investment. Key opportunities to overcome market failures include investing in the advancement of new technologies with transformative potential, supporting shared infrastructure, and accelerating the manufacturing process through targeted support for new methods and approaches.

These observations are also applicable to Australia.

PCAST recommended that, as part of an overarching strategy, the USA should:

1. Invest to overcome market failures, to ensure the development of new technologies and the success of technology-based enterprises by:
  - supporting applied research programs in new technologies with the potential for transforming impact
  - co-investing in public-private partnerships to facilitate the development of broadly applicable technologies with transformational potential
  - supporting the creation and dissemination of powerful design methodologies that dramatically expand the ability of entrepreneurs to design products and processes
  - investing in shared technology infrastructure that would help US companies to improve their manufacturing.
2. Create a fertile environment for innovation by:
  - encouraging firms to locate R&D and manufacturing activities in the USA through tax and business policies
  - supporting basic research
  - ensuring a supply of skilled workers through policies that cultivate and attract high-skilled talent.

Many of the PCAST findings are echoed in the chapters of this report.

In a subsequent Report to the President on capturing domestic competitive advantage in advanced manufacturing (PCAST 2012) the Council noted that:

- Over the previous decade that US had lost one third of its manufacturing workforce.
- Productivity issues alone are not to be blamed for this situation.
- There has been a general loss of competitiveness in manufacturing involving a number of contributing factors.
- There are growing concerns that this has impacted on US innovation, capabilities and investment.
- SMEs in the manufacturing sector are a critical component of the US economy.
- A healthy manufacturing sector is important – each manufacturing job in the USA supports 2.4 jobs in other sectors and each high-technology manufacturing job supports 16 others.
- Compared to all other sectors of the US economy, manufacturing has the largest multiplier.
- Manufacturing is critical to the US economy.

The Council made 16 recommendations.

Implementation of these recommendations is in progress. Those of particular relevance to Australia are summarised in Box 2.1.

The parallels between the situation in the USA and that in Australia are striking. With the loss of employment in the Australian car industry and in some of our older areas of manufacturing, Australia needs new competitive businesses to provide the jobs of the future.

## Europe

A 2012 European Commission industrial policy statement seeks to boost manufacturing in Europe through increasing the market uptake of European advanced manufacturing technologies. The EU's Task Force for Advanced Manufacturing Technologies for Clean Production is coordinating this effort by fostering the development, and speeding up the market uptake of advanced manufacturing technologies by industry.

## Box 2.1: PCAST's recommended strategy for US advanced manufacturing

### Enabling Innovation

- Establish a National Advanced Manufacturing Strategy.
- Increase R&D Funding in Top Cross-Cutting Technologies.
- Establish a National Network of Manufacturing Innovation Institutes.
- Empower Enhanced Industry/University Collaboration in Advanced Manufacturing Research.
- Foster a More Robust Environment for Commercialisation of Advanced Manufacturing Technologies (to connect manufacturers to university innovation ecosystems and create a continuum of capital access from start-up to scale-up).
- Establish a National Advanced Manufacturing Portal (a searchable database of manufacturing resources to support access by SMEs to enabling infrastructure).

### Securing the Talent Pipeline

- Correct Public Misconceptions About Manufacturing (through an advertising campaign to build excitement and interest in careers in manufacturing).
- Invest in Community College Level Education.
- Enhance Advanced Manufacturing University Programs (universities should develop educational modules and courses).
- Launch National Manufacturing Fellowships & Internships: (to bring needed resources and national recognition to manufacturing career opportunities).

### Improving the Business Climate

- Enact Tax Reform.
- Streamline Regulatory Policy.

During 2014, the Task Force presented a report *Advancing Manufacturing – Advancing Europe* (European Commission 2014a) which provided information about existing measures relevant to advanced manufacturing that have recently been implemented, as well as new measures endorsed by the Commission to support advanced manufacturing technologies. The Task Force's mission has three objectives.

- Accelerating the dissemination and commercialisation of advanced manufacturing technologies.
- Boosting the demand for advanced manufacturing technologies.
- Reducing skills shortages and competence deficits.

### Emerging trends in advanced manufacturing

A recent study by the Institute for Defense Analyses (Shipp, *et al.* 2012) provides a thorough analysis of trends in advanced manufacturing. This study is based on an extensive literature review and interviews with ninety industry, academic, and government experts. Four

technology areas: semiconductors, advanced materials, additive manufacturing and bio-manufacturing were selected for in-depth analysis. These four areas have the potential to fundamentally change manufacturing in the next twenty years and were chosen because they:

- collectively represent broad trends in manufacturing, such as mass customisation
- can act as platforms upon which other technologies or processes can be built
- are critical to national security
- are influenced by enabling factors such as intellectual-property rights and protections, regulations, immigration policies, and education quality
- enjoy a high level of research and development investment in major manufacturing countries.

The study identifies five large-scale 'converging' trends as instrumental in the shift from traditional labour-intensive processes to advanced-technology-based processes:

1. The ubiquitous role of information technology.
2. The reliance on modelling and simulation in the manufacturing process.
3. The acceleration of innovation in global supply-chain management.
4. The move toward rapid changeability of manufacturing in response to customer needs and external impediments.
5. The acceptance and support of sustainable manufacturing.

Among the mature technology areas, two trends were identified. Semiconductors are expected to continue to improve in performance and lead to the development of completely new devices. Secondly, advanced materials are also expected to evolve, with superior properties that facilitate transformative changes in manufactured products.

Two trends were seen emerging for the less mature technology areas: additive manufacturing (3D printers) which has the potential to change how future products are designed, sold, and delivered to customers. Secondly, synthetic biology was considered to have the potential to manufacture biological substances from radically engineered biological systems for novel purposes. Bio-manufacturing could bring about radical changes.

The report suggests that advanced manufacturing will continue to rely less on labour-intensive processes and more on sophisticated information technology. Over the next ten years, advanced manufacturing is expected to become increasingly globally linked, as automation and digital supply-chain management become the norm. Countries and companies that invest in information and communications technology, broadband and related physical infrastructure will be positioned to lead by exploiting the resulting increased flow of information. Advances in materials and systems design will accelerate and transform manufactured products. Establishing an advanced manufacturing sector will be a priority for many countries

Over the next twenty years, manufacturing is expected to advance to new frontiers, resulting

in an increasingly automated and data-intensive manufacturing sector that will replace traditional manufacturing as we know it today. An advanced workforce will be needed to develop and exploit these advances in manufacturing.

### Consequences for Australia

Other OECD countries have recognised the importance of advanced manufacturing and are developing national innovation policies to ensure that they are positioned to benefit from the adoption of new technologies in their manufacturing sectors. Australia needs to also move quickly in this direction. This can be achieved in part by enhancing existing initiatives in advanced manufacturing such as the Advanced Manufacturing CRC and the CSIRO Future Manufacturing Flagship.

Advanced manufacturing provides Australia with the opportunity to compete in international markets without relying on a large domestic market or low wages. Advanced manufacturing provides high quality, well-paid jobs in high value-added activities and products that make a greater contribution to our standard of living. Advanced manufacturing generates high-value exports. Manufacturing capabilities using advanced technologies and techniques are also important to Australia's national security.

Australian manufacturing firms, wherever they may be in a value chain, need to focus on value-adding. Those that use industrial and scientific advances and find unique market opportunities will be the successes of the future (DIISRTE 2012a). Australia is well placed to adopt policies that use our research expertise to build an advanced manufacturing capacity. Australia's research system is highly productive and is generally performing well relative to most EU-15 countries. Australia's research workforce is publishing at a faster rate, and in higher quality journals compared with other OECD countries. Australia has one of the highest rates of researchers in higher education employment – five per 1,000 workers. However, we have the lowest rate of researchers in business, with only two in every 1,000 employees (Pettigrew 2012). Figure 4.6 in Chapter 4 illustrates Australia's low percentage of researchers in business, by

comparison with other countries, and highlights the implications of this.

Increasing the quantity of our quality researchers into the business sector is one measure that would give Australia the capacity to position ourselves as a country that is strong in advanced manufacturing. It will need to be accompanied by strong intellectual property positions on the part of our firms and careful positioning in global value chains.

The majority of Australian businesses are currently adopters and modifiers of others' innovations (for instance, playing catch-up through technology adoption) rather than delivering world-first innovations (pushing the frontier). Australia has an extremely low proportion of 'new to the market international innovators' (1.5 per cent) compared with other OECD countries (between 10-40 per cent). Investment in novel forms of innovation is also lagging. Commercialising research ideas and technology is vital to increasing Australia's productivity and being at the forefront of advanced manufacturing (DIISRTE 2012b).

## 2.2. International trends in manufacturing and services

Internationalisation and technological advances are driving rapid changes in the ways that firms can do business and gain access to new markets. Australian firms need strong management skills and the ability to adopt new technologies in order to participate strategically in global value chains and realise the opportunities. Internationally, the manufacturing and services sectors are inextricably linked, and both remain a critical part of economies around the world.

Australia has captured the attention of some overseas high-technology companies, including BAE Systems and Boeing for specialist aerospace components; BASF, Bayer and DuPont in the chemicals industry; and Siemens in energy and water treatment technology (Australian Trade Commission 2013a; DFAT 2012). This suggests that globally, Australia has a competitive advantage in advanced manufacturing.

Investment in R&D, the up-skilling of workers, design and new business processes will all be required if Australian firms are to capture the value of these new advanced manufacturing technologies. Collaboration is discussed in more detail in Chapter 3.

### 2.2.1. Global Value Chains

Global value chains are a powerful driver of growth and productivity and play a part in supporting employment rates and aid in boosting the economies of developing countries. A global value chain (GVC) is the collection of operational activities which firms undertake to deliver an idea for a product or service to the market. These activities include research, development, design, assembly, production, distribution and marketing. The concept of a global **value** chain is closely related to that of a global **supply** chain. The latter concentrates on understanding the total flow of goods from suppliers to users, reducing costs and increasing efficiency, whereas the former seeks to understand where value is being added throughout the chain.

Global value chains are useful to firms as they provide a wider variety of choices and opportunities for processes to be carried out at optimal locations. Access to knowledge is a key motivator for the firms at the heart of GVCs, whether it is through engagement of skilled workers; institutes with high-quality facilities; or by engaging with firms that have wide knowledge and familiarity of their local market. There are few companies that undertake all the steps required to deliver a product, from concept development to marketing and customer service. In most cases firms leverage capabilities from others to build and capture new opportunities in GVCs.

It is becoming common practice for firms in various countries to cooperate in GVCs. This is driven in part by rising costs of business in some countries. Advances in technology have allowed firms to perform operations globally to increase efficiency, lower costs and speed up production. Firms today look to add value in the most economical and efficient way, such as producing a product or part in which they specialise, which is then used by other firms.

Technological developments have contributed to the fragmentation of manufacturing GVCs.

Cheaper and more efficient communication technologies enable ease of communication over long distances and co-ordination of activities across international borders. This enables different stages of a process to be conducted at various global locations. Involvement in international trade networks has been described as an 'organisational innovation' which has increased efficiency in the manufacturing process (OECD 2009).

The distribution of production globally is increasing in size, scope and frequency and includes both small and large firms. The principal actors in GVCs are multinational enterprises, their international affiliates and independent suppliers in both domestic and foreign markets (OECD 2013a). Advances in technology and improvements in access to knowledge, funds and resources are core drivers of global participation. Government policy is an important enabler of participation in GVCs. The real value within a GVC lies in being a 'price maker' rather than a 'price taker'. The value created in a GVC is often unevenly distributed among its participants. There is always a risk that some firms may end up being dependent on just one supplier, forgoing economic freedom and unable to gain any further value (Cattaneo, *et al.* 2013). This needs to be recognised by GVC participants.

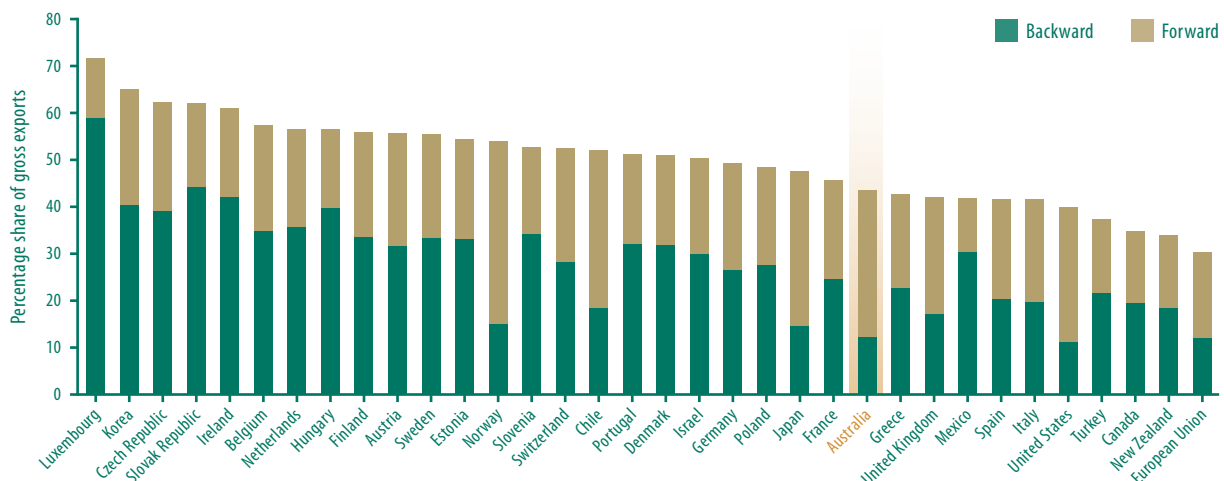
### Australian firms within global value chains

Australia's exports of merchandise and services doubled from \$146 billion in 2003-04 to \$315 billion in 2011-12. The OECD found that most Australian sectors, particularly manufacturing, are not well linked to GVCs because Australian exports depend less on imports of foreign components compared with other countries (Figure 2.6).

For example, the imported component content of Korea's exports is more than 40 per cent, while Australia's is less than 15 per cent. This is partly due to Australia's exports being concentrated in unprocessed minerals and fuels and therefore requiring minimal inputs to get to export stage (Department of Industry 2013).

Australian firms do contribute to many GVCs. Mining firms provide the highest level of such participation, while firms in the manufacturing sector lag in comparison to other OECD countries (OECD 2013a). However, there are challenges for Australian firms, particularly SMEs, participating in GVCs. SMEs recognise their dependence on Australian intermediaries, as they attempt to diversify their operations to achieve more opportunities and further sources of income (OECD 2008). Shortage of capital is a key barrier to Australian firms seeking to operate internationally. This issue is also reported by other countries such as Spain, Indonesia and Finland (OECD 2010).

Figure 2.6: GVC participation index as a percentage share of gross exports, 2009



Note: This figure is expressed as a percentage of gross exports and indicates the share of foreign inputs (backward participation, teal bars) and domestically-produced inputs (forward participation, gold).

Source: OECD 2013a. OECD-WTO database: Statistics on Trade in Value Added.

Continuous innovation to improve firm productivity is necessary to sustain GVC participation. The Textor Technologies case study clearly illustrates how a firm can adapt its business model and re-establish itself when markets change. The Researchers in Business Program assisted with the transformation that resulted in Textor Technologies becoming a lead global supplier (Box 2.2).

Investing in research and innovation is key to maintaining market share and keeping a strong position within supply and value chains. The Tasmanian firm, Botanical Resources Australia

(BRA), has innovated in all parts of the production and supply chain, including plant breeding, harvesting technologies, processing, and quality control. BRA has become the largest global supplier of pyrethrum, the active ingredient in many pesticide products. Collaboration between the Tasmanian Government and the University of Tasmania found new ways to diversify agriculture in Tasmania and utilise external specialist research providers. Working with the CSIRO through the Researchers in Business Program resulted in the development of a new method for analysis of the principal component (Box 2.3).

### **Box 2.2: Textor Technologies and their role within multinational Kimberly-Clark**

Textor Technologies manufactures non-woven textiles for the global hygiene fabrics market from imported raw materials. By focusing on optimising production technology and techniques with assistance from the Commonwealth Government's Textile Clothing and Footwear Strategic Investment Program and Strategic Capability Program, the company was able to become a preferred supplier to Kimberly-Clark, and was awarded 'Global Supplier of the Year' in 2011. In 2010, the Researchers in Business program led to a highly successful research partnership with CSIRO's textile laboratories in Geelong which has enabled Textor to function in the global value chain in hygiene fabrics.

Kimberly Clark is a US company that produces paper-based personal care products. It has manufacturing facilities in 37 countries (including Australia) and sales of US\$21.1 billion in 2012 in more than 175 countries. Its brands include Kleenex, Scott, Huggies, Kotex and Pull-Ups. It has 58,000 employees. One manufacturing facility is in Millicent SA where Kleenex, Kleenex Cottonelle, VIVA, Scott and Kimberly-Clark Professional tissue products are made. The Millicent plant is located near Forestry SA pine forests. However only 0.5 per cent of the fibre used at the mill comes from this source.

Today, all Kimberly-Clark tissue products manufactured at Kimberly-Clark's Millicent mill have the FSC® 'mixed sources' certification, which means that more than 50 per cent of the pulp sourced for all Kimberly-Clark products comes from forests that have been accredited and adhere to the stringent FSC sustainable forestry management standards. Textor Technologies provides product to Kimberly Clark locations around the world, wherever Huggies are manufactured.

### **Box 2.3: Botanical Resources Australia**

Botanical Resources Australia Pty Ltd (BRA) is a Tasmanian company which produces more than 60 per cent of the world's pyrethrum, which is the active ingredient in a range of consumer pesticide products and made from the dried flower heads of some chrysanthemum species. The company originated from public sector research through the University of Tasmania and the Tasmanian Government in the early 1980s, with the breeding of plants suitable for Tasmanian conditions and machines to harvest the crop. The company was originally owned by Commonwealth Industrial Gases (CIG) but was subject to a management buyout in 1996.

BRA is part of the global value chain of most of the world's consumer pesticide manufacturers, producing more than half of the world's pyrethrum. It maintains that position through attention to the quality and reliability of its product and close attention to its own supply chain in Tasmania. It owns and manages some farms but also leases other farms and contracts farmers to grow the crop. It harvests the whole crop with its contracted harvesting fleet and is the only chrysanthemum crop in the world to be harvested mechanically.

BRA has a strong R&D program across all of the aspects of its operations. It has worked closely with the University of Tasmania and more recently with the CSIRO through the Researchers in Business Program. This partnership has enabled the company to develop new methods and processes, leading to more market share and commercial gains. Through the Researchers in Business program, BRA was able to find the right people to help with their R&D, a challenge that the company had expressed in the past. Working with CSIRO has led to the development of a new method for the analysis of pyrethrosin (a compound extracted with the pyrethrins) which may lead to further commercial gains in the future. Funding support from the Commonwealth Government, research and development and highly focused management practices have contributed to the success of BRA.

## Global Value Chains and the vehicle industry

Mitsubishi, Ford, General Motors and Toyota have all decided to halt manufacturing automobiles in Australia. There are a number of reasons for this, including Australia's small and open domestic market, high costs and strong currency (Productivity Commission 2013). The future contribution of Australian manufacturing firms in global automotive value chains remains unclear. Both Ford and General Motors have said that they will keep design studios in Australia, and many of their suppliers will endeavour to continue supplying parts to these two firms and to other automotive manufacturers. The experience of Boeing Australia in the aviation industry may provide some hope for these firms.

Boeing Australia has worked with its parent company in Seattle to be the sole Australian supplier of flight control components for a number of Boeing commercial airplanes, including the new 787 Dreamliner. The structure of the GVC for development of the Dreamliner is shown in Figure 2.7. These are manufactured at Fishermans Bend in Victoria and exported to the USA for assembly. Further details can be found in Box 2.4.

Australia could use this strategy and function in GVCs by contributing to the assembly of vehicles abroad and manufacturing car components here in Australia. If our firms can persuade car manufacturers to source innovative products from Australia it may be possible to build a competitive advantage in some components and tap into GVCs (Productivity Commission 2013).

Australian automotive manufacturers have had long-term relationships with other companies where information has flowed between them.

They are therefore aware of the way the industry operates and its structure. They should utilise this knowledge to embed themselves in various innovative markets involving global supply and value chains (OECD 2008).

There is also potential for vehicle automotive manufacturing firms to see the closure of plants in Australia as an opportunity to diversify production and capabilities. This is likely to require financial support from government. The skills, workforce and machinery base still remains in Australia and is still world-class. Engaging in partnerships in Australia and abroad, either in the car industry, or other sectors can still see these firms engaged in GVCs. Diversification can take many forms. For example, diversifying into different supply chains and global markets, or products, processes and business models.

## Information and communications technology enables Global Value Chain participation

The rapid development of ICT has been an important factor in the development of global value chains. Development and adoption of ICT within the manufacturing sector acts as an enabler for increasing participation of Australian firms within GVCs and this will require larger numbers of highly-skilled individuals to enter the sector. However there are signs that this could be a problem for Australia – a recent study of 102 Australian manufacturing or wholesale businesses found that only 10 per cent of the companies could receive orders directly online (NetSuite 2013).

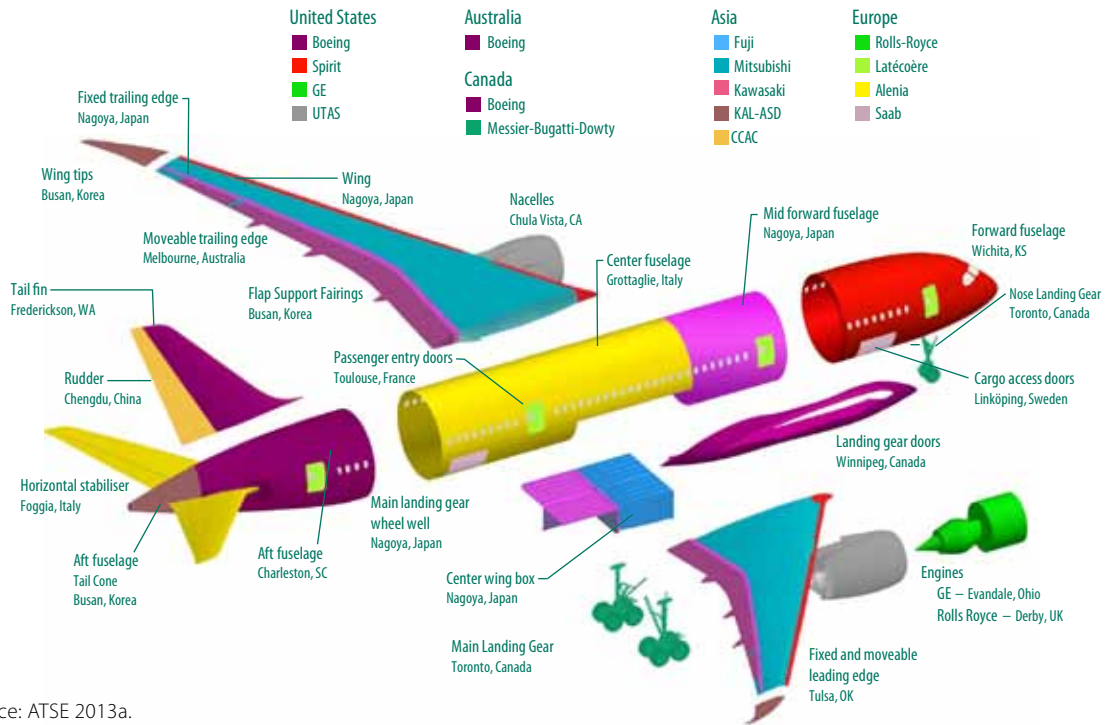
Transmission of data across continents, with the necessary speed and bandwidth, has expanded

### Box 2.4: Boeing

The Boeing 787 Dreamliner is assembled in the United States using components from around the world, including Italy, Japan, UK and Australia. Each country contributes a specific and vital component which, when brought together, form the Boeing 787 Dreamliner. This partnership is Australia's largest aerospace contract.

Boeing has collaborated with the CSIRO for over 23 years and in recognition of this collaboration, Boeing named CSIRO "Supplier of the Year" in 2011 out of 17,500 suppliers worldwide. The joint collaboration has worked on projects including research into sustainable aviation fuels, aircraft painting processes and aircraft maintenance management software. In 2012, CSIRO and Boeing commenced a five year, \$25 million research program in space sciences, advanced materials, energy and direct manufacturing. In the past decade, Boeing has transferred an estimated \$100 million in technological knowledge to Australia and has invested more than \$500 million in plant, equipment, training and research laboratories.

Figure 2.7: The Boeing 787 Dreamliner manufactured around the world



Source: ATSE 2013a.

the manufacturing and service sector and resulted in the introduction and integration of new kinds of products and services. There is a positive relationship between innovation and ICT deeply embedded in business models. There are three main effects that ICT can have on a firm to enhance performance which is to reduce cost, allow for focus on core skills and enhance flexibility. ICT enhances productivity by making processes more efficient and requiring investment in highly qualified employees and variation to organisational structure (Bertschek, *et al.* 2011).

### 2.2.2. Technology

Technology is a key driver of change and competitiveness in manufacturing. Some advanced technologies are already well established, such as additive manufacturing – some are emerging, and some cannot yet be anticipated. As noted previously, Australia is an adopter of technologies rather than a lead developer. Some 98 per cent of new technologies are sourced from outside the country (OECD 2012a; Cutler 2008).

ICT and advanced manufacturing technologies are leading to the production of materials with superior properties. At the same time,

biotechnologies are becoming more widespread. These technological advances are leading to new ways of doing business. For example, it is now possible to design a metal part at one location and manufacture it using a 3D printing machine at another location. An Australian example of this is the Perth bicycle business, Flying Machine, which uses 3D printing technology. Flying Machine sends customised specifications for the lugs of the bike, the small metallic socket-like sleeves that join the tubular frame of the bike, to the titanium lab at the CSIRO where these components are produced in titanium using 3D printing and then sent to Perth for assembly (Box 2.5).

Combinations of these technologies will allow firms to produce affordable yet customised products. This process has been termed ‘mass customisation’ (McKinsey Global Institute 2012). Substantial data can be generated from this process, particularly surrounding consumer preference, anticipating trends and allowing for ‘on-the-spot’ changes. If data is dealt with correctly then this increases a firm’s competitiveness by offering superior products and services (Foresight 2013). Customer input into early stage developments allows for high quality goods and services with shorter cycle-times and lower costs. Although customisation

## Box 2.5: Flying Machine

Perth manufacturer Flying Machine, has produced the first bicycle to contain parts that have been 3D printed in Australia. The product is called 3DP-F1. Using CSIRO's Melbourne additive manufacturing facility, Lab 22, components of the bike can be customised for a rider in Perth. The components are designed and produced from titanium using CSIRO's \$1.3 million 3D printer and then delivered to Perth for assembly.

This process would take 10 weeks if Flying Machine worked with an overseas supplier but using CSIRO's facility means it now takes only 10 days. With this proof of concept, the firm can commence refinement through Finite Element Analysis and Topological Optimisation technologies. This allows highly complex structures to be produced that would not be possible through traditional manufacturing. Titanium is a superior material, being as strong as steel but only 40 per cent the weight. 3D printing enables changes to be made for each lug fractionally, creating infinite flexibility so that all bikes can have a geometry tailored for each individual owner's size and riding style.

only represents a small part of the global economy, customers in developed economies are willing to pay a premium for personalisation (Piller & Kumar 2006; BDC 2013).

A high-speed open-access broadband and telephone network (broadband) has the potential to drive economic and social change and lift productivity by reducing business costs; reducing employee time; and improving the quality of goods and services. Australian businesses and households have shown their willingness to adopt this technology (ACMA 2013). However, the speed of broadband in Australia lags behind most OECD countries, currently sitting 30<sup>th</sup> in the world for average connection speed. Increasing connection speed across the entire country will have significant impact on further productivity increases (Akamai 2013).

### 2.2.3. Skills, management and innovation in manufacturing

Developing and supporting skills in the workforce will lead to higher value-added products and productivity increases, due to the linkages to innovation and R&D capabilities. Although employment within Australia's manufacturing sector is in decline, there are good opportunities for those with STEM qualifications and a mix of technical, commercial know-how and problem-solving skills. Further advances in technology will require highly skilled workers in all parts of the development-to-market process, particularly within high-value added manufacturing.

Leaders and managers have a central position in driving the future role of people in

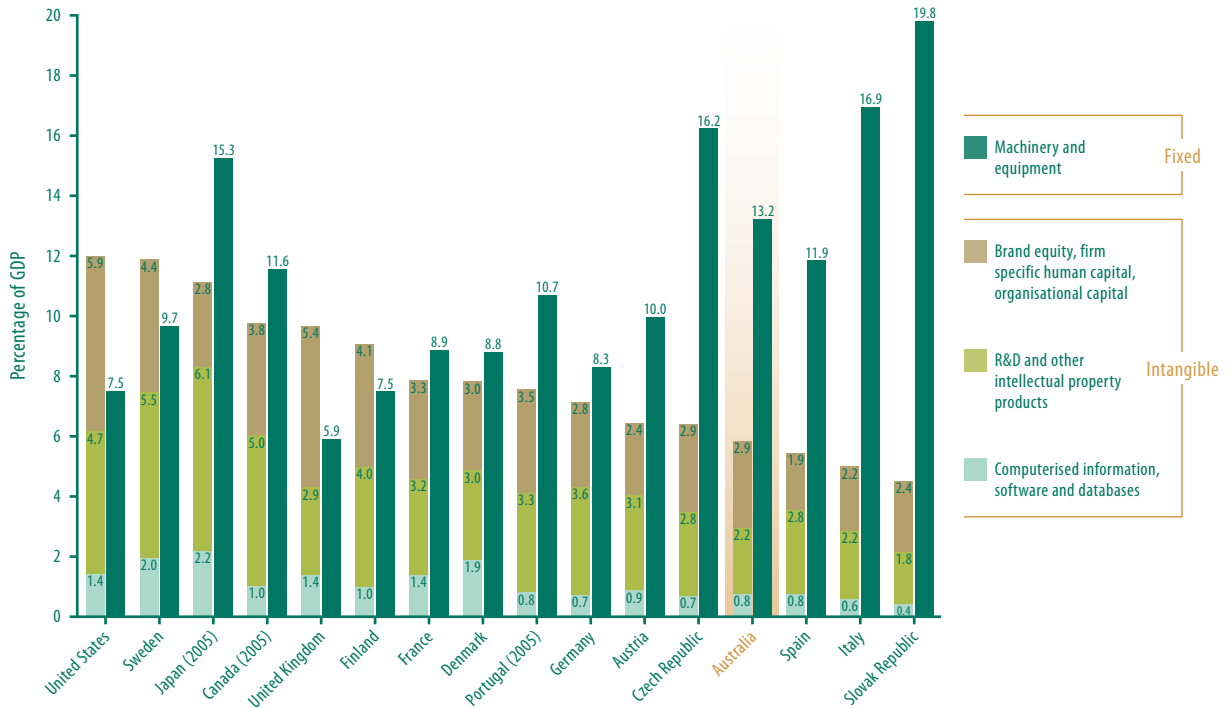
manufacturing activities. Strong management practices are associated with high quality firm performance and higher productivity (Bloom & van Reenen 2010). It is not only the role of Chief Executive Officer that is crucial, but also senior leadership teams and leaders throughout firms. Employees with a mix of technical and non-technical skills who are customer-focused will be in high demand.

Markets change, and firms need to evolve their business models to capture opportunities for growth. This requires an understanding of where firms sit within a GVC and the effects on upstream and downstream firms. Skills required for advancing technology will need to be constantly upgraded; investment in technical and vocational education training allows more people to move into higher-skilled jobs, boosting employment and increasing productivity. Government policies can *"facilitate the adjustment process through labour market and social policies and through investment in education and skills"* (OECD 2013a).

As industries expand their expertise and their share of the economy, particularly manufacturing, this will be dependent on the availability of a skilled workforce (TAFE Directors Australia 2013). While Australia's investment in machinery and equipment as a percentage of GDP is strong, Figure 2.8 shows that our investment in intangibles, such as skills, is below the OECD average (DIISRTE 2012b).

Unlike other OECD countries, productivity at the firm level in Australia has not been extensively studied (Syverson 2011; Doms & Bartelsman

Figure 2.8: Investment in tangible and intangible capital as a proportion of GDP, 2006



Source: DIISRTE 2012b, based on OECD 2010.

2000). Measuring productivity is difficult, as only broad knowledge about the outputs and inputs (labour, capital and materials expenditure) is known. Researchers therefore rely on other indirect information such as R&D expenditure, counts of intellectual property rights, or surveys of management processes to measure firm productivity (Palangkaraya, *et al.* 2011).

Firm-level productivity in Australia is an area that requires further analysis to understand the entry and exit of companies as well as the reallocation of resources from non-productive to productive companies (Breunig & Wong 2007). Therefore, as part of the preparation of this report, an analysis has been undertaken using firm-level data, with the assistance of the Australian Bureau of Statistics.<sup>1</sup> Initial results from this study indicate that increases in firm productivity are partly driven by the introduction of new or significantly improved organisational, managerial and operational processes (Palangkaraya, *et al.* 2014).

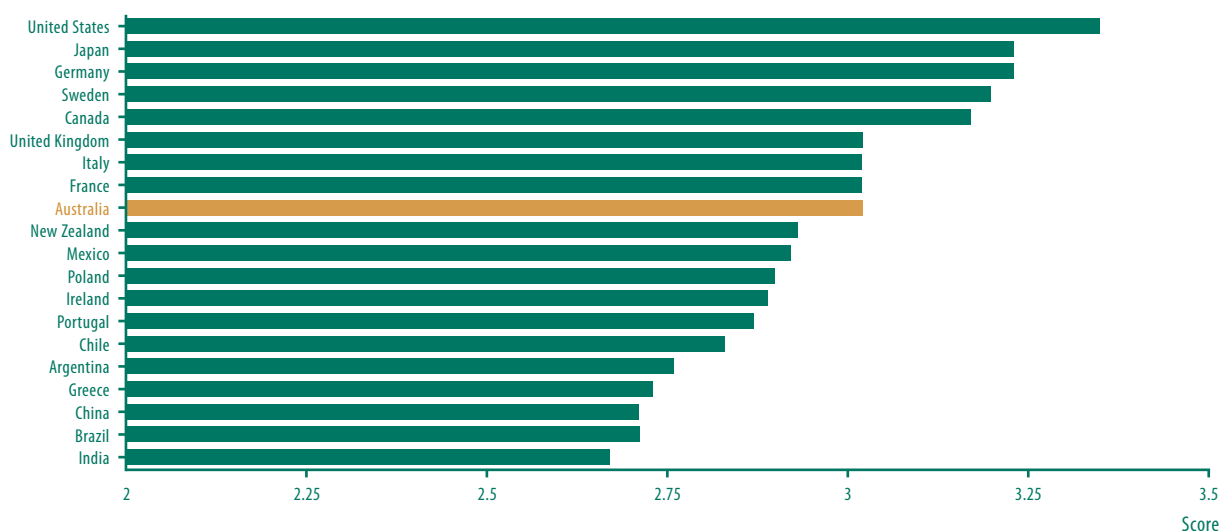
<sup>1</sup> The study used two firm-level datasets to test for the effect of innovation on future productivity. The first is an ABS SME dataset of 7,724 Australian firms for the period 2005-06 to 2011-12. The second dataset is based on the IBISWorld population of 220 large firms over the period 2001-12, where 'large' is defined as firms with annual turnover over \$A50 million.

The study had an SME and a large firm component. The data shows that about half of all firms innovate in any given year, although this is overwhelmingly new-to-the-firm, not new-to-the-world innovation.<sup>2</sup> The SME study revealed that innovation has a clear, positive and significant effect on the firm's subsequent productivity (from one to four years later). Furthermore, innovations which are sourced from science are more productive than innovations which are not. The large firm study showed that whereas innovation on its own does not raise productivity, innovation that is accompanied by verified 'good management' practices does raise productivity.

These findings immediately raise the question: why aren't all firms innovating, or at least adopting good management practices and innovating? The study pursued several lines of inquiry to test for possible reasons but did not find any clear and conclusive results. It is most probable that the relevant factors lie outside the data sets available to the research team.

<sup>2</sup> Innovation follows the OECD (2005) definition of a new or significantly improved good, service, operational process, managerial method or marketing method. It can be either new-to-the-firm or new-to-the-world.

Figure 2.9: Average management performance in manufacturing



Source: Bloom, *et al.* 2012. Note: Scale 1 = worst, 5 = best.

Some relevant factors are internal to the firm – such as firm awareness about both the returns to innovation and the process for becoming a successful innovator. Ideally, a study of innovation needs information on whether or not a company’s directors understand the potential benefits of innovation and whether or not they can recognise whether its senior management team has the aptitude and ability to transform the organisation. A study of innovation also needs data on factors that are external to the firm – such as the knowledge infrastructure to encourage the sharing of ideas and translate nascent discoveries into commercial products.<sup>3</sup> Also relevant is the depth of the Australian labour market for capable and experienced managers and the supporting infrastructure for bringing the current stock of managers up to world standard. A preliminary paper on this work is available on the ACOLA website.<sup>4</sup>

The USA is the top-performer in management in manufacturing, while Australia has a substantially lower ranking (Figure 2.9). Bloom, *et al.* (2012) have suggested that lifting management practices in Australian manufacturing firms to

the average level in the USA would raise the level of productivity in Australian manufacturing by around 8 per cent. Measures that focus on the number of poorly managed manufacturing firms in Australia would be one way of enhancing Australia’s overall performance. This could involve aiding firms to develop structured approaches to measuring and assessing management against benchmarks and initiating improvements. Raising the skills and education levels of managers and of the general workforce will also enhance firm management performance. This implies constant training and upgrading of skills (Green 2009). The issue of management performance in Australian firms is discussed in more detail in Chapter 4.

### 2.2.4. Services and manufacturing

Services are important to manufacturing. Logistics, ICT and business services help to transfer goods, data, technology and knowledge abroad, allowing manufacturing firms to succeed within GVCs (OECD 2013a). This phenomenon of integration of services with manufacturing is referred to as “servitisation”. The importance of servitisation is highlighted in the recent *Servitisation Impact Study* by the Aston Business School (2013). The study report focuses on UK manufacturers that have been engaged historically with original equipment, but have adapted their business models to become more services-focused rather than product-centric. The report comments that servitisation promises sustained annual business growth of 5-10 per cent, and companies which

<sup>3</sup> This includes measures to ensure knowledge spills over to other firms in the economy and that the originators of the knowledge are compensated in some way such as R&D tax credits; government procurement contracts; public investment into inter-firm and university-industry collaboration; royalties from IP.

<sup>4</sup> Available at <http://acola.org.au/index.php/the-role-of-science-research-and-technology-in-lifting-australian-productivity-contributing-reports>

move towards technology-led services can lower their own costs by as much as 30 per cent, driving business growth.

Xerox is an example of a company which has embraced servitisation. Xerox originally delivered on-site, small scale products but has now become a professional shared services provider which delivers substantial outsourcing to its customers, underpinned by its own technology. The provision of services has been a financial success for Xerox. In 2012, Xerox's revenue was \$US 22.4 billion, with services revenue growing by 6 per cent over the previous year to \$11.5 billion.

There are many other good international examples showing the benefits of providing a service alongside a product. IBM sold its personal computer manufacturing division to the Chinese company Lenovo in 2004. Today, IBM makes the majority of its profit from its service division, offering field service, installation, training and 'solutions' around IBM products (Dedrick & Kraemer 2006).

## 2.3. Australian manufacturing firms responding to trends

The future of manufacturing lies with recognising and embracing emerging trends. One trend includes globalisation. The opening

of international markets and the rise of India and China alongside rapid developments in ICT have led to the globalisation of the manufacturing sector. Increased offshoring to low wage economies has inevitably led to the closure of large manufacturing plants in Australia. Australia cannot compete with these countries on labour costs, but has the opportunity to engage in global markets with high value-added products and services (ESCAP 2009). Australia has a small domestic market, and local manufacturers struggle to produce goods at a scale that is economically beneficial when they supply only the Australian market. Australian firms that choose to focus on the domestic market need to aim for high-quality, high-value added products and services (Lenihan, *et al.* 2010).

### 2.3.1. Service integration

The Australian-based multinational enterprise, Orica Ltd, is an excellent example of the role of ICT in the transformation of a tariff-protected chemical manufacturing firm to become the world's largest supplier of mining services (including explosives and blasting systems) (Box 2.6).

Australian businesses can capitalise on science and technology-led services innovation by using services to differentiate themselves from global competitors and capitalise on niche opportunities. Establishing a product and promoting related services is an emerging trend for the

#### Box 2.6: Orica Ltd

ICI Australia became an independent Australian company in 1997 and changed its name to Orica in February 1998. Since then, Orica has transformed itself from a diversified chemical and paint company into the world's largest provider of commercial explosives and blasting systems to the mining and infrastructure market; a leading provider of ground support services for mining and tunnelling; and a supplier of sodium cyanide to the gold mining industry. In 2010, Orica split off its Dulux paint business but retained businesses that supply chemicals across a diverse range of markets, including water treatment. Orica has leveraged competitive advantage by using access to the Australian mining industry. In 1997 Orica was a typical chemical manufacturing company, supplying a diverse range a chemicals to a wide range of markets. In 2013, 84 per cent of its sales revenue came from the supply of mining services.

Orica has operations in more than 50 countries; major manufacturing sites in Australia, Brazil, Canada, Chile, China, India, Indonesia, Sweden and the USA; and customers in more than 100 countries. Its sales in 2013 were nearly \$7 billion. It has ground support services in Australia and the USA. Orica is a great example of how the service sector and manufacturing have become less distinct categories.

Investment in research and technology has been an important part of Orica achieving its global position. It has a portfolio of 74 US patents, with 33 granted since the start of 2010. Orica's range of patents illustrates the importance of information and communications technology in the firm's business. For example a 2009 patent is entitled 'Wireless detonator assembly, and methods of blasting'. Wireless detonators and corresponding wireless detonator systems enable blasting arrangements that avoid the need for physical wire connections between the components of the system.

manufacturing sector. Many manufacturing firms are not solely manufacturers but also deliver a key service (CSIRO 2012). For example, while Cochlear is generally considered to be a medical implants manufacturing company, it also provides services to give its customers a complete package. Similarly, Resmed provides services to prove compliance in treatment.

Positioning of firms in GVCs is critical to their success, and government programs assisting SMEs need to provide good information on this. Orica, Re-Time and BRA are good examples of Australian firms that understand and respond to market changes.

### 2.3.2. Innovation

Companies that are early adopters of new technologies, coupled with flexibility and good management to diversify operations, can mitigate the impact of softening markets. A W Bell is a good example of a firm that had to re-think and transform its business model, moving away from traditional products and markets when confronted with declining demand for its tooling and products for the automotive and commodity industries in 2007-08. In order to sustain its operation, A W Bell worked with the Researchers in Business program to develop a totally new

metal casting system to deliver complex metal components with high mechanical properties for the aerospace industry. Box 2.7 provides further details, including government measures that aided the transformation of A W Bell.

Innovation is driven by firms and individuals operating and interacting within competitive markets. To increase innovation across a broad range of industries requires a focus on all aspects of the economic environment; infrastructure; communications and connections; funding; human capital; and a stable business-operating environment (Elms & Low 2013).

The competitiveness of Australian industry is determined by a number of factors, of which innovation is the particular focus of this report. However it is important to recognise that other factors can determine the extent to which innovation can contribute to competitiveness and to productivity growth. These include access to finance and infrastructure; trade agreements; and education and skills. Achieving competitiveness in global value chains (GVCs) can be achieved by strengthening Australia's comparative advantages. This implies investment in human capital, skills, high quality infrastructure and advanced manufacturing technologies. Facilitating strong linkages between industry and publicly funded research organisations is also

#### Box 2.7: A W Bell

A W Bell is an established foundry and engineering services provider based in Melbourne, whose main customer was the automotive industry. It was founded in 1952 as a pattern-maker and the company has had a longstanding culture of innovation, but lacked an innovation strategy. With the decline of the manufacturing sector and the automotive industry, A W Bell sought to transform the company in order to remain internationally competitive. It started this in 2000, by focusing on high quality, high complexity metal parts for the defence and aerospace sector and utilising new technologies and processes such as additive manufacturing.

In order to achieve this, A W Bell needed to develop a new aluminium casting process to produce parts with the desired mechanical properties which required advanced expertise in this area. By engaging with the Enterprise Connect Program in 2010, A W Bell secured the placement of an experienced metallurgist from CSIRO through the Researchers in Business Program, and was able to successfully develop a totally new casting process which delivered the desired outcomes. Further funding through Commercialisation Australia accelerated the deployment of this new process, enabling A W Bell to secure the status of preferred supplier to international defence and aerospace industries. A W Bell has been inducted into the Victorian Manufacturing Hall of Fame and was 2013 Medium Manufacturer of the Year.

The range of innovation support available to A W Bell enabled them to undertake a detailed strategic review of their business operations; identify new growth areas in a declining industry sector; successfully develop new processes to take advantage of those opportunities; and rapidly move to commercialise these processes while also undertaking continuing improvements in efficiency and business operations.

important to enable firms to participate in GVCs (OECD 2013a).

Success in manufacturing can come from collaboration between R&D institutions and the manufacturing sector. Cooperative Research Centres (CRC) have been established to provide links between industry and the research community (DIISR 2009). However, only 2.4 per cent of Australian innovating firms engage in international collaborative innovation, which is 1.6 per cent of all Australian businesses (DIISRTE 2013b). Collaboration is discussed in detail in Chapter 3.

Clustering and networks of firms generate value and scale by sharing specialised investments, facilities, scientific capabilities, equipment, skills and ideas. Innovative companies need communication and support from one another; to be surrounded by the best minds, the best inputs and facilities; and support systems to develop products based on what the consumer actually wants (Hamdouch 2008). A firm closely embedded in a supportive entrepreneurial innovation system is likely to contribute to innovation and business growth (Hoang & Antoncic 2003).

The presence of a globally competitive firm can make a significant difference to the innovation and competitiveness of the local firms in their network (Dutta and Lanvin 2013). CRCs can help to commercialise technologies in specialist fields such as advanced composite structures, automotive technologies, cast metals manufacturing, polymers and spatial information; Australia also has research infrastructure capacity in these fields.

### 2.3.3. Finance

Successful participation in GVCs depends on promotion and facilitation of inward and outward investment. Lowering investment barriers is an effective way for countries to participate in GVCs, particularly given the important role of multinational enterprises in GVCs (OECD 2013a). Public and private funding is inter-dependent and complementary. There is a clear correlation

between the two, with potential for public investment to drive private investment and innovation, attracting international talent and companies (BIS 2014). Investment in an SME by a large multinational can provide the capital, know-how and support to grow and expand into global markets.

Nanosonics is an example of an Australian firm that is currently experiencing rapid growth in sales due to an equity partnership with a major overseas health care multinational, GE. This now sees an Australian-made product, an ultrasound transducer disinfecting system, widely distributed throughout the USA, Canada and Europe. GE believes that the \$7.5 million invested to further develop the product will complement their suite of ultrasound technologies, software and services, and expand their sales footprint (Box 2.8).

### Venture Capital

Venture capital has been shown to be an effective mechanism for commercialising innovative technologies and translating research into products and services. Venture capital provides early-stage start-up companies with funding, skills and expertise in commercialisation and early-stage firms with such access are more likely to be successful. Job creation, innovation, technology advancement and international competitiveness stem from venture capital and can impact social and economic outcomes for Australia.

However recent data from the ABS (2014a) reveals that new capital committed to Australian venture capital and later stage private equity funds decreased by 77 per cent (\$2.4 billion) in 2012-13, and Figure 2.10 shows that, compared to other OECD countries such as Israel, the USA and Canada, Australia has a significantly lower level of venture capital investments as a percentage of GDP. More investment in Australia is targeted to later-seed stage than early-stage firms. This is a problem for innovators who could be the founders of new and emerging industries. Australia's very substantial superannuation funds could be given incentives to invest in venture capital, following the example of other countries such as Israel.

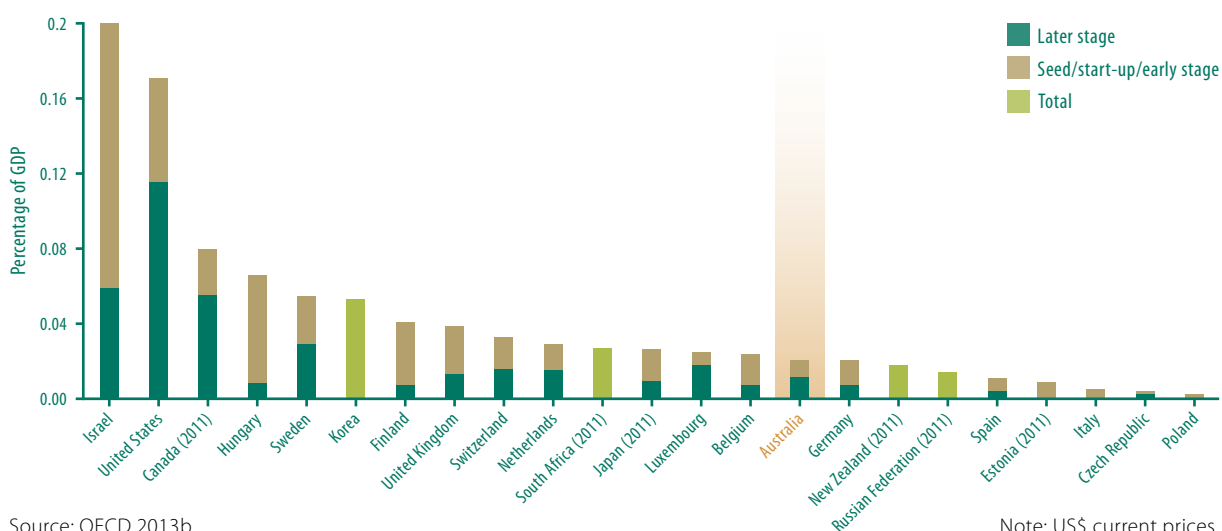
## Box 2.8: Nanosonics

Nanosonics, founded in 2001, has patented technology for a novel system to sterilise medical equipment. The traditional approach to disinfecting equipment such as probes and ultrasound devices used hazardous chemicals such as formaldehyde. This process, and the need to completely remove the chemicals before the next use, took time and created a problem of disposing of hazardous waste.

The Nanosonics system involves a low-temperature cleaning process based on high-frequency vibration, and hydrogen peroxide that breaks down into water and oxygen. Disinfection takes seven minutes and can be done in the consultation room, thus improving the productivity of expensive endoscopes and ultrasound devices. While the idea is simple, turning the concept into a functional product has taken several years. The company has produced several innovations associated with the product and now has 15 patent families and one design family. The market opportunity for Nanosonics is significant with 500,000 ultrasound machines in use and 600 million procedures conducted globally each year. This is growing at 8 per cent per annum with Nanosonics estimating that 30 per cent of these procedures would benefit from rapid and chemical-free disinfection. The sheer size of the market is a challenge for a small company. Its strategy is to capture customers quickly with a 'razorblade' business model, in which the machines themselves are profitable but the cartridges and disposables are highly profitable.

The key to realising its investment on R&D has been to distribute quickly and lock in big customers, but for a new company this is hard to achieve. The solution to this problem has been an alliance with GE Healthcare. Infection control is one of GE Healthcare's strategic technology areas and GE also controls around 25 per cent of the international ultrasound market. After collaborating with Nanosonics in 2011 to develop the North American market for the Nanosonics product, GE Healthcare purchased a \$7.5 million dollar off-market equity stake in the company in 2012. Success in the North American market has been rapid for Nanosonics since the GE collaboration, and the equity stake has given the company much-needed funds for further development and investment in production facilities. GE's marketing and distribution network has been very important with representation and relationships with hospitals and clinics across the USA and Canada: something that Nanosonics could never achieve alone. Nanosonics sales revenue has jumped from \$2.2 million in 2011 to \$12.3 million in 2012.

Figure 2.10: Venture capital investments as a percentage of GDP, 2012



Source: OECD 2013b.

Note: US\$ current prices.

## Incentives for business angels

Some countries provide incentives for business angels' investment in start-up companies. For example, Israel's Business Angels' Law offers a substantial tax benefit to individuals investing in qualified Israeli R&D companies. It allows private investors who invest in private Israeli resident companies between 2011 and 2015 to deduct

their investment from any other income source. The amount of the deduction is capped at 5M shekels (about US\$1.4M) per investee company per individual. Individual angel investors will be taxed on exit from a successful company. The conditions for eligibility are:

- Only individual investors are eligible, not a company nor a partnership.

- Only equity investments qualify, not debt, convertible notes, options etc.
- Investment must be made and payment made between 1/1/2011 and 31/12/2015.
- An investor must hold stock in the company for 3 tax years (i.e. current plus 2 years).
- The investee company must be an Israeli private company, operating in Israel.
- The company must be approved by the Chief Scientist's office.
- 75 per cent of the investment must be for R&D expenses carried out in Israel.
- 70 per cent of total company expenses must be in R&D.
- Any IP developed by the company must be the property of the company and remain so for the entire 3 tax years.
- Founders investing in their own company are also eligible.

This is similar to the arrangement operating in a number of US States but less generous than the Hawaiian scheme which provides a tax rebate.

### Crowd Sourced Equity Funding

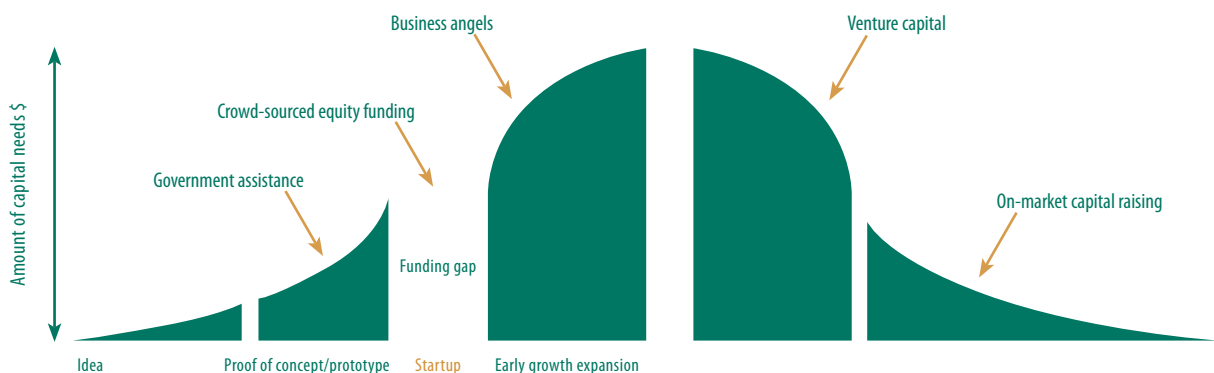
Crowd Sourced Equity Funding (CSEF) is one type of financial transaction in a group of activities referred to collectively as "crowdfunding", "crowdsourcing" or "crowd sourced equity funding". CSEF is a means to financially support early stage, high potential, high-risk firms and is a relatively recent phenomenon. It utilises online communities and social media to gain investors

in a firm, particularly for early stage development (Figure 2.11). The use of the Internet has provided the means for widespread CSEF as a means of generating investment in start-up companies. While it tends to be seen as 'seed capital' it can also be used by established businesses to raise capital. CSEF is a new mechanism that can bring together early stage companies and potential investors at relatively low cost. It has the potential to enhance traditional sources of funding. Investors could be located anywhere in the world.

The USA, Italy and New Zealand have enacted specific legislation to address this type of funding, and other countries are beginning to follow this trend. In most other countries, CSEF is subject to standard investment legislation. In Australia, CSEF is not specifically regulated. However if a firm raises more than \$2 million, with more than 20 investors, it is required to lodge a disclosure document with the Australian Securities & Investments Commission (ASIC 2012).

The Corporations and Markets Advisory Committee issued a discussion paper on crowd sourced equity funding in September 2013. This paper contains a very thorough analysis of the issues that need to be addressed to ensure an orderly investment market in Australia. The Committee is scheduled to report in the near future. It will be important for the government to act quickly on this matter. Australia is lagging behind other countries in CSEF, particularly in the more sophisticated crowdfund investing (CFI) platforms, where investors operate through an intermediary (Table 2.2).

Figure 2.11: Where crowdfunding fits on the funding lifecycle



Source: Adapted from infoDev 2013, p. 16.

**Table 2.2: The number of crowdfund investing platforms in selected countries**

Country	No. of CFI platforms	Country	No. of CFI platforms
United States	344	Brazil	17
United Kingdom	87	Italy	15
France	53	Australia	12
Canada	34	India	10
Netherlands	34	South Africa	4
Spain	27	Russian Federation	4
Germany	26	Belgium	1

Source: infoDev 2013, p. 18.

### Employee Share Schemes

Employee share schemes are an important mechanism used in other countries by start-up companies to encourage, attract, retain and motivate employees. These schemes attract talent by offering shares within the firm in lieu of paying higher salaries. This is beneficial for small start-up firms because it reduces their operating costs and gives them more time before they have to raise capital on the market or move offshore to gain further investment. This arrangement has become the international norm for start-ups around the world. The USA has the greatest experience with such schemes (O’Connell 2011), but a number of other countries now have supportive tax regimes that are the key to the success of employee share schemes.

In Australia a decision to tax employees on the unrealised value of employee shares in 2009 has disadvantaged Australian start-ups by comparison with their international counterparts. The result is that employees pay tax on the value of shares which, in most cases, they cannot sell. This decision has been strongly criticised by the Australian Private Equity and Venture Capital Association and the major accounting firms. Australia’s tax treatment of employee share schemes has been the subject of a review by Treasury and the Department of Industry for some months.

The creation of technology-based start-up companies is critical to Australia’s future. It is therefore urgent that the current taxation of employee shares is changed to more closely reflect arrangements in leading OECD countries,

and in particular, the USA. In the absence of such a change, we can expect to see more Australian start-up companies migrating to the USA.

## 2.4. Role of Government in supporting manufacturing

Government plays a critical role in providing knowledge infrastructure. Providing business information, network connections, assisting in skills development and providing knowledge to firms enables them to build capabilities. This generates many spill-over benefits for regions and the economy, including job creation. Often researchers and small firms working on the development of new products or processes face uncertainties in how best to proceed. While financial support is valuable, strategic and operational advice, as well as planning and evaluation should be embedded into Government support schemes.

The rationale for government support for innovation has been discussed extensively in the literature, and particularly in the OECD publications cited in this report. The evidence shows that, in the absence of government incentives, firms under-invest in innovation. Firms have difficulty in fully capturing the benefits from their investments in innovation. Firms can also encounter difficulties from not being aware of, or having difficulty in accessing the information they need in relation to innovation. Investment in innovation usually generates public benefits such as employment. These market failures need to be

seen in the context of the wider systemic failures discussed in this report. The result is sub-optimal productivity and economic growth. For all these reasons, governments around the world invest in innovation and in measures to ensure that firms are able to profit from innovation.

Firms that participate in GVCs innovate and grow and provide more economic benefits than firms that do not (OECD 2013a). Government policy should therefore encourage firms to internationalise and participate in GVCs and can do this in two ways: economy-wide measures and specific measures to foster innovation.

### 2.4.1. Innovation policy in Australia

Governments around the world use two types of measures to foster innovation; broad measures available to all firms and more targeted support measures. Public policy in Australia has predominantly used broad, non-targeted schemes; industry assistance measures; and some programs to encourage collaboration between firms and research organisations. Some Commonwealth Government support measures have been provided in one form or another for several decades. However there has been a tendency for frequent changes in programs. These changes in eligibility, levels of support, administrative arrangements and program names have led to confusion on the part of businesses (especially SMEs) and have made it difficult to assess the outcomes. Australia lacks some innovative support

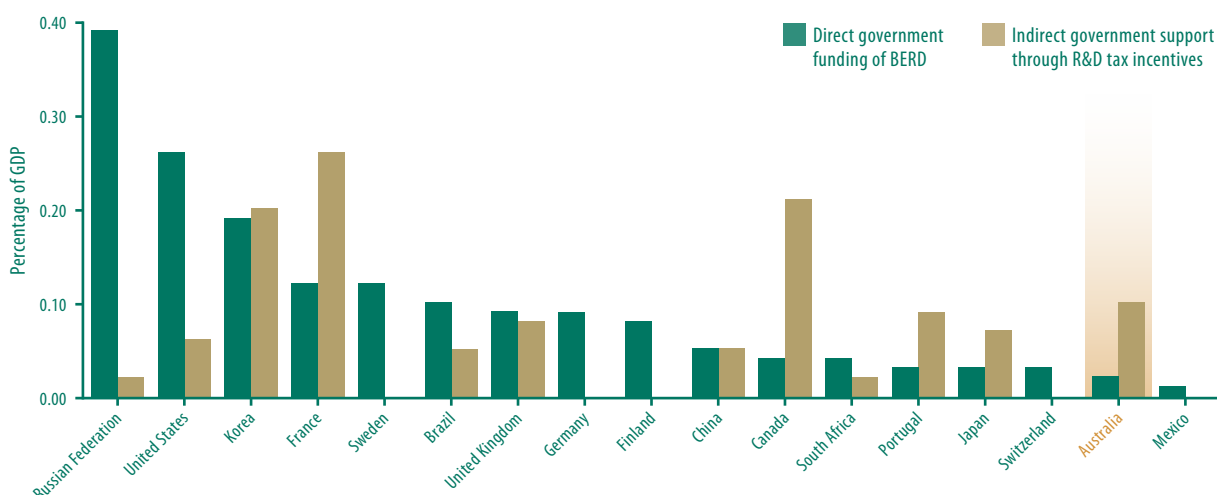
measures used in other OECD countries. The use of government procurement to grow new businesses is one example that will be discussed later.

Innovation significantly promotes economic growth and can provide solutions to challenges in Australia, with spill-over benefits to society. A study of 16 OECD countries found that higher private sector investment in R&D is likely to be correlated with a private sector that is better at adopting innovations (Guellec & van Pottelsberghe de la Potterie 2001).

Australia's R&D intensity is below the OECD average, putting us well behind the leaders. The share of R&D funded by industry increased to 62 per cent over the decade to 2008, while the share of government investment declined to 34 per cent. Total commonwealth government investment in R&D is lower than most OECD countries. Direct government support for business expenditure on R&D is very low. Indirect government support in the form of R&D tax incentives contributes to the performance of business R&D, and appears to be ranked third in the OECD (Figure 2.12). However the value of this indirect support is not measured, but is based on Treasury estimates.

Commonwealth Government support measures that support innovation include capability-building in higher education, government research laboratories and business R&D. In 2012-13, Australian Government expenditure on science, research and innovation was nearly \$9 billion. Of

Figure 2.12: Direct government investment in business R&D and tax incentives for R&D, 2011



Source: Adapted from OECD 2013c, p. 106.

this, about 20 per cent, or \$1.8 billion, was the estimated cost (revenue foregone) of the business R&D tax incentives (by comparison, revenue foregone to the mining industry in relation to a fuel tax rebate was around \$2 billion). Direct financial support for industry accounted for only 4.7 per cent or \$420.8 million of which schemes supporting the automotive industry accounted for \$298.5 million (Figure 2.13).

The Australian Government's main form of direct assistance to firms is for R&D. This goes back at least to the Industrial Research and Development Grants Act of 1967. Programs with similar intentions have continued since then, although their names have changed several times. Commercialisation Australia has been providing assistance in taking products, processes and services to market by offering specialist advice and services, and supporting proof of concept and early stage commercialisation activities. Commercialisation Australia commenced in January 2010 and had a budget allocation of \$60.7 million in 2012-13. The ability to take novel, innovative technologies from the bench to the marketplace has been a key deficiency in many industries in Australia. Commercialisation Australia's role is primarily to assist businesses bridge this gap.

The Enterprise Connect Program provides assistance to a wide range of innovative SMEs, offering business improvement services and grants, such as comprehensive Business Reviews, as well

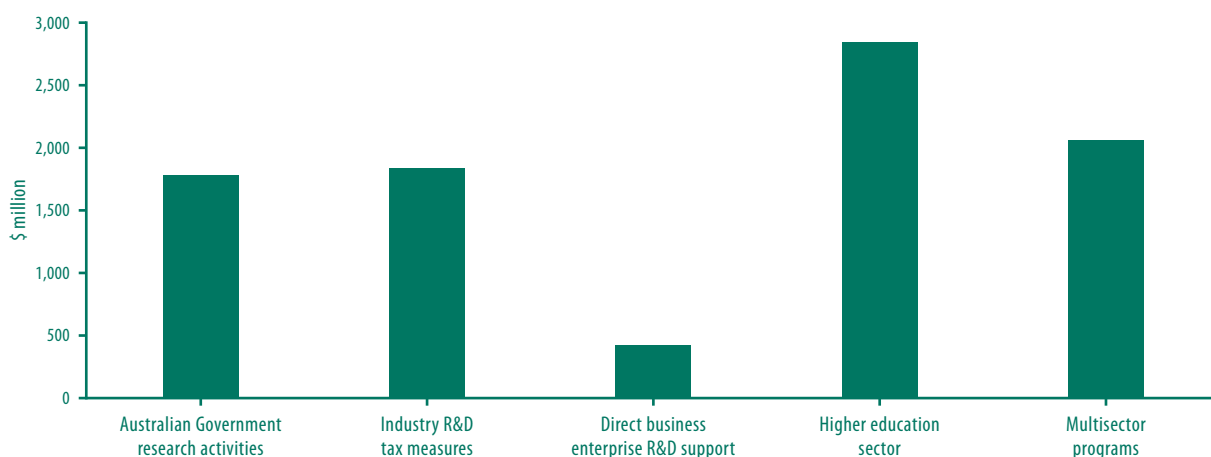
as delivering the Researchers in Business program as described in Box 2.7. Enterprise Connect has a budget allocation of \$50 million per year.

Commonwealth Government measures to assist firms are fragmented and lack scale and continuity. Unlike most other OECD countries, Australia has a history of frequent changes to assistance measures. This makes it difficult for business to plan for or rely on government assistance. In contrast, Canada's Industrial Research Assistance Program has been in operation since 1965, albeit with some minor adjustments over the years. Its budget in 2012 was more than \$A250 million.

A recent US report analysed government assistance programs for manufacturing firms in Canada, Germany, Japan and South Korea (GAO 2013). It noted that Canada is moving its focus from R&D tax credits to targeted, direct support to manufacturers, particularly SMEs, to encourage innovation.

State governments operate their own science research and innovation programs on a smaller scale than the Commonwealth. For example, assistance from the South Australian Government and the Flinders University Medical Device Partnering Program facilitated the remodelling of the firm Re-Time Pty Ltd, where changes to their business model now see the firm outsource research and concentrate on sales and marketing of their product to prosper in this market (Box 2.9).

**Figure 2.13: Estimated Government investment in science, research and innovation 2012-13**



Note: Industry R&D tax measures represent income forgone and are a treasury estimate. Australian Government research includes CSIRO, DSTO. Multisector Programs include NHMRC.

Source: Australian Government 2013.

### Box 2.9: Re-Time Pty Ltd

Re-Time Pty Ltd was spun-off by Flinders Technologies (now Flinders Partners), the Flinders University technology transfer company, in 2005 to commercialise a method to treat sleep disorders and jet lag using light therapy. This followed fundamental research by Flinders University scientists into the use of bright light for treating sleep disorders.

As a small business with a promising prototype, Re-Time sought funding from a wide range of investors including private equity firms and high net worth individuals. By April 2011, the manufacturer SMR Automotive Australia, also based in Adelaide, had expressed interest in investing in Re-Time. SMR develops and manufactures complex integrated automotive components, such as rear view mirrors, and was pursuing a growth strategy involving higher value products for markets such as the medical device sector.

SMR ultimately agreed to invest in Re-Time under a partnership agreement. SMR's in-house engineering department designed the commercial 'Re-Timer' product with input from Re-Time, and manufactures the units using their existing plant and equipment. This relationship was a win-win situation for Re-Time and SMR.

Today, the business is cash flow positive and 70 per cent of production is sent to export markets.

## 2.4.2. Australia can learn from international best practice

Evidence suggests that well-designed demand-driven policies (sometimes called 'market-pull' policies) can strengthen the innovation system and ensure that innovation spin-offs meet the needs of the public. They are effective in focusing innovation towards areas of societal need and stimulating private sector interest in public research. However, although Australia does have some measures in this area, such as the Enterprise Connect Program, we lag behind other OECD countries in their scope and scale. Some examples from other countries are discussed below.

One way of achieving this is to provide SMEs with the means to obtain help from our public research sector. Boosting the capacity of SMEs cohort to apply and commercialise more research should be a priority for Commonwealth and State governments. Only 3 per cent of Australian SMEs and 10 per cent of large firms collaborate on innovation with public research organisations (OECD 2009). There are many great examples of innovative Australian firms, particularly technology start-ups that have been assisted by government schemes. However, recent survey data reveals that only 39 per cent apply for some type of grant. There is a need to increase the awareness of support measures and provide more firms with the opportunity to succeed and improve their competitiveness, like some of the examples referred to in this Chapter.

Governments can use their own purchasing power to build innovative and successful firms. The US SBIR scheme, discussed below, is a good example of such a measure. Australian governments have been reluctant to use their purchasing power to promote innovation, but the Department of Defence's Global Supply Chain program is a small yet successful example.

### US Small Business Innovation Research Program

The US Small Business Innovation Research (SBIR) Program is an example of a market-pull procurement scheme that harnesses the purchasing power of government. It was established in 1982 by the Reagan administration. In 2010 it distributed over \$1 billion in contracts and grants. The program requires eleven US agencies with external R&D budgets of more than \$100 million per annum to spend 2.8 per cent of their budget on grants and contracts to small businesses. Firms are selected to develop products and technologies that are of interest to the government agencies. Individual agencies are responsible for selecting awardees in a way that conforms to rules set by the US Small Business Administration.

Evaluations of this Program have found strong economic and employment outcomes. For example, Lerner compared firms that had been awarded grants in 1985 with a matching set of firms over a ten year period. He found that the awardee firms had a five times greater increase in employment and a 2.5 times sales increase than

the control firms (Wessner 2008). In Australia, Victoria and South Australia have developed similar programs. These are discussed later in this Chapter.

The SBIR program aims to initiate small business engagement in R&D that has the potential for commercialisation and public benefit by 'setting aside' funding for this purpose. SBIR is funded through small business set-asides (see Box 2.10).

### UK Small Business Research Initiative

The UK Government has a similar scheme known as the Small Business Research Initiative. This scheme, which started in 2009, aims to bring innovative solutions to specific public sector needs by engaging a broad range of companies in competitions for ideas that result in development contracts. One year after it commenced operations, the program found strong support from both Government Departments and companies (Bound & Puttick 2010).

### Manufacturing Extension Partnership

The National Institute of Standards and Technology's Hollings Manufacturing Extension Partnership (MEP) has been running in the United States for 25 years, where through the assistance of both Federal and State governments, regional centres assist small to medium sized manufacturing firms to identify and adopt new technologies. The program provides a broad range of assistance, from facilitating collaboration between firms and world-class research institutes, strategies for product and process improvement and knowledge to compete in global markets.

The centres provide no direct funding to partnering companies. Assistance provided is technical, scientific and managerial and targets several critical areas: evolving supply chains; enhancing adoption of technology; implementing environmentally sustainable processes; workforce development; and promoting continuous innovation (Schacht 2011).

The MEP Program operates in 50 US States and Puerto Rico, and has been shown to have positive spill-over effects for the economy. For every \$1 invested by the Federal government, the MEP program generates nearly \$19 in sales growth, and annually generates nearly \$US2.2 billion, on top of generating employment opportunities. One successful example from the Program is the partnership involving AFrame Digital, a technology firm delivering intelligent non-intrusive and secure wireless wellness monitoring and alerting solutions for the aged at home. This partnership developed a market strategy through which a new FDA-approved medical device was commercialised. This generated over \$US1 million of investment.

### Patent box

The Patent box is a tax incentive introduced by the United Kingdom government in 2013, on income attributable to UK-developed patents. This incentivises the manufacture of new-to-market products and supports research and development in the UK by providing benefits to firms taking a product, process or service from concept to commercialisation (HM Revenue & Customs 2011).

### Box 2.10: Small Business set-asides for R&D – a new approach for Australia?

Federal law in the USA requires agencies to set aside (reserve) a percentage of their program funds for small business. The general argument for 'set-asides' is that, without them, opportunities to supply goods and service to government agencies would all be taken up by large firms. The Small Business Innovation Research Program is funded through a 'set-aside' for small business to engage in R&D that has the potential for commercialisation and public benefit.

In an Australian context, a 2 per cent set-aside for small business would impact on the ARC, NHMRC, the Industry, Agriculture and Education Departments. While the Defence Department, CSIRO ANSTO and AIMS each spend more than \$100 million on R&D annually, these are largely *internal* expenditures and therefore would not be caught in the set-aside rules.

In the USA, the Small Business Administration is responsible for ensuring that federal agencies are proactive in spending set-aside funds through SBIR initiatives.

The Patent box concept has already been adopted by Canada, as well as many European countries such as the Netherlands, Belgium, France, Ireland, Spain, Luxembourg, and Switzerland and is currently before Congress in the United States (Deloitte 2013b). Patent box is generating economic benefits by assisting innovative companies to achieve greater growth and build markets both nationally and overseas.

### **Finnish Funding Agency for Technology and Innovation (Tekes)**

Firms and research organisations operating in Finland can apply for Tekes funding to boost wide-ranging research and innovation activities. A priority of the agency is to provide funding and support to SMEs seeking growth from globalisation. Tekes understands that funding technological breakthroughs is not the only factor in supporting growth of firms. Support and advice is provided in relation to design, business, social innovations and how to strengthen global networks. Each year Tekes finances around 1,500 business research and development projects and around 600 public research project. Funding is targeted to those projects that aim to create long-term benefits to the economy and society.

### **Swedish Government Agency for Innovation Systems (VINNOVA)**

VINNOVA is Sweden's innovation agency which aims to promote sustainable growth by improving the conditions for innovations, as well as providing the necessary funding to drive research and long-term investment. VINNOVA aims to make Sweden an attractive place to invest and conduct business in by fostering collaborations between companies, universities, research institutes and the public sector, in Sweden and abroad. Funding assists business to undertake R&D and to strengthen the networks necessary for this to take place. It also facilitates knowledge diffusion, particularly with SMEs. VINNOVA programs address strategically important knowledge areas and the innovativeness of specific target sectors. VINNOVA's annual budget is close to €200 million (\$A303 million). It has 200 employees.

### **Danish National Advanced Technology Foundation**

The Danish National Advanced Technology Foundation (DNATF) is a Danish Government agency that invests in projects that will create value for the participating parties and Danish society. DNATF does this through a mediated funding model where DNATF staff not only monitor progress but also actively seek to mediate conflicts and misalignments that arise across institutional boundaries. DNATF projects involve at least one company and one public sector research institution. While the scheme is not primarily for SMEs, 77 per cent of its projects involve companies with less than 250 employees. A Harvard Business School study has compared the performance of firms funded by the scheme with firms that just missed out on funding. The study found that, three years after a firm commenced participation in the scheme, the likelihood of bankruptcy decreased by 2.7 times, the employment level increased by 14.2, filed patents increased by 5.2 times and peer-reviewed citations increased by a massive 13.7 times (Chai & Shih 2013). This study provides strong evidence that this scheme, which asks potential public and private sector partners to go through an application process followed by a mediated collaboration, reaps impressively high returns.

### **UK Knowledge Transfer Partnerships**

The UK Knowledge Transfer Partnerships (KTPs) support UK businesses wanting to improve their performance by accessing the knowledge and expertise available within UK Universities and research establishments. The KTPs are run by the UK Technology Strategy Board (which also administers the Small Business Research Initiative). More information about the UK Technology Strategy Board is provided in Box 2.11. A 2012 study of the program by found that KTPs can increase "absorptive capacity" in businesses by combining good-practice processes to overcome the barriers to knowledge transfer and stimulating organisational learning (Ternouth, *et al.* 2012). KTPs are discussed in more detail in Chapter 3.

### Box 2.11: The UK Technology Strategy Board

The Technology Strategy Board's (TSB) role is to accelerate economic growth by stimulating and supporting business-led innovation. The TSB focuses on supporting innovation by SMEs with high growth potential, which it sees as a major source of the UK's future economic growth. It works across business, academia and government – supporting innovative projects, reducing risk, creating partnerships, and promoting collaboration, knowledge exchange and open innovation.

The TSB strategy for 2011-15 focuses on five areas (TSB 2011):

1. Accelerating firms to move from concept to commercialisation.
2. Helping firms to navigate the innovation landscape through TSB's strategic relationships with sources of investment and advice.
3. Turning government requirements into business opportunities.
4. Investing in priority thematic areas based on UK skills and potential. In making investments the TSB applies four key criteria: Is there a large (global) market opportunity? Does the UK have the capability to develop and exploit the technology? Is the idea 'ready' – is the timing right? Can we make a difference?
5. Continuously improving their people and processes to be fast, flexible, and focused on business needs, ensuring that they are effective and deliver value for money.

Tools and programmes offered by the TSB can help businesses with accessing finance, accessing knowledge and skills, finding lead customers, finding partners and thriving in clusters. Its budget in 2013-14 is £440 million (\$A 857 million). The TSB is an executive non-departmental public body associated with the UK Department for Business, Innovation and Skills. A recent review by the BIS (BIS 2013) found that the TSB's status was crucial to its success, by giving it freedom to recruit specialists as required, and operate at arms-length from Government. The review considered that the TSB occupies a unique and valuable place in the UK's innovation landscape:

*The TSB has a key role to play both in building the UK's innovation capacity, supporting mission-led innovation and in helping to develop the policy framework.*

(BIS 2013)

### 2.4.3. Australian examples

The types of procurement programs described above are not generally found in Australia. However the future of manufacturing in Australia does lie with aiding small, medium and large firms to understand the GVCs of the multinational firms that supply most of the products bought by Governments and consumers.

#### Australian Defence Department

The Australian government has pursued initiatives to bring SMEs into contact with major defence contractors. For example, the Defence Materials Technology Centre (DMTC) based in Melbourne has a focus on developing technologies for end-users in the Australian Defence Force (ADF). An important objective of the DMTC is to expose SMEs to major defence contractors. For example, Thales and BAE are core members of the DMTC. Enabling SMEs to partner with other larger organisations is an important objective for the ADF innovation system and the Australian national innovation system.

The ADF has also developed the Capability Technology Demonstrator (CTD) program, which has been in existence since 1997 and has delivered a significant number of successful demonstrations since inception. Of the 117 projects initiated, 104 have progressed through the demonstration phase. Beyond demonstration, twelve technologies have been fully transitioned into service and twelve have potential to enter service. CTD success rates rival private sector new product development commercialisation rates (Barczak, *et al.* 2009).

The CTD program advertises technological challenges that need to be addressed in Australian military capability and then invites SMEs to apply for funding. Not only do these firms receive valuable feedback from users in the ADF and the opportunity to test the technology, but at the completion of the demonstration the company may be recommended to other partners including defence primes. The program assists SMEs to bridge the technological maturity gap where there is sufficient development and

de-risks attracting the attention of a major defence contractor.

Another example of such a policy approach to increase the participation of Australian companies in GVCs is from the Department of Defence through the Global Supply Chain (GSC) Program of the Defence Materiel Organisation. The GSC Program funds large multinational companies to establish staff within their organisations to act as an internal sponsor, promoting Australian industry to other business units of the company. The program also actively seeks out opportunities for Australian industry, trains and educates Australian industry in the company's purchasing practices and methods and overall helps make Australian industry globally competitive. Commonwealth defence initiatives have assisted in linking manufacturing SMEs into global supply chains within the defence industry, where they can compete in global markets.

A similar version of the Department of Defence GSC program could be adopted by other government departments. For example, in its 2013-14 Budget, the Commonwealth allocated \$9.878 billion to the Department of Health for expenditure on the Pharmaceutical Benefits Scheme. Most of this expenditure goes to multinational drug companies. A similar version of the Department of Defence GSC program could be developed between the Department of Health and the major multinational drug companies, where staff could actively seek out opportunities for Australia in all parts of the production and commercialisation process.

### Victoria & South Australia

Both the Victorian and South Australian Governments have developed programs similar to the US SBIR scheme. The Victorian government has allocated \$28 million to its Market Validation Program (MVP) which is modelled on the US SBIR program. The MVP supports a demand-led approach that funds R&D between Victorian SMEs and Victorian Government agencies to develop innovative solutions to technology challenges facing the public sector (DSDBI 2014).

The Victorian government operates an innovation and technology voucher scheme, which provides

SMEs with up to \$25,000 to collaborate with a research organisation on R&D and up to \$10,000 to develop innovative skills. One element of Victoria's voucher scheme is the Victorian Technology Voucher scheme, which targets the development and adoption of industrial biotechnology, ICT and small technologies such as nanotechnology and micro-technology sector (DSDBI 2014).

The South Australia Small Business Innovation Research Pilot Program (DMITRE 2013) is a three-phase initiative allowing SMEs to develop a solution to a 'problem' or 'challenge' identified by a Government Agency. It consists of:

- feasibility stage and development of proof of concept
- development phase – end result being a fully functional prototype
- commercial development and sale of the product or service.

### Cooperative Research Centres

At the Commonwealth Government level, the Cooperative Research Centres program supports end-user driven research partnerships between research organisations and end-users to address major challenges that require medium to long term collaborative efforts. At present, there are 40 CRCs that operate across agriculture, forestry and fishing, manufacturing, mining and services. In addition, the Researchers in Business Program supports the placement of researchers from universities and research organisations into businesses to help develop and implement new ideas with commercial potential. The initiative aims to increase the flow of knowledge and expertise across between researchers and industry and facilitate the adoption of new ideas and technologies. These are discussed in more detail in Chapter 3.

### Clusters

Clusters and other models of collaborative measures, discussed in Chapter 3, are a way of encouraging innovation between business and research organisations. Two networks, Food Innovation Australia Limited (food sector) and META (manufacturing sector), follow models used

successfully by other OECD countries. There is scope to establish more networks and clusters of this type in Australia.

#### 2.4.4. Physical infrastructure

To facilitate ease of entry and sustainability of firms into GVCs, large scale and high quality infrastructure must be available and accessible at reasonable prices. Quality and reliable digital infrastructure, such as the National Broadband Network, is a significant factor in investment decisions and for the competitiveness of the manufacturing sector. It can support globally connected businesses, giving opportunities to operate in import and export agreements abroad, deliver services in real-time and harness collaborative and competitive business practices (CSIRO 2012; AiGroup 2013a). The impact that broadband will have in manufacturing will be influenced by the way in which it is adopted, applied and used in business contexts.

Australia's increasing population places pressure on already established infrastructure, requiring expansion and/or new construction. Funding for this is becoming increasingly difficult for most governments, however investment is critical. Australia's investment in infrastructure sits around 6 per cent of GDP, and has done for four decades. Private investment currently contributes less than 50 per cent to the share of infrastructure investment. Government encouragement and assistance schemes could increase this and pave the way for the infrastructure we need to cooperate globally (Chong & Poole 2013).

## 2.5. Conclusions

Manufacturing plays an important role in Australia's economy. However, Australia's manufacturing sector is undergoing transformational change, while advanced manufacturing technologies are providing opportunities for Australia to build new industrial sectors and create high quality. Furthermore, manufacturing and services sectors are closely linked. Technological advances are opening up opportunities for the growth of high-tech manufacturing industries and services linked with global value chains.

To compete in the global environments, Australian firms need to understand trends in manufacturing. They need to invest in new knowledge and practices to benefit from emerging opportunities. Becoming an early adopter of technology and fostering advanced manufacturing techniques allows greater output and efficiency, enhancing a firm's competitiveness and share of the market. Australian firms need to increase their research and development to position themselves in new high-technology, niche industries.

Global value chains provide the ability to share knowledge, processes and skills and can initiate longer term collaborations. They can make an important contribution to productivity and growth. However, Australian firms are generally not well linked to global value chains compared to firms in other OECD countries. Information and communications technology infrastructure is critical to the operation of effective global value chains.

Manufacturing in Australia is dominated by small to medium enterprises. They have strong innovative potential but are faced with several barriers to growth, such as lack of funds; risk; and a lack of access to infrastructure, processes and knowledge networks. Facilitating the creation and growth of innovative firms of all sizes is essential to build Australia's future industries. This requires access to venture capital and new measures such as crowd sourced equity funding.

Examples of successful measures to support SMEs include the US Small Business Innovation Research Program and Manufacturing Extension Partnership, the Danish Funding Agency for Technology and Innovation, and the UK Knowledge Transfer Partnerships. Australia has some examples of measures that have been successful in assisting firms in this way (e.g. the Researchers in Business Program), however these are fragmented and lack scale and continuity. By working together and adopting some of these measures, Commonwealth and State governments could build innovative capability, enhance economic growth and improve productivity.

## 2.6. Findings

- 2.1 Some areas of Australia's innovation system are underperforming. These need urgent attention if Australia is to avoid being left behind international competitors.
- 2.2 The future of much of Australian manufacturing in many areas depends on enhanced interconnection with services.
- 2.3 Advanced manufacturing has been recognised by leading OECD countries as an important source of economic growth and quality jobs. Australia needs to build on existing initiatives such as the Advanced Manufacturing CRC and expand its efforts in this area.
- 2.4 Businesses find continual change to government assistance programs confusing. More stability is needed and unnecessary changes should be avoided.
- 2.5 New approaches to promoting the creation and growth of new firms, including small business 'set-asides', crowd-sourced equity funding, and support for innovation intermediaries, are worthy of serious consideration.
- 2.6 Australian firms need to adopt better management practices, improve their access to information on business opportunities and develop greater agility in order to be internationally competitive and, where appropriate, early adopters of new technologies.
- 2.7 Difficulties in raising capital continue to be a major barrier to firm growth. New measures are needed to assist start-ups, such as crowd funding, tax concessions for investors in start-up companies and reform of the tax treatment of employee share options.
- 2.8 SBIR-type procurement schemes, used successfully in many OECD countries and in place in Victoria and South Australia, could be adopted by the Commonwealth Government.
- 2.9 High-speed broadband communications are a vital element of industry competitiveness in the 21<sup>st</sup> Century. Australia needs to catch up to the leading OECD countries in this regard.

# 3

## Effective collaboration to improve Australian innovation and research impact

### Summary

- Collaboration between firms and researchers can increase innovation in many ways.
- There are many forms of collaboration.
- Collaboration can provide businesses, particularly SMEs, with opportunities to boost their productivity.
- Gaining benefits from collaboration is particularly important for Australia where the majority of researchers are based in the public sector, in contrast to Europe and the USA.
- The key drivers of innovation are firm size, formalised planning, and investment in employee skills, especially managerial.
- Despite the many recognised benefits of collaboration, evidence suggests that Australian businesses collaborate less than their OECD counterparts.



- There are fundamental systemic barriers to collaboration between businesses and research organisations.
- There are opportunities to learn from good practice approaches to improve collaboration.
- Broadening the criteria by which government evaluates research organisation collaboration performance would more accurately capture the breadth of their engagement activities.
- Effective collaboration is critical to improve Australian innovation and research impact.

Figure 3.1: The multifaceted role of the university

<p><b>Educating people</b></p> <ul style="list-style-type: none"> <li>• training skilled undergraduates, graduates and post-docs</li> </ul>	<p><b>Increasing the stock of 'codified' useful knowledge</b></p> <ul style="list-style-type: none"> <li>• publications</li> <li>• patents</li> <li>• prototypes</li> </ul>
<p><b>Providing public space</b></p> <ul style="list-style-type: none"> <li>• forming/accessing networks and stimulating social interaction</li> <li>• influencing the direction of search processes among users and suppliers of technology and fundamental researchers</li> <li>• meetings and conferences</li> <li>• hosting standards-setting forums</li> <li>• entrepreneurship centres</li> <li>• alumni networks</li> <li>• personnel exchanges (internships, faculty exchanges, etc.)</li> <li>• visiting committees</li> <li>• curriculum development committees</li> </ul>	<p><b>Problem-solving</b></p> <ul style="list-style-type: none"> <li>• contact research</li> <li>• Cooperative research with industry</li> <li>• technology licensing</li> <li>• faculty consulting</li> <li>• providing access to specialised instrumentation and equipment</li> <li>• incubation services</li> </ul>

Source: Dodgson, *et al.* 2008a, p. 75.

### 3.1. Collaboration between business and publicly funded researchers

The 2011 General Electric Global Innovation Barometer indicates that forty per cent of all innovation in the next decade is expected to be driven by collaboration across institutional and national boundaries (GE 2011). The nature of the relationships between business and research organisations is complex and changing. Old linear models of 'science push', where business avails itself of findings from self-directed researchers, and 'market pull', where researchers respond to the needs of business, are crude portrayals of a complicated reality. Notions of 'technology transfer', where one party supplies and another receives, have been replaced by the more relationship-based ideas of mutual 'engagement' and 'co-production of knowledge'.

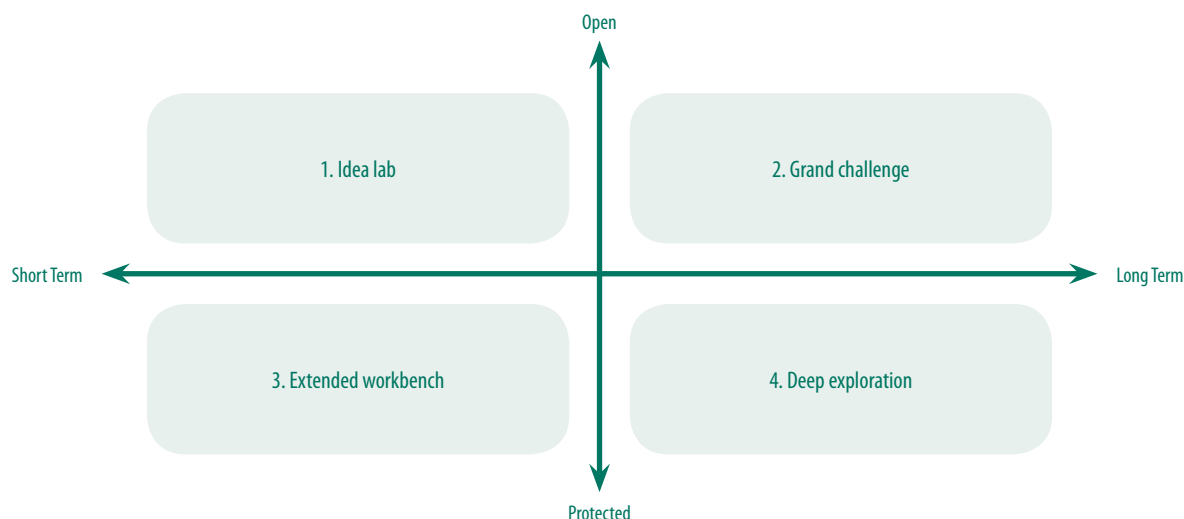
Collaboration between business and research occurs in a multiplicity of reinforcing ways, which 'single factor' models ignore. A recent study identified four major roles of universities that can benefit business (Figure 3.1). The study reveals that commonly used measures of collaboration, such as contract income, patents and licenses, cover only a small proportion of the many kinds of engagement between business and university researchers. The role of research organisations in network forming and building,

is especially under-appreciated. This finding is further confirmed in a major study of the external connections of UK academics. The conventional measures of collaboration were found to apply to a relatively small number of disciplines. The social sciences and humanities make substantial contributions in ways that were previously unreported (Hughes, *et al.* 2013).

When considering business-research collaboration it is essential, therefore, to have broad perspectives and to think in terms of wide-ranging relationships between parties, rather than depend on restricted criteria. This point is emphasised in a major review of over 6,000 academics and representatives of higher education (*The State of European University-Business Cooperation*). It identified eight different ways universities and businesses cooperate, through: R&D; mobility of academics and students; commercialisation of R&D results; curriculum development and delivery; life-long learning; entrepreneurship; and governance. Arguing that business-research collaboration is a complex ecosystem, the review shows that these ways of working together are closely related. When researchers and universities undertake one form of engagement, they tend to engage in other forms as well (Science-to-Business Marketing Research Centre 2011).

Perkmann and Salter (2012), in an article in *MIT Sloan Management Review*, develop a typology of

Figure 3.2: Different models of collaboration, balancing short and long term with openness and protection



Source: Adapted from Perkmann & Salter 2012.

partnerships based on their degree of openness and time horizons (Figure 3.2). They typify short-term projects with open agendas as *idea labs*, basically scouting for new ideas. Open projects with long-term horizons are described as *grand challenges*; these are big projects with many contributors searching for answers to common problems. *Extended workbenches* are short-term and protected arrangements – essentially contractual consultancies – that supplement businesses’ own efforts. When firms engage in long-term, protected projects these are described as *deep exploration*. Any consideration of engagement strategies by business or research organisation should account for these differences.

It is also necessary to appreciate differences between the academic disciplines in their collaborative activities. In contrast with the areas of science and engineering that work primarily with business, academics in the humanities, arts and social science sector (HASS) more often work with a range of different organisations, such as charities and cultural institutions etc. This implies there are a range of different pathways to enhance the impact of publicly funded research (Hughes & Martin 2012). In this report, references to research impact follow the ARC definition: *the demonstrable contribution that research makes to the economy, society, culture, national security,*

*public policy or services, health, the environment, or quality of life, beyond contributions to academia.*<sup>5</sup>

There is growing interest in developing broader indicators of university engagements. For example, initiatives such as the European Commission’s E3M project are examining ways to identify, measure, and compare engagement activities of higher education institutions (European Commission 2012a).

An important contextual factor is the highly concentrated nature of industry investment. In the UK, for example, the top 10 per cent of universities receive 60 per cent of industry research income, and 18 per cent of industry funding goes to just three universities: Imperial College and Oxford and Cambridge Universities. Similarly, the Group of Eight universities account for 67 per cent of industry funded research income to Australian universities and within the Group of Eight, three universities (Melbourne, Queensland and Sydney Universities) account for 36 per cent of all industry funding to Australian universities (Group of Eight 2013).

A large-scale, firm-level econometrical analysis of the effects on innovation (and

<sup>5</sup> <http://www.arc.gov.au/general/impact.htm> Accessed 16/05/2014.

collaboration) on firm productivity for Australia was commissioned for this report. This study examined two data sets involving a total of 8,000 firms, over a time series ranging from 2 to 11 years. Both datasets used information from several sources, adding credibility and robustness to the findings. The work has concluded that SMEs which previously introduced innovations were 24 per cent more productive than their non-innovating counterparts. Furthermore, firms that innovated and sourced their ideas from research organisations ('science-based' innovation) were 34 per cent more productive; and those that accompanied by their innovations with collaboration were 31 per cent more productive. The analysis indicates that successfully inculcating change through an organisation requires specialist management skills (Palangkaraya, *et al.* 2014).

### Opportunities for collaboration

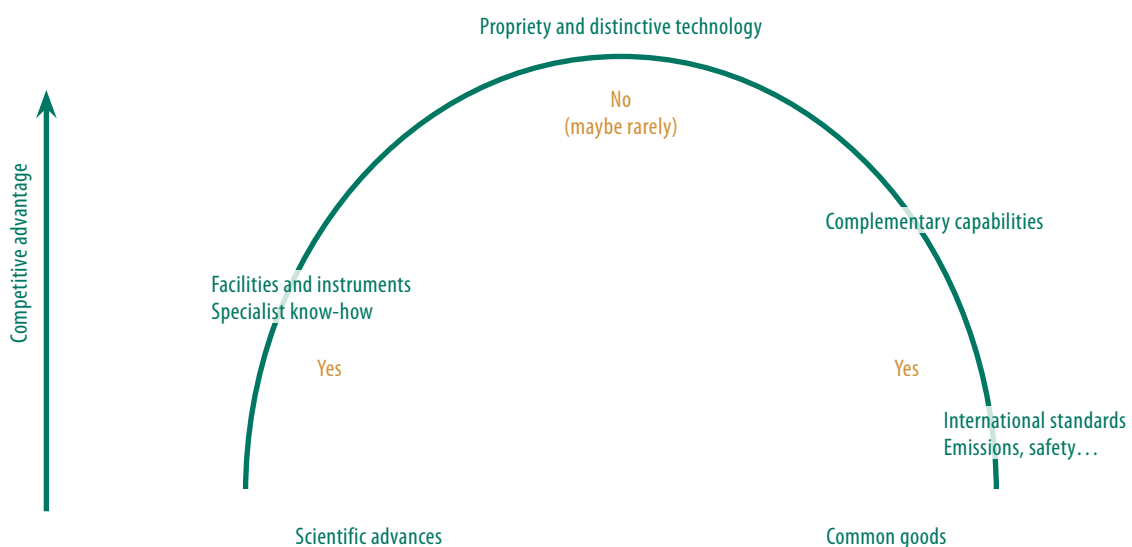
In devising programs and policies to address collaboration, it is important for policy makers to understand the processes involved. Having made a decision to undertake a research project, a business needs to decide whether to undertake it internally or to collaborate externally. For a business, the prospective benefits of collaboration have to exceed the costs. If a business wishes to collaborate it then needs to decide whom it should collaborate with and how many partners it wishes to have.

These decisions involve, amongst other things, assessment of partners' capability; potential, costs, time lines and intellectual property issues; and the organisation of project and contract management. Decisions need to be made in the light of knowledge that collaborations are challenging to manage and, by definition, their results are shared, limiting potential returns.

It is easier to collaborate in some areas than others, such as when little competitive advantage is at stake (Figure 3.3). Collaboration over broad scientific advances and specialised facilities, instruments and know-how is relatively straightforward. Similarly, research on common goods and interests, such as technical standards and safety, provides relatively secure ground for collaboration. Firms are also relatively comfortable collaborating when there are obvious complementary capabilities. The problem in this formulation arises when collaboration is sought in proprietary and distinctive technologies that provide major sources of competitive advantage.

Two implications can be drawn from this conceptualisation. First, it is unrealistic on the part of policy-makers promoting collaboration, and research organisations seeking it, to assume that collaborations have similar motivations and ease of conduct. Some are easier than others, and some are prohibitively hard. Second, although firms in the past have found it difficult

Figure 3.3: Scope for collaboration



Source: M Dodgson (unpublished).

to collaborate in proprietary and distinctive technologies, this does not mean that new engagement strategies should not focus on these in the future. The new partnership models found in some leading universities, and new more 'open' innovation strategies of firms, may see more collaboration occurring in areas where firms possess and seek high levels of competitive advantage. A key priority for policy development and collaboration management is to ensure that incentives and processes appropriate to each part of the curve are in place.

### Business-research organisation collaboration generates national economic benefits

There has been extensive research into the importance and nature of collaboration for innovation (for example: OECD 2013d; Belderbos, *et al.* 2004; Dodgson 1993). Much of this collaboration is aimed at developing new products and services. A review of international patent data demonstrates that up to 75 per cent of private sector patents draw on public sector research (ACIP 2012). On the other hand, companies participating in innovation surveys in Europe and Australia report that the most important sources are internal; clients and customers; suppliers; competitors; and trade fairs. Universities are ranked behind these other sources, but are an important source of more radical and disruptive innovations.

There are costs as well as benefits in all forms of collaboration. Returns can be shared, communications can be difficult, and transactional processes can be costly. Nonetheless, business-research collaboration can benefit both companies and research organisations in many ways, including: access to complementarities; enhanced learning and capabilities; and dealing with uncertainty and complexity (Dodgson 2014):

- Accessing complementary resources  
It is becoming increasingly necessary for organisations to access a wide range of expertise and resources to realise new opportunities and benefit from innovation. Collaboration can be the most cost-effective way of accessing new resources

and capabilities and helping to get ideas to market. Collaboration can create a 'critical mass' of skills and resources; knowledge exchange; facilitate mutual learning; enhance firm capability; provide firms with access to research facilities; and enable the development of new technologies (OECD 2004). Research organisations often have strong brands and international networks that can be leveraged by business.

- Enhancing learning and capabilities  
In circumstances where businesses are risk-averse and reluctant to attempt new approaches, collaboration can provide a stimulus to challenge conventional thinking and encourage learning about alternative practices, technologies and strategies. Collaboration can produce synergies between partners. Business-research collaboration can create talent pipelines to provide continuing access to skills. Collaboration with business can also bring direct financial benefits to research organisations, for example in project funding, scholarships and research infrastructure (ACIP 2012).
- Dealing with uncertainty and complexity  
The risks involved in radical or disruptive innovations introduce uncertainty that firms find difficult to deal with. Collaboration can reduce uncertainties through shared approaches to innovation challenges, particularly for new or emerging markets (e.g. collaboratively agreed technical standards to facilitate compliance for new products or services).

Collaboration with business can yield a range of intangible benefits to researchers including enhanced reputation; insights to shape research agendas; opportunity to engage in 'real-life' problems; engagement with the broader community; and improved employability for graduates. A recent survey indicated that the top motivating factor for engagement was a desire to see translation of research to impact in the community. The second motivating factor was engagement providing a good source of research topics and access to new information and ideas (Macpherson, *et al.* 2011).

Case studies undertaken for this project (see Appendix 1) provide strong examples of business-university and interdisciplinary collaboration:

- Cochlear recently relocated to Macquarie University to form part of the world's first precinct dedicated to hearing and related speech and language disorders.
- Westpac has recently liaised with academic institutions – in particular the University of Technology Sydney and University of Newcastle – to create a new, triangular design discipline that incorporates business and design thinking with university teaching.

Intellectual property (IP) can encourage collaboration by: attracting industry partners to work cooperatively with research organisations; assist in obtaining additional research revenue for research organisations; help transfer knowledge to industry; and translate research outcomes into improved practices, products and services (many research organisations consider these to be the indicators of the impact of their research) (ACIP 2012). IP can also provide an obstacle, with lengthy negotiations over ownership and the continuing potential for disputes.

### International collaboration

Australia accounts for between 1 and 2 per cent of global GDP and R&D expenditure. In the latter case, this means that 98 per cent of world's research is undertaken overseas – this situation is common to the great majority of industrialised nations. Australia collaborates internationally to engage with the 98 per cent of the world's research we do not do ourselves. This helps to position Australia to be a creator of some technologies and a 'fast-follower' in the adoption of others.

Innovation commonly has an international dimension. Ideas are sourced, products and services configured, and market applications finessed, across borders. There are many forms of international collaboration including: large international scientific programs, usually managed by governments; smaller-scale international collaborations between individual scientists and teams; business-international

research collaborations, such as international research consortia or alliances formed with overseas firms to access technology or research infrastructure. As an indication of increasing globalisation in the area, international R&D is increasing, both amongst large multinationals and small firms (Håkanson 2014). Firms usually undertake R&D overseas to better utilise their home-based assets, such as to configure products to local requirements, or to search for ideas and technologies that do not exist or are relatively expensive domestically; the latter especially may involve collaboration. Conducting R&D and collaboration internationally adds substantially to its management challenges.

The types of issues for international business-research collaboration are similar to those encountered in national business-research collaboration, but they are often more complicated, because of different regulatory requirements, cultural differences, and communications challenges across borders. Science, on the other hand, is inherently an international pursuit (for example: Royal Society 2011). International science collaboration builds networks and can provide a resource that can be drawn upon for international business-research linkages.

### International science collaboration

One way of measuring levels of international collaboration is through international co-authorship of publications in journals. This method does not capture all forms of collaboration, but is a useful indicator. International collaboration in science is on the rise: over 35 per cent of articles published in these international journals involve international researchers (Royal Society 2011). The extent of international collaboration varies across countries. Total UK research outputs based on international research activity increased from 30 per cent in the 1990s to around 40 per cent in 2005 in public and privately funded research organisations. China is becoming a centre of international scientific collaboration. The majority of the UK's international partnerships are with researchers in the United States, Germany and France, but the fastest growing international partnerships are with researchers in China (McCaig, *et al.* 2008).

Scandinavian countries are strong collaborators, particularly Finland. Finnish researchers publish more papers more frequently in international journals with a greater share via international cooperation. Finnish researchers had the most international collaboration with colleagues from other EU countries, and the number of collaborative research publications increased by 85 per cent in 1995-2004. The major partner countries are the United States, Sweden, the UK, Germany, France, the Netherlands and Russia. Scandinavian countries achieve significant impact in their R&D from their higher rates of overall R&D spending and in higher education; greater employment of researchers in business, manufacturing and services; higher levels of collaboration in R&D; and attract more foreign investment to support their R&D activity (Pettigrew 2012).

A recent report commissioned by the Office of the Chief Scientist highlighted that Australia has high-quality research publications and national and international collaborations in most scientific fields. Australia's research impact has been in part due to a doubling of internationally collaborative publications (between 2002 and 2010) and a tripling of the total number of internationally co-authored publications. Collaborative research partnerships were mainly with the US and Europe but, in some areas such as mathematics, engineering and chemistry, China is now Australia's leading collaborative partner (Pettigrew 2012). The USA remains the favoured nation for research collaborations with Australia, and for most other nations (Barlow 2011). Australia has strong medical research collaborations with Spain (clinical drug studies) and China (genetics/genomics). However, despite these areas of strength, Australia's overall performance in relation to international collaboration in science, research and technology is assessed as poor (Pettigrew 2012).

In the past decade, the Australian government supported international research collaborations under the International Science Linkages Program. A review of the \$10 million per year investment found that it had been highly successful with multiple benefits (DIISR 2011a). These included the creation of new research

collaborations and the strengthening and growth of existing research relationships. The Nobel Prize awarded to Brian Schmidt was based on work partially funded by the International Science Linkages Program. However, International Science Linkages funding was discontinued in 2011 and no equivalent was put in place. As a result, Australia lacks a source of funding to support strategic collaboration with countries other than China. The advantage of such a program would be to enable the government to support collaborative research with those countries with which Australia has science and technology agreements, in areas of identified mutual interest.

The Australian Research Council (ARC) and National Health and Medical Research Council (NHMRC) provide grants aimed at fostering knowledge, research and exchanges. Applicants for these grants can incorporate international collaboration in their proposal. However, these grants require a partner to already be in place, limiting grants to those who already have connections. Applicants normally receive significantly less funding than they have requested. Anecdotal evidence suggests that very little grant funds are spent on international collaboration.

The Australian Government Department of Industry has funded collaboration for Australian researchers with China and India in particular priority areas e.g. energy; engineering and materials science; agriculture and biological sciences; multidisciplinary projects relating to sustainable futures; and environmental sciences. The Australia-China Science and Research Fund, 2011-14, had a total budget of \$9 million, matched by the Chinese government. Its grants were small (maximum of \$45,000). The Australia-India Strategic Research Fund had a total budget of \$64 million, matched by the Indian government. The China and India collaboration funds have been fully allocated and it is not known whether there will be further funding. Furthermore, the recent *Science Technology Innovation: Australia and India* report, argued that there needs to be multiple layers of funding to cover the full spectrum of collaboration, from initial meetings, follow-up opportunities and delivery (All Taskforce on Science Technology Innovation 2013).

CAESIE (Connecting Australian European Science and Innovation Excellence) is a bilateral collaboration initiative between the European Union and Australia. It aims to establish science and technology collaboration and partnerships between SMEs businesses and researchers in Australia and Europe. Core priority areas include; clean energy; healthy ageing through enabling technologies; and sustainable cities. However, Australian entities wishing to work with European partners need to source funds from either existing resources or grant programs.

### International collaboration to address global challenges

Researchers are increasingly working together to tackle global challenges in areas such as energy, health and the environment. These challenges are complex and the associated scope, scale and budgets are far beyond the capacity of one country to address, necessitating working with the best knowledge, institutions and equipment that the world has to offer (OECD 2012b). Past examples of large-scale collaboration involving many countries include The Human Genome Project and Census of Marine Life (Box 3.1).

Australia has been a participant in many global scientific collaborations, for example: the Integrated Ocean Drilling Program, which involves 26 nations deploying state-of-the-art ocean drilling technologies to advance scientific understanding of the Earth; and the Australian Synchrotron, Melbourne, which seeks to advance

studies in biological, medical and industrial. The Square Kilometre Array (SKA) is another example, in which collaboration between Australia and South Africa will develop the largest radio astronomy project in history.

### CSIRO has extensive international collaboration

CSIRO is a large and important contributor to Australia's innovation systems (Marceau 2007) and, while its collaboration performance can be argued to be mixed, it displays examples of good practice. The CSIRO strategy 2011-2015 has 'deep collaboration and connection' as one of its five pillars, and its Flagship program has a collaboration fund that had committed \$120 million by 2011.

Although most of its connections are to universities, CSIRO claims to have worked with over 1,500 Australian companies in 2012, and to have worked with 350 multinationals. The focus here will be CSIRO's international collaborations, as this is an area of comparative expansion. Half of CSIRO's publications for the period 2007-11 had at least one Australian author outside of CSIRO, with this percentage only increasing slightly from 47 per cent in 2002-06. Just under half (48 per cent) of CSIRO's publications are co-authored with international institutions; this reflects an increase from 38 per cent in 2002. Publications with international partners have significantly higher citation rates than those produced without international collaboration, providing some indication of their higher impact.

#### Box 3.1: Examples of large-scale collaborations

**The Human Genome Project** was an international collaborative research program, involving the US Department of Energy and the National Institute of Health that formally began in 1990. To tackle the immense task of mapping and understanding all the genes within the human body, the HGP enlisted over one thousand researchers from 16 institutions across six nations (USA, Great Britain, France, Germany, Japan and China) to publish the final sequence in April 2003. Its success can be attributed to large-scale, technological, human knowledge and financial investments, which saw the project cost approximately three billion dollars (International Human Genome Sequencing Consortium (IHGSC) 2004).

The decade-long **Census of Marine Life** project involved more than 80 countries, with a combined effort of approximately 2,700 researchers globally, to assess the diversity, distribution and abundance of marine life. This task resulted in more than 2,600 scientific publications, community engagement opportunities, and provided a platform for future research in this field. In 2010 the results were presented at the UK Royal Society. A philanthropic organisation, the Alfred P. Sloan Foundation, initially provided the funding for the international infrastructure that allowed scientific collaboration and support from various programs, organisations, government agencies and foundations (Census of Marine Life 2010).

CSIRO's international research collaborations are strongly skewed towards the USA (28 per cent of connections), followed by the UK (9 per cent) and China (8 per cent). CSIRO reports that its international collaborations with the USA doubled over the 10 years to 2011 and increased two-and-a-half times with China. Domestically, while the majority of CSIRO's partners are from industry, most revenue comes from government. Internationally, most partners and revenue come from industry. CSIRO reported \$41 million in contract revenue from international industry in 2012.

Quality and relevance of research is the most obvious attraction to international partners. CSIRO leverages its connections as a member of the Global Research Alliance consisting of nine members, the other being: Battelle (USA), CSIR (India), CSIR (South Africa), Danish Technological Institute (Denmark), Fraunhofer Society (Germany), SIRIM Berhad (Malaysia), TNO (the Netherlands) and VTT (Finland). CSIRO reports a correlation, but not necessarily causation, in the relationship between international travel and international co-authorship of research papers. This reflects the point that while collaboration can often be sustained electronically, it needs to be built face-to-face.

### 3.1.1. Performance

As Figure 3.4 shows, Australian businesses collaborate less than their international counterparts (OECD 2013c). The 2012 and 2013

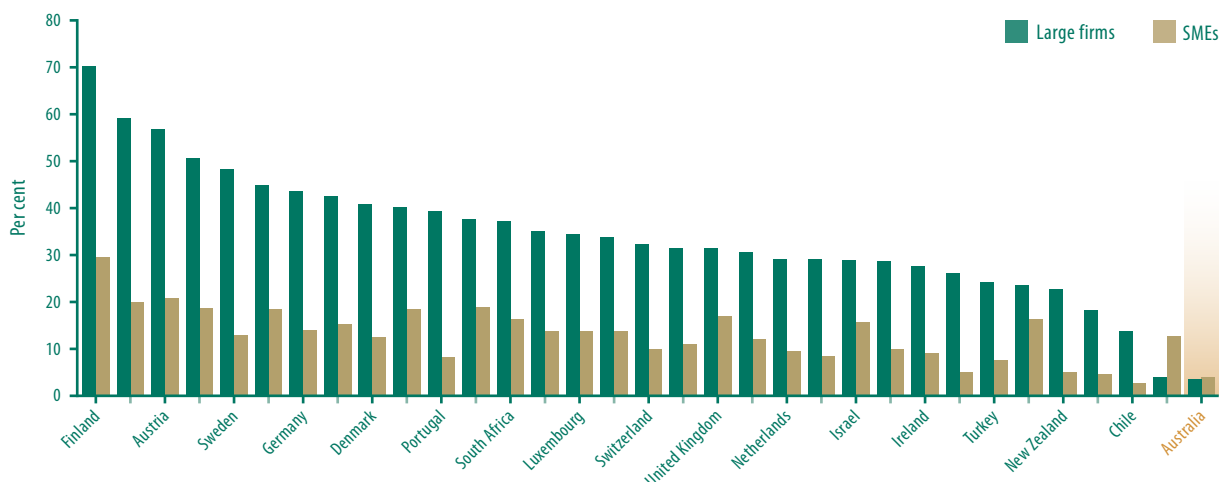
reports of the Australian Innovation System have both highlighted the problem (DIISRTE 2012b; Department of Industry 2013).

Reporting results for innovation-active business in Australia, the ABS (2012b) found that 4.4 per cent collaborate with research organisations and only 2.4 per cent collaborate with universities. ABS data shows Australian businesses do not collaborate with research organisations to the same extent as other leading OECD countries. Large businesses rank 21st at 21.9 per cent and SMEs rank 15th at 12.7 per cent out of 26 OECD countries.

The majority of researchers in Australia are based in the public sector. In contrast, the majority of researchers in Europe and the USA are based in the private sector. This makes it even more important that Australia should have measures to increase collaboration between researchers and publicly funded research organisations, as well as lift the engagement of researchers with business.

There are several avenues through which knowledge developed by research organisations can be captured, transferred and commercialised. A recent OECD report highlighted the challenges in measuring the effectiveness of different measures, due to limited statistics. For example, although invention disclosures do not directly provide data about commercialisation by an organisation, they can be used to indicate the number of potential patents an organisation could have.

Figure 3.4: Firms collaborating on innovation with higher education or public research institutions



Note: By firm size, 2008-10, as a percentage of product and/or process innovative firms in each size category.

Source: OECD 2013c, p. 127.

### 3.1.2. Constraints

There are systemic barriers to increasing collaboration between business and research organisations. Barriers to collaboration can occur at different levels; structural, organisational, career-related and geographic. Structural barriers are imposed through regulation, legislation, procedural rules or physical constraints. Organisational barriers relate to issues arising from the culture and values of an organisation. Researchers are driven by research objectives, whereas businesses are driven by commercial objectives. The difference between these objectives can lead to challenges in developing shared goals between researchers and business in collaboration. Career-related barriers are associated with differing advancement or promotion practices across organisations that may affect how a researcher is assessed and therefore how they collaborate. Geographical barriers relate to inadequate access to infrastructure, facilities, communication mechanisms and the location of partners (DEST 2004).

Other barriers to collaboration include:

- **Lack of understanding**  
A lack of understanding, especially on the part of SMEs, of what research organisations can do to help them. Lack of experience by research organisations in an industrial R&D environment can also be a problem. SME needs for rapid results may not be understood by researchers.
- **Finding the right partner, at the right time**  
Businesses can find it hard to know where to start and who might be best placed to help them. Negotiating collaboration agreements with publicly funded research organisations can be difficult, particularly in relation to intellectual property. Business-research collaboration is a 'people' business, and the key to successful knowledge exchange is a process of continuous dialogue and a build-up of social networks (Science-to-Business Marketing Research Centre 2011).
- **Financial impediments to collaboration, especially for SMEs**  
Transaction costs, both financial and effort related, associated with collaboration can be a high barrier to innovation for research

organisations and businesses, especially SMEs. Legal complexities, associated with risk avoidance, are also a high barrier to collaboration.

- **Usability of results**  
Business focus on practical, commercially oriented results and concerns for confidentiality can be difficult to align with university prioritisation of discoveries and publications (Science-to-Business Marketing Research Centre 2011).
- **Intellectual property**  
A number of reports have identified problems with research organisations in regard to intellectual property, including unrealistic expectations on the part of some researchers in relation to IP. Respondents to a recent Advisory Council on Intellectual Property (ACIP) consultation indicated that ownership of IP rights is a key issue to resolve at the negotiation stage of collaboration (ACIP 2012). Costing of contributions; insurance; publication rights; and warranties and indemnities, were also identified by the ACIP consultations as a potential challenge to negotiate and the cause of delays. The ACIP report notes that negotiations between industry and the research sector work well at a technical level, that is, researcher to researcher. Issues that were identified as usually easy to negotiate included: the scope of work; project milestones and timeframes; and definition of deliverables.

The Excellence in Research Australia (ERA), which has had an emphasis on publications in highly ranked journals, has put new emphasis on research quality but is widely considered to discourage university researchers from collaborating with business. The ERA influences university reward systems (e.g. promotion, tenure and prestigious awards). Around \$60 million per annum of government research investment is allocated on the basis of ERA results (for more detail see Group of Eight (2012)). Consultations with stakeholders, undertaken as part of this project, revealed that engagement with business is often considered to reduce the time available to undertake publishable research. There is no parallel incentive to the ERA to reward university researchers who collaborate with business.

Recently, the Australian Technology Network of Universities and the Group of Eight Universities carried out a joint trial, assessing the impact of research produced by the Australian university sector. However a more workable way of recognising research impact (which could be through collaboration with industry), equivalent to the ERA recognition of research excellence, could be developed.

One way of addressing the disincentive to collaboration with business arising from the ERA would be to develop an indicator of university engagement with industry (possibly revenue received from industry) and to reward this activity with research investment.

### 3.1.3. Current measures

Government policy plays an important role in encouraging and enabling collaboration between research organisations and business. In Australia, the Commonwealth Government supports collaboration, primarily through the mechanisms listed in Box 3.2. However, while these measures have been shown to have merit, their overall impact in encouraging collaboration must be considered as limited, given Australia's low-levels of collaboration (Section 1.2).

The Cooperative Research Centres (CRC) Program is a long-standing government measure to support collaborations between researchers and end-users of research, including businesses. Reviews of the CRC program show it has generated beneficial economic and social outcomes. A recent report found that the CRC program has generated a net benefit to the economy of \$7.5 billion since its inception in 1991, equating to around 0.03 percentage points of additional GDP growth, chiefly resulting from

increased export earnings (Allen Consulting Group 2012a). In the past, CRCs have been seen as difficult to access by SMEs, particularly in making a 7-year commitment. The CRC program guidelines now require CRCs to undertake strategies to build SME innovation and R&D capacity. The CRC Association has suggested a number of ways in which this can be achieved (CRCA 2010). Similarly, research has shown that numbers of Rural RDCs have been effective in building collaboration and generating economic benefits.

There are some State government programs to encourage collaboration. In some cases these are explicitly targeted at SMEs. For example, the Queensland Science and Innovation Action Plan has the goals of supporting: seamless and active interchange of people between universities and business; community engagement in science and innovation; and connecting research and industry. In Victoria and South Australia there are government schemes specifically targeted to support innovation in SMEs (see Section 2.4.3). Research organisations have also tried to encourage university-industry linkages with measures such as the Australian Technology Network Industry Doctoral Training Centre.

It is recognised internationally that effective collaboration between business and research organisations can assist in capturing the innovation dividend from publicly funded research. Consequently there are many government-sponsored programs in Europe, Asia and the US that offer grants to facilitate and encourage collaboration and to reward organisations that progress collaboration (ATSE 2011). Australia's poor performance in business-research collaboration suggests that there are opportunities to improve policies in this area.

#### Box 3.2: Current measures to encourage collaboration

- The Cooperative Research Centres Program
- ARC Linkage Grants
- ARC Industrial Transformation Research Program
- NHMRC Partnerships Projects
- NHMRC Industry Career Development Fellowships
- NHMRC Development Grants
- The Enterprise Connect Program
- Researchers in Business Program
- Rural Research and Development Corporations (RDCs)

It may be difficult for an organisation/company to assess the potential value of the collaboration if it has not collaborated previously. Commenting on the barrier between universities and business, one group of universities has observed:

*This barrier can only be broken down through an initial, positive experience of institutional engagement which builds trust between a firm and its university partner, and provides experience in the development and management of university engagement. An effective way for universities to encourage first-time business investment and build trust with prospective partners is through seed-funding for new and developing relationships. This funding gives the university a financial stake in the partnership and by sharing some of the investment risk, demonstrates to industry a commitment to mutually beneficial partnerships.*

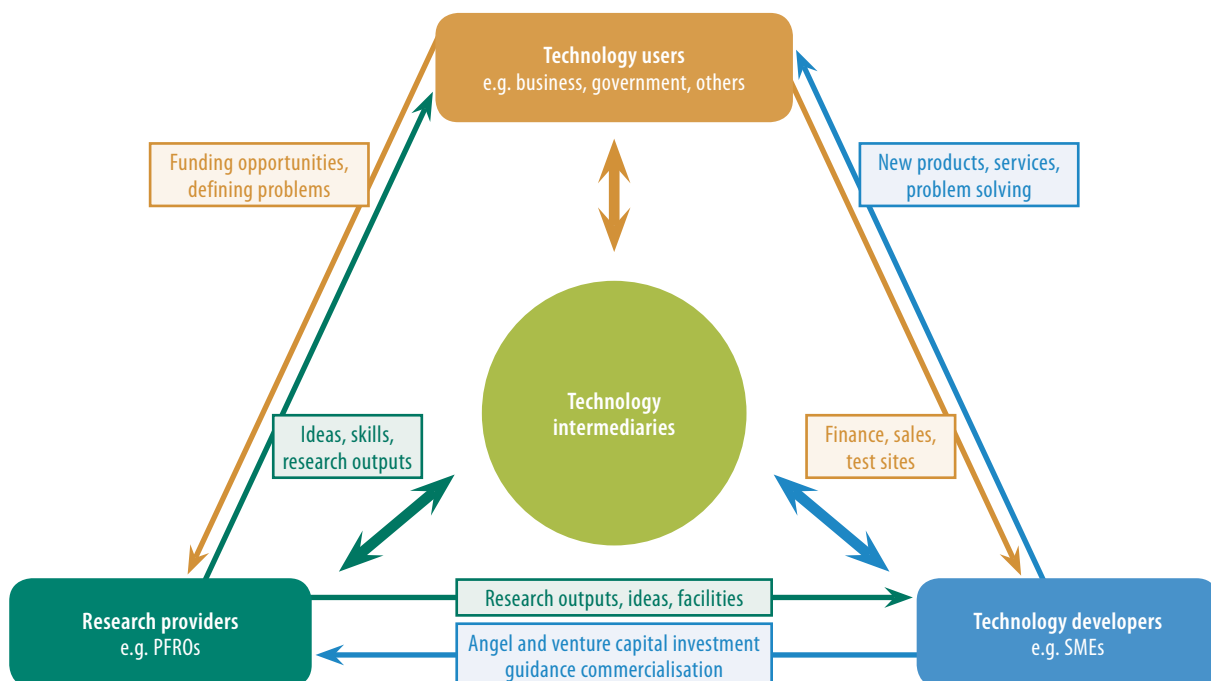
(IRU 2013)

### Intermediaries and technology brokers

A wide range of innovation intermediaries promote collaboration. They have long been a focus of innovation policy around the world (Dodgson & Bessant 1996). Innovation intermediaries are institutions and organisations that operate to connect sources of ideas with their application. They can take the form of clusters, technology brokers, Internet-based markets, incubators (physical spaces for business development) and accelerators (schools for improving business opportunities). Independent facilitation can help create effective collaborations between businesses and research organisations, by helping to find the most appropriate partner for collaboration, one who shares the same goals and values, building trust and establishing momentum (Figure 3.5) (ATSE 2013b).

'Intermediaries' and 'technology brokers' are broad terms that include the large intermediary

Figure 3.5: The role of intermediaries in the innovation system



Note: Government policies, programs and actions can affect each of the network nodes shown. Frequently a combination of different measures might be needed aimed at different nodes in the network. Examples of government influences include:

- For **research providers** government provides research grants and other incentives and set priorities.
- For **technology developers** government provides grants, procurement programs and measures such as a R&D tax concession.
- The National Collaborative Research Infrastructure Strategy (NCRIS) is a good example of an infrastructure support scheme that brings together users from public and private sectors.
- For **technology users** government provides procurement programs and measures such as a R&D tax concession.
- For **technology intermediaries** governments measures include ARC linkage, voucher programs, matching levies and programs such as the CRC program.

Source: ATSE 2013b, p. 6.

organisations used in many OECD countries to aid research translation and facilitate the uptake of new technologies. They facilitate connections between business and research organisations, helping to select partners and stimulate research collaborations. They can articulate market needs to researchers and interpret research findings to business. Many are research organisations that include the uptake of their technologies centrally in their missions. They include, for example, the Fraunhofer Society (Germany), the Steinbeis Foundation (Germany), Catapult Centres (UK), Inter-University Micro Electronics Centre (Belgium), Industrial Technology Research Institute (Taiwan) and the Electronics and Telecommunications Research Institute (South Korea). All of these organisations share a common focus on international markets. Government grants and procurement policies are important for their continuing success (Mina, *et al.* 2009) although other more commercial models exist, such as the various Research Associations in the UK.

Catapult Centres are a recent UK initiative and have some similarities with Australian CRCs. Managed by the Technology Strategy Board, Catapult Centres bring together the UK's businesses, scientists and engineers to work side by side on late-stage research and development – transforming high potential ideas into new products and services to generate economic growth. They appear likely to be a successful new model that Australia could follow.

Other brokers do not undertake research themselves and operate outside government but with government support. They can play an important role in facilitating connections between SMEs and publicly funded research organisations. Such intermediaries can catalyse collaborations between business and research organisations; help manage them to run smoothly; and hence reduce some of the risks of innovation. Through this role, brokers provide SMEs with appropriate sources of assistance and advice for a range of issues, from technology or R&D problems to developing a business plan. Another model is provided by AMIRA International, which develops and manages collaborative, jointly funded research projects on a fee for service basis. This approach provides

access to technologies and processes and a sharing of the costs and benefits of research – AMIRA estimates a leverage of 10-20 times the funds contributed (Dodgson & Steen 2008).

Most universities have an office that is charged with managing intellectual property and relations with business. These Technology Transfer Offices (TTOs) are a form of internal intermediary for universities (Mina, *et al.* 2009). TTOs are viewed as an aid but also as a potential hindrance in collaboration (ATSE 2011). A recent report by ACIP noted that some in industry tend to see TTOs as an unnecessary hurdle in establishing a direct relationship with researchers. TTOs are often blamed for unduly long contract negotiation processes with high transaction costs. On the other hand, TTOs report that they regularly have to fix problems created by researchers making unauthorised promises. TTOs also complain of being given little time to assess and protect IP before its disclosure by researchers in a journal article or conference paper. There can also be internal tension between a university's Research Office (typically responsible for the management of research grants) and the university's Technology Transfer Office (managing IP development, collaboration and licensing) (ACIP 2012).

Recent years have seen the emergence of Internet-based intermediaries, such as Yet2.com and InnoCentive, which serve as online markets for ideas, problems and solutions. These have rapidly achieved significant scale, with hundreds of thousands of contributors.

### **Business incubators and accelerators**

The Victorian Centre for Advanced Materials Manufacturing is an example of an Australian technology incubator that aims to help SMEs to collaborate with research organisations and government to take a technology from initiation to market realisation. Intermediary organisations can help SMEs to realise the benefits of government schemes, for example, by using vouchers to help SMEs collaborate with research organisations.

Technology accelerators serve as 'schools' that provide training and contacts to start-up

companies. Participants must undertake an application process and pay a fee if they are selected. Courses typically run for three months, during which time participants often work in teams on specific projects, undertake courses and receive mentoring. There are over 2,000 worldwide (The Economist 2014).

Håkanson, *et al.* (2011) identified three core capabilities for successful innovation brokers/intermediaries: i. Network spanning across a defined range of sectors; ii. Organisational memory including knowledge management systems, opportunities for social and professional interactions; and iii. Credibility as mediator. It is notable that each of these relies on long-term investment building capabilities over time. Australia, however, has a tradition of starting up schemes, such as the National Industry Extension Scheme and InnovationXchange (Box 3.3), but not sustaining them in the long term. Intermediary organisations such as these need some continuing support from government.

Of special interest to business-research collaboration is the scale and ambition of the series of substantial initiatives of globally leading universities in creating new campuses designed to create effective innovation ecosystems. These include: MIT's Kendall Square; Berkeley's new campus for interdisciplinary research centres and incubator; Stanford's Media X initiative; NYU's new collaborative research centre in downtown Brooklyn; Imperial College's Imperial West research translation campus; and the Francis

Crick Institute in London. The lesson for research organisations is that unless their strategy is to address relatively small-scale local issues, construction of a significant and productive innovation ecosystem requires substantial and continuing investment.

No discussion of current measures to encourage collaboration would be complete without a discussion of the relative roles of the Commonwealth, State and Territory governments. Both levels of government have an important role to play. While some measures, such as the CRC program, need to be national, others, such as business incubators and accelerators, are better delivered by state and territory governments. There is a strong case for all levels of government working together to provide 'one-stop shop' information sources for innovation support.

### 3.1.4. Examples of good practice measures

There are lessons to be learnt from successful measures to promote collaboration. There is a substantial literature on business-research collaboration, but there remains a paucity of high-quality, independent case studies of 'good practice'. This results partly from the high turnover of initiatives in this area in many countries, and partly from the length of time it takes to properly evaluate their contribution. Nonetheless, there are examples of well-researched initiatives that do demonstrate effectiveness in building and sustaining business-

#### Box 3.3: InnovationXchange

InnovationXchange (IXC) was an internationally active and initially highly successful innovation intermediary, founded in 2006. IXC, a not-for-profit organisation, was spun-out from the Australian Industry InnovationXchange network (funded by the AiGroup Tyree Foundation) in 2002 (Australian Life Scientist, 2011). IXC identified and matched partners, facilitated knowledge sharing and lowered the cost and risk of collaboration. The capability to span existing networks, organisational memory and mediation credibility and skills were integral to the success of IXC (Håkanson, *et al.* 2011). The strength of the IXC model lay in its arms-length relationship with government and its staffing with business professionals.

IXC is an example of a sound policy initiative that was undermined by uncertainty in funding arrangements. The Howard Government decided to allocate \$25 million to an SME initiative, much of which would have benefited IXC, but following a change of government this support was cancelled. IXC ceased operation in 2011, because of funding uncertainties. In contrast, the InnovationXchange schemes continue to operate in other countries, such as the UK.

The subsequent establishment of Enterprise Connect failed to include some of the best features of InnovationXchange.

research collaboration. For some of the measures discussed in this section there are currently no comparable programs in Australia.

### UK Knowledge Transfer Partnerships

Knowledge Transfer Partnerships (KTP) is a program in the UK that aims to help businesses improve their productivity and competitiveness through better use of technology, knowledge and skills by partnering individual businesses with an academic institution. Each partnership has a recently qualified person (postgraduate researcher, university graduate or other qualified individual) join the company to work on a project of strategic importance to the business. The costs are part-funded by government with the balance met by the participating business. Upon completing the project, both partners need to complete a final report reflecting on the collaboration and the outcomes, which is then used to measure the impact of the project and the performance of the program.

Currently there are over 800 partnerships across the UK with an average annual project cost of £60,000 (around \$111,000). The programme is funded by the Technology Strategy Board and 14 other Government bodies. Projects can vary in length between 12-36 months. Numerous evaluations of this scheme over its 35-year existence show high levels of effectiveness. The key findings and conclusions of the most

recent review (Regeneris Consulting 2010) are summarised in Box 3.4.

### Voucher schemes

Since the Netherlands first introduced them in 1997, governments in over 20 countries have introduced innovation voucher programmes to enable smaller firms to gain access to research infrastructure, knowledge and processes (OECD 2011a). The aim of voucher schemes is to ultimately enhance innovative capabilities in small firms by allowing them to form a partnership that will stimulate knowledge exchange and instigate longer-term relationships where ideas can flow freely. Voucher schemes subsidise the cost for SMEs to gain access to collaborative research, exposing them to the value of collaboration, and providing funds and resources to link with appropriate partners.

In Australia, the Victorian Innovation Voucher program aims to provide the capacity for SMEs in Victoria to work with research organisations to access R&D facilities, training, goods, services, advice and expertise. Independent evaluation of the Small Technologies Industry Uptake Program (STIUP) that preceded the Victorian innovation voucher program concluded that vouchers were an effective way to overcome barriers to engagement between companies and the State's innovation capability (Allen Consulting Group 2012b).

#### Box 3.4: KTP Strategic Review – summary of main findings and conclusions

- KTP is a well-liked and an effective product which generates good levels of client satisfaction and impact among the businesses, academics and associates it supports.
- KTP has a well-established delivery and management infrastructure in place and benefits from a great wealth of expertise and capacity among its delivery partners.
- KTP operates in a supportive policy landscape. Central government has emphasised the importance of knowledge transfer and high value business activities. Universities and other knowledge based institutions continue to be committed to business engagement activities.
- Between 2001-02 and 2007-08 overall net additional impacts secured by KTP were:
  - £4.2-4.6 billion (\$7.8-8.5 billion) in new sales
  - £1.6-1.8 billion (\$3-3.3 billion) gross value added
  - 5,530-6,090 jobs.
- On average each partnership has created three additional jobs.
- Return on investment is £4.70-5.20 (\$8.71-9.63) of net value added for every £1 of public investment.
- Non-economic benefits include feedback into academic teaching and the identification of new research themes.

### Improving university-business engagement: Imperial College UK

A number of universities have radically improved their strategies for engaging with business. An example is provided by Imperial College London, which receives more money from industry for research than any other UK university. It has a comprehensive strategy in place to improve its business engagement and a variety of organisational structures in place to build and sustain its collaborations with business (Box 3.5).

### US Small Business Innovation Research Program

The US Small Business Innovation Research Program (SBIR) is a highly competitive procurement program encouraging SMEs to engage in Federal Research/Research and Development that has potential for commercialisation. This program is described in more detail in Chapter 2.

Procurement programs are used in South Australia (the South Australian Small Business Innovation Research Pilot Program) and Victoria (the Market Validation Program) to help SMEs to innovate. However, the scale and duration of these programs does not rival that of the US SBIR program.

The US government also operates the Small Business Technology Transfer (STTR) program to support interactions between universities and businesses. The STTR program reserves a percentage of R&D funding to award to US non-

profit research institutions and small businesses and sits alongside the US SBIR program.

### UK Third Stream Funding

The UK has introduced a “third stream funding” approach for universities based on industry engagement metrics across a range of activities including consultancy, training, community engagement and collaboration as well as licensing. Through this process the UK research funding councils spend in the order of £150 million per year in supporting technology transfer, knowledge exchange and community development (DIISRTE 2012b).

### Scottish Enterprise Proof of Concept Programme

The Scottish Enterprise Proof of Concept Programme (PoCP) supports the pre-commercialisation of leading-edge technologies emerging from Scotland’s universities, research institutes and National Health Service Boards. PoCP assists researchers to transition their ideas and inventions from the laboratory to the marketplace. The programme funds projects with strong commercialisation potential, with the aim of creating high-growth companies based in Scotland with the potential and capability to achieve significant growth.

### Policy research institutes

Many nations have substantial policy research groups that conduct studies of innovation,

### Box 3.5: Imperial College mechanisms for engaging business

- **Imperial Innovations** – which has a technology transfer function and a venture support mechanism that also services Oxford and Cambridge University and University College London. It has been floated on the stock market and is driven by commercial objectives.
- **Imperial Consultants** – which offers consultancy, testing and analysis, project management and expert witness services.
- **Imperial Business Partners** – which manages relationships with carefully identified strategic business partners. Real time analysis of partners’ scientific and business development is conducted, and the broad-based engagement is managed through professional project managers and senior academics nominated as relationship managers.
- **Imperial West** – this is a large new \$5 billion research and translation campus being developed close to the main site. Its purpose is to enhance the university’s attractiveness to and effectiveness in working with industry.
- **Innovation and Entrepreneurship Group** – which is the largest collection of innovation and entrepreneurship researchers in the world, providing leading research, teaching and executive education in the field.

productivity and collaboration. Germany, Korea and Japan, for example, have strong policy analysis groups in these areas. The UK has numerous institutions working in this field, including the: Science Policy Research Unit; Manchester Institute of Innovation Research; UK Innovation Research Unit (presently being reformulated); National Endowment for Science, Technology and the Arts; and the Big Innovation Centre, amongst others. Australia has not had such a policy research group for over a decade.

### 3.1.5. Opportunities

Overcoming the barriers to business-research organisation collaboration can be achieved through a number of mechanisms that reduce the costs and risks of collaboration, increase incentives and reduce constraints. Making a collaboration work requires a solid sustained commitment from all parties. It is necessary to get the balance right between collaboration and competition, openness and protection, in the short and long term. To balance these competing priorities and chart the most appropriate course of action for a given partnership, good management is essential.

Encouraging business-research organisation collaboration involves:

- Increasing **incentives** for businesses to collaborate, by demonstrating value (for example by showcasing successful examples); stimulating initial connections (for example by facilitating networking opportunities and using vouchers); and by funding consortia to address common problems whose scale and scope deters investment by single organisations.
- Improved **engagement strategies** by research organisations, involving broad-based, well-managed strategic partnerships and appropriate incentives for research staff to collaborate. Calls for university research strategies to become market-led ignore what businesses actually want, i.e. knowledge and ideas they cannot obtain from other sources. Strategies would improve by becoming more market-facing i.e. more appreciative of the problems confronting business.

- Government collecting better **information** on the extent, nature, drivers and performance of collaboration and improving the capacity to integrate various sources of data. Extending the limited range of indicators used to evaluate the performance of research organisation's collaborations and research outcomes would more accurately reflect the realities of engagement.
- Greater **mobility** of people between research and business by increasing incentives (i.e. recognising mobility in career progression) and removing impediments (i.e. transfer of pension and leave rights).
- Providing greater support for intermediaries – this is discussed below.

Understanding how collaborations come about can help in developing approaches to overcome barriers. Collaborations are often formed through networks or informal personal contacts, as academics look for funding for a research opportunity, or through businesses trying to find solutions to a problem.

There is a lack of incentives for research organisations to collaborate with business in Australia. As noted earlier, the current reward structure incentivises researchers, particularly early career researchers, to focus on securing grants and publishing, in order to have the greatest impact on their career advancement. A new, complementary approach is needed that rewards researcher collaboration with businesses. The UK Imperial College is a good example of a university that balances excellence in research with collaboration with business. Although some Australian universities have recognised the benefits of building stronger links with industry, such as the University of Queensland Collaboration and Industry Engagement Fund, more such incentives are needed.

Good management of collaboration is essential to capture its potential benefits. Collaboration can experience instabilities and tensions and pose significant management and organisational challenges (Dodgson 2014). Strategic partner selection is essential and significant attention has to be paid to how these are structured and organised. An increase in collaboration

between research organisations and business will only pay dividends if suitably skilled managers are available. The management of the interfaces between business and university is a key challenge. There are a number of useful publications that provide information on how to make business-research organisations collaboration work and on government measures to encourage this activity (for example: OECD 2001; OECD 2004). Perkmann and Salter (2012) note that successful programs purposefully keep bureaucracy to a minimum, avoid intellectual property issues, choose low risk projects and ensure contracts are kept as simple as possible. Managing collaboration is an important aspect of the broader challenge of innovation management (see discussion in Chapter 4).

### 3.2. Collaboration between businesses

Collaboration between businesses takes many forms and can be attributed to a range of drivers. In this report, our interest is in collaboration that is based on, or related to research, science and technology. This section focuses primarily on collaboration between businesses and is especially concerned with international collaboration.

One reason for business collaboration is to share the costs of developing new technology. Examples of this include the Reagan administration decision to establish the Semiconductor Manufacturing Consortium (SEMATECH) – a partnership between the major

US semiconductor manufacturers and the US Department of Defense, to solve common manufacturing problems and address a decline in the competitiveness of that industry in the face of international competition. It was funded for its first five years by the US Department of Defense, but has not received direct financial support since that time.

A second reason for this sort of business collaboration is to share the cost of implementing a new technology obtained from overseas. The Victorian Direct Manufacturing Technology Centre is an example of the formation of a consortium of Australian SMEs (assisted by two international technology suppliers), to share experiences and facilities in the adoption of new technology for the manufacturing sector (Box 3.6).

The World Economic Forum (Schwab & Sala-i-Martin 2013) has also drawn attention to Australia's low ranking in the proportion of businesses collaborating in innovation among OECD countries: overall 23<sup>rd</sup> out of 26 OECD countries. Furthermore, Australia does not perform well in the World Economic Forum ranking of intensity of collaborations between industry and research organisations – Australia was listed at 19<sup>th</sup> place.

#### Clusters

The notion of clusters – or local agglomerations of companies with similar interests, often based around research centres – has been an important component of public policies for innovation and industrial and regional development for decades. Debate continues, however, about the extent to

#### Box 3.6: The Victorian Direct Manufacturing Technology Centre (VDMTC)

The VDMTC was established to adopt direct manufacturing technologies to meet the needs of a group of Australian SMEs. Direct manufacturing is a revolutionary concept where components are manufactured directly from powder, ribbon or wire in a layered manner, by-passing conventional manufacturing processes. It provides dramatic savings in labour, time, materials, energy and other costs, as well as significant reductions in adverse environmental impacts.

Direct manufacturing technologies have the potential to enable manufacturers in Australia to compete with countries where labour costs are low. They also offer the opportunity to progress faster from concept to product and to produce parts from difficult-to-fabricate materials for advanced applications in aerospace, defence, mining, petroleum, biomedical and automotive industries.

The VDMTC is supported by CSIRO and the Victorian Government.

which these clusters can be 'engineered' or grown organically; whether co-location is necessary or if the Internet makes it irrelevant; and the role of small start-ups versus large companies. There is also very little research into the innovation and productivity dividend resulting from clustering. More recent research interest has emerged into smaller phenomena, such as occurs in 'precincts', and more comprehensive connections found in 'innovation ecosystems'. The concept of ecosystems is defined as "a network of interconnected organisations that are linked to or operate around a focal firm or platform that incorporates both production and use-side participants and creates and appropriates new value through innovation" (Autio & Thomas 2014, p. 205). Ecosystems are communities of organisations that, while motivated by individual goals, are united around shared goals to create value that would not be achieved independently (Teece 2007). They are different analytically from clusters, which are geographical concepts and focus mainly on individual (usually small and medium-sized) firms.

In a current research project by ter Wal, Corbishley, Dodgson and Gann (unpublished, 2014), a series of case studies of successful clusters has been undertaken, with a matched sample of those emerging from government initiative, small firm emergence, large firm strategy and university policy. It argues that whatever their origination, cluster performance depends on the development of an innovation ecosystem in which governments, universities and large and small firms act together in concert.

Businesses that are both innovative and collaborative are more likely to report better performance across a range of indicators than businesses that are innovative but do not collaborate (DIISRTE 2012b).

- 23% more likely to report increased productivity
- 24% more likely to report increased profitability
- more than three times more likely to increase the number of export markets targeted
- 48% more likely to increase the range of goods or services offered

- 24% more likely to increase employment
- 34% more likely to increase training for employees.

### International collaboration

International collaboration can drive innovation by enabling Australian businesses and research institutes to tap into the latest developments overseas. The work of Griffith, *et al.* (2006) found that UK firms with a significant R&D presence in the USA show higher productivity growth. This correlates with growth seen in the USA rather than the more modest growth in the UK.

International collaboration brings numerous benefits, including:

- expanded expertise, through access to complementary skills and knowledge, infrastructure and equipment
- increased scale and diversity of expertise to deal with global problems (such as water and food security) – at the same time, globalisation also affords opportunities for national specialisation
- improved means for assessing developments and opportunities to inform decisions about our investments
- enhanced funding opportunities for research and for creating paths to commercialisation.

Australian productivity is profoundly impacted by international trends in manufacturing. The growth of developing economies, such as those in East Asia, has depended on productivity growth in manufacturing industries. Initially based on low labour cost advantage, sources of productivity in these nations are shifting as they move from 'imitation' to 'innovation', facilitated by high levels of collaboration and internationalisation (Dodgson, *et al.* 2008b).

Partly in response to this kind of competition, productivity in developed economies has relied on increasing high value: high skill activities based on science and design. There is considerable future uncertainty about the location of globally dispersed competitiveness based on innovation and high value exports. With more and more of the world's wealth

created by international trade and with more and more global trade being in knowledge and ideas, advantage will lie with those countries most adept at innovation, collaboration and internationalisation.

In a 2012 Economist Intelligence Unit report, almost two-thirds of company executives agreed that:

*"better cross-border collaboration has been a critical factor in the improvement of our organisation's performance in the past three years"*

(The Economist Intelligence Unit 2012)

### Access to knowledge and research

Increasing complexity of scientific and technical fields has motivated the growth of cross border and inter-firm collaboration. Some of the most significant advances in research come about as a result of 'fusion' of previously separate fields. New or emerging interdisciplinary fields are considered increasingly likely to form the basis of major new technologies (Haylor 2012). In an era when differentiation is a key to competitiveness, the search for enhanced impact is a key driver for international collaboration. For example: creation of radically new products and services; formation of new and more effective processes, allowing greater logistical efficiencies; or production of patentable materials, designs or operations that enhance competitive advantage.

Collaboration helps investigate research questions that cross multiple disciplines and require knowledge from organisations in many nations. Global challenges such as environmental sustainability, energy security, preventing and curing infectious diseases, and ensuring food security have to be addressed internationally. International collaboration in science and technology is needed to deal with these issues; as discussed in recent reports by the OECD (2012b) and the Royal Society, (2011).

### Access to foreign markets

Evidence suggests that when more businesses engage in international markets, there is an increase in the direct flow-on benefits to productivity (Bloom, *et al.* 2007). Eight of Australia's top-ten export markets are in the Asia-

Pacific region, so engaging with businesses and researchers in this region is an important priority for Australia. China, Japan, the Republic of Korea and the United States were Australia's top trading partners in 2011, but it was the USA that invested the most in Australia, followed by the UK. Foreign direct investment (FDI) to Australia doubled in the five years to 2012 compared to previous years and FDI inflows were the 9<sup>th</sup> largest in the world in the same year. Australia ranks 6<sup>th</sup> in the Foreign Direct Investment Confidence Index (A.T. Kearney 2013), however, business expenditure on R&D in Australia funded from overseas is very small.

Business-to-business and business-research organisation collaborations are important in global value chains (GVCs). GVCs include various stages of the production process, trade and investments, spanning many countries and offering an opportunity for a company to integrate into the global market. In Australia, the mining sector has the highest participation in GVCs, with several manufacturing industries involved. The OECD estimates that more than half of the value of today's world exports includes products produced in GVCs (DFAT 2012). This is discussed in more detail in Chapter 2.

Many companies enter a relationship with a foreign company by importing goods, but only begin to export their goods if demand is significant. Exporting can be a relatively fast and flexible step to enter foreign markets and reduce some associated risks (e.g. currency risk, product demand, political and cultural risk, product competition). Exporting allows SMEs to respond quickly to changes in various markets by increasing or decreasing their production to suit market trends. It gives firms some experience of overseas markets. FDI can help an Australian company to develop, expand and access foreign markets. This can be achieved through a merger or the acquisition of an existing company. Forming a joint venture with an overseas company gives access to their financial resources; pool of research efforts; product development and distribution channels; and market knowledge. All forms of internationalisation are confronted by integration issues, such as misalignments of objectives, values, goals and operational procedures. Internationalisation is

a significant step for SMEs, which are generally focused on domestic markets, have small base funds for investment and little or no experience of wider overseas networks and markets.

The relationship between internationalisation, exporting, innovation and productivity has been widely studied. The evidence suggests that they are positively linked, e.g. internationalisation boosts innovation and exports, and vice versa. However, not all SMEs aspire to internationalise. For example, only a small proportion of Australian SMEs have accessed funds from abroad. Furthermore, a study of one section of the UK economy found that 56 per cent of SMEs interviewed did not feel inclined to engage in international collaboration (Sear, *et al.* 2004).

### 3.2.1. Performance

Australia has some areas of effective international collaboration, valuably supported by well-established institutions such as the AMIRA International (Dodgson & Steen 2008). However, Australia is increasingly a net importer of technology and know-how and relies on foreign direct investment for technology more than most other OECD countries. Australia imports four times as much intellectual property (\$4.8b) as it exports (\$1.2b). Little of our business expenditure on R&D (about 1 per cent) is funded from overseas (ABS 2012b). In contrast, in the UK in 2011, 21 per cent of R&D funded by business

was sourced from overseas. Which was sourced overseas – the R&D or the funding?

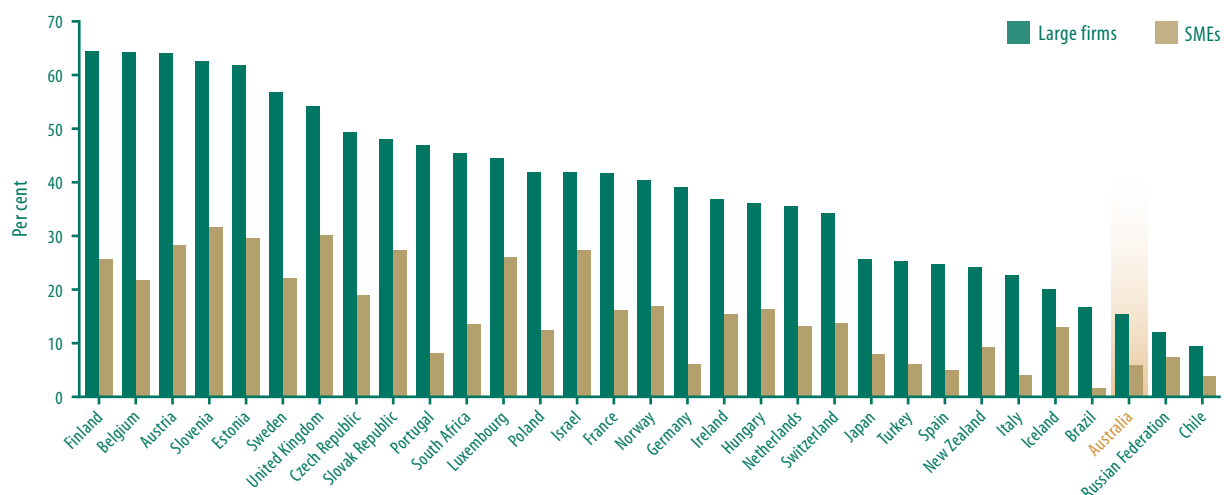
Worldwide, countries recognise the benefits of international collaboration and have articulated international innovation strategies that remove barriers. This facilitates the movement of human resources, the attraction of foreign investment in R&D and the linking of the innovation and foreign aid and development initiatives. Despite, these benefits, networking and collaboration remains the most significant flaw in the Australian Innovation System, particularly large firm collaboration, international collaboration and business-to-research collaboration (DIISR 2011b).

The evidence suggests that Australian businesses have low levels of international collaboration in comparison with their OECD counterparts (Figure 3.6). SMEs are even less likely to collaborate than larger firms.

Only 3.6 per cent of Australia's innovative firms have international collaborations on innovation, compared, for example, with over 30 per cent of Finnish firms. Australia ranks 25th out of 26 OECD countries in international collaboration on innovation. New Zealand ranks 17<sup>th</sup>, challenging the idea that distance from international markets is a key influence on Australia's poor placing.

In order to develop a better understanding of the underlying issues in Australia, a study was commissioned for this project from Assoc. Prof

Figure 3.6: Australian firms have low levels of international collaboration



Note: Firms engaged in international collaboration by firm size, 2008-2010, as a percentage of product and/or process innovative firms in each size category.

Source: OECD 2013c, p. 129, based on Eurostat (CIS-2010) and national data sources, June 2013.

John Steen on productivity, exporting and innovation, using a unique Australian panel dataset<sup>6</sup>, based on the Community Innovation Survey and adapted by the University of Cambridge.<sup>7</sup> The survey found that the key drivers of innovation were size of firm; the existence of formalised planning: business, financial and human resources; and investment in employee skills, especially managerial, followed by professional and worker. Essentially, well-managed firms are more innovative. The key findings of the survey are complementary to similar international and ABS studies, with the virtue of being more contemporary, addressing additional questions (ABS surveys, for example, do not ask about the impact of the ), as well as producing a number of novel insights. The study highlights the existence of a number of virtuous cycles between productivity, internationalisation and innovation. It showed that there is a cyclical relationship between innovation and collaboration, where collaboration improves the innovativeness of firms and innovation also supports further collaboration (Steen 2013).

Previous international research shows exporting is the preferred internationalisation strategy for SMEs and product innovation is the stimulus to export (Cassiman & Golovko 2011). It also shows internationalisation enhances a firm's capacity to improve performance through innovation (Kafourous, *et al.* 2008). A recent Australian report (Findlay, *et al.* 2012) demonstrates the diversity in the way Australians do business internationally. It found that the distribution of exporting activity is highly skewed to SMEs and that exporting companies out-perform non-exporters. It reaffirms the importance of global value chains and the ways in which intangibles underpin business performance. The DIISR 2011 Australia Innovation System report reveals that compared to businesses that do not innovate, innovative businesses are twice as likely to export (DIISR 2011b). The Steen study interestingly finds that innovation is a

precursor to collaboration, in contrast to the usual presumption of the reverse (Steen 2013).

The relationship between innovation and productivity has attracted substantial international research attention, as addressed in other components of this project. The Steen findings show the relationship is not straightforward, revealing in particular the lag effect between investment in R&D and productivity. R&D expenditure can be disruptive for companies, especially for SMEs, while the findings show labour productivity payoffs can take 3-4 years.

The Steen study measures company performance as measured by self-reported perceptions of competitive advantage. It finds that performance is highly correlated with innovation breadth (innovating across products, services and processes), and therefore might be argued to be aligned to innovation in overall business models.

The study shows how international sales are strongly correlated with companies' digital strategies, particularly how they use the Internet as a source of ideas, to improve customer experiences, and to integrate with supply chains. It also finds the use of the Internet as a source of ideas is correlated with performance.

### 3.2.2. Constraints

International industrial collaboration is recognised as an essential strategy for surviving severe competition. Australia stands to gain significantly by developing more structured and strategic links with the global community (Cutler 2008).

Limited empirical research had been carried out to understand the barriers for entry to internationalisation from an Australian perspective. One study examined the impact of certain barriers to internationalisation of Australian firms operating in foreign markets. It highlighted significant barriers for Australian businesses, particularly SMEs, to engage in a collaborative partnership and enter global markets (Julian 2009). These include the high Australian dollar, high manufacturing and business costs and pressures from Asian exports worldwide.

The OECD has examined barriers to effective international collaboration (Box 3.7).

---

<sup>6</sup> The survey was conducted during 2010-11 and 2012 and captures a representative cross section (stratified sample) of 413 Australian firms.

<sup>7</sup> For details of the surveys undertaken at the Centre for Business Research at Cambridge University, see [http://www.cbr.cam.ac.uk/research/RA\\_SurveysandDatabases.htm](http://www.cbr.cam.ac.uk/research/RA_SurveysandDatabases.htm)

### Box 3.7: Important barriers to international collaboration on the part of SMEs

- Shortage of working capital to finance exports.
- Identifying foreign business opportunities.
- Limited information to locate/analyse markets.
- Inability to contact potential overseas customers.
- Lack of managerial time, skills and knowledge.

Source: OECD 2009.

In an Australian context, barriers to international collaboration are discussed below:

#### Lack of knowledge of overseas markets

According to 95 per cent of respondents in a study of Victorian SMEs, inadequate knowledge of overseas markets has emerged as a top barrier to international collaboration (DBI 2011). International collaboration carries risk and organisations need to find the right partner with the right alignment that offers shared goals, values and cultures. Finding such a partner is not always easy to do; mentoring and resources for education can help overcome the problem.

#### Intellectual property

Intellectual property is a significant concern for many companies. Engaging in partnerships both domestically and internationally can raise concerns over IP ownership and theft, revenue sharing, lack of trust and fear of talent poaching. These are deterrents that are difficult to manage due to their high personal and financial considerations. Pre-existing background IP brought into the collaboration can be legally retained, but project IP is shared. So technology sharing by organisations does not mean giving up IP rights, but it does entail a sense of giving up exclusive rights over property on a contractual shared basis (European Commission 2012b).

#### High costs

Exporting and trading globally is expensive and the high cost of transportation and varying exchange rates make it difficult to quote product prices to consumers and collaborators. Transportation prices are higher than for domestic trade, pushing prices up compared to local suppliers. A way of spreading this financial burden is to establish a joint venture

or collaboration partnership with a company abroad. There are high costs associated with building industry and research infrastructure to address globally important scientific problems with large, multidisciplinary and widely distributed teams.

#### Cultural and personal barriers

Personal barriers to international collaboration come in various forms. Collaborating with another individual or company in another country often brings language and cultural challenges. Different cultures have different value systems. People may find that they approach and execute tasks differently, which may limit the efficiency of the collaboration. When a partnership occurs between two companies of unequal size, the larger company may not value the input of the smaller company. These have been noted as causes of failure in partnerships (Doz 1987).

#### There are constraints to SMEs participating in global value chains

SMEs account for more than 95 per cent of all Australian businesses and contribute more than a third of GDP. Australia has 1.2 million SMEs, which employ over 5 million people across various industries (KordaMentha 2011). The PwC report *“The Startup Economy: How to Support Tech Startups and Accelerate Australian Innovation”* estimated the Australian technology start-up sector has the potential to contribute \$109 billion (4 per cent of GDP) and 540,000 jobs to the Australian economy over the next 20 years, provided the appropriate conditions are created (PwC 2013).

There are considerable benefits for Australian SMEs, as well as for the overall economy, when SMEs participate in global supply chains, but

they find it difficult to do so. Larger firms are more likely to have higher levels of international collaboration than SMEs. These larger organisations invest more in training; they have qualified management and staff; and they use more formal or structured processes to capture and exploit innovation opportunities. They are likely to network and collaborate on innovation more frequently (Arnold 2005).

### 3.2.3. Current policy

Most OECD countries have recognised the system (and market) failures described above and have developed measures to encourage collaboration between businesses and between business and publicly funded researchers and business.

Government policy is also an important driver and enabler of international collaboration. Most countries have a variety of government programs to facilitate international collaborations. Although Australia does participate in international scientific collaborations and there are some government schemes to fund international collaboration, there are opportunities to greatly improve the nature and level of government support for collaboration. Key criticisms of Australian funding for international collaboration include the inconsistency of measures; disproportionate levels of funding for collaborations with some countries over others; and the lack of stable, continuing funding commitments to international collaborations.

The 2008 Cutler report *Venturous Australia* made the following recommendations for Australian government policy to create and support global connections:

- Internationalisation through **talent and mobility** by attracting talent to Australia and encouraging a culture of internationally connected researchers and entrepreneurs.
- Internationalisation through **business and enterprise** by enhancing inward and outward FDI in innovation and ensuring that Australian firms are integrated within global supply chains.
- Internationalisation through **institutions and infrastructure**: encouraging the

internationalisation of Australia's publicly funded institutions through measures and programs to enhance collaboration, share knowledge and to ensure access to foreign innovation networks.

The Australian Government's overseas aid program AusAID funds a small amount of aid-related research through partnerships with Australian, international and developing country institutes. A few state government schemes provide small amounts of funding, such as Queensland's International Fellowships and Victoria's Postdoctoral Research Fellowships (which includes a State-national government scheme, the Victoria-Israel Science and Technology R&D fund).

Only R&D undertaken in Australia is eligible for the R&D tax incentive, but Innovation Australia can allow overseas research in special circumstances. It is yet to be seen what the impact will be of the proposed changes to R&D tax incentives for large companies and how this affects connections with international research networks.

### 3.2.4. Good practice

A small proportion of companies operate internationally from their foundation and these are deeply connected into global webs of enterprise. An Australian Business Foundation study of 'born globals' reveals some of the characteristics and contributions of 18 of these firms in Australia across a wide range of sectors (Liesch, *et al.* 2007). They included companies such as Beeline, producing GPS-guided, hands-free steering of agricultural vehicles; Ellex Medical Lasers; MYOB business software; Rising Sun Pictures, producing visual effects for Hollywood; and Indigo Technologies, reducing toxic emissions from power stations.

The study found that these companies augmented Australia's technological capacity, enhanced the skills of managers and workers, sustained industrial clusters and in some cases created new global industries. They are deeply embedded in international business networks, often through tapping into the distribution channels of larger overseas clients.

The study makes the observation that the success of these born globals rests with factors that are replicable by other firms. They are characterised by: agility, persistence, hard-headedness and adroit management of a range of business functions and risks. They experiment, absorb new knowledge quickly, overcome obstacles imaginatively and are adept at recovering and learning from mistakes. Critical to their success is the high level of engagement with intended customers and users.

There are some examples of overseas companies, such as Dow and Boeing, which invest in R&D in Australia. The Boeing case is discussed in Chapter 2.

### 3.2.5. Opportunities

Most business-to-business collaborations begin informally, often the result of fortuitous conversation. Network events focused at bringing SMEs together to meet and discuss common interests can encourage the creation of new collaborations. Identifying who to connect with and how on a worldwide scale is challenging. Given that identifying export opportunities is an important objective for many businesses seeking to grow and internationalise, particularly SMEs, tapping into worldwide networks can be an important priority.

Australian businesses seeking to internationalise need to develop their understanding of global supply chains and what their target markets are. There are some Australian Government initiatives which aim to link SMEs in the global supply chains and improve their awareness of them, such as the 'Buy Australia at Home and Abroad' initiative and defence initiatives (Chapter 2). It remains unclear the extent to which AusTrade initiatives facilitate international technological collaboration in its various forms.

#### Technology facilitates international collaboration

While the initiation of collaborations are often depends on face-to-face meetings that help build strong relationships and gain trust, the operation and maintenance of collaboration can be assisted technologically. The capacity to collect, capture, analyse, represent and communicate data is

massively enhanced by new technologies. By using technology, such as video-conferencing, email and shared databases on the cloud, business people and researchers can remove geographical barriers, reduce costs and increase efficiency in their transactions.

Questions remain on the issue of social networks in international research collaboration. Do younger generation researchers need face-to-face connections to build trust? To what extent are any vexatious problems that arise in a project manageable over the Internet? How secure is data? Also of relevance is the question of the contribution of social network analysis, telling us who has most to contribute, who works with whom, and who are the blocks to collaboration (Kastelle & Steen 2014).

#### Opportunities from collaboration in Australia's food sector

Food is one of Australia's major industries, with the annual food chain valued at \$230 billion. The situation in the Australian food industry is one of considerable ambition and opportunity, but it faces a number of challenges, including declining productivity and R&D spending, and growing trade deficits in key areas such as horticulture and fisheries. It is recognised that a key to realising the opportunities in the industry is enhanced scientific linkages and international collaboration, yet the capacity in business to build international links, especially between SMEs and multinational companies, is not matched by the levels of experience found in some elements of the research community.

## 3.3. Conclusions

The evidence shows that Australia's international collaborative performance is low by OECD standards. While our international scientific collaboration in *basic research*, as indicated by co-authorship of journal articles, reflects international trends, engagement of Australian business in international research collaboration is weak. Further, there is currently no program to support international collaboration in strategic research.

We are not making effective use of international collaboration to build Australia's national innovative capacity. This limits Australia's opportunities to leverage our investment in research. It also limits our ability to be a 'fast follower' in the adoption of new technologies. International collaboration could help to address declining productivity and trade performance in key sectors, such as the food industry. Australia's SMEs find it difficult to participate in global supply chains, and there are considerable benefits when they do so.

Business-research collaboration takes a number of forms and provides benefits to both businesses and researchers. Firms can tap into a research organisation's equipment and facilities, skills, knowledge and new ideas to achieve productivity gains through innovation and improve business performance. Research organisations can gain access to funding and a range of intangible benefits. Australia can increase the 'dividend' from its investment in research, science and technology through new measures and expanding successful existing measures, to increase links between business and research.

### 3.4. Findings

3.1 Collaboration plays an important role in innovation, but is under-recognised by government. The level of Australian collaboration, both nationally and internationally, is low by OECD standards. This limits our ability to capitalise on research investments and access knowledge from overseas.

3.2 Current measures to encourage collaboration between firms and researchers are inadequate. New approaches are needed. Examples of successful measures used in other countries include:

- enhanced incentives and rewards, and removal of disincentives for public sector researchers to engage with business
- additional funding for collaborative activities, including voucher schemes to encourage SMEs to collaborate with research organisations, and increased funding for the Researchers in Business Program
- encouragement of dynamic clusters integrating small and large firms, research organisations and government.

3.3 Innovation intermediary organisations operating outside government but with government support are an effective way of assisting SMEs to develop collaboration with other businesses and with research organisations.

3.4 Australia should take a strategic approach to research collaboration with other countries, supporting activity in areas of mutual interest, particularly with those countries with which Australia has science and technology agreements.



# 4

## An innovative workforce to meet Australia's future needs

### Summary

- An innovation-capable workforce is critical to achieving the goal of increasing productivity.
- Urgent efforts are needed to improve language, literacy and numeracy skills.
- Innovation involves more than technical skills. It also needs people who understand systems, cultures and the way society uses and adopts new ideas.
- Innovation management is becoming increasingly important to enable firms to adapt to new challenges.
- Business management in Australian firms falls well short of best practice.
- Entrepreneurial skills are needed to encourage and enable graduates to set up new business enterprises, particularly those with strong technical backgrounds.
- There is a positive association between investment in training and firm performance.



## 4.1. Key issues for an innovative workforce

As the OECD has noted:

*Skilled people play a crucial role in innovation through the new knowledge they generate, the way they adopt and adapt existing ideas, and their ability to learn new competencies and adapt to a changing environment.*

(OECD 2011b)

This chapter discusses the attributes of an innovative workforce. It examines the extent to which the Australian labour force provides these attributes, and considers issues such as how we generate increased awareness and acceptance of the value of a science degree in business and in industry, and how we build a broader science, research and technology base in the workforce. It also discusses how best to ensure that Australia is training a sufficiently well prepared workforce to meet future needs.

Skilled labour is one of the key contributors to productivity gains through innovation. The attributes required for innovation have been widely discussed (OECD 2011b; Toner 2011). Those attributes that are most often identified as requirements for an innovative workforce are:

- basic reading, writing and numeracy skills
- information and communications technology skills
- academic skills (including qualifications in science, technology and engineering (STEM) and humanities arts and social sciences (HASS))
- analytical skills (including problem solving, critical and creative thinking, ability to learn and manage complexity)

- social skills (including the ability to work in teams, communication, receptiveness to new ideas, etc.)
- management and leadership skills (including the ability to form and lead teams, negotiation, coordination and ethics).

The results of the Programme for International Student Assessment (PISA) show that Australian mathematical and scientific literacy scores are above the OECD average, but around 10<sup>th</sup> behind countries in our region such as Singapore, Hong Kong, Japan and Korea. Like other OECD countries, Australia has been experiencing a decline in secondary school student interest in core science subjects (Office of the Chief Scientist 2012).

Many of the other skills in the list above are acquired through tertiary education. Australia is well placed to develop these skills, with more universities ranked in the top 100 in the world than would be expected for a country of our size. Australian universities determine their own admission standards and the evidence suggests that recent deregulation of student numbers has not led to a decline in standards. Any assessment of the adequacy of the *numbers* of graduates from our universities has to take into account the strong foreign student participation rates and the fact that many of these students will return home after completing their course (and their skills are therefore not available to the Australian economy).

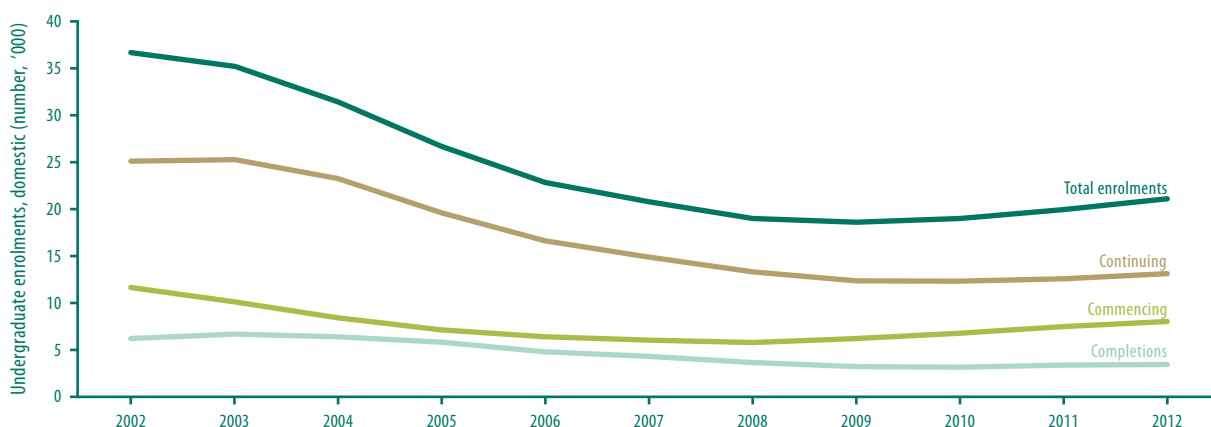
A recent analysis of STEM training by Australian universities (Office of the Chief Scientist 2012) indicates that, while this is generally satisfactory,

there are some areas of concern. University enrolments in science and engineering have increased in recent years in most STEM subjects. In 2012 there were 27,892 new domestic enrolments in undergraduate courses studying natural and physical sciences, 15,489 studying engineering and related technologies, and 7,942 studying information technology, representing an increase over 2011 of 14, 5, and 8 per cent respectively (Department of Education 2014). However there was a decline in total domestic undergraduate enrolments in information technology from 2002 to 2010 by 50 per cent. Student loads in electrical and electronic engineering and technology over the same period fell by 40 per cent, indicating a decrease in enrolments in this area (Office of the Chief Scientist 2012).

The changes in levels of domestic undergraduate enrolments for students studying information technology since 2001 are shown in Figure 4.1. Following the drastic decline in total enrolments since the peak in 2002, levels of new enrolments have begun increasing gradually since 2008. Since 2003, the number of undergraduate completions in IT has more than halved, but this decline has stabilised and is slowly recovering following the turn-around in new enrolments.

An analysis of the determinants of firm-level productivity in Australia finds that firms citing core business skills in engineering, IT, science and research professionals were 33 per cent more productive than those that did not claim these as core skills (Palangkaraya, *et al.* 2014).

Figure 4.1: Domestic IT undergraduate enrolments, by student status, and completions



Source: Department of Education 2014.

People with research skills are an important part of Australia's workforce. These skills are needed in our universities and government laboratories. They are also needed by businesses that wish to secure niches in global value chains. Research skills go beyond the STEM competencies needed in the wider workforce, to involve a depth and a currency of knowledge that keeps us at the leading edge of new technologies.

Mobility in the research workforce has been identified as an issue that needs attention (DIISR 2011d). Cultural and structural impediments to researcher mobility limit movement between publicly funded research organisations and business. Promoting collaboration between universities and industry, discussed in Chapter 3, should help to address this issue. The Researchers in Business program has the potential to enable collaboration and researcher mobility. However, it would be more effective if it was extended and expanded. Maintaining a strong research training scheme in our universities is also important. Students in research training courses would benefit from spending some time working in firms. Meeting the research skills needed by business is discussed later in this Chapter.

#### 4.1.1 Role of skills in driving innovation at firm level

Skilled personnel recruited by firms bring with them the knowledge to improve processes, or adopt new processes that lift firm productivity. Innovation involves more than technical skills, it also needs people who understand systems, cultures and the way society uses and adopts new ideas. This project has undertaken case studies that illustrate the significant contribution of social sciences and humanities to innovation and productivity improvement.

Differences between nations in the quantity and quality of workforce skills have been shown to be a significant factor in explaining patterns of innovation and economic performance. Furthermore, there is clearly a strong circular and cumulative interaction between knowledge, skills, and innovation (Toner 2011). Workforce skills alone are not a sufficient condition for successful innovation.

Increasing the numbers of STEM-qualified personnel in business will help to generate a greater awareness and acceptance by firms of the benefits such skills can bring them. Ensuring an adequate supply of graduates at both VET and university level is a first step. Universities that provide placements in industry for their undergraduate students are also helping to address this issue. Government programs such as ARC Linkage grants, the Cooperative Research Centres Program and Researchers in Business all help to build business appreciation of the value of STEM skills. Greater business engagement with universities, government laboratories and CRCs will help to develop an appreciation of the benefits of STEM skills in the workforce. Management skills are particularly important to driving innovation at the firm level. The ability to apply 'systems thinking' and effectively manage the production, acquisition, and application of intellectual property are central to successful innovation. This issue is discussed in more detail later in this Chapter.

#### 4.1.2. Humanities, Arts and Social Sciences (HASS) skills contribute to innovation

While the importance of technical disciplines to innovation is well known, the importance of HASS skills and expertise to innovation is often overlooked. Australian firms need a workforce which combines disciplinary and/or technological expertise with the ability to effectively and efficiently integrate various knowledge bases and skill sets including team building capacity, emotional intelligence, strategic visioning, market analysis and cultural sensitivity. This intersection of science, technology, engineering and mathematics (STEM) and humanities, arts and social sciences (HASS) disciplinary inputs is critical to the success of Australian knowledge-based enterprises.

HASS research and development has been shown to offer advantages in user-driven innovation, by contributing to the ability to link and synthesise the varying types of understandings of customers, the market and the firms themselves (DEA 2011). In a survey of

Danish firms (DEA 2007), a significant number of companies reported the need for interdisciplinary research that identifies the ways in which creative processes can be maximised.

A report from Sweden (Trendethnography AB 2009) offers a practical analysis of the value of interdisciplinary expertise-mixing in a range of local industries of varying sizes through case studies into the interdisciplinary practices of successful Swedish companies. Strategies adopted by these companies include mixing skills in interdisciplinary teams, leading to a better understanding of the customer, recruiting from different educational backgrounds, including young people gathered from the global workforce, and a clear view of company purpose.

Actual and potential benefits of 'cross-sectoral collaborations' that combine HASS and STEM expertise have been examined in an Australian study that identified characteristics that typified a successful collaboration (Metcalf, *et al.* 2006). Cross-sectoral collaboration was found to lead to innovative solutions to problems; development of commercial products; collaboration with community services; more diverse education opportunities; and a more engaged public and end-users. Teams and individuals involved in these collaborations gained from the process, which also broadens social and professional networks. The findings included observations that "cross-sectoral collaborations will not flourish in Australia without positive actions by government, funding institutions, researchers and industry" and that given the high transaction costs of collaboration – in particular cross-sectoral collaboration – the practice is "most likely to be profitable when the issues or problems being tackled cannot be dealt with by one sector alone". The report's recommendations included removing institutional impediments; investment in cross-sectoral research; and training 'boundary spanners' – postgraduate students working across STEM and HASS disciplines.

## Case studies illustrating HASS-STEM mix

Six case studies illustrating HASS and STEM skill mixing in high technology, high performance

Australian firms have been conducted as part of this project. The mix of small and large companies selected have adapted over their lifespan to foster multi-disciplinary collaboration in order to meet new challenges. This includes iconic companies relying on STEM-based R&D, but also companies in the financial, entertainment and manufacturing design sectors, in order to illustrate how STEM and HASS knowledge and skills are being brought together to address complex problems in the context of productivity and growth-through-export challenges. This may be the first time that such a skills mix study has been undertaken in Australia. The companies studied were:

- Resmed (medical devices)
- Cochlear (medical devices)
- Invetech (high tech design for manufacturing solutions)
- Halfbrick Studios (games, mobile applications)
- MBD Energy Limited (waste management)
- Westpac (financial services).

More detail can be found in Appendix 1.

The study found that as companies grow, and face obstacles in the external environment or as a consequence of increased organisational complexity, there is a stabilisation of the relationship of HASS-STEM skill sets over time. An increased, deeply embedded recognition of the centrality of the relationship evolves, even if not of their equal contribution. It follows that, while good data on qualifications and backgrounds in Australian business enterprises will tell us a good deal about the HASS-STEM relationship, exploring the evolution of that relationship within companies and individuals quantitatively will tell us even more about performance, innovation, efficiency and productivity.

At a superficial level, the mix may seem self-evident and obvious: at Resmed and Cochlear, most of the foundation science R&D and industrial/product design is done in Sydney, while the great majority of the sales and marketing, and client interface is conducted in the dozens of foreign markets in which they operate. But for other companies, the deployment of STEM and

HASS skills is more integrated. For Halfbrick, the mix between creatives (storytellers, designers, and animators), technologists and business changes over time – particularly as social media marketing and community engagement in the games/apps space depends on analytics as much as on traditional marketing.

The STEM-driven companies – Invetech, Resmed, Cochlear, MBD Energy – all recruit initially for scientific and technical competency and then provide additional training in non-technical skills such as communication, design thinking, understanding cultural diversity, marketing and community engagement. These firms approach the further training of non-technical skills in different ways. Invetech perform formalised in-house training and mentorship with senior staff, while Resmed achieve this through the creation of cross-functional teams. Westpac and Halfbrick are somewhat different examples: the ability to work effectively in multidisciplinary teams from the outset is a critical factor.

The study showed that paying great attention to a firm's client, customer, or user base gives rise to successive waves of innovation and the stabilisation of the STEM-HASS knowledge base and dynamic within the organisation. Getting the HASS-STEM relationship right is a critical factor in efficiency and productivity at the firm level, that is getting alignment between production inputs, the production process and uptake in the market. This can require firms to face up to the not inconsiderable challenges of building effective and productive multidisciplinary teams. The example of Cochlear is presented in Box 4.1.

### 4.1.3. Business management skills need improvement

While technology is a driver of business transformation, innovation management is critical for corporate competitiveness, enabling business to deal with disruption and flourish in a rapidly changing environment of new innovations and emerging markets (Dodgson, *et al.* 2014). The evidence suggests that many Australian business managers are not well equipped to operate in this environment and Australia ranks well behind leading countries (Green 2009). Some

reasons for the lag in Australia's performance include an overly short-term focus in business and a lack of an entrepreneurial culture. There is evidence to suggest that lifting the quality of management, particularly in SMEs, would make a strong contribution to lifting Australia's overall productivity.

Work commissioned for this project has shown that both innovation and good management are necessary for companies to innovate, grow and achieve productivity gains: work by Steen (2013) illustrates the role of innovation, collaboration and internationalisation in firm productivity; work by Palangkaraya, *et al.* (2014) shows that there is a significant interaction between innovation activities by large businesses and their management practices. This work is discussed in Chapter 3 and Chapter 4.

Businesses face a number of challenges, from disruptive technologies, globalisation and changing market structures. Firms often need to adjust their business model in order to maximise gains from investment in new technology. Innovation management is becoming increasingly important to enable adaptation to new challenges. However the **quality** of business management is critical.

The concept of management, specifically innovation management, covers a wide area incorporating governance, leadership, culture, finance, skills and strategy, new product and service developments and intellectual property management. Collaboration, problem solving capability, harnessing employee skills and technology and the ability to monitor and respond to changing customer needs are all key attributes of high performing businesses (Boedker, *et al.* 2011; Boedker, *et al.* 2013).

There is a clear link between the quality of management and firm productivity (Bloom & van Reenen 2010). The quality of management practices has a measurable impact on labour productivity, as well as sales and employment (Green 2009). High management scores are positively correlated with various measures of success including: sales, productivity, employee numbers and market valuation. The determinants of management practices include firm size and ownership.

#### Box 4.1: Cochlear HASS-STEM mixing case study

Cochlear is an Australian-founded company that develops electro-acoustic implants to restore hearing to the deaf and offers a lifelong commitment to upgrade and service its technology, and support the local communities of their clients. In 2013, Cochlear celebrated the thirtieth anniversary of the manufacture and implant of their first device. With their permanent implants and upgradeable external components, Cochlear has established a 'rest of life' brand commitment that depends on deep client loyalty. Says CEO Chris Roberts, "The value proposition of Cochlear's product involves a two-part system: the implant lasts a lifetime, but a great deal of intelligence sits external to the ear and essentially sends power and sound data to the implant. We don't have anything in the implant to wear out, but as the technology advances patients can replace the external piece." The company has had to deal with, and survive, controversy. Roberts notes that although the early years of the company saw protest from deafness advocates over offering hearing where it was not wanted, "in countries like Australia and the US, the majority of new recipients getting Cochlear implants are not children. More people over the age of 65 are getting an implant than children. Increasingly, there is an order of magnitude more deafness in adults than there is in children – the adults actually had speech and language; they heard, and then they went deaf."

Cochlear maintains their brand integrity – in particular, with potential clients – and retains their market share by building communities, and using volunteer networks, social media and events. In the US – and to a smaller extent in other regions around the world – the company coordinates 'Celebration', an event that allows implant recipients and those considering the process to gather and exchange stories and experiences. This 'Cochlear Community', and Cochlear's associated volunteer networks, offer a living example of the value of peer-to-peer consultation in marketing a product, rather than relying solely on the expert-to-user experience. Roberts notes, however, that these methods are chosen on a "country to country" basis – a technique that might be successful in Germany may not work in China for embedded cultural reasons.

A key example of the success of peer-to-peer (and even user-to-expert) engagement is the work of Mike Noble, who received an implant as a child after going deaf. He won a Graeme Clark Scholarship as an adult, and now works with clinicians, implant recipients and new clients to promote the Cochlear "experience". As a digital native and having a lifetime of experience with the company's products, Noble acts as an effective social media ambassador for Cochlear.

Since its establishment in 1978, Cochlear has gained more than 70 per cent of the global market, with operations extending to the United States, Europe, India, Korea and Japan. Through innovation, internationalisation and an appreciation of cultural diversity, the company offers autonomy to regional operations and encourages locally developed engagement programs. Each region has dedicated country managers who address cultural and regulatory diversity and coordinate multi-disciplinary teams that can handle local issues. At the clinical coalface, Cochlear works closely with surgeons and clinicians who have self-selected a very specific career in managing hearing disability. Through careful clinical and patient diplomacy and management, the company has established a powerful and loyal lobby that allows it to maintain its market share. Cochlear currently employs more than 2,600 staff globally, with 75 per cent of its \$A120 million R&D program based in Australia, and the balance in Belgium, Gothenburg and Colorado.

Technological innovation is at the core of Cochlear. However, a diverse range of disciplines and collaborations are vital to Cochlear's success. For example, key non-technical skill sets include design thinking, social science (studies on social isolation), communication, understanding cultural diversity, marketing, and strategy for deep community engagement.

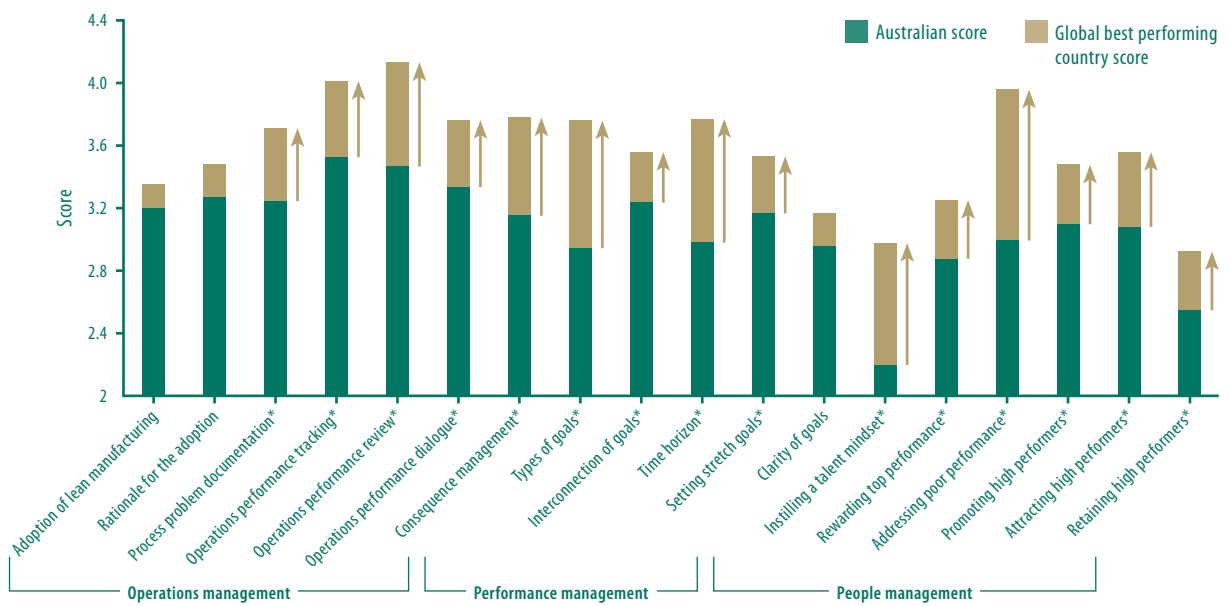
A recent study which examined practices and performance of more than 4,000 medium sized manufacturing operations in Europe, the US and Asia found that firms across the globe that apply accepted management practices well, perform significantly better than those that do not (Bloom, *et al.* 2007). The study also found that improving management practices is one of the most effective ways for a firm to outperform its peers.

Recent studies have found Australian management practices to be only moderately

above average when benchmarked globally, with a significant proportion of firms that are mediocre (Figure 4.2) and considerable variance in management practices within Australian firms (Green 2009).

Figure 4.2 shows Australia's score in various areas of business management performance, compared to the best performing country's score globally in each category, with the arrows illustrating the gap between the two. Categories in which there was a significant difference between Australia's score

Figure 4.2: Australian firms' performance in business management, compared to global best performers



Source: Green 2009.

and the best performing score are denoted with an asterisk (at the 10 per cent significance level).

The Centre for Workplace Leadership surveyed 2,310 Australians to gauge their views of leadership in Australian workplaces (CWL 2014). Three quarters of respondents agreed that Australian workplaces need better management and leadership. One quarter of respondents reported that there was no leadership role-model in their workplace, but this rose to 35 per cent of people in senior or middle management roles. This work illustrates the need for a stronger focus on improving management and leadership in Australian workplaces.

A recent report (Samson 2011) examined the extent of implementation of the recommendations of the 1995 Karpin review of management in Australia, *Enterprising Nation*, and found that while some progress has been made, there are still significant areas needing improvement. Areas requiring further work include: leadership; sustainable development; innovation, entrepreneurship and ICT; management education; diversity; global influence and international business opportunities; people management; risk and volatility; Australian demographics and culture. Although the Karpin report did not look specifically at *innovation management*, some of the areas requiring improvement are relevant.

### Management challenges facing Australian businesses

There are a number of interconnected innovation management challenges facing Australian businesses including: leadership, collaboration, risk management, dealing with disruption, accessing international opportunities, management of intangible assets and access to skills. These can be addressed only by government, business, universities and industry associations/organisations all working together.

Businesses can deal with disruptive technologies or other challenges by approaching them as an opportunity rather than a threat. Foresighting exercises can enable business to anticipate new developments. Industry associations can assist by linking into existing foresighting initiatives and translating these to businesses. Government can reduce overly prescriptive regulation and help industry sectors to develop action plans. Sectoral Action Plans, developed by industry working groups with the support of the Commonwealth Department of Industry have been useful in helping businesses to form a shared view of the future for their sector.

The international transfer of skills and ideas creates opportunities for business. However, internationalisation presents a range of

challenges for business. Some Australian businesses have a tendency to be insular. In addition, SME managers are time-poor. They need help to take advantage of international opportunities, including assistance to:

- identify international opportunities
- develop strategies, planning, risk management and negotiation skills
- navigate cultural barriers.

There are some existing models to help SMEs internationalise and connect with international networks (e.g. AusTrade, CAESIE<sup>8</sup>, Academy missions) but more needs to be done. State government trade missions can also help develop international networks. Intermediary and industry organisations as well as government bodies all have a role to play in facilitating international linkages and helping SMEs to internationalise. The Government's New Colombo Plan should provide opportunities to develop international relationships.

Collaboration is an enabler of innovation and improved firm performance. International evidence shows that collaboration is key to competitive advantage but Australia lags on measures of collaboration (OECD 2009). Benchmarking the activities and capabilities that produce successful, as well as unsuccessful, collaborations would be helpful. Although there are some successful programs placing researchers in industry (e.g. Researchers in Business Program), more are needed.

Australian firm-level econometric studies have found that intangible assets, such as intellectual property, are significant determinants of business profits (Griffiths, *et al.* 2011). These assets have to be managed so they translate to tangible value for businesses and their customers. Effective management of intangible assets can multiply opportunities for innovative SMEs. SMEs can benefit from assistance to identify the intangibles

that are most valuable to their business and understand the drivers behind them.

Lack of knowledge about the strategic management of innovation and lack of diversity in leadership teams limits firm performance. Industry associations, supported by government, have a role to play in facilitating the development of networks and connections to sharing best practice approaches. Such action will help to develop new skills that are critical to improved management of innovation and productivity improvement.

Innovation needs to be valued and supported at every level with a risk-tolerant culture that allows diversity, flexibility and inclusivity. Businesses need to ensure that opportunities and incentives are provided for all staff to contribute ideas and that processes are in place through which ideas can be translated to outcomes. Innovation managers, who can realise opportunities from disruption, can come from a wide variety of backgrounds. This convergence of skills can be encouraged through the provision of training and incentives, such as equality in pay structure with technical and business specialists. Attracting and retaining the best people requires an understanding of skills required and barriers to retention. Businesses should celebrate and learn from success and accept and learn from failure. Industry associations have a role to play in advocating best practice in people management.

### Lifting business management performance

A major international study has suggested that encouraging the take-up of good management behaviour could be the single most cost-effective way for governments to improve the performance of their economies (Bloom, *et al.* 2007). This study also found that strong competition and flexible labour markets both lead directly to improved management performance. Multinational companies have a strong positive influence throughout the regions in which they operate.

The overall performance of most countries is strongly influenced by the numbers of poor performers, not by the performance of its leading

---

<sup>8</sup> The Connecting Australian European Science and Innovation Excellence (CAESIE) initiative is a bilateral partnership program between the EU and Australia that aims to establish science and technology collaboration between SMEs and researchers.

companies. Raising the performance of firms in the middle of the performance spectrum could pay significant dividends. The study suggests that by developing environments that promote good management practices across all firms and taking measures to help poorer performers, governments can drive the competitiveness of their entire economies.

Green (2009) has reinforced these findings with the conclusion that focusing on the large number of poorly managed manufacturing firms may be the best way of enhancing management capability and performance in Australia. He also sees a role for government in this regard. Boedker, *et al.* (2013) suggest that management issues in the services sector also need attention.

#### 4.1.4. Improving the innovation capacity of Australia's workforce

There is a need to improve management education and equip science and engineering graduates for innovation and leadership: absorptive capacity for innovation, problem solving capabilities, creativity, and adaptability are critical attributes for innovative business. Innovation training should be a feature of all university business courses as well as other disciplines, such as engineering, to provide graduates with skills that business needs. This could be achieved by enhancing practice-based training in university courses to develop ability to define a problem and communicate a solution and opportunities to work on real industry problems and/or in interdisciplinary teams.

Internships, work experience opportunities and mentoring are important and more are needed. These could be facilitated by increasing opportunities for connections between university and business, especially for early career researchers and business leaders (e.g. Consult Australia program to train future business leaders). Increasing connections between university and business could be achieved by involving business leaders or alumni in delivering and developing course content and mentoring.

Alternative, more targeted, post-graduate business education programs to the Master of

Business Administration (MBA) course are now in demand. For example: the University of California Berkeley and Stanford University offer a suite of degrees in executive education, innovation management and entrepreneurship; Carnegie-Melon offers degrees in business design. Increasingly, Australian universities are exploring this market and the range of non-MBA business degrees has been expanding. Progressive universities in Australia are now offering MBAs that include a core component on innovation leadership. Government should ensure that funding programs such as the ARC Linkage Program provide opportunities for early career academics to engage with business.

Entrepreneurship and intrapreneurship<sup>9</sup> are characterised by the freedom to make mistakes, continuous learning, risk taking and sharing, success and failure. Innovation requires a range of skills. Australia is good at creating start-up businesses – but struggles to grow them. Relationship management with large firms is important, as well as understanding how to play a role in global supply chains. Larger businesses can help by providing a mentoring role to start-ups. Schools may be able to provide opportunities to nurture entrepreneurship and innovation skills. Government can help build capabilities in start-ups and in more mature firms. It can also provide investment guarantees. More researchers in business could promote entrepreneurship and commercialisation opportunities.

## 4.2. Building a broader science, research and technology base in Australia's workforce

Reviewing the broad STEM skill base in Australian industry requires consideration of the current STEM workforce, the adequacy of flows into that workforce and the extent to which managers understand and value STEM skills.

---

<sup>9</sup> Intrapreneurship is the practice of entrepreneurial activities by employees within an existing organisation.

### 4.2.1. Australia's STEM workforce base

Analysis of the 2011 Australian Census has shown that employment rates are high among all STEM-qualified people (81 per cent), and that unemployment remains low (less than 4 per cent). From 2007 to 2011, the number of employed people across the Australian economy grew by 8.1 per cent, while the top-eight STEM occupations (75 per cent of employed STEM graduates) grew by an average of 11.1 per cent. The strongest growth in employment among STEM occupations was for Design, Engineering, Science and Transport Professionals and for ICT Professionals. The STEM-qualified population is much more male-dominated (72 per cent) compared to the general university-qualified Australian population (45 per cent) (Healy, *et al.* 2013).

Despite the strong growth in STEM occupations, their growth in average full-time weekly earnings from 2007 to 2011 remained slower than the economy in general (Healy, *et al.* 2013). This suggests an absence of systemic skills shortages for STEM occupations in general.

The Australian Council of Learned Academies' 2013 report *STEM: Country Comparisons* examined the international landscape of science, technology, engineering and maths education in the context of the take-up of STEM skills in the labour market and research system (Marginson, *et al.* 2013). The report found that there was little existing data on the take-up of STEM qualified graduates in international labour markets. Better data are available in relation to the output of graduates than the use of graduate labour. In particular, the *deployment and utilisation of*

STEM graduates' human capital by industry is not readily apparent from the data and needs specialist labour market analysts to reveal the state of play (Webster, *et al.* 2001).

The ABS recently published a report examining the STEM qualifications and occupations of the Australian workforce – *Perspectives on Education and Training: Australians with Qualifications in science, technology, engineering and mathematics*. In 2010-11, 2.7 million people aged over 15 years had a STEM qualification (Certificate III or above) – approximately 15 per cent of this population. Almost two thirds of these people had a qualification in engineering and related technologies (ABS 2014). This is described in more detail in Table 4.1.

Of the 2.7 million people with a STEM qualification (Certificate III or above), 19 per cent also had qualifications in a non-STEM field. This included 18 per cent of people with a qualification in information technology whose highest qualification was in a different field.

While women made up 60 per cent of those with qualifications at Certificate III or above in non-STEM fields, they only comprised 19 per cent in STEM fields. In engineering and related technologies, women only accounted for 8 per cent of people with these qualifications.

Of those with STEM qualifications, 35 per cent were born overseas. Almost one in five of Australia's STEM qualified population spoke a language other than English at home.

Of the total Australian workforce, people with STEM qualifications accounted for 18 per cent. This is illustrated in more detail in Table 4.2.

**Table 4.1: Summary of STEM qualifications in the Australian population, 2011**

STEM field	Vocational ('000)	University ('000)	Total ('000)
Natural and physical sciences	65	397	455
Information technology	191	206	388
Engineering and related technologies	1,404	334	1,719
Agriculture, environmental and related studies	170	102	266
Total ('000)	1,829	1,039	2,868

Note: Totals exceed the number of people with STEM qualifications due to some people having more than one.

Source: ABS 2014.

**Table 4.2: Employment characteristics of people with STEM qualifications, by selected occupation groups, 2011**

Occupation	STEM qualified workers ('000)	Total employed ('000)	STEM as a % of total employed	% working in job relevant to STEM qualification
Design, engineering, science and transport professionals	219	374	59	97
Specialist managers	207	737	28	81
Automotive and engineering trades workers	195	311	63	96
Electro-technology and telecommunications trades workers	171	273	63	94
ICT professionals	147	224	65	96
Engineering, ICT and science technicians	135	249	54	89
Business, human resource and marketing professionals	91	652	14	66
Education professionals	77	546	14	93
Total employed <sup>1</sup>	2,116	11,504	18	76

Note: 1) 'Total employed' refers to the entire workforce, not just these occupation groups.

STEM qualified workers includes anyone with a Certificate III or higher qualification in one of the following fields: Natural and Physical Sciences; Information Technology; Engineering and Related Technologies; or Agriculture, Environmental and Related Studies.

Source: ABS 2014.

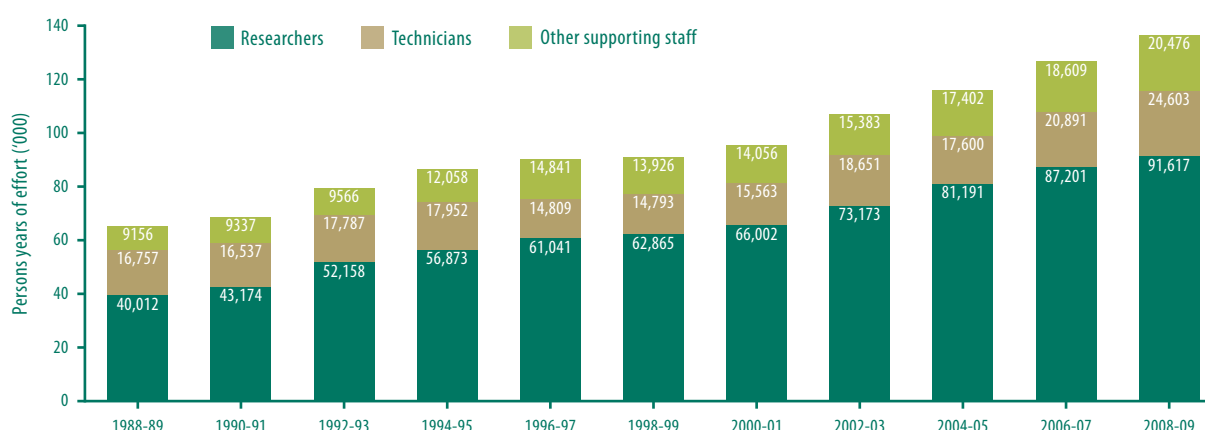
While only 59 per cent of people employed as design, engineering, science and transport professionals had STEM qualifications, practically all of those people were working in a job relevant to their qualification.

In education, only 14 per cent of professionals had a STEM qualification, while 93 percent of those people worked in an area relevant to their qualification. This implies that teachers with STEM

qualifications are in demand to teach in STEM-related fields. The ACOLA report *STEM: Country Comparisons* found that “the incidence of ‘out of field’ teaching in science and mathematics is especially high in Australia by comparison with other countries”, which appears to be borne out by these statistics (ACOLA 2013).

Australia’s research workforce has more than doubled in the 20 years since 1989, as shown in Figure 4.3.

**Figure 4.3: Human resources devoted to R&D in Australia, by occupation type**



Source: DIISR 2011b.

As a proportion of total employment, Australia's R&D workforce generally compares favourably with other OECD countries, at just over 12 R&D personnel per 1,000 employment, as illustrated in Figure 4.4. However, Australia is well behind the leaders in this field – countries such as Israel and Finland. This is of greater concern when considered in conjunction with Figure 4.8 and Figure 4.9 which show that significantly less than half of Australia's R&D workforce is employed in business enterprises.

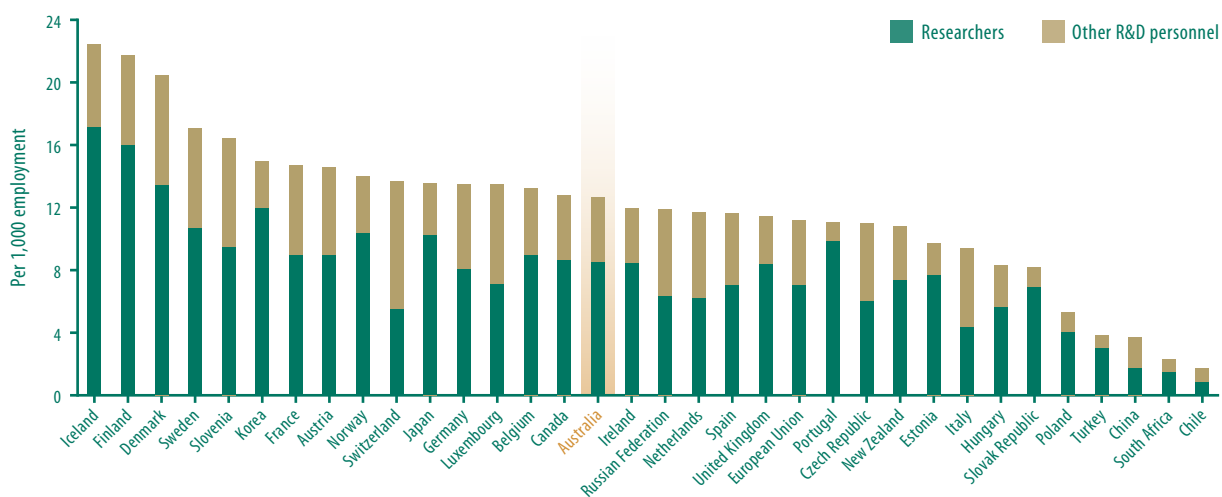
The OECD's *Science, Technology and Industry Scoreboard 2013* reports that knowledge-intensive market services are significant users of high technology (e.g. ICT capital) and/or have a relatively highly skilled workforce able to meet the demands of modern, highly competitive business environments (OECD 2013c). This

category is therefore a useful proxy to compare Australia's STEM skilled workforce with other OECD countries, as illustrated in Figure 4.5. As a percentage of the whole workforce, Australia's employment in knowledge-intensive market services is in the top third of OECD countries, at approximately 13 per cent, similar to the USA.

Another important aspect of Australia's STEM skilled workforce is the engineering workforce. Engineers Australia conducted an investigation into the supply of engineers in Australia in 2012, focusing on the role of skilled migration. As noted by Engineers Australia:

*Australia does not produce sufficient engineers to meet its requirements and the case for ongoing supplementation of Australia's*

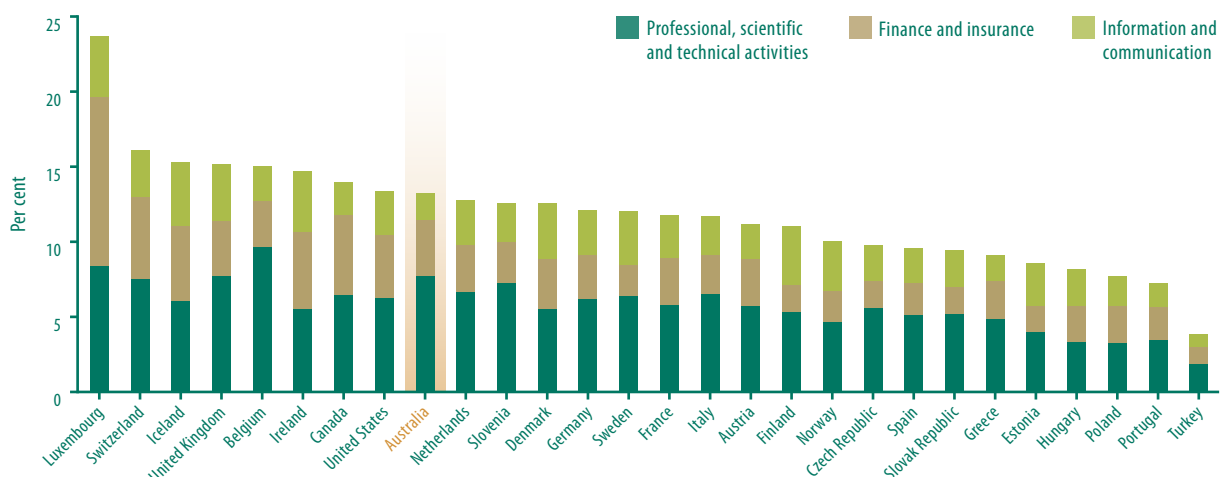
Figure 4.4: R&D personnel, per 1,000 employment, 2011



Source: OECD 2013c.

Note: Australian data for 2008.

Figure 4.5: Employment in knowledge-intensive services as a percentage of total employment, 2011



Source: OECD 2013c.

education output from permanent migration is strong. Graduations are increasing, but gains to date are just sufficient to offset contractions that occurred earlier in the decade. In the absence of skilled migration, the number of newly graduated engineers adding to supply would be grossly insufficient to cope with the demand changes evident in the labour market.

(Engineers Australia 2012)

This issue is illustrated clearly in Figure 4.6, where domestic education completions have contributed less than half the number of new professional engineers employed in Australia since 2004-05.

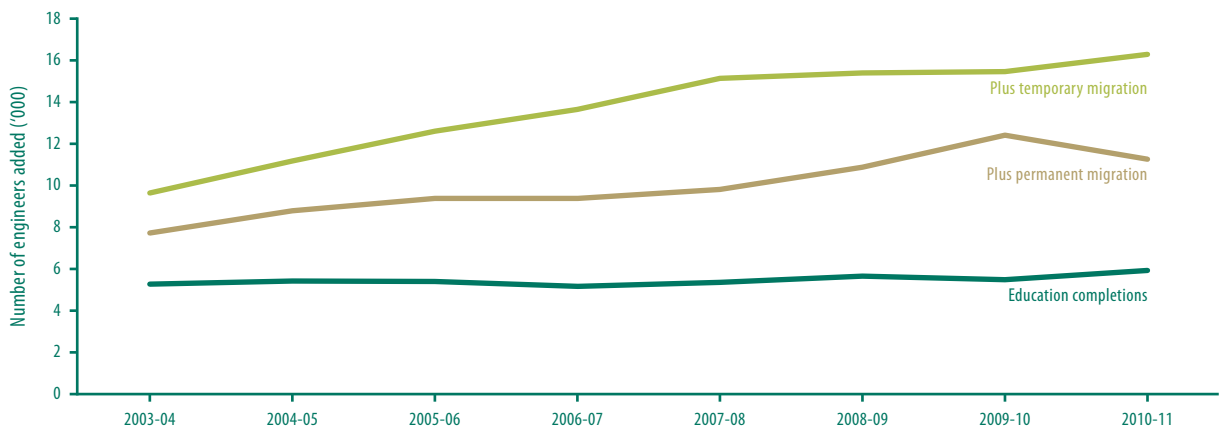
While high migration has been a key contributor to the success of Australia's economy and workforce, the situation outlined above may not be sustainable. The clear increase in demand for engineers in the first half of the past decade was not matched by an increase in completions

of engineering degrees. The role of industry in developing a suitable base of locally qualified engineers, compared to relying on temporary skilled migration to meet demand, must be examined.

#### 4.2.2. The business research skill base

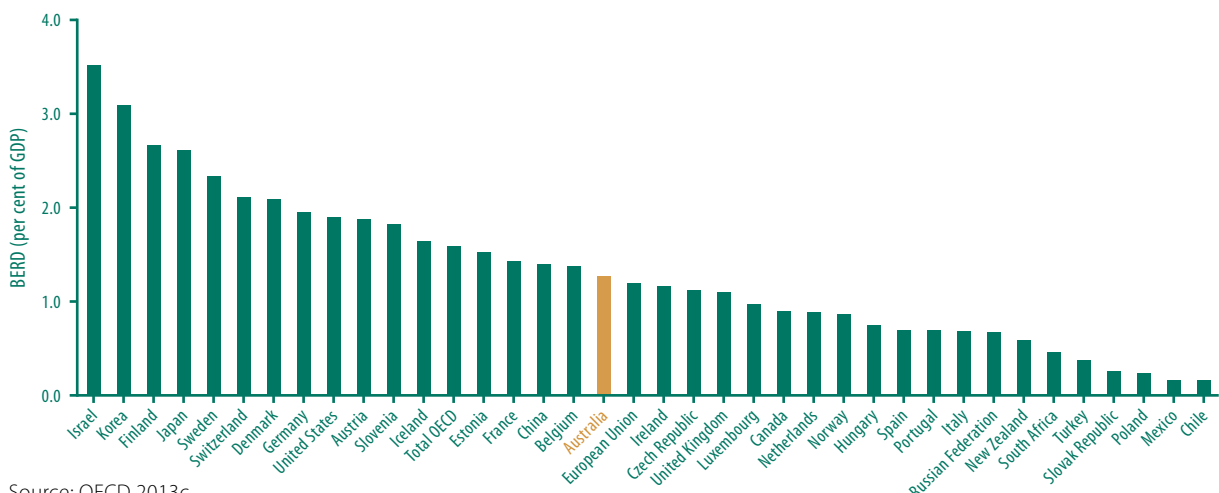
One important part of the STEM skill base in business is the workforce undertaking R&D. Businesses invest in R&D in order to develop or improve products and processes, impacting on economic growth and productivity. Thus national expenditure on R&D by business is generally regarded as an indicator of investment in innovation. Business expenditure on R&D in Australia as a percentage of GDP is low compared to other countries, as illustrated by Figure 4.7. As a result, the number of researchers in business is also low.

Figure 4.6: Contributions of education completions and skilled migration to the supply of professional engineers in Australia



Source: Engineers Australia 2012.

Figure 4.7: International comparison of business expenditure on R&D, 2011



Source: OECD 2013c.

The OECD's 2013 *Science, Technology and Industry Scoreboard* provides a snapshot of OECD nations' R&D workforces according to the relative proportion in business, government, higher education, and private non-profit. This is illustrated in Figure 4.8.

As Figure 4.8 shows, the majority of Australia's research workforce is in the higher education sector. This is sharp contrast to leading industrialised countries such as Korea, Japan and Sweden. However, the number of research personnel in business enterprise in Australia has been growing strongly since about 2000, although it still lags behind the number of researchers in higher education – as illustrated in Figure 4.9.

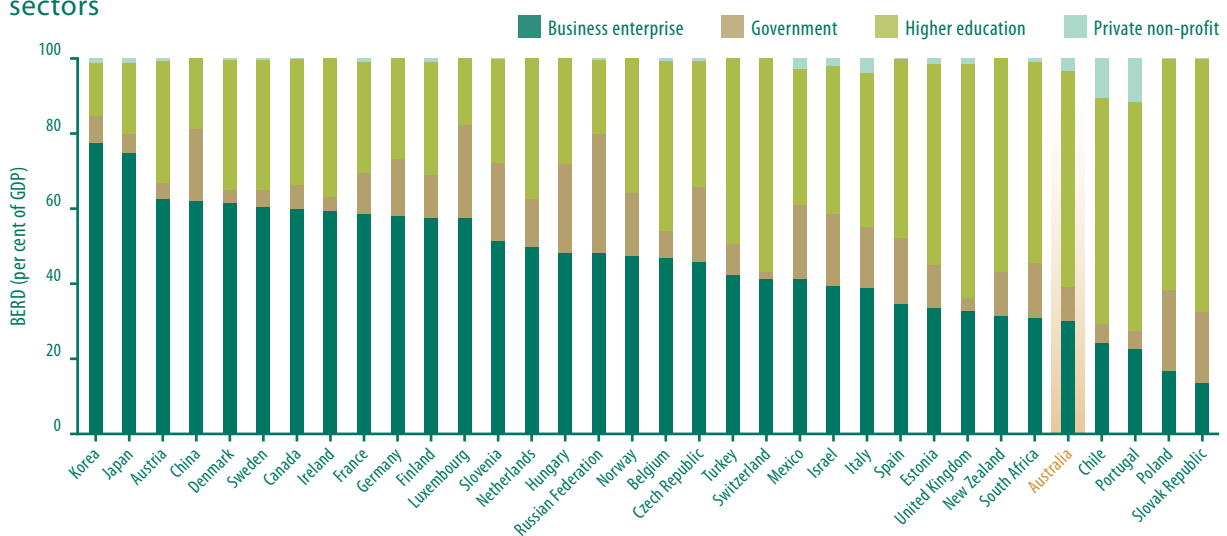
As shown in Figure 4.9, the major part of the workforce undertaking research in Australia has traditionally been in the university sector. Thus

encouraging links between the universities and business and creating mobility between these sectors of employment is important. As the Department of Industry, Innovation, Science and Research noted:

*Increasing the number of businesses investing in R&D in Australia will require more people with the research and technical skills to conduct and support the additional R&D. Similarly, enhancing levels of research and innovation-based collaboration will require improvements in the increasingly people-based networks and communication channels used to convey demand and source expertise. Finally, provision of world-class research infrastructure capabilities to Australian researchers will require skilled research and technical staff to operate and maintain the facilities.*

(DIISR 2011d)

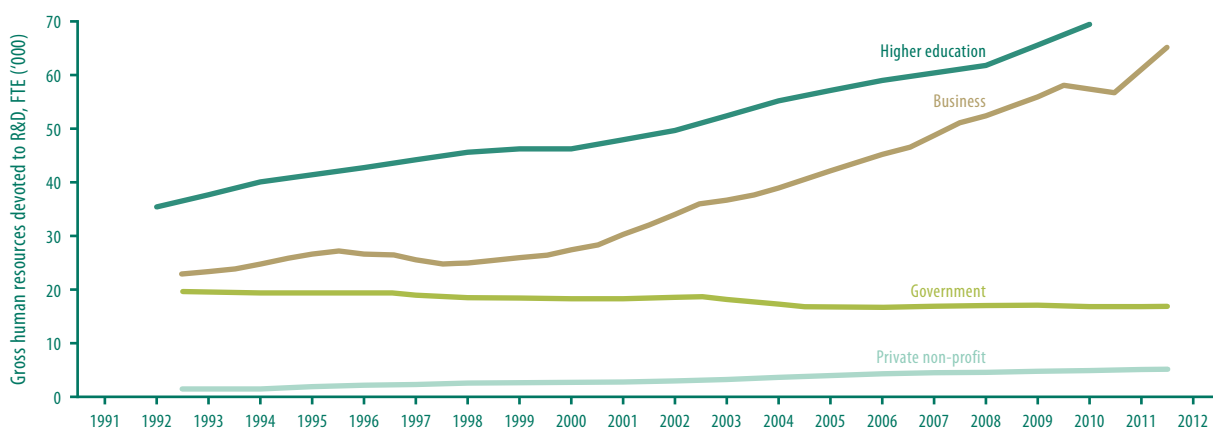
**Figure 4.8: Proportion of research personnel in business, higher education, and government sectors**



Source: OECD 2013c.

Note: Data for 2011 or nearest available year.

**Figure 4.9: Evolution of Australia's research workforce by sector, 1992-2011**



Source: Data from: ABS 2012c; ABS 2013e; ABS 2013f.

Note: FTE = full-time equivalent.

The report *Research Skills for an Innovative Future* outlines a strategy to meet Australia's needs for its research workforce to 2020. The key issues identified for improvement include:

- meeting anticipated demand for research skills in the workforce
- strengthening the quality of supply through the research training system
- enhancing the attractiveness of research careers
- facilitating research workforce mobility
- increasing participation in the research workforce.

These issues result from a number of factors, including: age-related retirements; employment growth in relevant sectors; increased demand for high-level research skills across the economy; and a stalling in domestic student uptake of research degrees (DIISR 2011d).

### 4.2.3. Role of the education system in preparing an innovation-capable workforce

The role of schools in preparing an innovation-capable workforce is covered in a previous ACOLA report<sup>10</sup>. In this report we address the role of the tertiary education system in this regard. In the report *Skills for Innovation and Research* further education and training are identified as providing “people with a deeper, more specialised and more sophisticated set of knowledge and competencies with which to enter the working world” (OECD 2011).

In addition to developing and honing skills for innovation such as critical thinking, investigation, and problem-solving, it is important for education to provide sufficient levels of literacy and numeracy in the overall workforce. Continued innovation and technological change require a basic level of understanding to allow full participation in the economy and society. By improving base levels of achievement in

mathematics, science and literacy, a more innovative workforce and stronger economy will follow (OECD 2011).

Australia's tertiary education system needs to meet the needs of business and industry. This includes issues such as the breadth versus the depth of knowledge acquired. Ensuring that curricula are forward-looking is also important. The education system needs to produce graduates with an ability to learn and to acquire new knowledge over their working life (life-long learning). Some level of specialisation will always be necessary: employers usually hire people based on their specialised skills. It is difficult to give the depth of training required for these kinds of skills in the workplace.

### STEM courses in Australian universities

As part of this project, a survey of Australian university deans of science and engineering was conducted to investigate how universities address the current and future demand from industry for STEM-related skills and qualifications. Those deans responding considered the systematic knowledge of basic disciplines to be the most important quality to develop in their graduates. More general skill sets were considered to be more important than developing specialised technical knowledge, or having a close fit with the needs of employers, whether immediately or in the future.

Over half of all respondents identified some level of compulsory inter- or cross-disciplinary modules in their courses. These generally included elective subjects from other parts of the university, but also specifically designed modules. Only one respondent did not offer any such modules. Some institutions also offer extracurricular opportunities to engage in cross-disciplinary learning, such as the University of Western Australia's Masterclass program, although this particular program is specifically aimed at postgraduate students (IAS 2014).

Faculty colleagues were by far the most frequently considered source of input for course design with more than half of respondents indicating they received input from their faculty colleagues at least once a month, or more often.

---

<sup>10</sup> Marginson, S, Tytler, R, Freeman, B and Roberts, K (2013). *STEM: Country Comparisons*. Report for the Australian Council of Learned Academies, [www.acola.org.au](http://www.acola.org.au).

The most important source of input for modifying course offerings and course design was “industry associations or professional organisations”. It is likely this reflects the importance of course accreditation. Faculty colleagues were a highly-rated source of input, while alumni and current students were rated significantly lower. Attempting to meet the specific current and future needs of employers through the university curriculum was a low priority.

Examples of changes to course design or offerings given by respondents could be placed into four broad categories: a new course being offered; more generic skillset development in existing courses; revision or refocusing of existing courses; and greater industry cooperation. All respondents indicated that their institution operated a strategy to adapt their course offerings based on external input.

### Vocational Education and Training

A recent report on the future of vocational education and training has stated:

*The clear purpose of the Australian vocational education and training (VET) sector over the coming decade is to meet the nation’s demand for the additional skills that will be required to address economic and demographic change and to improve workforce participation and productivity.*

(Skills Australia 2011a)

Skills Australia (now Australian Workforce and Productivity Agency, AWPA) considers that Australia’s VET sector, as a whole, is not realising its full potential. The need for action in the VET sector is based on analysis of the demand for future skills requirements and their use to enhance Australia’s productivity. To help meet projected demand for higher level qualifications and skills, the report argues that progression between education sectors should be as simple as possible.

The report also recognises the role of VET skills in boosting Australia’s innovation skills and capability. It notes that Australia’s global competitiveness is ranked 16th by the World Economic Forum, based on a broad range of measures, including skills. The 2010 edition of

this report mentions a lack of sophistication in Australian companies’ strategy.

There is a need for better integration of training with developments within firms, as a necessary reform of the VET sector. Financial incentives and services for employers, apprentices and trainees need to be redesigned. In particular, reform of the current employer incentive scheme is needed to ensure that financial assistance is targeted to achieve workforce development outcomes (Skills Australia 2011a).

VET training has an important role in building an innovation capable workforce. As noted in the *Australian Innovation System Report 2013*:

*Many of the business management skills and trade/technician skills required for these mixed mode innovations prevalent in advanced countries come from the development of a large and skilled, vocationally trained workforce.*

(Department of Industry 2013)

In a feature written for the 2013 *Australian Innovation System Report*, Professor Gavin Moodie goes on to say that vocational training institutes have a significant role to play as innovation intermediaries. In particular, by developing the skills of the existing workforce and engaging with businesses production processes, they can facilitate the take-up and adaption of existing knowledge solutions to local environments (Department of Industry 2013). There is an opportunity to expand the role of vocational training institutes, by improving their integration into and connections with the broader innovation system.

### 4.2.4. STEM labour market issues

As the Australian Industry Group has noted:

*Australia’s productivity and competitiveness is under immense pressure. A key way to meet the emerging challenge of developing an economy for the 21st century is to grow our national skills base – particularly the Science, Technology, Engineering and Mathematics (STEM) skills of our school leavers. Our relative decline of STEM skills is holding back our national economy and causing real frustration for employers.*

(AiGroup 2013b)

A recent decline in participation in STEM subjects in Australian schools and higher education may be leading to a decline in STEM skills in the workforce in general (AiGroup 2013b). According to the Australian Industry Group, three quarters of the fastest growing occupations require STEM skills and knowledge, and employers are facing recruiting difficulties for STEM occupations citing a lack of STEM skills, workplace experience, and qualifications not being relevant to business needs (AiGroup 2013b). AiGroup has called for the establishment of an industry-led working group, in conjunction with the Office of the Chief Scientist, to develop a national framework and strategies to implement “school-industry” STEM skills initiatives and to support increased university and industry participation.

Demographics is a workforce issue of common concern. The age profile of the Australian population may provide a challenge in meeting future workforce needs. The proportion of the Australian population over 65 is forecast to rise from 17 per cent as of 2010 to more than 20 per cent by 2020, and to 24 per cent by 2030 (Australian Government 2010). This demographic change will result in a dependency ratio of 2.7 people of working age to support each Australian aged over 65 years by 2050, compared to 5 in 2010. As the 2010 Intergenerational Report notes, with the ageing of the population reducing participation, productivity growth will be the major contributor to real GDP per person growth in Australia over the next 40 years (Australian Government 2010). However, high levels of youth unemployment and under-employment continue to exist and their engagement in the workforce would improve participation rates.

Maintaining high levels of workforce participation will also be important to mitigate some of the consequences of this demographic change. Businesses will need to be encouraged to take advantage of the experience of older employees and to provide appropriate opportunities, as many people are willing and able to continue to make significant contributions up to and beyond the traditional retirement age, yet find it hard to get employment.

## Workforce diversity

The longstanding issue of workforce diversity is of great importance for maximising participation rates. In particular, the issue of gender diversity in the STEM workforce is a well-documented obstacle to participation and expansion of that workforce.

Greater workforce diversity has been shown to correlate with better business performance in general (Herring 2009). Workforce diversity is also recognised as a key driver of innovation. A Forbes Insights survey found that an overwhelming majority of respondents agreed that “A diverse and inclusive workforce is crucial to encouraging different perspectives and ideas that drive innovation” (Forbes Insights 2011).

Despite this, the place of women in Australia’s STEM workforce has been an ongoing problem. The Senate Education, Employment and Workplace Relations References Committee examined the issue of women in engineering in their 2012 inquiry ‘*The shortage of engineering and related employment skills*’. The committee found that:

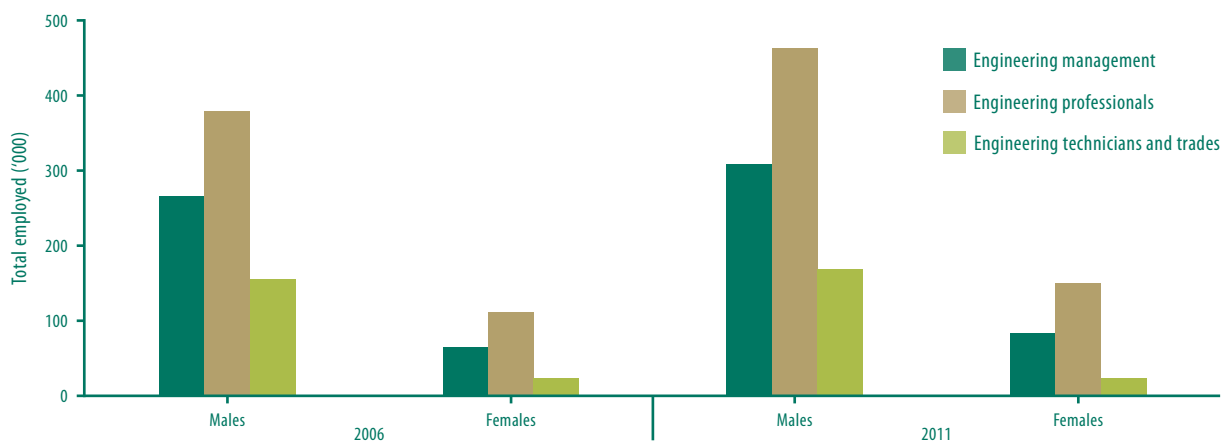
*The low participation rates of women in engineering professions and trades are clearly an important factor in the skills shortage. As demonstrated by the graph [below], the participation rate of women in engineering professions has increased by 1.7 per cent since 2006, but remains low at only 21.5 per cent.*

(Senate Education, Employment and Workplace Relations References Committee 2012)

This is illustrated in Figure 4.10.

The low numbers of women in engineering jobs is partly a result of low numbers of women studying engineering degrees (18 per cent of domestic commencing students in 2010), but is also due to the poor retention of women within engineering-related fields. Despite women having a slightly higher completion rate of engineering degrees than men, this does not translate into the workplace. Women working in science remain hugely underrepresented in leadership roles. It was observed that major barriers exist for women in engineering that arise from entrenched cultures in the industry. Further,

Figure 4.10: Total males and females in selected engineering occupations



Source: Skills Australia 2012a.

if the participation of women in the engineering workforce were to increase, this would go some way to addressing any skills shortages. In order to attempt to address these issues, the Committee recommended that the government work with the Australian Workforce and Productivity Agency to continue to develop targeted policies that encourage women and mature engineers to remain in or return to the workforce (Senate Education, Employment and Workplace Relations References Committee 2012).

Goldman Sachs JBWere (2009) has reported that closing the gap between male and female employment rates would have important implications for the Australian economy, boosting the level of Australian GDP by 11 per cent. According to the Australian Businesswomen's Network, women are starting small businesses at twice the rate of men. The Network reports that only 12 per cent of directors on ASX200 boards are female.

These issues are common across many STEM fields internationally, and have been recognised as such for a significant period of time. There are a range of initiatives and strategies in various countries to increase the participation of women in STEM, many of which are outlined in a Consultant Report for ACOLA's *STEM: Country Comparisons* titled "Snapshots of 23 Science, Technology, Engineering and Mathematics (STEM) consultants' reports: Characteristics, lessons, policies and programs" (Freeman 2013). Some of these initiatives are outlined in Box 4.2. Australia must continue to work to improve the participation

of women in all STEM fields, and to improve the diversity of the STEM workforce in general.

#### 4.2.5. Role of business in training an innovation-capable workforce

As the OECD has noted:

*Business cannot expect graduates to have all the "skills that business needs". Innovation training may consist of undergraduates being involved in workplace projects which require and teach innovation on the job.*

(OECD 2011b, p. 119)

There are major advantages to training in workplaces. Firstly, workplace training offers a high quality learning environment for acquiring practical skills, using current equipment alongside current working methods and technologies. A two-way flow of information between employers and employees and open lines of communication allows for productive contribution to systems and processes. Training in the workplace offers on-the-job opportunities to acquire skills specific to that area. Businesses will need to invest in ongoing skills development to promote the deepening and broadening of skills; commit to flexible organisational practices to facilitate retention; and effectively utilise skills. Another key aspect of workplace-based training is that of professional mentoring.

AWPA's *Human Capital and Productivity* literature review (AWPA 2013b) found that, overall, there is a positive association between training and firm performance, in particular where this forms

## Box 4.2: Initiatives to increase participation of women in STEM

### Million Women Mentors

The US *Million Women Mentors* initiative aims to support the engagement of one million women (and men) in STEM to serve as mentors to girls and women, from high school to the workplace, by 2018. The aim is to increase the interest and confidence amongst women and girls to persist and succeed in STEM programs and careers. The initiative, launched in January 2014, was founded by four partners including STEMconnector, a consortium of companies, non-profit associations and professional societies. There are now 52 national partners. The initiative recommends five pathways of mentoring: face-to-face; online; offering paid internships for high school or college age young women with a designated mentor; workplace mentoring to engage and support younger and newer employees; and sponsorship. It will use a web portal with matching capabilities, able to pair organisations with educational institutions (STEMconnector 2014).

The US has shown a commitment to increasing participation of women and girls in STEM disciplines, launching the *Educate to Innovate* initiative in 2009 that aimed, among other things, to expand STEM education and career opportunities for women. The 2011 Department of Commerce report *Women in STEM: A Gender Gap to Innovation* revealed that women represent only 24 per cent of the STEM workforce, but earn on average 33 per cent more when they work in these fields (Executive Office of the President 2013).

### Go MINT

The German *Go MINT* initiative is part of the German federal government's qualification initiative, focusing on increasing female participations in the 'MINT' subjects (Mathematics, Informatics, Natural Sciences and Technology). It was launched in 2008 with the aim to increase young women's interest in scientific and technical degree courses and to attract female university graduates into careers in business. The initiative is a network of over 180 partners from government, business, research organisations, universities and professional associations. Partners are encouraged to share ideas and best practice approaches within the network. One outcome of the initiative is a 6-month technical course to enable qualified young women to go to university, to gain practical experience of MINT subjects before embarking on a degree or training course. One university that participated in the program reported a 100 per cent success rate of the participants commencing a STEM degree or course after the program (Go MINT 2014).

part of a business or wider human resource management strategy. Effective workplace training is also an important aspect of a firm's response to potential skills shortages.

Changing business models in the manufacturing sector are changing workforce requirements. Many traditional industries in Australia are undergoing a transformation from established modes of operation to new, innovative business models as a result of globalisation; new technologies; and competition from low-cost base countries. This is particularly evident in the manufacturing sector, where Australian firms are unable to compete with the low-cost, high-volume producers that have come to dominate the market. The evolution of new and innovative business models in industry sectors such as manufacturing will require a qualitatively different workforce than previous traditional models.

Professional associations have an important role to play in promoting broader requirements from education and training, inside and outside the

workplace, to promote cross-sectoral awareness and cultural change.

## 4.3. Future workforce needs of Australian industries

As the nature of global economies has changed over the previous decades, the types of skills sought by employers have also evolved. In general, job skills have been classified into three broad categories (Handel 2012):

- cognitive skills (e.g. reading, writing, numerical, technical and problem-solving)
- interpersonal skills (e.g. people management, team work, communication)
- manual skills (e.g. physical activities, tool use, machinery operation of varying complexity).

There has been a broad shift in developed economies away from jobs requiring manual skills towards greater requirements for cognitive and

interpersonal skills (Handel 2012), coinciding with increased levels of education.

### 4.3.1. Skill shortages

Skill shortages are, from time to time, portrayed as a significant problem for the Australian economy. The effects of skill shortages on the economy and specific firms are difficult to gauge, due to the complex nature of skill gaps or recruitment difficulties and a lack of reliable data and research. A recent analysis of skill shortages in the Australian economy found that simple and complex shortages needed to be differentiated, in order to formulate an appropriate policy response and that the causes of skill shortages are very diverse (Healy, *et al.* 2012). Importantly, a lack of availability of adequate training was *not* identified as a major cause of skill shortages.

#### Engineering skills

In 2012, the Senate Education, Employment and Workplace Relations References Committee published *The shortage of engineering and related employment skills*, following a public consultation process (Senate Education, Employment and Workplace Relations References Committee 2012). The Committee took the term 'skills shortage' to mean either "employers experiencing difficulty in recruiting a person for a specific vacancy; or existing employees not having the skills necessary for the position that they hold."

The Committee found that the engineering skills shortage has impacted on the manufacturing and local government sectors in particular, through engineers migrating to more lucrative fields such as the mining and resources industries. It has also "resulted in poorly conceived and poorly delivered projects by both the public and private sectors, culminating in cost blow outs and delays" (Senate Education, Employment and Workplace Relations References Committee 2012).

Adding to the observations in Section 4.2.1 and Figure 4.6 about the contribution of skilled migration to the supply of engineers, the Committee found that the skills shortage had flow-on effects on the training of engineers. As noted in the report:

*Many industries feel like they do not have time to train graduates, particularly as graduates*

*with more than three or four years' experience are highly employable and likely to move to another job. Training and development for experienced staff can fall by the wayside amidst high workloads and low retention rates, further worsening an already deficient situation.*

(Senate Education, Employment and Workplace Relations References Committee 2012)

This implies that businesses would prefer to meet the demand for more experienced engineers through skilled migration, particularly through the 457 Visa Program, rather than training graduates. This may have a long-term detrimental effect on Australia's engineering workforce and capabilities and on good career opportunities for young Australians.

The Committee recommended a range of actions to address the engineering skills shortage and avoid future shortages, including: developing strategies to improve completion rates for VET and higher education students in engineering; engage with industry peak bodies to develop measures to encourage the provision of practical, paid work experience to engineering students; encourage women and mature engineers to remain in, or return to, the engineering workforce; and consider creating senior technical engineering roles in the Australian Public Service, in part to ensure that the government can be an informed purchaser of engineering infrastructure.

#### Information and communication technology skills shortages

Other areas of potential skills shortages have also been examined in Australia recently, such as information and communications technology (AWPA 2013c). The AWPA report notes that generic ICT skills and 'digital literacy' have emerged as prerequisites or highly desired skills for jobs across the economy, as well as being central to the process of learning (AWPA 2013c). ICT skills are important for an innovative workforce to be able to deliver and manage technological change.

The report observed that businesses have had difficulty recruiting ICT specialists to fill the roles that they require. As discussed in Section 4.2.1 and Figure 4.1, there was a drastic reduction in domestic students studying ICT from 2001 to

2008. Despite recent gradual improvements in this area, more needs to be done to increase the domestic supply of ICT specialists, in particular to increase both the number of enrolments and completions in ICT-related disciplines, particularly for women, as well as the number of entry-level opportunities available in the industry.

### Manufacturing skills

Skills shortages can be caused and resolved in a variety of ways, depending on the nature of the shortage, required skills, and industry sector. In the manufacturing sector, a recent UK report states that the right skills are central to manufacturers being able to achieve their ambitions on innovation, exporting and growing their businesses (EEF 2012). The lack of availability of a skilled workforce was found to act as a barrier to growth. UK companies are responding to skills shortages by increasing their investment in skills, recruiting apprentices and developing stronger links with schools and colleges.

UK businesses reported having difficulty recruiting candidates with the right experience and technical skills needed, as well as a lack of candidates. Many manufacturers are reliant upon an ageing workforce, with the lack of a new generation of workers to fill the gap. In order to fill this gap the EEF report highlights the need to encourage, inspire, actively promote and educate at the base level the opportunities available for younger generations and the benefits of choosing a career in the manufacturing sector.

In the UK, the demand for skills is set to rise in the coming three years and, as the EEF report highlights, access to these skills is crucial to manufacturers' growth strategies. The areas where manufacturers expect skills needs to increase include those required to develop and launch new products and services; undertake R&D, introduce new processes; project management, craft and technician skills. The EEF report indicates that UK industry is aware of the issue and that employers are taking greater ownership of the skills agenda but they are constrained by the current training setting. In order to overcome this issue the report recommended that "the government must remove the barriers faced by employers in accessing appropriate training and

work harder to create the conditions under which firms can produce the workforce of the future".

The UK EEF report argues that there are three benchmarks on skills that should drive government action in this area relating to the pipeline of skills flowing out from the education system, ambitions to invest in apprenticeships and the ease of which employers can recruit and invest in skilled staff. The report suggests that the development of a skills pipeline can be achieved through:

- reforming qualifications, increasing teacher quality and increasing the number teachers who have specialist knowledge in STEM subjects
- providing appropriate, high quality, impartial career advice
- bridging the gap between employers/industry and school
- enhanced uptake of STEM education at all levels
- ensuring teachers understand industry roles better to enable them to be in a position to advise students of the opportunities and options they have
- short-term work placements that could potentially function as a trial period for apprenticeships or permanent placements
- encouraging employer investment in apprenticeships.

### Skills utilisation

The extent to which human capital contributes to productivity depends on how effectively it is utilised. Changes in industry structure and workforce demographic mean that skills-matching is critical now and for the future. Skills utilisation policy is becoming increasingly important in improving innovation and productivity in workforces internationally. Compared to supply-side issues, such as increasing the proportion of the population with higher qualifications, this kind of demand-side consideration is a relatively new approach. In particular, addressing whether, and how, increasingly well-educated citizens have their

skills deployed in the workplace is a key part of this approach (Buchanan, *et al.* 2010).

Skills Australia (now AWPA) reviewed the importance of skills utilisation in workforce development in 2012. The report states that “Skills utilisation is ... increasingly recognised by governments and policymakers as just as valuable to productivity as skills acquisition. In tight labour markets ... skills utilisation has the potential to drive innovation and lead to positive outcomes for both employers and employees” (Skills Australia 2012b).

The report found that many Australian firms undertake skills utilisation practices, across a range of industries, sectors, and sizes of businesses. These practices were triggered in Australian businesses by tight labour markets and the need to attract and retain employees when faced with strong competition. The key workplace dynamics for skills utilisation to succeed were identified as good leadership and management, good HR practices, communication and consultation, and employee commitment and motivation. Businesses reported that skills utilisation had delivered benefits including improvements to innovation, productivity, profitability, staff retention and safety, while employees reported that they experienced increased job satisfaction, motivation and commitment through skills utilisation, and had greater access to learning, leadership and career pathways in the workplace (Skills Australia 2012b).

Skills Australia identified some key areas for policy makers to emphasise to promote skills utilisation across the Australian labour market, including (Skills Australia 2012b):

- **Supporting good leadership:** leadership plays a crucial role in adopting and implementing strategies to optimise the use of employee skills, but also in identifying the need for such strategies
- **Encouraging good practice human resources management:** good practice human resource management was found to be a key element in underpinning skills utilisation
- **Disseminating good practice:** there is a role that governments can play in sharing and

promoting good practice – there is clearly an appetite among employers to learn more about skills utilisation.

### 4.3.2 Issues relating future STEM skill supply to demand

AWPA commissioned modelling of future scenarios for skills demand and supply in Australia from Deloitte Access Economics (Deloitte Access Economics 2012) to inform their 2013 National Workforce Development Strategy. This report modelled four separate future scenarios for Australia’s economic growth to 2025 and the effects on the workforce in each case.

The scenarios are described by AWPA (2013d) as:

1. **Long Boom:** the high demand for resources traded with China and other countries continues. Industries challenged by the high terms of trade undertake structural adjustment.
2. **Smart Recovery:** the challenges facing Europe and the United States affect financial markets. This means low growth for Australia to 2014-15. Growth then improves and Australia benefits from industry and government strategies to implement a knowledge economy.
3. **Terms of Trade Shock:** resource prices fall mainly due to increased supply from other countries, the Australian dollar falls and we move to a broader-based economy.
4. **Ring of Fire:** a risky world with multiple economic and environmental shocks.

There is a significant increase predicted by AWPA in the proportion of employed people with post-school level qualifications under all scenarios – the “long boom”, “smart recovery” and “terms of trade shock” scenarios saw an average annual increase in these qualifications of between 2.7 to 3.7 per cent, with only 1.4 per cent in the “ring of fire” scenario. However, predicting the future workforce needs of industry with any long-term precision is very difficult.

These scenarios were used by AWPA for modelling Australia’s future workforce needs and developing policies to help meet those needs in their 2013

National Workforce Development Strategy – *Future Focus*. As AWPAs states in *Future Focus*:

*The challenge now is to sustain this prosperity by developing the nation as a knowledge intensive economy, growing our capacity for cutting-edge innovation and supporting productivity growth while also building our communities and supporting environmental sustainability.*

(AWPA 2013d)

AWPA identified a widening gap between the expected future industry demand for higher level skills and the expected supply of workers with these skills. If this issue is not addressed, it has serious consequences for Australia's ongoing productivity growth. According to AWPAs modelling, by 2025 Australia could be facing a gap of 2.8 million higher-skilled qualifications.

In order to realise Australia's growth potential, the development of a highly skilled and adaptable workforce needs to focus on: providing knowledge and skills in tertiary education; matching tertiary provision to the needs of industry, individuals and society; using knowledge and skills effectively at work; and further developing knowledge and skills in the workplace (AWPA 2013d).

To achieve these outcomes, Australia's workforce development capability will require action in the following areas (AWPA 2013d):

- positioning Australia as a knowledge economy through skills development and targeted planning
- improving productivity in the workplace
- building labour force participation to meet the current and future needs of industry and individuals and promote social inclusion
- equipping Australians with the language, literacy and numeracy skills needed for full participation in community life, education and work
- enabling individuals and the tertiary system to respond flexibly and creatively to change
- strengthening quality in the tertiary sector
- investing in the tertiary system and workforce development strategies to meet our skills needs.

## Skills monitoring

Another approach is the monitoring of skills needs. For example, the Department of Employment collects and publishes information about occupational labour markets and skills imbalances. The Department tracks job vacancies through a count of advertisements on major jobseeker websites and through a targeted, phone-based Survey of Employers who have Recently Advertised (SERA). The SERA provides valuable evidence of demand conditions and recruitment difficulties for the particular occupations that it covers (120-150 key skilled trades and professional occupations) and is therefore an essential resource for analysing skills imbalance in Australia and is a key source of information for the Department's *Skill Shortages, Australia* reports.

Both the international literature and *A System for Monitoring Shortages and Surpluses in the Market for Skills* supports the view that the level of difficulty experienced by employers in recruiting skilled workers is indicative of the degree of over or under supply of a particular skill. The Department's SERA provides Australia with a reliable source of data. The key issue is not only how many skilled vacancies there are, but how hard they are to fill (Mavromaras, *et al.* 2013).

## Convergence – cross-disciplinary skills

One of the challenges faced by employers is the ways in which some disciplines are coming together. This makes recruitment an even more challenging task. An example is illustrated in Box 4.3.

While businesses often look for employees based on specific knowledge and skill sets, many of the required skills can be generic. That is, the skills required to perform in a particular role can be possessed by graduates from a range of different disciplines (including both STEM and HASS). By recognising this, and being prepared to recruit new employees from disciplines that may not traditionally be perceived as being aligned to a given job, businesses can bring in new knowledge and ideas that can be applied creatively to problems in innovative ways.

### Box 4.3: Convergence of life sciences, physical sciences and engineering

Life sciences, physical sciences and engineering are taught in our universities as separate disciplines. However since the year 2000 there has been a convergence between these areas that is starting to have important implications for our future STEM workforce, particularly in the field of medicine. The emergence of interdisciplinary research areas such as bioinformatics, computational biology, tissue engineering and systems biology are examples. Researchers from engineering, the physical sciences and life sciences are coming together, using new conceptual approaches to develop diagnostics and therapeutics (MIT 2011).

Convergence can occur in other areas of science and technology. The convergence of telecommunications, data management, and computing technologies brought together through the Internet is an important example of this. Convergence involving the life sciences is leading to new developments in biomedicine, enabling us to start to address disease at the molecular level. It is making possible new drug delivery mechanisms, sensors that detect disease, new possibilities to treat genetic disorders and personalised medicine.

The Australian Synchrotron and the Victorian Life Sciences Computation Initiative's supercomputer in Melbourne facilitate convergence by providing state-of-the-art research tools. However the cross-disciplinary nature of convergence is challenging the historic structure of our universities, with their departments organised by discipline.

There is an opportunity for universities to offer more future-oriented courses which take advantage of this convergence, which will shape the future of Australia's STEM-based industries. For example, so that electrical engineering students can get an introduction to life sciences, and vice versa.

### 4.3.3. Measures to help match supply with demand

#### Australia

In Australia, there exists a government organisation specifically designed to address the issues related to matching workforce supply with demand – the Australian Workforce and Productivity Agency. AWPA's 2013 National Workforce Development Strategy (AWPA 2013d) provides a roadmap to develop Australia as a knowledge intensive economy, supporting productivity growth through cutting-edge innovation. This would be achieved through workforce development, focusing on:

- providing knowledge and skills in tertiary education
- matching tertiary provision to the needs of industry, individuals and society
- using knowledge and skills effectively at work
- further developing knowledge and skills in the workplace.

AWPA forecasts the total demand for 'qualifications held' will increase by between 3 and 3.9 per cent per year on average to 2025, with the strongest growth in higher qualification levels (postgraduate, undergraduate, diplomas and advanced diplomas). To achieve this level of growth, AWPA recommends

an annual expansion in qualification completions of at least 3 per cent per year. This will "require greater participation in tertiary education from less advantaged sectors of the population", and urgent efforts to improve language, literacy and numeracy skills in general to enable the skill deepening and increased participation that the Australian economy will require.

As discussed in Section 4.2.1, this kind of national workforce development strategy will be the key in ensuring that future supply is capable of meeting future demand.

Career choices by students need to be informed by high quality labour market information. Only the government has access to this information and can make it available in a productive way.

AWPA is also investigating the issues facing the manufacturing workforce, with an issues paper published for consultation in October 2013 (AWPA 2013a). This investigation will consider the current makeup of Australia's manufacturing workforce in detail, focusing on the kinds of jobs that currently exist and the skills that these jobs require. It is also considering issues around leadership and management skills within Australia's manufacturing sector. The study will ultimately develop a comprehensive workforce development strategy for the manufacturing sector into the future.

## International

The United Kingdom offers two examples of approaches to measuring and responding to skills imbalances. Firstly, the UK Commission for Employment and Skills (UKCES) is a public authority that collects and disseminates information about the UK labour market to provide advice to policy makers and market participants on skill supply and demand strategies. The Commissioners are drawn from diverse backgrounds. The UKCES conducts an Employer Skills Survey (ESS) to gather data on UK employer skill needs, utilisation and investment. The UK ESS gathers data on vacancies to provide potential measures of skills imbalance. In contrast, the available Australian data do not provide a comparable level of detail on vacancies (Mavromaras, *et al.* 2013).

Secondly, the UK Migration Advisory Committee (MAC) is a non-statutory authority that advises the government on migration issues including monitoring skills needs and recommending skilled occupations that could be given preferential status in immigration decisions. Reviews of the Shortage Occupation List (SOL) found support for using a suite of indicators to assess the evidence about skill shortages and for combining macroeconomic and microeconomic evidence drawn from both national statistics and employer surveys. Reviews of the MAC framework support the approach of monitoring potential shortages at the occupational level (Mavromaras, *et al.* 2013).

Institutional linking mechanisms have been found to have supported strategic state intervention in Singapore, Taiwan and S Korea in the process of skill formation. By ensuring cohesion between decisions made about education and training, with the existing and future demands of the economy. Those governments were able to create conditions under which they could manage the relationship between capital and labour, human resources and sustain growth by moving into higher value-added product markets in selected industries (Ashton, *et al.* 2002).

A study by Keating (2008) found that virtually all countries have some form of government intervention, frequently in conjunction with

industry partners, in their national training or skills development systems. International examples of measures designed to better align the supply of VET training with the demand for skills include the recognition of informal learning, national qualifications frameworks and competency-based approaches. There are three broad types of strategies: state planning and associated interventions; use of the key elements of 'civil society' (i.e. industry and employers) and 'social partners'; and the market. For example, Singapore concentrates on developing high skills. Norway devolves responsibility for VET to regional levels; the German Dual System focuses on intermediate skill development; while England uses a mixed market-based approach with multiple planning agencies (Keating 2008).

The OECD's *Skills for Innovation and Research* report provides some recommendations for policy makers to consider about better matching supply and demand in the labour market. These are outlined in Box 4.4.

## Workplace training

As discussed in Section 4.2.3, effective workplace training is important in building an innovative capable workforce, as well as having a positive correlation with firm performance. It also has an important role to play in meeting the demand for skills and addressing skills shortages.

In-house training is crucial to giving employees the right mix of skills, complementing technical knowledge and skills with business and communication skills, but many SMEs will not have the resources to achieve this. There is space for policy makers to address this issue for SMEs, which could have the potential to significantly lift productivity in poorly performing enterprises.

Initiatives such as the Work Integrated Learning agreement between Universities Australia, the Australian Chamber of Commerce and Industry, the Business Council of Australia, the Australian Industry Group, and the Australian Collaborative Education Network Ltd. provide an important opportunity for higher education providers to work with industry in producing graduates with the appropriate mix of skills and experience for the workplace. A key recommendation of AWPAs

#### Box 4.4: Linking the developmental capacities of tertiary education to labour market demands

Policy issues requiring consideration to link more closely the capacities of tertiary education institutions and labour market demands include:

- Co-ordinating labour market and education policies across government ministries, and integrating policy approaches at a high level, through the cabinet.
- Improving data and analysis on graduates' labour market outcomes, to increase responsiveness to labour market signals.
- Strengthening career services at secondary and tertiary education levels, particularly through the use of quality data on educational alternatives and labour market outcomes.
- Reinforcing the capacity of institutions to respond to labour demand.
- Including labour market perspectives and actors in policy development and institutional governance.
- Encouraging tertiary education institutions to play a greater role in lifelong learning, and design education and training alternatives that are tailored to the needs of employers and industries through partnerships with the business sector, student and teacher internships, liaison offices and employer participation in governance.
- Exploring the potential of a national qualifications framework to co-ordinate the demands and needs of students, employers and institutions, and to facilitate flexibility in students' study trajectories.

Note: adapted from OECD 2011b, *Skills for Innovation and Research*.

2013 National Workforce Development Strategy is the expansion of work-integrated learning initiatives (AWPA 2013d).

#### Flexibility, adaptive capacity

A key factor in making the most of future opportunities will be 'adaptive capacity', that is the ability of people, workplaces and educational institutions to respond flexibly to changing circumstances.

In order to enable this kind of flexibility, the workforce needs to be prepared for life-long learning, both through workplace training and other forms of education. As the labour force and economy evolve over time, people must be able to continuously undertake training and development activities to enable further innovation. However it can be difficult for mature-age people to finance re-training. There is significant market failure in both the formal and informal training sectors. The government has a strong role to play in this area, by facilitating ongoing training using measures such as tax deductions for self-education expenses.

## 4.4. Conclusions

In order to increase productivity growth in both the short and long-term, Australia will need a workforce that is innovation-capable, and technologically literate. This will require strong foundations in both STEM and HASS skills, which will be developed through formal education at all levels and through workplace training.

As Australia's population continues to age, increased levels of workforce participation, particularly from young people and women, will be necessary. This is particularly true of the research and engineering workforce, where women still make up a minority of employees.

Workforce development strategies have an important role to play in meeting the future needs of Australian industry. Workforce forecasting is likely to be much less important than preparing the workforce for life-long learning and reinforcing their adaptive capacity in order to meet changing demands in the future.

The education system and governments have important roles to play in ensuring

the development of an innovation-capable workforce, reinforcing the importance of STEM qualifications, building adaptive capacity and providing high quality information to the workforce to enable better linkages between the education system and the labour market.

## 4.5. Findings

- 4.1 Long-term market demand for STEM skills is difficult to predict – many of today's STEM jobs did not exist a decade ago, as illustrated by the convergence between the life sciences, physical sciences and engineering.
- 4.2 The best way to ensure that supply meets demand is to improve the quality and currency of information available to students when they make career choices and throughout their education. By preparing students for life-long learning, the education system will help to meet evolving workforce needs. Government has an important role to play in this regard.
- 4.3 Productivity improvements driven by innovation rely on a mix of STEM and HASS skills, together with an understanding of innovation systems.
- 4.4 Government, universities and industry organisations should work together to improve entrepreneurship, and business management skills, including the ability to manage innovation.
- 4.5 STEM training needs to encourage entrepreneurship and the development of management skills both at university and VET levels. Education providers need to engage with business to gain a better understanding of trends in STEM skill needs.
- 4.6 Providing work experience for university students as part of their training is a way of increasing the awareness of the benefits of STEM skills on the part of employers. Programs such as Researchers in Business are also valuable in this regard.

# 5

## The contribution of innovation to productivity and economic growth

### Summary

- There is widespread agreement in the literature that research and innovation are major driving forces behind long-term productivity and economic growth.
- Australia's productivity grew during the mid-1990s as a result of the adoption of ICT and microeconomic reform.
- There is a wide dispersion in the aggregate productivity performance of Australia's 'market sectors'.
- OECD work has found that a one per cent increase in business research and development could be expected to generate a long-run increase in productivity of 0.11 per cent and a similar increase in public research would increase productivity by 0.28 per cent.



- Increasing levels of R&D in the medium-term to at least the OECD average would be an appropriate immediate policy objective.
- Research undertaken for this project suggests that direct public sector R&D expenditure by government research agencies, the Australian Research Council and universities has strong spill-over benefits with positive impacts on productivity.

## 5.1. Productivity growth: definition, importance and sources

Productivity growth, simply stated, is the ratio of output growth to input growth; that is, the amount of growth in output that cannot be explained by the growth in measured inputs. Thus labour productivity is based solely on labour inputs (which can be measured by hours worked to produce the outputs). Multifactor productivity (MFP) takes into account the multiple inputs used in production (e.g. labour, capital and land).

In a world defined by a finite endowment of resources, the contribution to economic growth through exploitation of natural resources is limited. Sustained economic growth in the long term has to come from productivity enhancements. Possible sources of productivity growth that have been proposed and examined extensively in the literature are

listed in Box 5.1. Investments in research and innovation are central drivers of productivity. They include information and communications technology, research and development (R&D), skills development, design and organisational improvements and other types of intangible assets. They create more efficient services and production processes, more effective workplace organisation and open up new markets (Hall 2011; Aghion, *et al.* 2009; Gorodnichenko 2010; Yaşar & Morrison-Paul 2012).

Over recent decades, productivity growth has played a key part in the growth of the Australian economy, with a particularly notable and well-documented role during the mid-1990s. This is generally attributed to microeconomic reform and the uptake of ICT. See Kretschmer (2012) and references cited therein.

However, more recently there has been concern in Australia and other developed economies about the apparent slowdown in innovation

### Box 5.1: Sources of productivity growth

1. **Changes in the quality and quantity of labour and other inputs:** examples include human capital (e.g. skills) improvements through education, improvements in physical capital (such as ICT capital) and reliability of energy supply.
2. **Diffusion of ideas:** new knowledge spreads through training and adoption of new equipment that embodies the current “state of the art”.
3. **Technological improvements:** new techniques, inputs and products result from the conscious efforts by scientists, engineers, entrepreneurs, and various other inventors, both formal and informal, to improve the existing state of technology.
4. **Sources of new knowledge:** production of economically valuable new knowledge depends, at least in part, on new scientific knowledge produced in universities and other institutions, both at home and abroad.
5. **Changes in efficiency:** improvements in management and workplace organisation.
6. Changes in the functioning of markets: regulatory change that removes barriers to efficient operation of markets.
7. **Returns to scale:** Large markets:
  - justify the design and set up costs for the large scale production of standardised goods
  - provide an outlet for specialised goods
  - allow “technological convergence,” where firms can produce multiple outputs for diverse consumers using the same machinery.
8. Changes in incentives, due to changes in:
  - the regulatory environment
  - taxes
  - trade opportunities.

Adapted from: Rosenberg 1963; Rosenberg 1981; Schmookler 1966; Griliches 1998; Diewert 2001; Isaksson 2007; Wong, *et al.* 2007; Hall & Rosenberg 2010; Soames, *et al.* 2011; Syverson 2011.

and productivity growth (see Parham (2012) and Connolly & Gustafsson (2013) for Australia, and Gordon (2012) and Phelps (2013) for the USA). To illustrate the source of this concern, Figure 5.1 shows labour productivity for OECD countries, along with an OECD average, for two periods: 1995-2004 and 2005-12.

An analysis of Australian labour productivity shows that there has been a slowdown in all sectors except construction.

Real Gross Domestic Product (GDP) as a ratio to hours worked is a rough but standard measure of labour productivity growth. By using hours worked as the labour measure, there is no adjustment for variations in work intensity or changes in the composition of the labour force due to education and training. Such adjustments to labour input may be of interest for productivity analysis, but require additional assumptions and require more data, posing problems for the international comparability of results.

To get a better understanding of the productivity performance of Australia, it is useful to refer to the detailed Estimates of Industry Multifactor Productivity produced by the Australian Bureau of Statistics (ABS). These take into account additional inputs, in particular, capital and land, and adjust labour for compositional changes

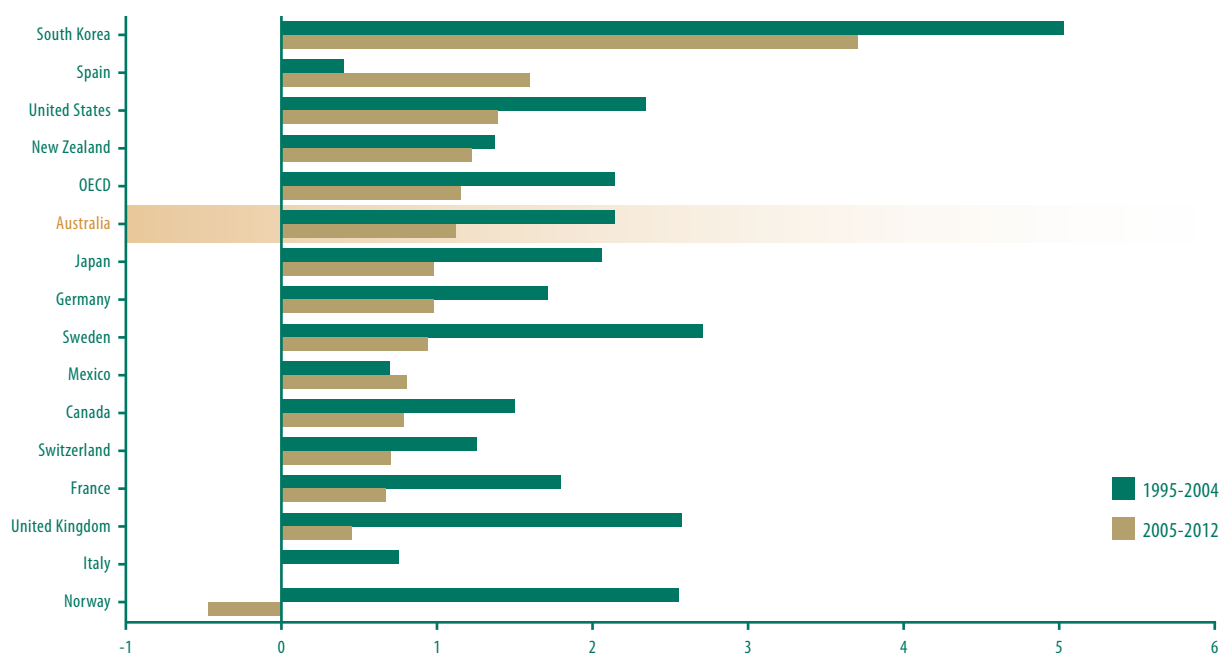
(see: ABS 2007; ABS 2013e). These accounts report annual results for sixteen “market” (i.e. non-government) sectors of the economy. In this Chapter the focus is on the original twelve industries (ABS 2007) for which the longest time series is available.

From the multifactor productivity statistics from the ABS for these industries over the period 2003-04 to 2012-13, the overall level of market sector multifactor productivity declined by around 5 per cent. Given the importance of both labour and multifactor productivity in determining living standards in the long-run, such periods of declining productivity are of significant public policy concern.

To provide further insight, Figure 5.2 shows the cumulative multifactor productivity performance for each of twelve core market sectors, as well as for the aggregate of these market sectors, which we call ‘Market sector 12’, over the period 1989-90 to 2012-13.

The base for the index series for each sector is set equal to one in 1989-90, with the values for the following years indicating the growth that has occurred between 1989-90 and each subsequent year. Although market sector productivity grew by 16 per cent over this period, there have been significantly different experiences over time

Figure 5.1: Labour productivity growth, real GDP per hour worked, annual average



Source: Lowe 2014, based on IMF, OECD and RBA data, 1995-2004 period estimated based on 28 out of 34 countries.

Percentage

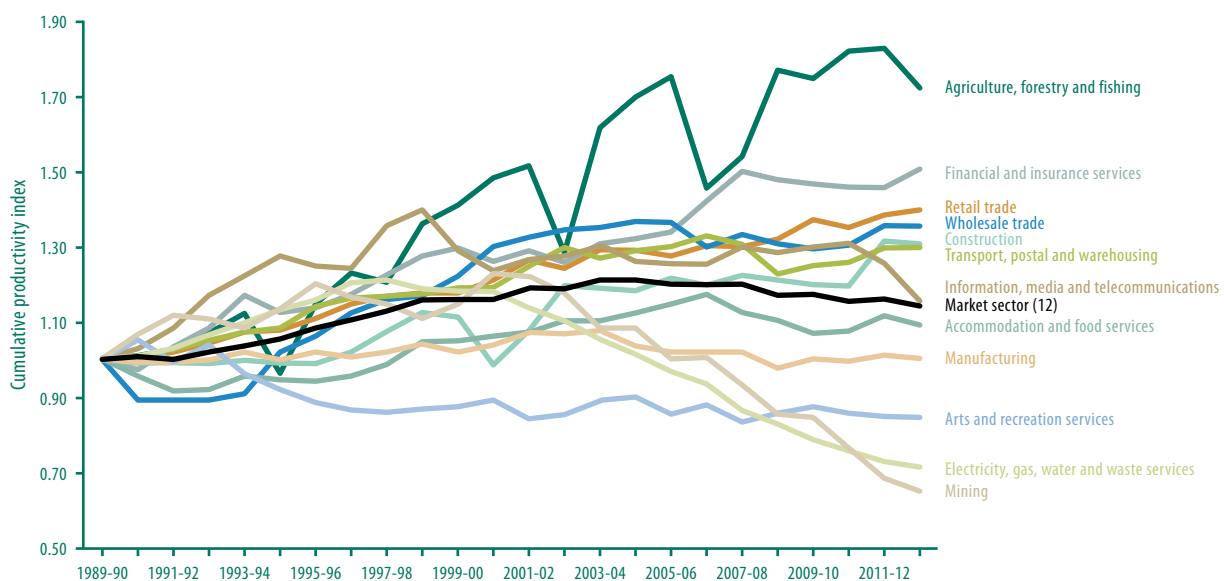
and across industries. Mining is 35 per cent less productive in 2012-13 than in 1989-90, while Agriculture, Forestry and Fishing is 72 per cent more productive, with most of the productivity gains coming before 2004-05. Given the pattern of productivity growth before and after 2004-05, the slowdown in the latter sector, which is also seen in labour productivity, cannot be entirely explained by adverse weather effects.

Much of this dispersion in productivity performance can be explained. For example, the Mining industry has made long-term investments in infrastructure which take years to complete and will take more time before they result in higher levels of output (Productivity Commission 2009). The Electricity, Gas, Water and Waste Services industry also experienced a significant decline in productivity over the period (28 per cent) which can be partially explained by the electricity sector making catch-up investments in infrastructure following privatisation, without corresponding increases in outputs. Some commentators have suggested that this was “gold plating” on the part of the networks. Such investments do not immediately result in increased production and therefore have a downward impact on annual productivity figures.

As might be expected from these examples of extensive capital investment without any corresponding increase in output, labour productivity growth (on an hours worked basis) generally paint a more positive picture, with 76 per cent growth over the same period for the ‘Market Sector 12’. However labour productivity in Mining has fallen by almost 100 per cent since the peak in 2001-02, reflecting the large increase in employment in this sector without, as yet, a corresponding increase in output.

Other factors may have also contributed to the mixed productivity performance over time and over sectors. Reducing trade barriers, increasing competition and privatising large public sector organisations may have had greater significant productivity impacts on some sectors than others. In addition, improvements in public infrastructure, changes in public support for R&D, unmeasured quality changes in outputs, workplace relations, new regulation and legislation, and even a possible slide in Australia’s take-up of productivity-enhancing technologies could all have had differential effects on sectors. Boxes 5.2 and 5.3 provide summaries of two recent studies that assessed some explanations of the recent productivity performance.

Figure 5.2: Market sector cumulative multifactor productivity indexes



Note: These official “Multifactor” productivity statistics, while including more than just labour input, do not include all inputs to production. For Agriculture, Forestry and Fishing, omitted inputs such as water and sunshine are particularly important. Hence, adverse weather conditions, such as drought, can affect measured productivity growth, as can be seen from the downward spikes of the index series in this Figure. As the Productivity Commission (2014, p. 19) states: “Persistent and widespread drought conditions were the main cause of negative MFP growth [in agriculture] between 2003-04 and 2007-08.”

Source: ABS 2013g, Table 1: Gross value added based multifactor productivity indexes, quality adjusted hours worked basis.

### Box 5.2: Connolly & Gustafsson 2013, Australian Productivity Growth: Trends and Determinants

1. **Technology Adoption** – there may have been a level shift in productivity from information technology investment in the 1990s that may have largely passed by the mid-2000s.
2. **Innovation and Human Capital** – R&D expenditure has tended to increase relative to the economy over the past decades, as has patent applications by Australian residents relative to the population. It thus seems unlikely that variations in R&D would explain the productivity slowdown. Labour quality in the market sector has been increasing at the same rate in the 2000s as in the 1990s, so changes in labour quality do not explain the productivity slowdown.
3. **Regulatory Reform** – The economic reforms of the 1980s and 1990s are thought to have boosted productivity growth. The Productivity Commission has estimated that further reforms to address regulatory impediments to productivity could raise GDP by up to 2 per cent in the long run (Productivity Commission 2006; Hilmer 2013).
4. **Infrastructure and Capacity Utilisation** – During the mid-2000s, evidence began to emerge of infrastructure bottlenecks, particularly in the mining and transport industries, as these industries sought to increase production in response to rising commodity prices. More recently, investment in infrastructure has picked up, helping to alleviate infrastructure capacity constraints.

Connolly and Gustafsson conclude:

The current labour intensive mining investment phase is beginning to wind down and is expected to be followed over the period ahead by a substantial pick-up in mining output, which should boost measured productivity in the mining industry and the economy more generally. Looking ahead, there is reason to believe that productivity growth will return to being the main driver of improved living standards.

### Box 5.3: Parham 2012, Australia's Productivity Growth Slump: Signs of Crisis, Adjustment or Both?

Considered in detail, and by sector, each of what he describes as “the usual suspects”, as follows:

1. **Volatility and cyclical effects** – productivity can decline when there is a temporary downturn in the production of outputs or if there is a build-up of capital due to ‘lumpy’ investment cycles.
2. **Compositional shifts** – to the extent that productivity levels differ across industries (and firms), shifts in the relative size of industries (and firms) toward those with relatively low measured productivity would reduce aggregate productivity.
3. **Adjustment pressures** – some change in the economic environment induces responses among producers that require a period of investment in new capital (physical, intangible and human) and this leads to greater use of inputs in the adjustment period, without a matching output response.
4. **Measurement error** – some ‘true’ growth in output (such as through quality improvements) can remain unrecorded.

Parham finds that a combination of these factors may explain the productivity slump, with their potential relevance varying across the market sectors.

The key point is that, to the extent that such explanations are at work, a drop in measured productivity growth does not represent a prosperity-sapping misallocation of resources or loss of knowledge or efficiency.

With such potentially diverse contributing factors, there are obvious complexities in disentangling the influences on productivity at this level. This in turn impedes an analysis of the fundamental drivers of productivity. A better understanding of the transmission of public policy and innovation through to measured productivity growth is thus important for informing effective innovation policy.

#### The role of innovation

While there are many possible influences on productivity, the literature shows that innovation is recognised as being the key to increasing productivity in the economy. Productivity has been shown to be positively correlated to innovation performance. Significant work in this regard includes Hall (2011), Crepon, *et al.* (1998), Janz, *et al.* (2003), Mairesse & Robin (2010),

Siedschlag, *et al.* 2010, Criscuolo & Haskel (2003) and Loof & Heshmati (2006).

Innovation is defined by the OECD as:

*The implementation of a new or significantly improved product (good or service), or process, a new marketing method or a new organisational method in business practices, workplace organisation or external relations.*

(OECD 2005)

It is important to understand that research and development (R&D) is just one input to innovation. Not all science, research and technology contribute to productivity growth, and not all innovations arise from R&D. Figure 5.3 provides a stylised representation of the system of relationships that govern R&D, innovation and productivity growth.

Innovations contribute to productivity growth either by lowering the cost of production or by improving the quality of goods and services. Some innovations, such as those that lead to improvements in the quality of goods and services, may make only a small contribution to improved productivity. However, some of these lead to improved well-being and quality of life, such as technological improvements in aged care. Increasing the stock of knowledge may, at

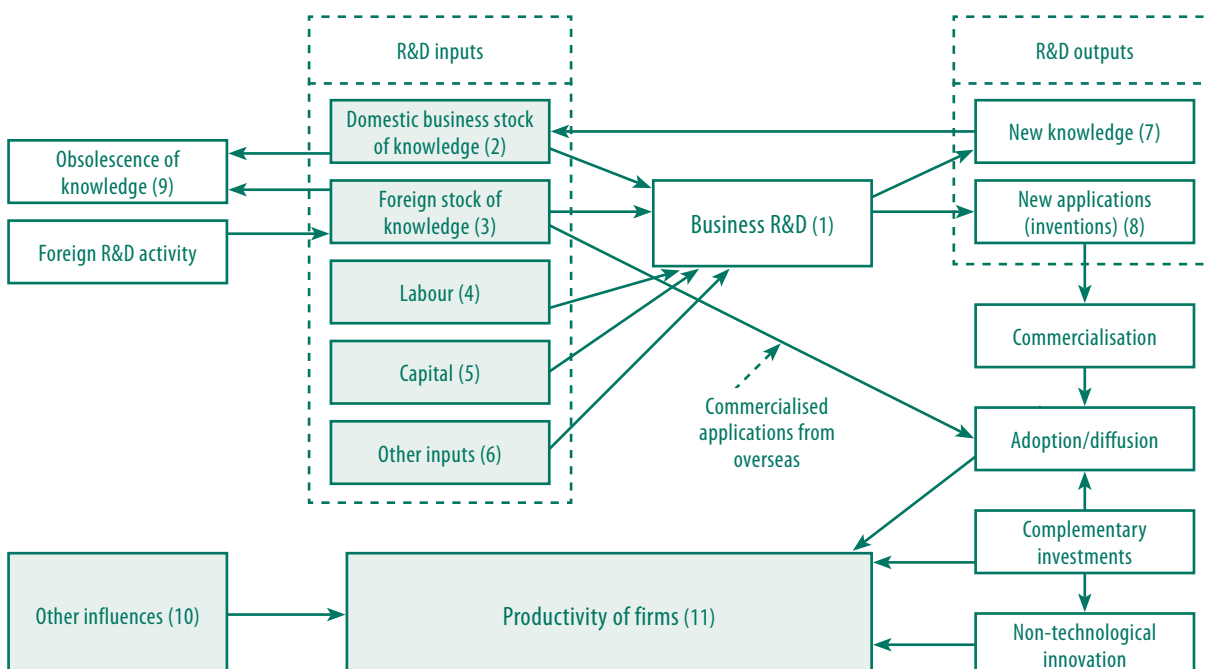
times, make large and unexpected contributions to productivity (e.g. the development of WiFi technology by the CSIRO researchers working in the field of radio-astronomy).

In Figure 5.3, business R&D activity (1) is viewed as a knowledge accumulation process. Inputs of the existing stock of knowledge (2, 3), together with systematic investigation (4, 5, 6), create outputs of new knowledge (7) and new applications (technological inventions) based on the existing stock of knowledge (8). Accumulated R&D expenditure represents the stock of 'effective' knowledge, once allowance is also made for some knowledge becoming obsolete (9).

The diagram serves to illustrate that R&D is not the same as innovation. While R&D is the foundation for technological innovation, there is also non-technological innovation (for example, in management and organisational arrangements). Furthermore, R&D does not necessarily result in new technologies. Even when it does, other investments must be made, for example, in commercialisation, acquisition of technologies, and new skills.

Information and communications technology has been shown to be a major factor in productivity gains experienced towards the end of the 20<sup>th</sup>

Figure 5.3: R&D, innovation and productivity growth



Source: Shanks and Zheng 2006, p. XXIX.

century (Oliner, *et al.* 2007; Connolly & Fox 2006; Kretschmer 2012). These gains have been described as spectacular in ICT-producing industries and more modest in ICT-using industries (Syverson 2011). Australia has only a small ICT-producing industry and most of the productivity gains from ICT are via our use of ICT. For example, Australia's banking sector now operates with fewer tellers and relies extensively on Internet transactions.

However, ICT has had a positive impact on manufacturing productivity. Firms in Australia's manufacturing sector that adopted ICT have secured productivity gains and competitive advantage, e.g. computer-aided design and manufacture (CAD-CAM), and computer numerically controlled (CNC) machining centres.

New technology-based products and product improvements impact on productivity. The mechanisation of the farming sector provides a number of examples such as the use of GPS to guide tractors, which frees up the time of farmers to undertake other farm-related tasks. Some product innovations can have an indirect impact on national productivity, the import of which is not entirely captured by productivity statistics. For example, someone who is implanted with a bionic ear may be able to gain employment where, without this innovation, the person might have been unemployed.

Early adoption of new technology can provide Australian firms with productivity gains that position them ahead of their international competitors. If their competitors survive, they will eventually catch-up. This means that, to stay competitive, firms need to be continuously innovating. Science, research and technology make a critical contribution to such competitiveness.

In addition, from a national priority point of view, it has been argued that Australia has the potential to develop innovative solutions to address national challenges such as climate change, water security, energy security, food security, demographic ageing and population growth, all of which are global challenges (Syverson 2011). An innovative approach to these challenges could create opportunities for Australia to produce and

deliver the goods and services that the world needs, improving Australia's competitiveness and maintaining its prosperity.

## 5.2. Investment in knowledge capital and economic growth

The New Growth Theory literature (for example: Arrow 1962; Romer 1990) has emphasised two points. First, the accumulation of knowledge, innovation or human capital by economic agents (such as firms) is the principal source of technological change (a key source of productivity growth) and hence economic growth. Second, there can be limits to productivity growth from simply adding more capital inputs. However these limits can be extended by the benefits of increases in knowledge stocks that flow between firms and sectors. What this means is that positive externalities and spill-over effects of a knowledge-based economy can reduce the diminishing returns to capital accumulation, and hence lead to economic growth.

In the context of this literature, the existence of knowledge spill-overs is explained by the distinctive characteristics of knowledge: 'non-rivalry' and 'non-excludability'. Knowledge is considered to be a good which is non-rival in nature because it can be made available to a number of users simultaneously without extra costs to the supplier. Unlike a tangible asset, knowledge is not consumed by those who use it. It can be used multiple times, and by multiple users. On the other hand, the non-excludability means that if the knowledge is provided at all, it is available to everyone and its users cannot be denied access to it. The non-rivalry and non-excludability properties of knowledge are the attributes that drive economic growth. Accumulation of more ideas will enable the economy to develop further. Ideas are not subject to diminishing returns; rather, the increasing returns to knowledge boost economic growth.

Economic growth can be considered to have two components: growth of factor inputs (such as capital, labour and land) and growth of productivity. Productivity is a measure of how

efficiently an economy utilises finite resources to produce goods and services. Thus, it is a ratio of output to an input measure. Total output can be increased by either increasing the utilisation of resources or by improving the efficiency with which resources are employed. With contributions through increased utilisation of resources being limited by the finite endowment of resources, sustained economic growth will have to come mainly from productivity increases.

There are several ways to improve productivity (see Box 5.1), but increasing knowledge capital (through new technology, skills, R&D and efficient services and production processes) is a significant factor. New technology enables the same level of output to be produced with fewer inputs. Also, technology diffusion reduces inefficiencies because it enables firms to reach, or come closer, to the efficient production frontier.

The effect of knowledge capital on productivity may work through various channels depending of the source of the knowledge. For example, R&D, a major component of knowledge capital, can be performed either by the business sector, public sector or beyond the borders of a country. Each of these types of R&D performers can be a source of significant domestic technological change. R&D performed by the business sector results in new goods and services, higher quality of output, and new production processes. These are sources of productivity growth at the firm and national levels. Many empirical studies confirm the positive impact of business R&D on productivity (for example: Griliches 1998; Nadiri 1993).

A study using data from 16 countries over nearly two decades analysed the impacts of private and public R&D on productivity (Guillec & van Pottlesberghe de la Potterie 2001). The study found a relationship between increases in R&D and productivity growth. A one per cent increase in business R&D led to a long run increase in productivity of 0.11 per cent. By comparison the increase resulting from a one per cent increase in public research was 0.28 per cent. These are significant increases when compared with the average annual rate of growth of Australian multifactor productivity of around 0.8 per cent over the last decade (DIISR 2009).

Besides their support for business R&D, governments are major R&D performers through government research agencies or through investment in higher education R&D. Research agencies and university R&D are seen to have a strong effect on scientific, basic knowledge and on public missions. Basic research performed by universities enhances the stock of knowledge available for the society (Mowery & Sampat, 2010). It may open new opportunities for business research, which in turn might improve productivity. Nevertheless, there have been few attempts to measure the impact of public R&D on productivity. In a group of studies only some components of public research have been used in empirical frameworks. For example, Adams (1990) examined the contribution of fundamental stocks of knowledge, using accumulated academic scientific papers as a proxy. He found significant contributions to productivity growth in US manufacturing industries.

Knowledge originating from abroad is a third source of new technology for any national economy. Evidence demonstrates many avenues through which knowledge can cross national borders and, depending on the absorptive capacity, it may improve other countries' productivity (Mohnen 2001).

The Australian literature has a limited number of studies that have quantitatively examined Australia's innovation system and its impact. Most of these studies have focused on the link between productivity and R&D, ignoring other types of innovation such as innovation in management and organisational arrangements (Figure 5.3). The R&D measures employed by these studies largely relate to business R&D (for example: Shanks & Zheng 2006; Louca 2003).

There are a small number of cases in which the role of higher education R&D is assessed. One example is a study by Burgio-Ficca (2004) who found evidence of a positive relationship between higher education R&D and gross state product. With the exception of Productivity Commission (2007) there is no study which has explicitly scrutinised the effects of publicly funded R&D. There are a small number of studies which have partially addressed this question

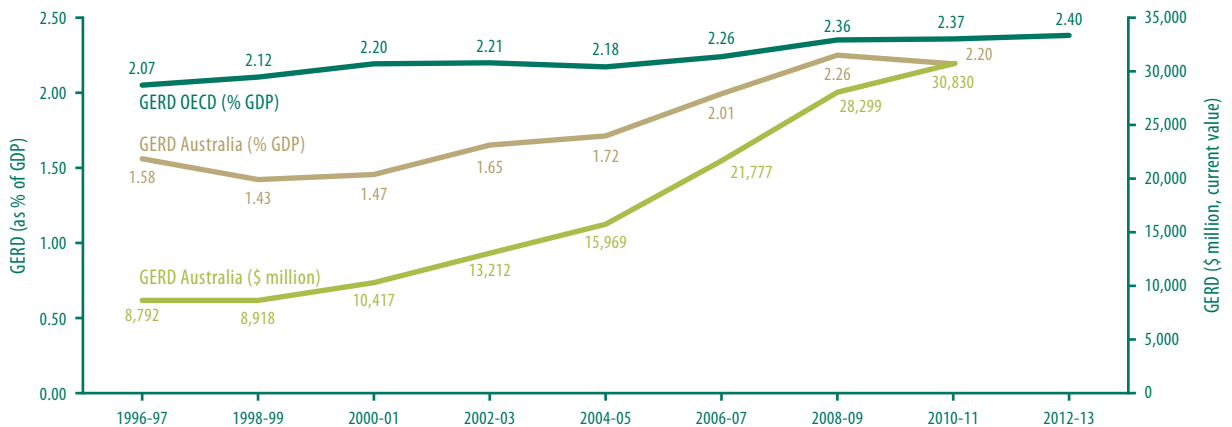
by employing data on the gross expenditure on R&D: Gross Expenditure on R&D (GERD), an aggregate measure of business, government and higher education R&D.

Australia's GERD has been growing in recent years. Our research intensity, GERD as a share of GDP, has also increased and is starting to approach the OECD average (Figure 5.4). At the same time, Australian business expenditure on R&D has also been approaching the OECD average (see Figure 5.5). Increasing levels of R&D in the medium-term to at least the OECD average would be an appropriate policy objective. This would increase productivity although it would still leave Australia well behind leading OECD countries. The objective to try to achieve these OECD averages was proposed by the then Department of Innovation, Industry, Science and Research in a submission to the House Standing Committee on Economics (DIISR 2009) and remains valid today.

However, GERD is an overall measure and does not provide information on such issues as the impact of government investment, or higher education R&D. Because much of Australia's expenditure on R&D is funded from the public sector it is more focused on research than on development. Thomson (2009) uses firm-level data to examine the effectiveness of the R&D tax concession as an effective policy tool, but does not consider other kinds of support for R&D. Although the results suggest significant aggregate economic, social and environmental benefits from publicly supported science and innovation, the Productivity Commission (2007) study stated that the quantitative estimates are statistically unreliable.

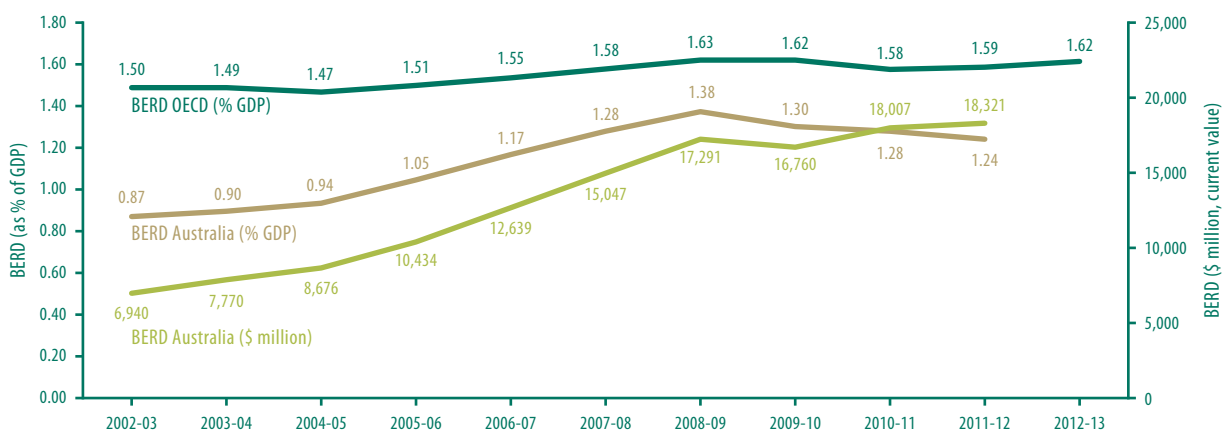
Not only is Australian BERD below the OECD average – it is also well behind the leaders (Figure 5.6).

Figure 5.4: GERD as a proportion of GDP, Australia and OECD average, 1996-97 to 2012-13



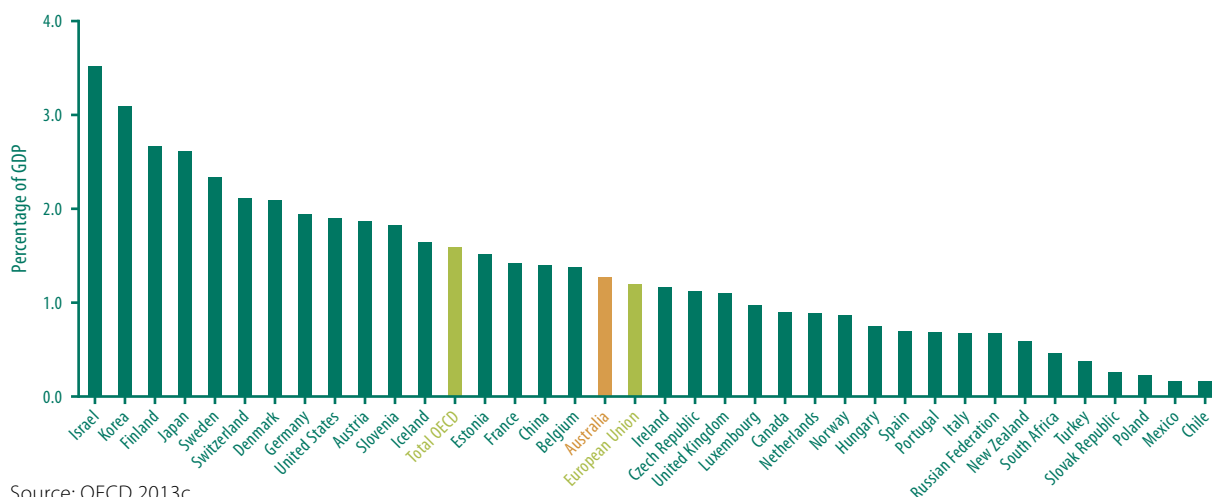
Source: Department of Industry 2014.

Figure 5.5: BERD as a proportion of GDP, Australia and OECD average, 1996-97 to 2012-13



Source: Department of Industry 2014.

Figure 5.6: BERD as a percentage of GDP, 2011



Source: OECD 2013c.

Despite its importance, R&D is not the only source of new technology. Innovation can result from the contribution made by other types of intangible capital, and extends beyond physical capital accumulation. We now consider this broader class of intangibles.

### 5.3. R&D and other intangibles

Research, innovation and intellectual property are examples of intangible assets. The importance of these assets has increased in prominence in recent years (Box 5.4). Accounting for intangible assets can have a significant impact on the assessment of productivity performance – ignoring knowledge capital in productivity analysis can significantly impact on the understanding of productivity and therefore the formulation of productivity-enhancing policy.

Despite this, in many countries R&D and other intangibles are largely ignored in National

Accounts and corporate financial reports. This is largely due to difficulties in understanding and measuring them. The importance of measuring and capitalising intangibles has been highlighted in two recent studies by Corrado, *et al.* (2005; 2006).

Following the recommendations of the System of National Accounts (SNA) 1993, Australia was one of the first countries to capitalise computer software, artistic originals and mineral exploration in 1993, rather than treating them as intermediate inputs. In addition, as part of the revisions to implement the recommendations contained in SNA 2008, Australia started to capitalise scientific R&D from 2009. However, intangible assets are not restricted to these four elements, with firms also investing in other types of intangible assets which may represent a source of economic growth; these investments are still treated in the Australian National Accounts as current expenses.

Elnasri & Fox (2014) have shown that Australian investment in intangibles has increased over

#### Box 5.4: Measuring intangible capital

“A major shift in the composition of investment and capital formation toward intangibles has occurred over the last 60 years. We have argued that this shift is of critical importance for the analysis of growth over this period, and, in particular, for understanding how the recent wave of innovation has shaped the US economy. The message is clear: the innovation that has shaped recent economic growth is not an autonomous event that falls like manna from heaven. Nor is it a result of R&D and ICT investments alone. Instead, a surge of new ideas (technological or otherwise) is linked to output growth through a complex process of investments in technological expertise, product design, market development, and organisational capability. This process affects all sources of growth to one extent or another but is most clearly detected in the growing contribution of intangible capital.”

Source: Corrado & Hulten 2010, How Do You Measure a “Technological Revolution”?

time and reached about \$80 billion in 2012-13, constituting 28 per cent of market sector total investment in that year. With the exception of the last decade or so, total investment in intangibles has grown more rapidly than investment in tangibles (see Annex). Excluding investment in intangibles underestimates total investment, which in turn may misrepresent the measures of output, capital services, factors income shares and consequently productivity.

## 5.4. Public R&D investment and productivity performance

### Public investment in R&D and innovation

In this section, the nature of public support for R&D and innovation is presented, before examining the effectiveness of this support in raising private sector productivity. Research and innovation fulfils public needs, such as improving the products and services offered or better delivery of functions.

Sometimes the productivity gains are captured by innovating firms, but often the benefits of innovation also flow to firms *using* new products or copying the ideas that have been developed by others. This market failure is an important economic rationale for governmental involvement in the area of research and innovation.

Market failure is typically due to the diffusion of knowledge beyond the control of the inventor, which implies that the private rate of return to research and innovation is lower than its social return. Additionally, the high risks involved in innovation discourage firms from engaging in such activities. For both reasons, the amount invested by firms in research activities in a competitive framework is likely to be below the socially optimal level. Thus, there is a potential role for governments to intervene to eliminate this gap between private and social returns.

Another reason for the provision of public support is that governments want to stimulate research and innovation performed by the

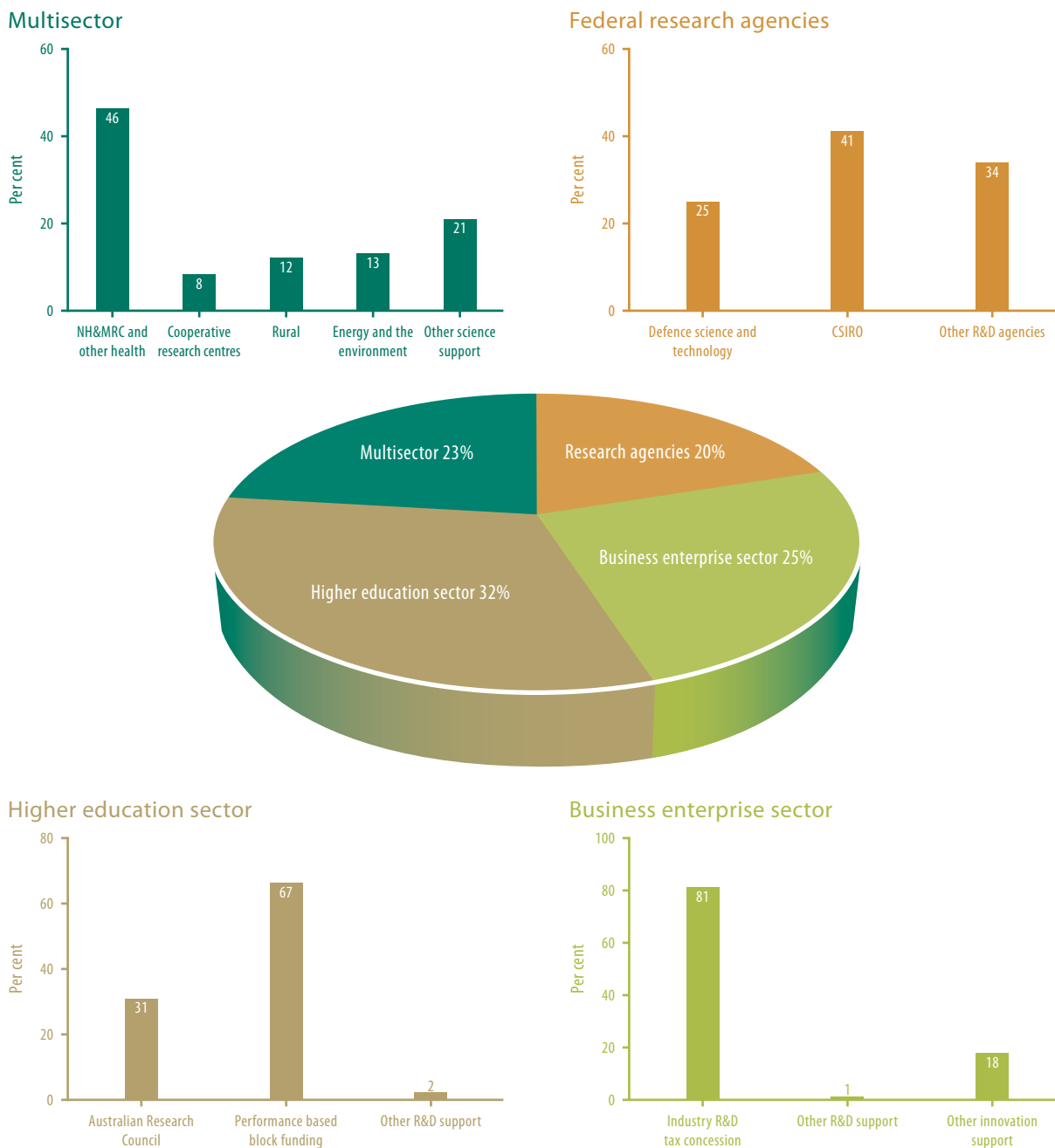
business sector. This is likely to be below the socially optimal level as firms are often discouraged from engaging in research activities by the inherently high risk of research (Arrow 1962). Therefore, governments intervene to assist firms either by mitigating their private costs or by raising awareness of the technological opportunities that are available to reduce both the cost and uncertainty of research and innovation.

Data on public support for R&D and innovation in Australia are available from the Science, Research and Innovation Budget Tables (SRIBTs) and the ABS survey on R&D. The SRIBTs classify government support for research and innovation into four sectors of performance: Commonwealth research agencies, the higher education sector, the business enterprise sector, and a "multisector". The components of "multisector" are shown in Figure 5.7, which presents the distribution of \$8.9 billion of public spending estimated for the year 2012-13. The higher education sector is the recipient of the largest share of science and innovation funding from the Australian Government, receiving around 32 per cent of total public support followed by the business enterprise sector and the multisector, which respectively received 25 per cent and 23 per cent of the total support. The research agencies sector has received the smallest portion of support which is equivalent to 20 per cent of total support.

Figure 5.8 shows the components of support for research and innovation over time. Taking the sum over these components, total support has increased in real terms over the past two decades. However, as Figure 5.9 shows, it has fallen as a share of GDP.

There have been noticeable changes in the role of the government support across its four components of funding. In particular, indirect public support for the business enterprise sector and the multisector has grown in real terms during the past two decades. However, support to higher education and direct support to research agencies has barely grown. This has meant that the share of public support to the multisector has roughly doubled between

Figure 5.7: Australian Government investment on science and innovation 2012-13



Note: The cost to revenue of the industry R&D tax concession is a Treasury estimate.  
Source: Australian Government 2012.

1993-94 and 2012-13 while support to the higher education sector has halved. A number of factors can account for this changing pattern in government investment including, an increased funding for NHMRC in the multisector and increased claims on the R&D Tax Concession in the business enterprise sector.

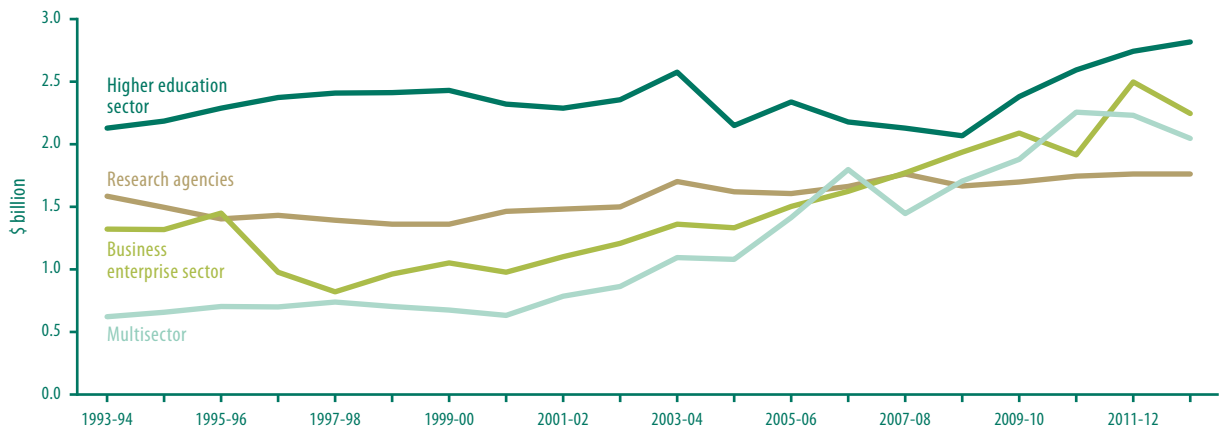
### Productivity performance

This section discusses the relationship between productivity growth and the growth of the publicly funded R&D capital stock. Most of the

literature that has examined the relationship between R&D and economic or productivity growth has avoided the problem of obtaining an estimate of R&D capital stock by employing a measure of R&D intensity (i.e. a ratio of R&D expenditures to the value of production) (see: Griliches 1998; Haskel & Wallis 2013). However, this method implicitly assumes that the depreciation rate of R&D is zero, which is not very realistic.

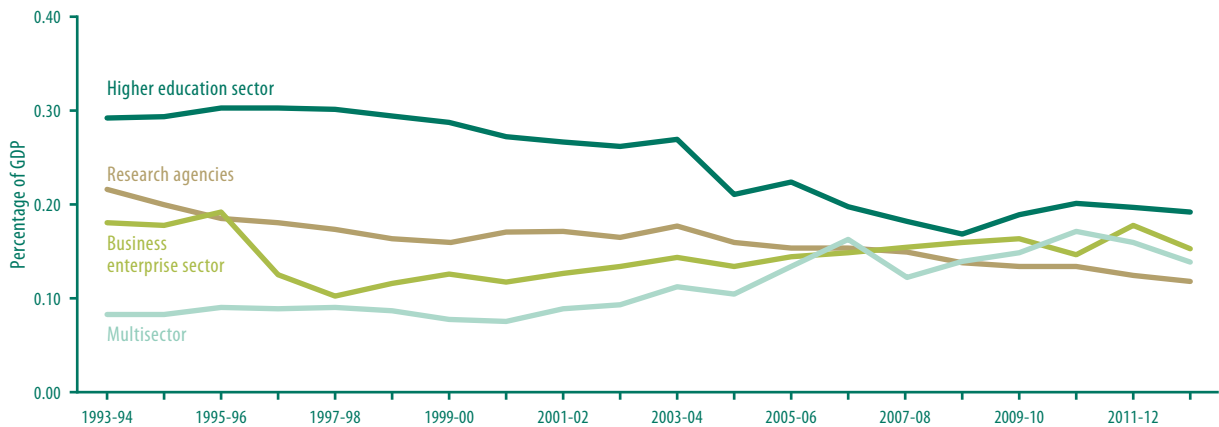
Elnasri & Fox (2014) have used the stock of public sector R&D estimated by using the method of Corrado, *et al.* (2005; 2006) (see the Annex for

Figure 5.8: Australian Government support for research and innovation 1993-94 to 2012-13, 2011-12 \$ billion



Source: The Australian Government's Science, Research and Innovation Budget Tables, 2002-03 to 2012-13.

Figure 5.9: Australian Government support for research and innovation 1993-94 to 2012-13, per cent of GDP



Source: Elnasri & Fox 2014; derived from the Australian Government's Science, Research and Innovation Budget Tables, 2002-03 to 2012-13.

details). They have confirmed that private sector knowledge capital is a source of positive spill-overs to market sector productivity in Australia (i.e. not all the benefits from research, innovation and other intangibles are captured privately). They also find strong evidence of productivity benefits from public spending on research through bodies such as the Australian Research Council and the universities. This finding is supported by international evidence of the positive impacts of universities and research agencies on firm productivity, especially through the development of skilled labour (see Annex for details).

#### Data availability and policy analysis

In the course of undertaking this project some major data challenges have been encountered. With the help of the Australian Bureau of

Statistics it has been possible to undertake some analysis of firm data that, until now, has not been possible. However, it is striking that, while comprehensive multi-purpose databases are available in areas such as education, health and the labour market, equivalent information sources are not readily available to analysts of science, innovation and industry policy. While some data exist, these are not linked and are not easily accessible. While the assistance of ABS on this project is appreciated, it is hoped that in the future, a more liberal interpretation of the ABS legislation could overcome some data access difficulties and enable more extensive analysis.

It is also noted that, unlike many other OECD countries, Australia lacks substantial independent research institutes that conduct studies of innovation, productivity and collaboration.

## 5.5. Conclusions

The chapter confirms that research and innovation are major driving forces behind long-term productivity and economic growth. The chapter analyses these relationships for Australia through a review of Australia's recent productivity performance. It examines the international and domestic literatures and draws on recent empirical research.

## 5.6. Findings

- 5.1 There is strong evidence that research, science and technology contribute positively to productivity.
- 5.2 Measuring research and innovation by focusing only on those assets which are currently capitalised in the System of National Accounts distorts analysis of growth in capital services and consequently, productivity. Different countries have capitalised intangibles to different degrees, making international comparisons difficult.
- 5.3 Private sector knowledge capital is a source of positive benefits (spill-overs) to productivity. This implies that innovative activity has broad benefits that diffuse throughout the economy.
- 5.4 Public sector R&D expenditure by Australian government research agencies, the Australian Research Council and the universities have strong spill-over benefits and are important sources of gains in productivity.
- 5.5 Increasing levels of R&D in the medium-term to at least the OECD average would be an appropriate policy objective.
- 5.6 More comprehensive and better-linked databases are needed to inform science, research and innovation policy analysis in Australia. There is also a case for the establishment of sustained, independent research effort in this area.



# Annex

## Intangibles and the productivity decline

Using US data, Corrado, Hulten and Sichel (2005; 2006) (referred to here as CHS) developed a methodology to capitalise a broad range of intangibles and, by applying a growth accounting framework, demonstrated how the conventional growth rates of inputs, output and productivity measures changed as a consequence. Table A.1 presents the CHS classification of intangible assets, and the corresponding summary statistics for estimates for Australia from Elnasri & Fox (2014).

Following CHS, researchers in a number of other advanced countries (e.g., United Kingdom, Japan, Netherlands, Canada and Australia) have conducted similar studies, and found results similar to those of CHS. While the CHS approach is becoming more widely accepted, there are alternatives to capitalising intangibles (see Griliches 1981; Webster & Jensen 2006; Diewert & Huang 2011).

**Table A.1: Estimates of nominal intangible investment in the Australian market sector**

CATEGORIES	1974-75	1984-85	1994-95	2004-05	2012-13
	millions of dollars				
Computerised information	26	627	3,512	7,262	9,948
Innovative Property	917	3,857	9,342	19,414	38,264
Scientific R&D; Social sciences R&D (Business R&D)	199	614	2,782	7,010	14,483
Mineral exploration	203	1,271	1,567	2,074	7,849
Copyright and licence costs (Artistic originals)	35	172	256	1,045	2,450
Other product development, design and research	480	1,800	4,737	9,286	13,841
New product development in financial industry	342	1,310	3,133	5,311	8,338
New architectural and engineering designs	137	490	1,604	3,975	5,504
Economic competencies	1,259	492	11,276	23,374	33,428
Brand equity	653	2,830	4,679	8,365	10,362
Advertising	648	2,774	4,420	7,391	9,463
Market research	5	56	260	974	899
Firm-specific human capital	301	1,024	2,669	3,870	5,791
Organisational capital	306	1,073	3,927	11,138	17,276
Purchased	21	232	1,944	7,058	9,143
Own account	284	840	1,983	4,081	8,133
<b>Total intangibles investment</b>	<b>2,202</b>	<b>9,410</b>	<b>24,130</b>	<b>50,050</b>	<b>82,000</b>
New intangibles	1,739	6,726	16,013	32,659	47,270
National Accounts intangibles	463	2,684	8,118	17,391	34,730
Tangibles	9,251	32,333	54,984	106,195	227,751
<b>Total Investment</b>	<b>11,453</b>	<b>41,743</b>	<b>79,114</b>	<b>156,245</b>	<b>309,751</b>

Source: Elnasri & Fox 2014.

For Australia, Elnasri & Fox (2014) have extended the work of Barnes & McClure (2009) and de Rassenfosse (2012) in applying the methodology of CHS to measure and classify a range of ‘new’ intangibles. However, as Barnes and McClure have noted:

*“Given the experimental nature of the methodology, the assumptions required, measurement challenges and data limitations, the estimates should be interpreted as only indicative”*

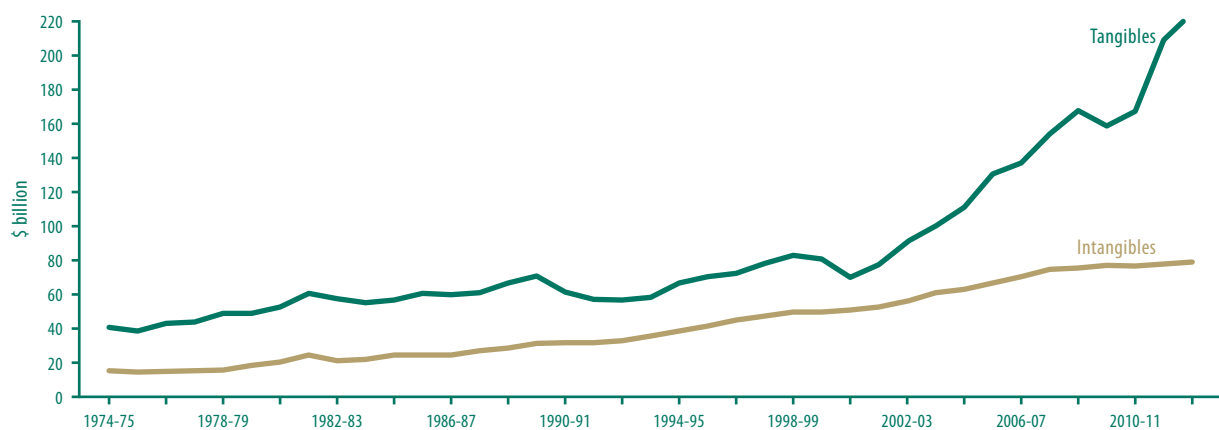
(Barnes and McClure 2009, p. XIII)

Elnasri & Fox (2014) show that investment in intangibles has increased over time and reached about \$80 billion in 2012-13, constituting 28 per cent of market sector total investment in that year. With the exception of the last decade or so, total investment in intangibles grew more rapidly than investment in tangibles (Figure A.1).

The ratio of intangibles to tangibles grew to 0.53 in 2004-05. However, it subsequently decreased, falling to 0.38 by 2012-13. Only computer software, artistic originals, mineral exploration and R&D have been capitalised in the Australian System of National Accounts, and these constitute less than half of total intangible investment. In 2012-13, National Accounts intangibles accounted for 41 per cent of total intangible investment while the new intangibles accounted for 59 per cent.

Table A.1 and Figure A.2 show that the composition of the intangible investment has changed considerably over the last three and a half decades. For the first four years presented in Table A.1, the group labelled ‘economic competencies’ is the largest component of intangible investment with an average share of 51 per cent. The second largest component was innovative property with an average share of 40 per cent.

**Figure A.1: Market sector real tangible and intangible investment, 2011-12 dollars, chain volume measures, \$ billion**



Source: Elnasri and Fox 2014.

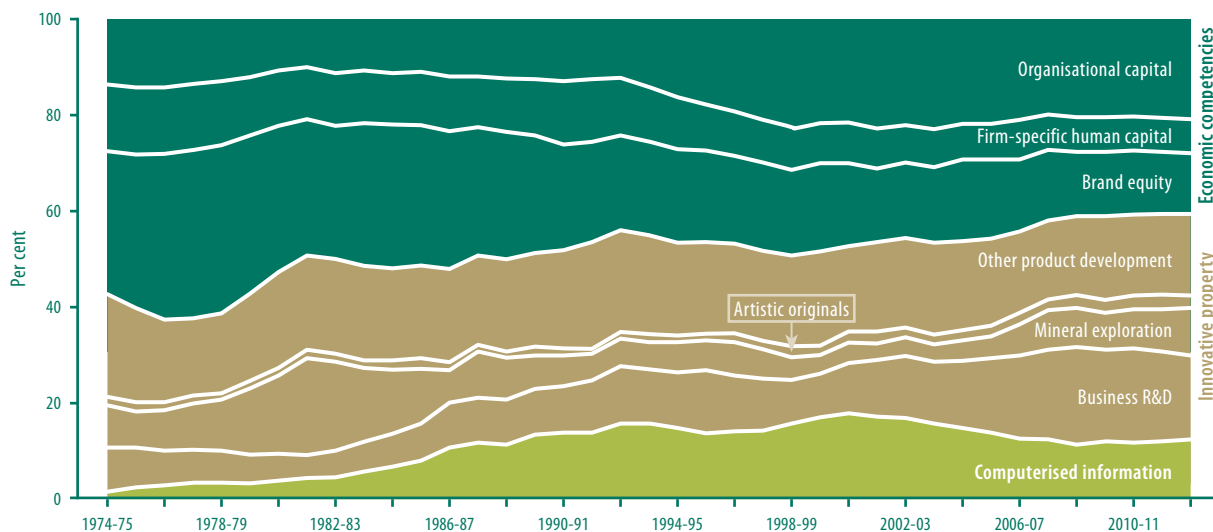
However, by 2012-13, these two categories of intangibles had reversed their contribution ranking; economic competencies decreased to 41 per cent while the share of innovative property increased to 47 per cent. Investment in computerised information has dramatically increased over time, although remaining the smallest component of intangibles. Figure A.2 illustrates the extent of the shift towards investment in computerised information and organisational capital over time. The share of organisational capital has increased, while that of economic competencies as a group has decreased, influenced by the decrease in brand equity and firm specific human capital. The share of innovative property decreased slightly; however, it started to recover by the end of the period as the involvement of firms in business

R&D has increased noticeably in recent years.

Elnasri & Fox (2014) have used the CHS methodology to capitalise the new, broader class of intangibles, and compare the impact on multifactor productivity (MFP) growth for the market sector from different treatments of intangibles investment. Figure A.3 shows that capitalising expenditure on intangibles changes the rate of MFP growth. In particular, it indicates that MFP growth decreases as more knowledge, innovation and other intangible assets are accounted for.

This can be explained by the fact that the inclusion of intangibles has raised output growth by a lower rate than it has raised the growth in inputs. Although, the rate of MFP growth has decreased across the period, the pattern of the growth

Figure A.2: Shares of nominal total intangible investment, by asset type – per cent



Source: Elnasri and Fox 2014.

Figure A.3: Multifactor productivity, market sector, 1974-75 to 2012-13, Index 1974-75 = 100



Source: Elnasri and Fox 2014.

remains unchanged. Specifically, the improvement in productivity during the productivity growth cycle of 1998-99 to 2003-04 and the overall decline during the recent productivity growth cycle is still present after capitalising intangibles. Hence, enhanced measurement through capitalising intangibles in this way does not resolve the recent productivity decline.

### R&D investment and productivity

Elnasri & Fox (2014) have built on previous work by Haskel and Wallis (2013) to examine possible relationships between government R&D investment and productivity. Figure A.4 plots Australian multifactor productivity (MFP) growth, smoothed by a three year centred moving average, against the capital stock growth of public support for research agencies, higher education, and business enterprise. Productivity and public support for higher education activities move together throughout the period, which gives the appearance of a strong relationship. Similarly, with the exception of the early years, there is similarity in the movement between productivity and research agencies' activities. Again, this suggests a positive correlation between them.

Conversely, productivity and the public support for the business enterprise sector show quite divergent trends. However, this presupposes a contemporaneous relationship between R&D and productivity. In reality it is more likely that there are lagged effects of R&D expenditure

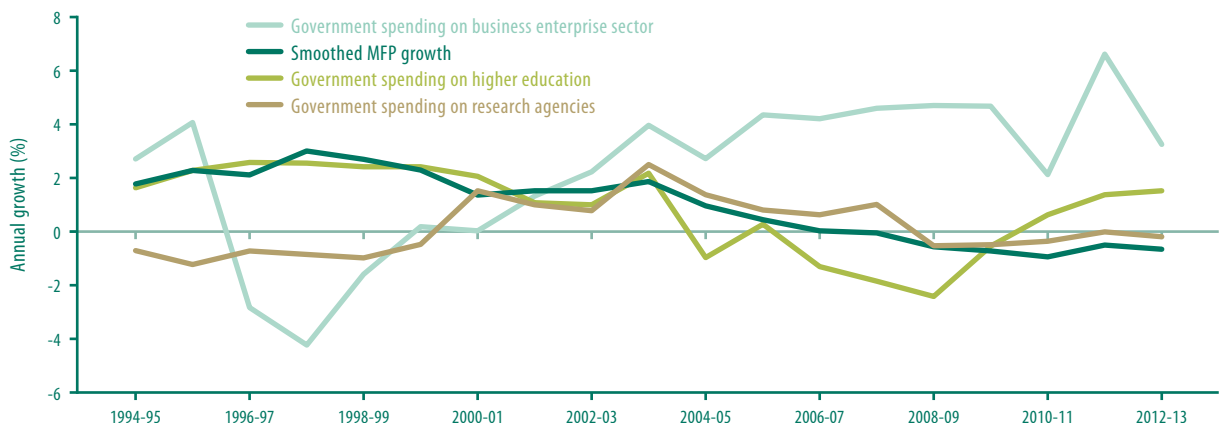
on productivity. This is therefore an overly simplistic analysis. There are also likely to be other influences on productivity that are more significant than R&D expenditure.

Elnasri & Fox (2014) have attempted a more detailed analysis, isolating social returns from private returns while controlling for various factors that can affect Australia's productivity performance, such as the provision of public infrastructure, the business cycle, trade openness and the terms of trade. Although this work has been restricted by data availability, they have presented results from alternative models, and conducted numerous robustness checks. The sample size is similar to that used in the related study of Haskel & Wallis (2013) for the UK. Essentially, Elnasri and Fox confirm the relationships found by Haskel and Wallis. The conclusions from this analysis can be summarised as follows.

There is evidence that private sector knowledge capital is a source of positive spill-overs to market sector productivity. That is, not all benefits of research, innovation and other intangibles are captured privately, but there are "social" benefits which diffuse throughout the market sector.

There is strong evidence of productivity benefits from public spending by Commonwealth agencies such as the Australian Research Council and by the universities. However, the analysis does not show evidence of social returns in excess of private returns from public support

**Figure A.4: Market sector MFP growth and public support for research agencies, higher education and business sector**



Source: ABS 2013g, Table 1 Gross value added based multifactor productivity indexes, quality adjusted hours worked basis; the Australian Government's Science, Research and Innovation Budget Tables, 2002-03 to 2012-13.

to the business enterprise sector, multisector or defence R&D. Some reasons for this can be postulated.

Health research funding makes up almost 50 per cent of the public expenditure on the multisector in 2012-13; see Figure 5.7. Its output is not part of market sector value added, and any productivity effects are likely to be very long-run, through improvements in the health of the workforce and population more generally; hence there is a bias against finding a positive significant result.

Similarly, it is expected that while some select components of the expenditure on defence may result in innovations with commercial value that appear in the market sector, defence services will not, again biasing the results against finding a positive relationship.

The main public support for the business enterprise sector research and innovation is the industry R&D Tax Concession, comprising a large percentage of R&D support to the sector in 2012-13; see Figure 5.7. There are strong financial incentives for firms to maximise the expenditures classified as being related to R&D, potentially biasing the results. In addition, there may be other policy goals of the R&D Tax Concession than raising productivity. Indeed, providing incentives for the establishment of small innovative firms may actually lower productivity of the sector, as new entrants often initially have lower productivity compared with established

firms (Baldwin 1995; Aw, *et al.* 2001). A start-up firm may spend several years developing a product to the point that it is ready for the market. In this period, it is spending on R&D without any matching production.

On the other hand, universities and research agencies are important sources of knowledge and technology creation and, ultimately, diffusion. While the above analysis has focused on the aggregate market sector, there is substantial international evidence of the positive impacts of universities and research agencies on firm productivity, through the development of skilled labour and positive externalities (Malecki 1997; Medda, *et al.* 2005). Adams (2002) found evidence of academic spill-overs from US R&D laboratories that induce clustering of firms with universities and research agencies, while Anselin *et al.* (1997) and Woodward *et al.* (2006) found that R&D-intensive production tends to be located close to universities. Jaffe (1989) found that patented inventions at the state level in the USA depend significantly on university research.

Such evidence is not restricted to the USA. For example, Yaşar, *et al.* (2012) found more patent activity in Chinese firms with university and research institution connections. In addition, they found that linkage with research institutions in particular raised firm productivity. The introduction of new products, processes, and new businesses was also positively associated with linkages with research institutions.



# References

- ABF 2011, *Manufacturing futures*, paper by the Australian Business Foundation for the NSW Business Chamber, Australian Business Foundation, Sydney.
- ABS 2007, *Information paper: Experimental Estimates of Industry Multifactor Productivity*, cat. no. 5260.0.55.001, Australian Bureau of Statistics.
- ABS 2011a, *Research and Experimental Development, Businesses, Australia, 2011-12*, cat. no. 8104.0, Australian Bureau of Statistics.
- ABS 2011b, *Innovation in Australian Business, 2009-10*, cat. no. 8167.0 customised output, Australian Bureau of Statistics.
- ABS 2012a, *Year Book Australia 2012*, cat. no. 1301.0, Australian Bureau of Statistics.
- ABS 2012b, *Innovation in Australian Business, 2008-09*, cat. no. 8158.0, Australian Bureau of Statistics, DIISRTE special data request.
- ABS 2012c, *Research and Experimental Development, Higher Education Organisations, Australia, 2010*, cat. no. 8111.0, Australian Bureau of Statistics.
- ABS 2013a, *Australian System of National Accounts, 2012-13*, cat. no. 5206.0, Australian Bureau of Statistics.
- ABS 2013b, *Labour Force Australia, detailed, quarterly*, cat. no. 6291.0.55.003, Australian Bureau of Statistics.
- ABS 2013c, *Counts of Australian businesses*, cat. no. 8165, Australian Bureau of Statistics.
- ABS 2013d, *Australian industry 2011-12*, cat. no. 8155, Australian Bureau of Statistics.
- ABS 2013e, *Research and Experimental Development, Businesses, Australia, 2011-12*, cat. no. 8104.0, Australian Bureau of Statistics.
- ABS 2013f, *Research and Experimental Development, Government and Private Non-Profit Organisations, Australia, 2011-12*, cat. no. 8109.0, Australian Bureau of Statistics.
- ABS 2013g, *Estimates of Industry Multifactor Productivity*, cat. no. 5260.0.55.002, Australian Bureau of Statistics.
- ABS 2014, *Perspectives on Education and Training: Australians with qualifications in science, technology, engineering and mathematics (STEM), 2010-11*, cat. no. 4250.0.55.005, Australian Bureau of Statistics.
- ACIP 2012, *Collaborations between the Public and Private Sectors: The Role of Intellectual Property, Final Report*, Advisory Council on Intellectual Property (ACIP), Canberra.
- ACMA 2013, *Communications report 2012-13*, Australian Communications and Media Authority, Australian Government.
- ACOLA 2013, *STEM: Country Comparisons*, Australian Council of Learned Academies.
- Adams, J 1990, 'Fundamental stocks of knowledge and productivity growth', *Journal of Political Economy*, vol. 98, no. 4, pp. 673-702.
- Adams, JD 2002, 'Comparative localization of academic and industrial spillovers', *Journal of Economic Geography*, vol. 2, pp. 253-278.
- Aghion, P, Blundell, R, Griffith, R, Howitt, P, and Prantl, S 2009, 'The effects of entry on incumbent innovation and productivity', *Review of Economics and Statistics*, vol. 91, no. 1, pp. 20-32.
- AiGroup 2010, *Innovation: New thinking, new directions*, A report to the Australian Industry Group by the Innovation Review Steering Committee, Australian Industry Group.
- AiGroup 2013a, *Submission: Manufacturing workforce issues paper to the Australian Workforce and Productivity Agency*, Australian Industry Group.
- AiGroup 2013b, *Lifting our Science, Technology, Engineering and Mathematics (STEM) Skills*, Australian Industry Group.
- All Taskforce on Science Technology Innovation 2013, *Science Technology Innovation: Australia and India*, Australia India Institute Task Force Report, Australia India Institute & The Australian Academy of Technological Sciences and Engineering.
- Akamai 2013, *The state of the Internet: 3rd Quarter, 2013 Report*, vol. 6, no. 3, Akamai Technologies Inc.
- Allen Consulting Group 2012a, *The economic, social and environmental impacts of the Cooperative Research Centres Program*. Final report to the Department of Industry, Innovation, Science, Research and Tertiary Education, Allen Consulting Group, Canberra.
- Allen Consulting Group 2012b, *Interim Assessment of the Small Technologies Industry Uptake Program (STI-UP)* report to the Victorian Department of Business and Innovation, Allen Consulting Group, Canberra.
- Anselin, L, Varga, A and Acs, Z 1997, 'Local geographic spillovers between university research and high technology innovations', *Journal of Urban Economics*, vol. 42, pp. 422-448.
- Arnold, E 2005, *Making Technological Knowledge Work: A study of Absorptive Capacity of Irish SMEs*, Technopolis report for Forfás, Ireland.
- Arrow, K 1962, 'The economic implications of learning by doing', *The Review of Economic Studies*, vol. 29, pp. 155-173.
- Ashton, D, Green, F, Sung, J and James, D 2002, 'The Evolution of Education and Training Strategies in Singapore, Taiwan and S Korea: A development model of skill formation', *Journal of Education and Work*, vol. 15, no. 1, pp. 5-30.

- ASIC 2012, *12-196MR ASIC guidance on crowd funding*, media release, Australian Securities & Investments Commission, 14 August.
- Aston Business School 2013, *Servitization impact study: How UK based manufacturing organisations are transforming themselves to compete through advanced services*, Aston University, Birmingham.
- A.T. Kearney 2013, *The 2013 A.T. Kearney Foreign Direct Investment Confidence Index. Back to Business: Optimism Amid Uncertainty*, A.T. Kearney Inc.
- Atkin, T and Connolly, E 2013, *Australian Exports: Global Demand and the High Exchange Rate*, Reserve Bank of Australia.
- ATSE 2011, *Strengthening Links Between Industry and Public Sector Research Organisations*, Workshop Report, Australian Academy of Technological Sciences and Engineering.
- ATSE 2013a, 'Dreamliner is real collaboration', *Focus*, no. 180, p. 8, Australian Academy of Technological Sciences and Engineering.
- ATSE 2013b, *Rethinking linkages: translating research into economic benefits for Australia*, Position Paper, Australian Academy of Technological Sciences and Engineering.
- Australian Government 2010, *Australia to 2050: future challenges*, Commonwealth of Australia.
- Australian Government 2012, *2012-13 Science, Research and Innovation Budget Tables*, Commonwealth of Australia.
- Australian Government 2013, *2013-14 Science, Research and Innovation Budget Tables*, Commonwealth of Australia.
- Australian Growth Partnerships 2012, *Australian Growth Partnerships (AGP) Program*, CSIRO, accessed November 2012, available at <http://www.csiro.au/Portals/Partner/Collaborate/AGP.aspx>.
- Australian Trade Commission 2013a, *Aerospace Manufacturing and Services*, Canberra.
- Australian Trade Commission 2013b, *Fast. Forward. Australia: Growth – Reform and Good Management*, Canberra.
- Autio, E and Thomas, L 2014, 'Innovation Ecosystems', in Dodgson M, Gann, D and Phillips, N, *The Oxford Handbook of Innovation Management*, Oxford University Press, Oxford.
- AVCAL 2013, *2013 Yearbook Australian Private Equity and Venture Capital Activity Report – December 2013*, Australian Private Equity & Venture Capital Association Limited.
- Aw, BY, Chen, X and Roberts, MJ 2001, 'Firm Level Evidence on Productivity and Turnover in Taiwanese Manufacturing', *Journal of Development Economics*, vol. 66, pp. 51-86.
- AWPA 2013a, *Manufacturing workforce issues paper*, Australian Workforce and Productivity Agency, Commonwealth of Australia, Canberra.
- AWPA 2013b, *Human Capital and Productivity: Literature review*, Australian Workforce and Productivity Agency, Commonwealth of Australia, Canberra.
- AWPA 2013c, *ICT workforce study*, Australian Workforce and Productivity Agency, Commonwealth of Australia, Canberra.
- AWPA 2013d, *Future focus: 2013 National Workforce Development Strategy*, Australian Workforce and Productivity Agency, Commonwealth of Australia, Canberra.
- Baldwin, JR 1995, *The Dynamics of Industrial Competition: A North American perspective*, Cambridge University Press, Cambridge.
- Barczak, G, Griffin, A, and Kahn, KB 2009, 'Trends and Drivers of Success in NPD Practices: Results of the 2003 PDMA Best Practices Study', *Journal of Product Innovation Management*, vol. 26, no. 1, pp. 3–23.
- Barlow, T 2011, *US-Australian Research Collaboration Survey*, United States Study Centre, University of Sydney.
- Barnes, P and McClure, A 2009, *Investments in Intangible Assets and Australia's Productivity Growth*, Productivity Commission Staff Working Paper, Productivity Commission, Commonwealth of Australia, Canberra.
- Barson, RJ, Foster, G, Struck, T, Ratchev, S, Pawar, K, Weber, F and Wunram, M 2000, 'Inter- and Intra-Organisational Barriers to Sharing Knowledge in the Extended Supply-Chain', in *e-2000 – Proceedings of the International Conference on e-Business and e-Work*.
- BDC 2013, *BDC Study: Mapping your future growth, Five game-changing consumer trends*, Business Development Bank of Canada.
- Belderbos, R, Carree, M and Lokshin, B 2004, 'Cooperative R&D and firm performance', *Research Policy*, vol. 33, pp. 1477-1492.
- Bell, J 2011, 'New Incentives for public-private sector collaboration', *ATSE Focus*, no. 168, October, p. 4.
- Bertschek, I, Cerquera D, and Klein, G 2011, *More bits – more bucks? Measuring the impact of broadband Internet on firm performance*, ZEW Discussion Papers 11-032, Center for European Economic Research.
- BIAC Committee for Technology and Industry 1996, *Barriers to International Technology Co-operation Involving Enterprises*, Business and Industry Advisory Committee to the OECD.
- BIS 2013, *Technology Strategy Board: Triennial Review*, Department for Business Innovation & Skills, UK.

- BIS 2014, *Science and innovation system: international benchmarking*, Department for Business, Innovation & Skills, UK.
- Bloom, N, Griffith, R and van Reenen, J 2002, 'Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979-1997', *Journal of Public Economics*, vol. 85, no. 1, pp. 1-31.
- Bloom, N, Dorgan, S, Dowdy, J and van Reenen, J 2007, *Management Practice and Productivity: Why They Matter*, Centre for Economic Performance, London School of Economics.
- Bloom, N, and van Reenen, J 2010, 'Why Do Management Practices Differ across Firms and Countries?', *Journal of Economic Perspectives*, vol. 24, no. 1, pp. 203-24.
- Bloom, N, Christos Genakos, C, Sadun, R, and Van Reenen, J 2012, *Management Practices Across Firms and Countries*, Working Paper No. 17850, National Bureau Of Economic Research.
- Boedker, C, Cogan, J, Langford, P, Meagher, K, Mouritsen, J, Runnalls, M, Sheldon, P, Simmons, S, and Vidgen, R 2011, *Leadership, Culture and Management Practices of High Performing Workplaces in Australia: Literature Review and Diagnostic Instruments*, Society for Knowledge Economics.
- Boedker, C, Bogg, P, Chong, KM, Meagher, K, and Mouritsen, J 2013, *Leadership, culture and management practices of high performing workplaces in Australia: Indicative Guidelines through Case Studies of High and Mid performing Workplaces*, Society for Knowledge Economics.
- Bound, K and Puttick, R 2010, *Buying Power? Is the Small Business Research Initiative for Procuring R&D Driving Innovation in the UK?*, National Endowment for Science, Technology and the Arts.
- Breunig, B and Wong, MH 2007, 'The Role of Firm Dynamics in Australia's Productivity Growth', *The Australian Economic Review*, vol. 40, no. 1, pp. 90-6.
- Buchanan, J, Scott, L, Yu, S, Schutz, H, Jakubauskas, M 2010, *Skills Demand and Utilisation: An International Review of Approaches to Measurement and Policy Development*, OECD Local Economic and Employment Development (LEED) Working Papers, OECD Publishing.
- Burgio-Ficca, C 2004, *The impact of higher education research and development on Australian gross state product*, Economics Series 01/2004, School of Accounting, Deakin University.
- Cairney, T 2000, *The Knowledge based Economy: Implications for VET*, Centre for Regional Research & Innovation, University of Western Sydney, and Centre for Research & Learning in Regional Australia, University of Tasmania.
- CAMC 2013, *Crowd sourced equity funding*, Discussion Paper, Corporations and Markets Advisory Committee, Commonwealth of Australia.
- Cassiman, B and Golovko, E 2011, 'Innovation and internationalisation through exports', *Journal of International Business Studies*, vol. 42, pp. 56-75.
- Cattaneo, O, Gereffi, G, Miroudot, S and Taglioni, D 2013, *Joining, Upgrading and Being Competitive in Global Value Chains: A Strategic Framework*, Poverty Reduction and Economic Management Network, International Trade Department, The World Bank.
- Census of Marine Life 2010, *Census of Marine Life*, Office of Marine Programs, University of Rhode Island, Graduate School of Oceanography, accessed September 2013, available at <http://www.coml.org/>.
- Chai, S, and Shih, W 2013, *Fostering Translational Research: Using Public-Private Partnerships to Improve Firm Survival, Employment Growth and Innovative Performance*, Working paper 13-058, Harvard Business School, Boston.
- Chong, S and Poole, E 2013, *Financing Infrastructure: A Spectrum of Country Approaches*, Reserve Bank of Australia.
- CIE 2014, *The economic impacts of mobile broadband on the Australian economy, from 2006 to 2013*, a report by the Centre for International Economics for The Australian Communications and Media Authority.
- Clemes, D, Arifa, A, and Gani, A 2003, 'An empirical investigation of the spillover effects of services and manufacturing sectors In ASEAN countries', *Asia-Pacific Development Journal*, vol. 10, no. 2, pp. 29-40.
- Connolly, E and Fox, KJ 2006, 'The Impact of High-Tech Capital on Productivity: Evidence from Australia', *Economic Inquiry*, vol. 44, no. 1, pp. 50-68.
- Connolly, E and Gustafsson, L 2013, 'Australian Productivity Growth: Trends and Determinants', *Australian Economic Review*, vol. 46, no. 4, pp. 473-482.
- Corrado, C, Hulten, C and Sichel, D 2005, 'Measuring Capital and Technology: An expanded framework', in Corrado, C, Haltiwanger, J and Sichel, D (eds.), *Measuring Capital in the New Economy*, Studies in Income and Wealth Vol. 65, University of Chicago Press.
- Corrado, C, Hulten, C and Sichel, D 2006, *Intangible Capital and Economic Growth*, NBER Working Paper No. 11948, National Bureau of Economic Research.
- Corrado, C and Hulten, C 2010, 'How Do You Measure a "Technological Revolution"?', *American Economic Review Papers & Proceedings*, vol. 100, pp. 99 – 104.
- CRCA 2010, *Small & Medium Size Enterprise Engagement with CRCs*, CRC Association.
- Crepon, B, Duguet E, and Mairesse, J 1998, 'Research, Innovation, and Productivity: An Econometric Analysis at the Firm Level', *Economics of Innovation and New Technology*, vol. 7, pp. 115-156.
- Criscuolo, C, and Haskel, JE 2003, *Innovation and Productivity growth in the UK: Evidence from CIS2 and CIS3*, CeRiBA Working Paper, London School of Economics.
- CSIRO 2012, *What does sustainable manufacturing mean to Australia? A summary of the CSIRO Future Manufacturing Industry Engagement Workshop*, Future Manufacturing Flagship, CSIRO.
- Cutler, T 2008, *Venturous Australia: Building strength in innovation*, Report to the Minister for Innovation, Industry, Science and Research. Cutler & Company Pty Ltd.
- CWL 2014, *Australian Workplace Leadership Poll: February 2014*, Centre for Workplace Leadership.
- Daley, J, Reichl, J & Ginnivan, L 2013, *Education and Innovation Theme, Australian government spending on innovation*, Grattan Institute, Melbourne.
- DBI 2011, *A more competitive manufacturing industry: New directions for industry policy and manufacturing*, Victorian Department of Business and Innovation, Melbourne.

- de Mooij, MK 2010 'Culture and Communication', in *Global Marketing and Advertising: Understanding Cultural Paradoxes*, SAGE Publications.
- DEA 2007, *When Social Science and Humanities Research Generates Profit*, Danish Business Research Academy.
- DEA 2011, *The Social Sciences and the Humanities – use it don't lose it*, Danish Business Research Academy.
- Dean, T 2011, *IXC Australia closes doors*, Australian Life Scientist, 4 July, accessed April 2014, available at <http://lifescientist.com.au/content/biotechnology/news/ixc-australia-closes-doors-1079493972>.
- Dedrick, J and Kraemer, K 2006, *Globalization of innovation: the personal computing industry*. Working paper prepared for the National Academy of Sciences STEP Project.
- Deloitte 2012, *Silicon Beach Building Momentum: A Study of the Australian Start-up Ecosystem*, Deloitte Australia.
- Deloitte 2013a, *Super-growth sectors worth \$250b to build Australia's 'lucky country': Deloitte report*, media release, Deloitte Australia, accessed April 2013, available at [http://www.deloitte.com/view/en\\_au/au/514b317cfb181410VgnVCM3000003456f70aRCRD.htm#](http://www.deloitte.com/view/en_au/au/514b317cfb181410VgnVCM3000003456f70aRCRD.htm#).
- Deloitte 2013b, *Patent Box: Are you inside the box?* Deloitte LLP, London.
- Deloitte Access Economics 2012, *Economic modelling of skills demand and supply*, Australian Workforce and Productivity Agency.
- Department of Education 2014, *uCube – Higher Education Statistics*, Commonwealth of Australia, available at <http://www.highereducationstatistics.deewr.gov.au>.
- Department of Industry 2013, *Australian Innovation System Report 2013*, Commonwealth of Australia.
- Department of Industry 2014, *Australian Key Innovation Indicators*, Department of Industry, Commonwealth of Australia, available at <http://industry.gov.au/Innovation/ReportsandStudies/Pages/AustralianInnovationDataCard.aspx>
- de Rassenfosse, G 2012, *Intangible assets and productivity growth – an update*, Melbourne Institute of Applied Economic and Social Research University of Melbourne, commissioned by the Department of Industry, Innovation, Science, Research and Tertiary Education.
- DEST 2004, *Review of Closer Collaboration Between Universities and Major Publically Funded Research Agencies*, Department of Education, Science and Training, Commonwealth of Australia.
- DFAT 2012, *Trade at a Glance 2012*, Department of Foreign Affairs, Commonwealth of Australia.
- DFAT 2013, *Germany country brief*, Department of Foreign Affairs and Trade, Commonwealth of Australia, accessed January 2014, available at [http://www.dfat.gov.au/geo/germany/germany\\_brief.html](http://www.dfat.gov.au/geo/germany/germany_brief.html).
- Diewert, WE 2001, *Productivity Growth and the Role of Government*, Discussion Paper No. 01-13, Department of Economics, The University of British Columbia, Vancouver.
- Diewert, WE and Huang, N 2011, 'Capitalizing R&D Expenditures', *Macroeconomic Dynamics*, vol. 15, pp. 537-564.
- DIISR 2009, *Innovation and Raising Australia's Productivity Growth*, submission to the House of Representatives Standing Committee on Economics Inquiry into Raising the Level of Productivity Growth in the Australian Economy, Department of Innovation, Industry, Science and Research, Commonwealth of Australia.
- DIISR 2011a, *Evaluation of the International Science Linkages Program*, Department of Innovation, Industry, Science and Research, Commonwealth of Australia.
- DIISR 2011b, *Australian Innovation System Report 2011*, Department of Innovation, Industry, Science and Research, Commonwealth of Australia.
- DIISR 2011c, *Focussing Australia's publically funded research review: Maximising the innovation dividend review key findings and future directions*, Department of Innovation, Industry, Science and Research, Commonwealth of Australia.
- DIISR 2011d, *Research Skills for an Innovative Future*, Department of Innovation, Industry, Science and Research, Commonwealth of Australia.
- DIISRTE 2012a, *Report of the non-Government Members of the Prime Minister's Manufacturing Taskforce: Smarter Manufacturing for a Smarter Australia*, Department of Industry, Innovation, Science, Research and Tertiary Education, Commonwealth of Australia.
- DIISRTE 2012b, *Australian Innovation System Report 2012*, Department of Industry, Innovation, Science, Research and Tertiary Education, Commonwealth of Australia.
- DIISRTE 2013, *Australian Small Business Key Statistics and Analysis*, Department of Industry, Innovation, Science, Research and Tertiary Education, Commonwealth of Australia.
- DITR 2007a, *How R&D Assistance Influences Company Behaviour*, Department of Industry, Tourism and Resources, Commonwealth of Australia.
- DITR 2007b, *High Variation in R&D Expenditure by Australian firms*, Department of Industry, Tourism and Resources, Commonwealth of Australia.
- DMITRE 2012, *Manufacturing Works – A strategy for driving high-value manufacturing in South Australia*, South Australian Department of Manufacturing, Innovation, Trade, Resources and Energy, Adelaide.
- DMITRE 2013, *SA Small Business Innovation Research Pilot Program – Guidelines*, South Australian Department of Manufacturing, Innovation, Trade, Resources and Energy, Adelaide.
- Dodgson, M 1993, *Technological Collaboration in Industry: Strategy, Policy and Internationalisation in Innovation*, Routledge, London.
- Dodgson, M and Bessant, J 1996, *Effective Innovation Policy*, Routledge/International Thomson Business Press, London.
- Dodgson, M 2007, 'Technological collaboration', in Hanusch, H and Pyka, A, *The Elgar Companion to Neo-Schumpeterian Economics*, Elgar, Cheltenham.
- Dodgson, M and Steen, J 2008, 'New innovation models and Australia's old economy', in Bessant, J and Venables, T, *Creating Wealth from Knowledge*, Elgar, Cheltenham.
- Dodgson, M, Gann, D, Salter, A 2008a, *The management of technological innovation: strategy and practice*, Oxford University Press, Oxford.

- Dodgson, M, Mathews, J, Kastelle, T, and Hu, MC 2008b, 'The evolving nature of Taiwan's national innovation system: The case of biotechnology innovation networks', *Research Policy*, vol. 37, pp. 430-445.
- Dodgson, M 2014, 'Collaboration and innovation management', in Dodgson, M, Gann, D and Phillips, N, *The Oxford Handbook of Innovation Management*, Oxford University Press, Oxford.
- Dodgson, M, Gann, D and Phillips, N 2014, *The Oxford Handbook of Innovation Management*, Oxford University Press, Oxford.
- Dolman, B and Gruen, D 2012, *Productivity and Structural Change*, speech given at 41st Australian Conference of Economists, 8-12 July 2012, Melbourne, accessed December 2013, available at <http://www.treasury.gov.au/~media/Treasury/Publications%20and%20Media/Speeches/2012/Productivity-and-Structural-Change/Downloads/Productivity-and-Structural-Change-Speech-DGruen.ashx>.
- Doms, M and Bartelsman, EJ 2000, 'Understanding Productivity: Lessons from Longitudinal Microdata', *Journal of Economic Literature*, vol. 38, no. 3, pp. 569-594.
- Doz, Y 1987, 'Technology Partnerships between Larger and Smaller Firms: Some Critical Issues', *International Studies of Management & Organisation*, vol. 17, no. 4, p. 31.
- DPMC 2012, *Australia in the Asian Century*, Department of Prime Minister and Cabinet, Commonwealth of Australia.
- DSDBI 2014, *Driving Business Innovation*, Department of State Development, Business and Innovation, State Government of Victoria, accessed March 2014, available at <http://www.business.vic.gov.au/industries/science-technology-and-innovation/programs/driving-business-innovation>.
- Dutta, S and Lanvin, B (ed.) 2013, *The Global Innovation Index 2013: The Local Dynamics of Innovation*, Cornell University, INSEAD, and the World Intellectual Property Organisation.
- Edge, D 1979, 'Quantitative measures of communication in science: A critical review', *History of Science*, vol. 17, pp. 102-134.
- EEF 2012, *Skills for growth: a more productive and flexible labour force*, EEF The Manufacturers' Organisation.
- Elms, DK and Low, P (eds.) 2013, *Global value chains in a changing world*, Fung Global Institute, Temasek Foundation and World Trade Organization.
- Elnasri, A and Fox, KJ 2014, 'The Contribution of Research and Innovation to Productivity and Economic Growth', *School of Economics Discussion Paper*, University of New South Wales.
- Engineers Australia 2012, *The Supply of Engineers in Australia: A Decade of Skilled Migration*, Engineers Australia.
- ESCAP 2009, 'Globalization of Production and the Competitiveness of Small and Medium-sized Enterprises in Asia and the Pacific: Trends and Prospects', *Studies in Trade and Investment*, vol. 65, United Nations Economic and Social Commission for Asia and the Pacific.
- European Commission 2012a, *E3M: European indicators and ranking methodology for university third mission*, Centre For Quality and Change Management, Valencia University of Technology, available at <http://www.e3mproject.eu>.
- European Commission 2012b, *Working Paper Expert Group Report on Role and Strategic Use of IPR (Intellectual Property Rights) in International Research Collaborations Final Report*.
- European Commission 2014a, *Commission Staff Working Document Advancing Manufacturing – Advancing Europe*, Report of the Task Force on Advanced Manufacturing for Clean Production, Brussels, SWD(2014) 120 final, Brussels.
- European Commission 2014b, *Innovation Union Scoreboard 2014*.
- Eurostat Press Office 2013, *Seventh Community Innovation Survey: Highest proportions of innovative enterprises in Germany, Luxembourg and Belgium*, 11 January, media release, available at [http://epp.eurostat.ec.europa.eu/cache/ITY\\_PUBLIC/9-11012013-AP/EN/9-11012013-AP-EN.PDF](http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/9-11012013-AP/EN/9-11012013-AP-EN.PDF).
- Executive Office of the President 2013, *Women and Girls in Science, Technology, Engineering and Math (STEM): Fact Sheet*, United States Government.
- Export Finance and Insurance Corporation 2008, *Are you ready to take on the world? EFIC Global Readiness Index: National results Report*.
- Findlay, C, Kennedy, N, Lin, F, Parham, D and Harcourt, T 2012, *Borders blurred – the changing nature of trade in a globalised world*, Australian Business Foundation, Sydney.
- Food Processing Industry Strategy Group 2012, *Food Processing Industry Strategy Group: Final Report of the Non-Government Members*, report to the Minister for Industry and Innovation, Commonwealth of Australia.
- Forbes Insights 2011, *Fostering Innovation Through a Diverse Workforce*, Forbes.
- Foresight 2013, *The Future of Manufacturing: A new era of opportunity and challenge for the UK – Project Report*, The Government Office for Science, London.
- Freeman, B 2013, *Consultant Report – Securing Australia's Future – STEM: Country Comparisons – Snapshots of 23 Science, Technology, Engineering and Mathematics (STEM) consultants' reports: Characteristics, lessons, policies and programs*, Australian Council of Learned Academies.
- GAO 2013, *Global Manufacturing: Foreign Government Programs Differ in Some Key Respects from those in the United States*, Report to the Chairman, Committee on Commerce, Science and Transportation, US Senate, United States Government Accountability Office.
- GE 2011, *GE Global Innovation Barometer 2011: An Overview*, General Electric, available at [http://www.ge.com/europe/downloads/EU\\_Innovation\\_Barometer\\_GlobalExternal.pdf](http://www.ge.com/europe/downloads/EU_Innovation_Barometer_GlobalExternal.pdf).
- Gleckman, H 2006, *Tax Incentives – Do they Work, and are they Worth the Cost?*, transcript of the 2006 Tax Analysts Conference Series, Washington DC. As cited in Rashkin, MD 2007 *Practical Guide to Research and Development Tax Incentives. Federal, State and Foreign*, 2nd Ed., p. 30, Wolters Kluwer Business.
- Go MINT 2014, *Komm, mach MINT*, Federal Ministry for Education and Research, available at <http://www.komm-mach-mint.de/Komm-mach-MINT/English-Information>.
- Goldman Sachs JBWere Investment Research 2009, *Australia's Hidden Resource – the Economic Case for Increasing Female Participation*, Research report: Economics, November 2009, Goldman Sachs JBWere.

- Goodnight, JA, Pucie, S, Karsten, S, Firester, L, Pion, G, Smith, A and Kephart, M 2009, *National Survey to Evaluate the NIH SBIR Program*, Office of Extramural Research, National Institutes of Health, US.
- Gordon, RJ 2012, *Is US Economic Growth Over? Faltering Innovation Confronts the Six Headwinds*, NBER Working Paper no. 18315, National Bureau of Economic Research.
- Gorodnichenko, Y, Svejnar, J and Terrell, K 2010, 'Globalization and innovation in emerging markets', *American Economic Journal: Macroeconomics*, vol. 2, no. 2, pp. 194–226.
- Green, R 2009, *Management Matters in Australia: Just how productive are we?*, Department of Innovation, Industry, Science and Research, Commonwealth of Australia.
- Griffith, R, Harrison, R and van Reenen, J 2006, 'How Special is the Special Relationship? Using the Impact of US R&D Spillovers on UK Firms as a Test of Technology Sourcing?', *American Economic Review*, vol. 96, pp. 1859–75.
- Griffiths, W and Webster, E 2010, 'The Determinants of Research and Development and Intellectual Property Usage among Australian Companies, 1989 to 2002', *Technovation*, vol. 30, pp. 471–481.
- Griffiths, W, Jensen, P, and Webster, E 2011, 'What Creates Abnormal Profits?', *Scottish Journal of Political Economy*, vol. 58, no. 3, pp. 323–346.
- Griliches, Z 1981, 'Market Value, R&D and Patents', *Economics Letters*, vol. 7, pp. 183–87.
- Griliches, Z 1988, 'Productivity Puzzles and R&D: Another Nonexplanation', *Journal of Economic Perspectives*, vol. 2, no. 4, pp. 9–21.
- Griliches, Z 1998, *R&D and Productivity: The Econometric Evidence*, University of Chicago Press, Chicago.
- Group of Eight 2012, *Research Performance of Australian Universities*, Policy Note Number 4, The Group of Eight Limited, available at [https://go8.edu.au/sites/default/files/docs/go8policynote4\\_researchperformance.pdf](https://go8.edu.au/sites/default/files/docs/go8policynote4_researchperformance.pdf).
- Group of Eight 2013, *Indicators of Australia's Group of Eight Universities*, The Group of Eight Limited, available at [https://go8.edu.au/sites/default/files/docs/page/go8\\_indicators\\_final2013.pdf](https://go8.edu.au/sites/default/files/docs/page/go8_indicators_final2013.pdf).
- Guellec, D and van Pottelsberghe de la Potterie, B 2001, *R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries*, OECD Economic Studies No. 33, OECD, Paris.
- Guellec, D and van Pottelsberghe de la Potterie, B 2004, *From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter?*, Working Papers CEB 04-010.RS, Universite Libre de Bruxelles.
- Håkanson, L, Caessens, P and MacAulay, S 2011, 'InnovationXchange: A case study in innovation intermediation', *Innovation: Management, policy & practice*, vol. 13, pp. 261–274.
- Håkanson, L 2014, 'Internationalisation of Research and Development' in Dodgson, M, Gann, D and Phillips, N, *The Oxford Handbook of Innovation Management*, Oxford University Press, Oxford.
- Hall, BH and Rosenberg, N 2010, *Handbook of The Economics of Innovation*, Volumes 1 & 2, North-Holland, Amsterdam.
- Hall, B 2011, *Innovation and Productivity*, NBER Working Paper No. 17178, National Bureau of Economic Research.
- Hamdouch, A 2008, *Conceptualising Innovation Clusters and Networks*, paper presented at "The Spirit of Innovation III" Forum: Innovation Networks, May 14–16 2008, Tacoma.
- Handel, M 2012, *Trends in Job Skill Demands in OECD Countries*, OECD Social, Employment and Migration.
- Harrigan, KR 1985, *Managing joint ventures success*, Praeger, New York.
- Haskel, J and Wallis, G 2010, 'Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector', *IZA Discussion Paper Series*, no. 4772.
- Haskel, J and Wallis, G 2013, 'Public Support for Innovation, Intangible Investment and Productivity Growth in the UK Market Sector', *Economics Letters*, vol. 119, pp. 195–198.
- Haylor, G 2012, *Breaking Fences May Make for Good Neighbours in Collaborative Research. Why the International Foundation for Science will introduce a Collaborative Research Approach*, International Foundation for Science.
- Healy, J, Mavromaras, K and Sloane, P 2012, *Skill shortages: prevalence, causes, remedies and consequences for Australian businesses*, National Centre for Vocational Education Research.
- Healy, J, Mavromaras, K and Zhu, R 2013, *Consultant report – Securing Australia's Future – STEM: Country Comparisons – The STEM Labour Market in Australia*, Australian Council of Learned Academies.
- Herring, C 2009, 'Does Diversity Pay?: Race, Gender, and the Business Case for Diversity', *American Sociological Review*, vol. 74, no. 2, pp. 208–224.
- Hilmer, F 2013, 'The Red Tape Challenge – from Meat Axe to Scalpels', paper presented at the *IARIW-UNSW Conference on Productivity Measurement, Drivers and Trends*, 27–28 November 2013, Sydney.
- HM Revenue & Customs 2011, *The Patent Box: Technical Note and Guide to the Draft Legislation*, CT Reform, Corporate Tax Team, HM Treasury, London.
- Hoang, H and Antoncic, B 2003, 'Network-based research in entrepreneurship – A critical review', *Journal of Business Venturing*, vol. 18, pp. 165–187.
- House Standing Committee on Economics 2010, *Inquiry into raising the productivity growth rate in the Australian Economy*, House of Representatives, Parliament of the Commonwealth of Australia.
- Hughes, A and Martin, B 2012, *Enhancing Impact: The value of public sector R&D* Centre for Business and Higher Education, UK Innovation Research Centre.
- Hughes, A, Kitson, M, Bullock, A, and Milner, I 2013, *The Dual Funding Structure for Research in the UK: Research Council and Funding Council Allocation Methods and the Pathways to Impact of UK Academics*, Report from the Centre for Business Research and the UK Innovation Research Centre to the UK Department for Business, Innovation & Skills.
- IAS 2014, *Institute of Advanced Studies: Postgraduate Masterclasses*, Institute of Advanced Studies, University

- of Western Australia, available at: <http://www.ias.uwa.edu.au/masterclass>.
- IFS 2011, *International Foundation for Science Strategy 2011-2020: Working Together*, International Foundation for Science.
- Independent Economics 2013, *Cost-benefit analysis and returns from additional investment in Vocational Education and Training*, report prepared for TAFE Directors Australia, Canberra.
- infoDev 2013, *Crowdfunding's Potential for the Developing World*, Finance and Private Sector Development Department, infoDev, and The World Bank.
- International Human Genome Sequencing Consortium (IHGSC) 2004, 'Finishing the euchromatic sequence of the human genome article Initial sequencing and analysis of the human genome', *Nature*, vol. 431, pp. 931-945.
- IRU 2013, *Engage, Collaborate, Innovate*, Innovative Research Universities.
- Isaksson, A 2007, *Determinants of Total Factor Productivity: A literature review*, Staff Working Paper 02/2007, United Nations Industrial Development Organization.
- Jaffe, A 1989, 'Real effects of academic research', *American Economic Review*, vol. 79, pp. 957-970.
- Janz, N, Loof, H and Peters, B 2003, *Firm Level Innovation and Productivity – Is there a Common Story Across Countries?*, ZEW Discussion Paper No. 03-26.
- Julian, C 2009, 'The Empirical Link Between Entry Mode Selection and Barriers to Internationalisation', *International Journal of Trade and Global Markets: Special Issue on Advances in Market Entry Mode Theory Development*, vol. 2, no. 3-4, pp. 237-249.
- Kafouros, M, Buckley, P, Sharp, J, and Wang, C 2008, 'The role of internationalisation in explaining innovation performance', *Technovation*, vol. 28, no. 1-2, pp. 63-74.
- Kastelle, T and Steen, J 2014, *Networks of Innovation*, in Dodgson, M, Gann, D and Phillips, N 2013, *The Oxford Handbook of Innovation Management*, pp. 102-121, Oxford University Press, Oxford.
- Keating, J 2008, *Matching supply of and demand for skills: International perspectives*, National Centre for Vocation Education and Research.
- KordaMentha 2011, *SMEs – In a World of Pain*, KordaMentha Pty Ltd.
- Koźluk, T and Zipperer, V 2013, *Environmental policies and productivity growth – a critical review of empirical findings*, Economics department working papers no. 1096, OECD, Paris.
- Kretschmer, T 2012, *Information and Communication Technologies and Productivity Growth: A Survey of the Literature*, OECD Digital Economy Papers No. 195, OECD Publishing.
- Lampel, J, Bhalla, A and Jha, P 2012, *The Employee Ownership Advantage: Benefits and Consequences*, Cass Business School, City University, London and Department for Business, Innovation and Skills, London.
- Lenihan, H, Andréosso-O'Callaghan, B and Hart, M 2010, 'Conceptual Issues', in *SMEs in a Globalised World*, Edward Elgar Publishing, UK.
- Liesch, P, Steen, M, Middleton, S, Weerawardena, J 2007, *Born to be global: A closer look at the international venturing of Australian born global firms*, Australian Business Foundation.
- Loewendahl, H 2009, *Foreign direct investment landscape 2009-2013: insights and intelligence from the Financial Times Ltd*, FDI Intelligence, London.
- Loof, H and Heshmati, A 2006, 'On the relationship between innovation and performance: A sensitivity analysis', *Economics of Innovation and New Technology*, vol. 15, pp. 317 – 344.
- Louca, J 2003, 'Multifactor productivity and innovation in Australia and its states', in Williams, C, Draca, M and Smith, C (eds.), *Productivity and Regional Economic Performance in Australia*. Collection of papers prepared by the Office of Economic and Statistical Research, Queensland Treasury.
- Lowe, P 2014, *Demographics, Productivity and Innovation*, speech to The Sydney Institute, Sydney, 12 March 2014, accessed April 2014, available at <http://www.rba.gov.au/speeches/2014/sp-dg-120314.html>.
- Macpherson, G, Plewa, C, Korff, N and Baaken, T 2011, 'Evolution of success factors in university industry linkages', abstract in *Technology Transfer Conference 2011*, Augsburg, as cited in DIISRTE 2012, *Australian Innovation System Report 2012*, Department of Industry, Innovation, Science, Research and Tertiary Education, Commonwealth of Australia.
- Mairesse, J and Robin, S 2010, *Innovation and Productivity: a Firm-Level Analysis for French Manufacturing and Services Using CIS3 and CIS4 data (1998-2000 and 2002-2004)*, CREST-ENSAE, Paris.
- Malecki, EJ 1997, *Technology and economic development: the dynamics of local, regional and national competitiveness*, Longman, London.
- Marceau, J 2007, 'The knowledge tree: CSIRO in Australia's innovation systems', *Innovation: Management, Policy & Practice*, vol. 9, pp. 98-112.
- Marginson, S, Tytler, R, Freeman, B and Roberts, K 2013, *STEM: Country comparisons*, Australian Council of Learned Academies.
- Mavromaras, K, Healy, J, Richardson, S, Sloane, P, Wei, Z, and Zhu, R 2013, *A System for Monitoring Shortages and Surpluses in the Market for Skills*, National Institute of Labour Studies.
- McCaig, C, Drew, S, Marsden, D, Haughton, P, McBride, J, McBride, D, Willis, B and Walstenholme, C 2008, *International Research Collaboration in UK Higher Education Institutions*, Centre for Education and Inclusion Research and Centre for Research and Evaluation, Sheffield Hallam University, DIUS Research Report 08 08, UK Department for Innovation, Universities & Skills
- McKinsey & Co. 2006, *Mapping the Value of Employee Collaboration*, McKinsey Quarterly.
- McKinsey Global Institute 2012, *Manufacturing the future: The next era of global growth and innovation*, McKinsey & Co.
- Medda, G, Piga, C and Siegel, DS 2005, 'University R&D and firm productivity: evidence from Italy', *Journal of Technology Transfer*, vol. 30, no. 1/2, pp. 199-205.

- Metcalfe, J, Riedlinger, M, Pisarski, A and Gardner, J 2006, *Collaborating across the sectors: The relationships between the HASS and STEM sectors*, Council for Humanities, Arts and Social Sciences.
- Mina, A, Connell, D and Hughes, A 2009, *Models of technology development in intermediate research organisations*, Working Paper No. 396, Centre for Business Research, University of Cambridge.
- Minifie, J, Cherastidtham, I, Mullerworth, D and Savage, J 2013, *The mining boom: impacts and prospects*, Grattan Institute, Melbourne.
- MIT 2011, *The third revolution: The convergence of the life-sciences, physical sciences and engineering*, Massachusetts Institute of Technology, Boston.
- Mohnen, P 2001, 'International R&D spillovers and economic growth', in Pohjola, M (ed.), *Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development*, pp. 50 – 71, Oxford University Press, London.
- Mowery, DC and Sampat, BN 2010, *Universities in National Innovation Systems*, unpublished manuscript, Haas School of Business, University of California, Berkeley, available at <http://innovate.ucsb.edu/wp-content/uploads/2010/04/Mowery-Sampat-Univ-National-Innovation-Systems.pdf>.
- Nadiri, I 1993, *Innovations and technological spillovers*, NBER Working Paper No. 4423, Cambridge, MA.
- National Research Council 2008, *An Assessment of the SBIR Program*, The National Academies Press, Washington.
- NetSuite 2013, *Australian manufacturers and wholesale distributors lag behind in e-commerce adoption*, media release, 29 October, NetSuite Inc., accessed March 2014, available at <http://www.netsuite.com.au/portal/au/press/releases/nlpr10-29-13b.shtml>.
- O'Kane, M 2008, *Collaborating to a purpose: Review of the Cooperative Research Centres Program*, Department of Innovation, Industry, Science and Research, Commonwealth of Australia.
- O'Connell, A 2011, *Employee Share Ownership Plans – A Comparative Report*, Research Report, Employee Share Ownership Project, Melbourne Law School, The University of Melbourne.
- OECD 2000, *Science, Technology and Industry Outlook 2000*, OECD Publishing.
- OECD 2001, *Innovative Networks: Co-operation in National Innovation Systems*, OECD Publishing.
- OECD 2003, 'Foreign Direct Investment Restrictions in OECD Countries', in *OECD Economic Outlook*, vol. 2003, no. 1, OECD Publishing.
- OECD 2004, *Networks, Partnerships, Clusters and Intellectual Property Rights: Opportunities and Challenges for Innovative SMEs in a Global Economy*, Report of 2nd OECD Conference of Ministers Responsible for Small and Medium-Sized Enterprises – Promoting Entrepreneurship and Innovative SMEs in a Global Economy: Towards a More Responsible and Inclusive Globalisation.
- OECD 2005, 'Guidelines for collecting and interpreting innovation data', in *Oslo Manual: The measurement of scientific and technological activities*, 3rd edition, p. 46, OECD, Paris.
- OECD 2008, *Enhancing the Role of SMEs in Global Value Chains*, OECD, Paris.
- OECD 2009, *Top Barriers and Drivers to SME Internationalisation*, Report by the OECD Working Party on SMEs and Entrepreneurship, OECD, Paris.
- OECD 2010, *Measuring Innovation: A new perspective*, OECD, Paris.
- OECD 2011a, *Demand-side Innovation Policies*, OECD Publishing.
- OECD 2011b, *Skills for Innovation and Research*, OECD Publishing.
- OECD 2012a, *OECD Science, Technology and Industry Outlook 2012*, OECD, Paris.
- OECD 2012b, *Meeting Global Challenges Through Better Governance: International Co-Operation in Science, Technology and Innovation Policy Brief*, OECD Publishing.
- OECD 2013a, *Interconnected Economies: Benefiting from Global Value Chains*, OECD Publishing.
- OECD 2013b, *Entrepreneurship at a Glance 2013*, OECD Publishing.
- OECD 2013c, *OECD Science, Technology and Industry Scoreboard 2013: Innovation for Growth*, OECD Publishing.
- OECD 2013d, *Commercialising Public Research: New Trends and Strategies*, OECD Publishing.
- OECD 2013e, *Mapping Global Value Chains*, Trade Policy Paper no. 159, OECD, Paris.
- OECD 2013f, *New Sources of Growth: Knowledge-Based Capital – Key Analyses and Policy Conclusions*, OECD, Paris.
- OECD 2013g, *Economic Policy Reforms 2013: Going For Growth*, OECD, Paris.
- Office of the Chief Scientist 2012, *Health of Australian Science*, Office of the Chief Scientist, Australian Government.
- Oliner, S, Sichel, D and Stiroh, K 2007, 'Explanation of a productive decade', *Brookings papers on economic activity*, vol. 1, pp. 81-137.
- Oracle Insight 2010, *The Business Case for Enterprise Collaboration*, White Paper, Oracle.
- Palangkaraya, A, Stierwald, A, Webster, E, and Jensen, P 2011, *Examining the Characteristics of Innovative Firms in Australia*, A Report for the Australian Government Department of Innovation, Industry, Science and Research, Melbourne Institute of Applied Economic and Social Research, The University of Melbourne.
- Palangkaraya, A, Spurling, T, and Webster, E 2014, *Consultant Report – Securing Australia's Future – The role of science, research and technology in lifting Australia's productivity: Is science-based innovation more productive? A firm-level study*, Australian Council of Learned Academies.
- Parham, D 2006, 'Empirical Analysis of the Effects of R&D on Productivity: Implications for productivity measurement?', paper presented at *OECD Workshop on Productivity Measurement and Analysis*, 16-18 October 2006, Bern.
- Parham, D 2012, *Australia's Productivity Growth Slump: Signs of Crisis, Adjustment or Both?* Visiting Researcher Paper, Productivity Commission, Commonwealth of Australia.

- PCAST 2011, *Report to the President on ensuring American leadership in advanced manufacturing*, President's Council of Advisors on Science and Technology, Executive Office of the President, Washington.
- PCAST 2012, *Report to the President on capturing domestic competitive advantage in advanced manufacturing*, President's Council of Advisors on Science and Technology, Executive Office of the President, Washington.
- Perkmann, M, and Salter, A 2012, 'How to create productive partnerships with universities', *MIT Sloan Management Review*, vol. 53, no. 4.
- Pettigrew, A 2012, *Australia's Position in the World of Science, Technology & Innovation*, Occasional Paper Series, Office of the Chief Scientist, Australian Government.
- Phelps, E 2013, *Mass Flourishing: How Grassroots Innovation Created Jobs, Challenge, and Change*, Princeton University Press, Princeton.
- Piller, F and Kumar, A 2006, 'Mass customization: providing custom products and services with mass production efficiency', *Journal of Financial Transformation*, vol. 18, pp. 125-131.
- PMSEIC 2006, *Australia's Science and Technology Priorities for Global Engagement: A report of the PMSEIC working group*, Working Group for the Prime Minister's Science, Engineering and Innovation Council, Australian Government.
- PMSEIC 2010, *Australia and Food Security in A Changing World*, Prime Minister's Science, Engineering and Innovation Council, Australian Government.
- Productivity Commission 2006, *Potential Benefits of the National Reform Agenda*, Productivity Commission Research Paper, Productivity Commission, Commonwealth of Australia.
- Productivity Commission 2007, *Public Support for Science and Innovation*, Productivity Commission Research Report, Productivity Commission, Commonwealth of Australia.
- Productivity Commission 2009, *Australia's Productivity Performance*, Submission to the House of Representatives Standing Committee on Economics: Inquiry into Raising the Level of Productivity Growth in Australia, Productivity Commission.
- Productivity Commission 2011, *Rural Research and Development Corporations*, Report No. 52, Final Inquiry Report, Productivity Commission, Commonwealth of Australia.
- Productivity Commission 2013, *Australia's Automotive Manufacturing Industry*, Productivity Commission Preliminary Findings Report, Productivity Commission, Commonwealth of Australia.
- Productivity Commission 2014, *PC Productivity Update*, Productivity Commission, Commonwealth of Australia.
- PwC 2013, *The Startup Economy: How to Support Tech Startups and Accelerate Australian Innovation*, a report by PricewaterhouseCoopers for Google Australia.
- Regeneris Consulting 2010, *Knowledge Transfer Partnerships Strategic Review*, report by Regeneris Consulting to the Technology Strategy Board.
- Romer, PM 1990, 'Endogenous Technological Change', *Journal of Political Economy*, vol. 98, no. 5, pp. S71-102.
- Roos, G 2012, *Manufacturing into the future*, a report for the South Australian Department for Manufacturing, Innovation, Trade, Resources and Energy.
- Rosenberg, N 1963, 'Technological Change in the Machine Tool Industry, 1840- 1910', *Journal of Economic History*, vol. 23, pp. 414-443.
- Rosenberg, N 1981, 'Why in America?', in Mayr, O and Post, RC (eds.), *Yankee Enterprise and the Rise of the American System of Manufactures*, Smithsonian Institution Press, Washington, reprinted in 1995, *Exploring the Black Box*, Cambridge University Press, Cambridge.
- Royal Society 2009, *Hidden wealth: the contribution of science to service sector innovation*, *The Royal Society*, London.
- Royal Society 2011, *Knowledge, Networks and Nations: Global Scientific Collaboration in the 21st century*, The Royal Society, London.
- Samson, D 2011, *Karpin Report revisited: leadership and management challenges in Australia*, Innovation and Business Skills Australia.
- Schacht, WH 2011, *The Technology Innovation Program*, Congressional Research Service.
- Schmookler, J 1966, *Invention and Economic Growth*, Harvard University Press, Cambridge, MA.
- Schwab, K and Sala-i-Martin, A 2013, *The Global Competitiveness Report 2013-2014: Full Data Edition*, World Economic Forum, Switzerland.
- Science-to-Business Marketing Research Centre 2011, *The State of European University-Business Cooperation Final Report*, European Commission.
- Scottish Enterprise 2014, *Overview of the Proof of Concept Programme*, Scottish Enterprise, available at <http://www.scottish-enterprise.com/services/support-for-entrepreneurs/proof-of-concept-programme/overview>.
- Scott-Kemmis, D, Darling, T, Johnston, R, Collyer, FM, and Cliff, C 1989, *Strategic Alliances in the Internationalisation of Australian Industry*, The Centre for Technology and Social Change, University of Wollongong.
- Sear L, Mughan T, and Lloyd-Reason L 2004, 'The Global SME: Understanding and Segmenting the Experiences of 'International' Small and Medium-Sized Enterprises in the UK', in *Proceedings of the 27th Institute for Small Business Affairs (ISBA)*, National Small Firms Policy and Research Conference, November, 2004, University of Teeside.
- Senate Education, Employment and Workplace Relations References Committee 2012, *The shortage of engineering and related employment skills*, Senate, Parliament of the Commonwealth of Australia.
- Shanks, S and Zheng, S 2006, *Econometric Modelling of R&D and Australia's Productivity*, Productivity Commission Staff Working Paper, Productivity Commission, Commonwealth of Australia.
- Shipp, SS, Gupta, N, Lal, B, Scott, JA, Weber, CL, Finnin, MS, Blake, M, Newsome S and Thomas, S 2012, *Emerging Global Trends in Advanced manufacturing*, IDA paper P-4603, Institute for Defense Analyses, Alexandria.

- Siedschlag, I, Zhang, Z and Cahill, B 2010, *The effects of the internationalisation of firms on innovation and productivity*, ESRI Working Paper No. 363, Economic and Social Research Institute, Dublin.
- Skills Australia 2011a, *Skills for prosperity: a roadmap for vocational education and training*, Skills Australia, Commonwealth of Australia.
- Skills Australia 2011b, *Skills Utilisation Literature Review*, Skills Australia, Commonwealth of Australia.
- Skills Australia 2012a, *Skills Australia submission to the Senate Education, Employment and Workplace Relations Committees: Inquiry into the shortage of engineering and related employment skills*, Skills Australia.
- Skills Australia 2012b, *Better use of skills, better outcomes: A research report on skills utilisation in Australia*, Skills Australia, Commonwealth of Australia.
- Slaughter, M 2010, *How U.S. Multinational Companies Strengthen the U.S. Economy Data Update*, Business Roundtable and United States Council for International Business.
- Soames, L, Brunner, D and Talgaswatta, T 2011, 'Competition, Innovation and Productivity in Australian Businesses', *Methodology Research Papers*, cat. no. 1351.0.55.035, Australian Bureau of Statistics.
- Steen, J 2013, *Consultant Report – Securing Australia's Future – The role of science, research and technology in lifting Australia's productivity: Productivity, exporting and innovation in Australian SMEs: Evidence from a longitudinal dataset*, Australian Council of Learned Academies.
- STEMconnector 2014, *Women in STEM: Realizing the potential – White Paper*, STEMconnector and Million Women Mentors.
- Sullivan, K and Muthukrishnan, R 2013, *Connected Services – New Manufacturing Models Increase Revenue Growth*, Cisco Internet Business Solutions Group.
- Syverson, C 2011, 'What Determines Productivity?', *Journal of Economic Literature*, vol. 49, no. 2, pp. 326-65.
- TAFE Directors Australia 2013, *National Conference for TAFE Directors Australia 2013: TDA Redefined*, Occasional Paper One 2013, TAFE Directors Australia.
- Teece, DJ 2007, 'Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance', *Strategic Management Journal*, vol. 28, pp. 1319-1350.
- Temperley, N, Galloway, J and Liston, J 2004, *SMEs in Australia's Higher technology Sector: Challenges and Opportunities*, Australian Electrical and Electronic Manufacturers' Association.
- Ternouth, P, Garner, C, Wood, L, and Forbes, P 2012, *Key Attributes for Successful Knowledge Transfer Partnerships*, Commissioned by the Technology Strategy Board and the Research Councils, Council for Industry and Higher Education (CIHE), London, UK.
- The Economist 2014, *Accelerators: Getting up to speed*. Special Report: Tech Startups 18 Jan 2014, The Economist.
- The Economist Intelligence Unit 2012, *Competing Across Borders: How Cultural and Communication Barriers Affect Business*, a report from the Economist Intelligence Unit, The Economist.
- Thomson, R 2009, *Tax Policy and R&D Investment by Australian Firms*, Intellectual Property Research Institute of Australia, Working Paper No. 05/09, The University of Melbourne.
- Thomson, R 2012, 'National scientific capability and R&D offshoring', *Research Policy*, vol. 42, no. 2, pp. 517-528.
- Toner, P 2011, *Workforce Skills and Innovation: An Overview of Major Themes in the Literature*, OECD Education Working Papers, No. 55, OECD Publishing.
- Trendethnography AB 2009, *Mix to Max: an ethnographic study of skills mixing*, DIK and Sveriges Ingenjörer.
- TSB 2011, *Concept to Commercialisation: A strategy for business innovation, 2011-2015*, Technology Strategy Board, UK.
- UNCTAD 2013, *World Investment Report 2013: Global Value Chains: Investment and Trade for Development*, United Nations Conference on Trade and Development, United Nations Publishing, Switzerland.
- Varian, H 2005, *Technology Levels the Business Playing Field*, University of California, Berkeley.
- Webster, E, Dockery, M, Bainger, T and Kelly, R 2001, *Training for the Skilled Trades in Australia, 1980 to 2000: Training Reforms*, National Centre for Vocation Education and Research.
- Webster, E and Jensen, PH 2006, 'Investment in Intangible Capital: An enterprise perspective', *Economic Record*, vol. 82, no. 256, pp. 82-96.
- Wessner, C (ed.) 2008, *An Assessment of the Small Business Innovation Research Program*, National Research Council (US) Committee for Capitalizing on Science, Technology, and Innovation, National Academies Press.
- Wilson, K 2006, 'Encouraging The Internationalisation of SMEs', in Potter, J and Proto, A (eds.), *Promoting Entrepreneurship in South East Europe: Policies and Tools*, LEED Programme, OECD.
- Wong, M, Page, D, Abello, R and Pang, K 2007, 'Explorations of Innovation and Business Performance Using Linked Firm-Level Data', *Methodology Research Papers*, cat. no. 1351.0.55.020, Australian Bureau of Statistics.
- Woodward, D, Figueiredo, O and Guimaraes, P 2006, 'Beyond the Silicon Valley: university R&D and high-technology location', *Journal of Urban Economics*, vol. 60, pp. 15-32.
- Yaşar, M and Morrison Paul, CJ 2012, 'Firm performance and knowledge spillovers from academic, industrial and foreign linkages: the case of China', *Journal of Productivity Analysis*, vol. 38, pp. 237-253.

# Expert working group

## Dr John Bell FTSE (Chair)

Dr John Bell FTSE is a senior Associate with ACIL Allen Consulting. He has held senior positions with the Commonwealth Government, including Deputy Secretary and Chief Science Adviser in the (now) Department of Industry. He has also spent more than seven years working with the Organisation for Economic Co-operation and Development (OECD) in Paris, including four years as Head of the Division responsible for analysis of science, technology and innovation. In 2003, Dr Bell was awarded a Centenary of Federation medal for his strategic contribution to research and development in Australia.

## Dr Bob Frater AO FAA FTSE (Deputy)

Over more than 50 years, Dr Bob Frater has researched electronics, telecommunications, electroacoustics, radioastronomy instrumentation, electroacoustics and biomedical devices. In 1996, he was made an Officer of the Order of Australia for his contributions to science, including his work on the construction of the Australia Telescope at Narrabri in northern NSW. The telescope has just celebrated its 25<sup>th</sup> anniversary. Bob has been Vice President for Innovation with ResMed Ltd and Chief Technology Officer for Innovation Capital since leaving CSIRO in 1999, where he had been Deputy Chief Executive for 11 years. He serves on a number of advisory committees.

## Leslie Butterfield, BSc Civ Eng; MAICD, MAIPM

Ms Butterfield is Chief Executive Officer of a specialist Project and Strategy Advisory company which operates in the business, property and infrastructure sectors with a client group spanning Government, large corporates, and not-for-profits. She is also Managing Director

Australia for its NYSE listed company parent company. She has served on numerous Boards and advisory panels including the Federal IRD Board, and was one of a panel of three industry representatives appointed by the nine government ministers to review the progress, strategies and future direction of the National Building Codes Board. Leslie was the Inaugural NSW President and National Vice President for the National Association of Women in Construction (NAWIC), was inducted to the Inaugural Businesswomen's Hall of Fame, and was Telstra NSW Businesswoman of the Year. She was one of six Australian Women selected in 2007 for the prestigious Veuve Clicquot annual tribute to outstanding women achievers in business and industry.

## Professor Stuart Cunningham FAHA

Stuart Cunningham is Distinguished Professor of Media and Communications, Queensland University of Technology, and Director of the Australian Research Council Centre of Excellence for Creative Industries and Innovation. His current research focuses on digital transformations of the screen sector, which he will pursue as a Fulbright Senior Scholar in 2014-15. He has served in several leadership roles in advocacy, advice and governance in research and higher education, and in the screen and library sectors. His book *Hidden Innovation: Policy, Industry and the Creative Sector* gathers much of his research into innovation and the humanities, arts and social sciences.

## Professor Mark Dodgson FASSA

Mark is Director of the Technology and Innovation Management Centre at the University of Queensland Business School, Brisbane, and Visiting Professor at Imperial College Business School, London. He is non-executive director of

Nestlé Australia Ltd. and member of the Advisory Board of Thiess Pty Ltd. Recent books include *The Management of Technological Innovation*; *Innovation: A Very Short Introduction*; and the *The Oxford Handbook of Innovation Management*, all published by Oxford University Press.

### Professor Kevin Fox FASSA

Kevin Fox is a Professor of Economics and Director of the Centre for Applied Economic Research in the Australian School of Business at the University of New South Wales. He works primarily in the field of economic measurement, with a focus on productivity, prices and efficiency analysis. After studying Japanese in Tokyo for two years, he studied economics at the University of Canterbury and the University of British Columbia. He joined UNSW in 1994, and served as the Head of the School of Economics 2008-12. He chaired the Australian Consumer Price Index Review Advisory Group in 2009-2010. He is a member of the Methodology Advisory Committee and the Productivity Measurement Reference Group of the Australian Bureau of Statistics. He has been a consultant for agencies such as the Reserve Bank of New Zealand, the Swiss National Bank, the Australian Bureau of Agricultural and Resource Economics, the Asian Development Bank, and the New Zealand Treasury. He is an Associate Editor of the *Journal of Productivity Analysis*, and a council member of the International Association for Research in Income and Wealth.

### Professor Tom Spurling AM FTSE

Professor Tom Spurling is the Director of the Centre for Transformative Innovation, Swinburne University of Technology. He is a member of the CSIRO Board and is the Chair of the Board of Advanced Molecular Technologies Pty Ltd. He is

a Fellow of ATSE and was made a Member of the Order of Australia in 2008 for his contributions to national innovation policies.

### Professor Elizabeth Webster

Professor Beth Webster is the Director of Intellectual Property Institute of Australia (IPRIA) and Professorial Fellow, Melbourne Institute of Applied Economic and Social Research at the University of Melbourne. She has authored over 100 articles on the economics of innovation, intellectual property and firm performance and has been published in *RAND Journal of Economics*, *Review of Economics and Statistics*, *Oxford Economic Papers*, *Journal of Law & Economics* and *Cambridge Journal of Economics*. She has been appointed to a number of committees including the CEDA Advisory Council; the Advisory Council for Intellectual Property; Expert Review Group – New Sources of Growth – Intangible Assets, OECD; Board Member, European Policy for Intellectual Property Association; and Board Member, Asia Pacific Innovation Network.

**All EWG members have declared any relevant interests.**

### Project Managers

#### Harriet Harden-Davies

*Manager, Policy & Projects*

Australian Academy of Technological Sciences and Engineering

#### Dr Andrew Hastings

*Research & Policy Officer*

Australian Academy of Technological Sciences and Engineering

#### Sarah Parker

*Research & Policy Officer*

Australian Academy of Technological Sciences and Engineering

# Acknowledgements

The Expert Working Group is grateful to the experts who contributed to this Project through participating in meetings, workshops and interviews. The names of people who contributed to workshops and consultations sessions are listed under Evidence Gathering.

The Expert Working Group undertook part of its research through subgroups. It gratefully acknowledges the contributions of Dr Amanda Caples, Professor Roy Green, Mr David Hind FTSE, Professor Shirley Leitch, Professor Sue Richardson FASSA, Dr Jack Steele, and Mr Glenn Wightwick FTSE to the work of these subgroups.

We also wish to thank Professor Ron Johnston FTSE, Australian Centre for Innovation (ACIIC), who facilitated workshops and provided other advice.

The Expert Working Group thanks the Australian Bureau of Statistics for help in accessing data needed for this report.

Project management services were provided by the Australian Academy of Technological Sciences and Engineering (ATSE) – Harriet Harden-Davies, Andrew Hastings and Sarah Parker – on behalf of ACOLA Secretariat. These contributions are gratefully acknowledged.

The Expert Working Group thanks Dr Simon Prasad, Office of the Chief Scientist, for guidance and advice throughout the project, and the ACOLA Secretariat for their assistance.



# Evidence gathering

## 1. Workshops and consultation sessions

The Expert Working Group held a total of nine workshops throughout the project, to seek input from key stakeholders to the project and to discuss in detail aspects of the project aims:

- Project workshop, 18 March 2013, Melbourne
- Project workshop, 20 March 2013, Sydney
- Project workshop, 8 August 2013 Brisbane
- ATSE-ACOLA Workshop *translating research into productivity*, 9 August, Brisbane
- Project workshop, 14 August 2013 Adelaide
- Project workshop, 15 August 2013 Perth
- Management Challenges Workshop, 5 December 2013 Sydney
- Project workshop, 18 March 2013, Adelaide
- Project workshop, 13 March 2014, Canberra

The Expert Working Group is grateful to have had the opportunity to consult widely with 169 experts and key stakeholders during these workshops, including:

Professor Thushara Abhayapala, *Australian National University*

Dr Renu Agarwal, *University of Technology Sydney*

Professor Peter Andrews AO FTSE, *State Government of Queensland*

Professor Robin Batterham AO FEng FAA FTSE, *University of Melbourne*

Mr Lee Bell, *ChemCentre*

Mr Doron Ben-Meir, *Department of Industry Innovation Science Research and Tertiary Education*

Dr John Best, *Thales Australia Ltd*

Emeritus Professor Harry Bloch, *Curtin University*

Dr Bernard Bowen AM FTSE

Mr Alan Brien, *Scitech*

Dr Matthew Brown, *Australian Technology Network of Universities*

Ms Sarah Brown, *Universities Australia*

Professor Aidan Byrne, *Australian Research Council*

Dr Amanda Caples, *Department of Business and Innovation*

Mr Robert Chalmers, *Adelaide Research & Innovation Pty Ltd*

Dr Bruce Chapman, *Australian National University*

Prof Ian Chubb AC, *Office of the Chief Scientist*

Mr Drew Clarke FTSE, *Department of Communications*

Professor Russell Cooper, *Australian Defence Force Academy*

Assoc/Professor Jerry Courvisanos, *University of Ballarat*

Mr Mark Cully, *DIISRTE*

Ms Rosanna De Marco, *Dow Chemicals*

Mr Peter Dwyer, *IBSA*

Ms Elizabeth Eastland, *University of Wollongong*

Professor Adrian Egan FTSE

Dr Michael Egan, *SME CSIRO*  
Dr Amani Elnasri, *University of New South Wales*  
Dr Ian Elsum, *CSIRO – Corporate Centre*  
Ms Kathryn Fagg FTSE, *Reserve Bank of Australia*  
Professor Katrina Fairley-Grenot FAICD FTSE, *University of Sydney*  
Mr Andy Farrant, *One Degree Advisory*  
Professor Christopher Fell AM FTSE, *Fell Consulting Pty Ltd*  
Dr Alan Finkel AM, FIEAust, FTSE, *Monash University*  
Professor John Foster, *University of Queensland*  
Professor Neil Foster FTSE, *School Of Chemical Engineering – UNSW*  
Dr Geoff Garrett AO FTSE, *State Government of Queensland*  
Dr Rowan Gilmore FTSE, *EM Solutions Pty Ltd*  
Dr Bruce Godfrey FTSE, *Wyld Group Pty Ltd*  
Ms Denise Goldsworthy FTSE  
Mr Albert Goller, *META*  
Ms Karen Gomez, *Australian Institute of Management*  
Mr Alexander Gosling FTSE, *Capstone Partners Pty Ltd*  
Dr Ian Gould AM FTSE, *University of South Australia*  
Professor Quentin Grafton FASSA, *Crawford School, ANU*  
Professor Peter Gray FTSE, *The University of Queensland*  
Dr Roy Green AO FTSE  
Professor Roy Green, *UTS Business School*  
Mr Bruce Grey FTSE, *Advanced Manufacturing CRC*  
Mr Allan Groth, *Universities Australia*  
Professor Yingjie Jay Guo FTSE, *Australia-China Research Centre for Wireless Communication*  
Mr Simon Handford, *University of Western Australia*  
Dr Michael Harris, *ABARES*  
Dr Ian Harrison, *Alcoa of Australia Ltd*  
Ms Virginia Hart, *Department of Education, Employment & Workplace Relations*  
Adj/Professor Erol Harvey FTSE, *MiniFab*  
Mr Stephen Harvey, *Australian Industry & Defence Network*  
Dr Michael Heard FTSE, *Meta Limited*  
Dr Alex Heath, *Reserve Bank of Australia*  
Ms Yvonne Hickling, *CSL Limited*  
Dr Anita Hill FTSE, *CSIRO – Division of Process Science & Engineering*  
Mr David Hind FTSE, *Barefoot Power Pty Ltd*  
Mr Bruce Hockman, *Australian Bureau of Statistics*  
Professor Peter Hoj FTSE, *University of Queensland*  
Dr John Howard, *Howard Partners*  
Mr Michael Hubbard, *Business Council of Australia*  
Professor Alan Hughes, *University of Cambridge*  
Dr Brent Jackson, *Engineers Australia – Canberra*

Professor Paul Jensen, *University of Melbourne*  
Professor Archie Johnston FTSE, *The University of Sydney*  
Professor Ron Johnston FTSE, *The University of Sydney*  
Mr Duncan Jones, *Science Industry Australia*  
Dr Tim Kastle, *UQ Business School*  
Ms Narelle Kennedy AM, *The Kennedy Company*  
Dr Glen Kile AM FTSE  
Professor Robin King FTSE, *Australian Council of Engineering Deans*  
Ms Anne-Marie Lansdown, *Universities Australia*  
Mr Peter Laver AM FTSE HonFIEAust  
Mr Andrew Lawson, *MBD Energy*  
Mr Mark Ledson, *Department for Manufacturing, Innovation, Trade, Resources and Energy*  
Professor Shirley Leitch, *Swinburne University of Technology*  
Mr Hugo Lemessurier, *LeMessurier Solutions*  
Professor David Lewis, *Flinders University*  
Professor David Lindsay AO FTSE, *University of Western Australia*  
Dr Catherine Livingstone AO FAA FTSE, *Telstra Corporation*  
Dr Terry Longhurst, *Meat and Livestock Australia*  
Professor Max Lu IChemE FTSE, *University of Queensland*  
Ms Ruby Lucas, *Frontline Management Institute*  
Mr Steve Ludlam, *ASC Pty Ltd*  
Mr Ian MacKinnon, *Queensland University of Technology*  
Professor Kostas Mavromaras, *National Institute of Labour Studies*  
Mr Peter Meurs FTSE, *Fortescue Metals Group Ltd*  
Professor Michael Miller AO FTSE  
Professor Suzanne Miller, *Queensland Museum*  
Ms Kate Morrison, *Vulture Street*  
Mr Dean Moss, *UniQuest Pty Ltd*  
Dr Craig Mudge FTSE  
Dr Tony Mulcahy, *Hospira*  
Mr John Murray, *Enterprise Connect, Department of Industry*  
Mr Peter Mylius-Clark, *Dept Further Education, Employment, Science & Technology (DFEEST)*  
Dr Ian Nisbet, *AIBN*  
Mr Peter North AM FTSE HonFIEAust, *The Warren Centre for Advanced Engineering*  
Dr John O'Callaghan FTSE  
Mr Ben Olsen, *Re-Time Pty Ltd*  
Mr Mick O'Neill, *Adelaide City Council*  
Mr Philipp Orth, *Fisher Adams Kelly*  
Mr Dean Parham, *Australian National University*  
Dr Christina Parolin, *The Australian Academy of the Humanities*  
Professor Ian Petersen  
Mr Bill Petreski, *Australian Industry Group*  
Professor John Phillimore, *John Curtin Institute of Public Policy, Curtin University*  
Ms Zoe Piper, *Australian Chamber of Commerce and Industry*  
Professor Barbara Pocock, *Centre for Work + Life, University of South Australia*  
Dr Ian Poiner FTSE, *IMOS/UTas*  
Dr Rob Porteous, *Department of Industry*  
Dr Simon Prasad, *Office of the Chief Scientist*  
Dr Roslyn Prinsley, *Department of Industry, Innovation, Science, Research & Tertiary Education*  
Mr Hutch Ranck, *Iluka Resources*  
Dr Leanna Read FAICD FTSE, *BR-Angels Pty Ltd*

Professor Timothy Reeves FTSE  
Professor Sue Richardson FASSA, *Academy of the Social Sciences in Australia*  
Dr Patricia Ridgway, *NHMRC*  
Ms Leigh Roach, *DSITIA*  
Dr Philip Robertson FTSE, *NICTA*  
Professor Alan Robson AO FTSE, *University of Western Australia*  
Dr Derek Rogers, *Saab Systems*  
Dr Jim Ross AM, *Western Australian Technology and Industry and Advisory Council*  
Mr Jonathan Russell, *Consult Australia*  
Mr Allan Ryan, *Hargraves Institute*  
Dr Les Rymer, *Group of Eight Universities*  
Mr Bill Scanlan, *ACIL Allen*  
Dr Retha Scheepers, *University of the Sunshine Coast*  
Dr Len Sciacca FTSE, *DSTO – Defence Science & Technology Organisation*  
Ms Carmela Sergi, *Flinders University*  
Mr Robin Shreeve, *Australian Workforce & Productivity Agency*  
Professor Kadambot Siddique AM FTSE, *University of Western Australia*  
Ms Gail Silman, *Australian Industry Group*  
Dr Ross Smith, *Science & Technology Australia*  
Mr Richard Snabel, *Department of Industry*  
Mr Peter Staley, *Australian Industry Group*  
Dr Jack Steele, *CSIRO – Corporate Centre*  
Assoc/Professor John Steen, *University of Queensland*  
Professor Deborah Sweeney, *University of Western Sydney*  
Dr David Thomson, *Department of the Prime Minister and Cabinet*  
Professor Michael Tobar FAA FTSE, *University of Western Australia*  
Dr Les Trudzik, *Allen Consulting*  
Mr Garrett Upstill, *UNSW Canberra*  
Dr Geoffrey Vaughan AO FTSE, *Board of the Advanced Manufacturing CRC*  
Dr Meera Verma FTSE, *Headland Vision*  
Assoc/Professor Martie-Louise Verreynne, *The University of Queensland*  
Mr Chris Vonwiller FTSE, *Appen Butler Hill*  
Ms Leonie Walsh FTSE, *AIRG*  
Ms Jennifer Wegner, *Department of Science Information Technology Innovation and the Arts*  
Mr Hui Wei, *ABS*  
Professor Terri-Ann White, *UWA Publishing*  
Mr Glenn Wightwick FTSE, *IBM Research – Australia*  
Mr Mark Wigley, *RDA Sydney*  
Dr David Williams, *CSIRO Information Services*  
Professor Mary-Anne Williams, *University of Technology Sydney*  
Mr Bob Williamson FAA, *Australian National University NICTA*  
Mr Bruce Wilson, *Department of Resources, Energy & Tourism*  
Mr David Wilson, *AusIndustry*  
Professor Marie Wilson, *University of South Australia Business School*  
Dr Sharon Winocur, *Business / Higher Education Round Table*  
Dr Glenn Withers AO FASSA, *Australian National University*  
Ms Amanda Wood, *Enterprise Connect*  
Dr Katherine Woodthorpe, *Australian Private Equity & Venture Capital Association Ltd*  
Dr Shiji Zhao, *Productivity Commission*  
Dr Paul Zulli FTSE, *Blue Scope Steel Pty Ltd*

## Consultation with international experts

The Expert Working Group (EWG) brought international experts to Australia to contribute to the development of the report:

### **Professor Jonathan Haskel, Imperial College, UK**

Professor Haskel is a leading international researcher on the relationship between public support for innovation and productivity growth.

### **Professor Alan Hughes, Cambridge University, UK**

Professor Hughes is the Director of the Centre for Business Research, Cambridge University. Professor Hughes delivered the keynote address to the Brisbane workshop organised by the Expert Working Group and the Australian Academy of Technological Sciences and Engineering (August 2013). Professor Hughes provided an international policy comparison of mechanisms for enhancing the impact of university-based research on company innovation and business performance.

### **Dr Dennis Fixler, US Bureau of Economic Analysis, USA**

Dr Fixler is the Chief Statistician of the Bureau of Economic Analysis, the US agency responsible for key policy variables such as Gross Domestic Product.

### **Professor Daniel Sichel, Wellesley College, USA**

Professor Sichel has had a distinguished career as a senior manager at the US Federal Reserve Board in Washington, DC, and published consistently in leading international journals.

## Conference participation

Expert Working Group members also participated in other conferences and events to gather input to the project:

- Expert Working Group members participated in a conference on Productivity Measurement, Drivers and Trends, organised by the International Association for Research on Income and Wealth (IARIW) and the Centre for Applied Economic Research at the University of New South Wales (UNSW), Sydney, 26-27 November 2013. The conference provided a valuable opportunity for the Expert Working Group to meet with and discuss productivity issues with the leaders in this field.
- Expert Working Group members participated in advanced manufacturing workshops organised by ATSE in February 2013 and February 2014, Adelaide.

## 2. Interviews and surveys

As part of the evidence gathering process, the following companies were interviewed by the Expert Working Group:

### Interviews

- AW Bell
- Botanical Resources Australia
- Cochlear Limited
- Halfbrick Studios
- Invetech
- MBD Energy
- Re-Time Pty Ltd
- ResMed
- Textor Technologies
- Westpac

### Surveys

As part of the evidence gathering process, a survey of Australian university Deans of science and engineering was conducted to investigate how universities address the current and future demand from industry for STEM-related skills and qualifications. Some 48 people were invited to take part in the survey, from a total of 36 institutions. Eleven responses were received from 10 different institutions.

## 3. Consultancy reports

The following work was commissioned by ACOLA Secretariat Ltd for the project.

**Title:** The relationship between innovation, productivity and internationalisation from a longitudinal dataset of Australian SMEs

**Prepared by:** Professor John Steen

**Date:** January 2013

**Title:** The effects of innovation on firm performance

**Prepared by:** Professor Elizabeth Webster and Professor Alfons Palangkaraya

**Date:** April 2014

All contributing reports can be found at:  
<http://acola.org.au/index.php/the-role-of-science-research-and-technology-in-lifting-australian-productivity-contributing-reports>

# Appendix 1

## HASS-STEM skill mixing in innovative Australian firms

Case studies of Australian businesses describing HASS-STEM skill mixing.

### Halfbrick Studios

Since its inception in the early-2000s, Brisbane-based games developer Halfbrick has come to be regarded by some as a metaphorical canary down the mine for Australian games companies, if not globally. Excelling in an industry that experiences radical changes almost weekly – from shifts in the global economy to the growing sophistication in customer needs – Halfbrick has garnered multiple industry and innovation awards and been lauded by the Australian government – in its white paper *Australia in the Asian Century* – as an exemplar for other growing companies. More than two years after its first release in 2010, their game *Fruit Ninja* was still in 2<sup>nd</sup>-place on the Top Paid iPhone Apps list.

Originally, Halfbrick – like most Australian games developers at the time – was a developer of licensed titles for platforms like GameBoy Advance, Nintendo DS, and PlayStation portable. Recently, though, the company has transformed its business model to become an independent games developer and publisher of its own titles for mobile devices. Halfbrick's principal business model depends on high-volume sales of games via micro-purchased App downloads – principally from Apple's iTunes store – and merchandising sales from branded T-shirts, posters, mugs and other products featuring characters and iconography from the games. The viability of this business model depends on the radical disintermediation pioneered by the iTunes store,

and Halfbrick earns an unprecedented 70 per cent return on every download.

But there are consequences for such growth, as CEO Shaniel Deo notes, "As we've evolved and moved more into publishing, we've had to move into the marketing and business side. When we started out, we just had the engineering and artwork design – we didn't even do the audio back then." This growth from a predominantly engineering background into software engineering, creative design, user-centred design, art design, storytelling, community relations management and advanced technical skills in cloud computing and social media analytics has required an evolution in recruiting and a cultural shift in what is expected of new staff and their peers.

Arguably, no other industry sector exhibits quite the same complex range but roughly equal balance of STEM-HASS inputs. For this mix to work, new staff members need to demonstrate a shared background in and passion for games, and this is a key plank in the Halfbrick recruiting platform. As an export-oriented company working into a global market, Deo explains that Halfbrick has few misgivings about maintaining their headquarters in Australia, "There are specific roles that are easier for us to hire from overseas and bring them back to Australia. But the bulk of what we do will be done here, and we'll continue to look for sharp young people who have a passion for making great entertainment." And besides, their target market is almost truly global: "It's pretty much world-wide – if they have electricity and the Internet, they like our

games! The glue that ties us all together here at Halfbrick is games – that’s a very important trait that we test for, regardless of the actual job ... We wouldn’t hire someone who didn’t have that because we need to have that common thread. It’s very important to bring everyone together and to be able to make something that requires all those different skills, *and* to have a shared knowledge. Even if they are an accountant, that’s fine – my cousin works here and he’s the CFO; for all intents and purposes he’s an accountant, but he still has that love of games, that passion for games – not as deep as everyone here, but he has that shared history and knowledge.”

Halfbrick has 75 staff based in Brisbane, with a new office recently established in Sydney, and there are plans to establish a San Francisco office. Forty per cent of staff have an engineering background, while 20 per cent having training in art, and 10-15 per cent in design, with the remainder a mix of sound specialists, quality assurance, community managers and administration. In recent years, however, the company has been forced to cast its recruiting net wider in response to the social media phenomenon, which has transformed the way games are used. *Cloud services* innovation in this fast-cycle global entertainment sector requires new skills mixes, as games lead the way in the creative industries moving from entertainment *products* to a *service*. In a ‘games as service’ model, new classics like *Fruit Ninja* need to maintain longevity, and this is only possible when the game can be integrated into new platforms and social media, and offer real-time virtual feedback.

Providing such qualities in the games industry requires the input of specialised skills in cloud services, virtual economies, and social media analytics, skills that while rare in the relatively new electronics entertainment industries in Australia, have been well-established in places like the US West Coast for more than a decade – hence the plans to build a foothold in San Francisco. As Deo notes, “We need to look outside our own industry – we’re going to move to *free-to-play* business models, premium models, and we need to build economies around our games. We’re already bringing in data analysts to look at what’s going on in the games and within the economy, and we want to bring in more people with backgrounds in economics.”

While internationally renowned economists like Hal Varian have been recruited by global corporations like Google, sourcing economics-literates for the games industry is a challenge says Deo, “These are people who love numbers and crunch numbers, and look at trends and figure out what’s going on. They might go to university and get an economics degree, but the last place they’ll think they might end up is in the games industry.” Despite this, lateral-thinking executives in European and US-based games companies have recruited well-known economists from places like the European Central Bank.

Ongoing challenges for Deo and his colleagues include “building economies around our games”, extracting profit from “virtual economies”, and recruiting those people “who love numbers”. In creative industries like Halfbrick, however, such recruiting can generate tension, particularly

among the foundation creative cohort, which questions the need for this bolstering of economics and social media analytics capacity. Says Deo, "As we align our strategy and say this is really about embracing our users and capturing them, and helping to increase retention and engagement with them, the creatives are starting to see why we're doing this. But initially there definitely was some pushback – they wanted to be left alone to create games and not have to worry about this stuff. Part of the overall process is definitely educating and showing these guys the cool things we can do with this stuff to enhance and amplify the work they do."

## Cochlear Limited

Cochlear is an Australian-founded company that develops electro-acoustic implants to restore hearing to the deaf, and offers a lifelong commitment to upgrade and service its technology, and support the local communities of their clients. While the story of the company is primarily about technological innovation, CEO Chris Roberts is quick to point out that in the context of the medical story of Cochlear, the technology came before the science, "We develop new technologies, new ways of doing things. But it's not until you put it the hands of the surgeon or the audiologist and they go out and use it clinically that you really understand what you have. Then you understand which aspects need to change."

In 2013, Cochlear celebrated their thirtieth anniversary of the manufacture and implant of their first device. While Professor Graeme Clark is credited with the first successful cochlear implant in the late 1970's, the intervention is a wonderful example of the power of iteration, miniaturisation and advances in technology. Chris Roberts also credits Cochlear as a visionary and collaborative company, "that by and large has been able to make sensible decisions for the long term, have invested technological innovation and R&D, and worked with the key opinion leaders around the world to develop these products and innovations."

With their permanent implants and upgradeable external components, Cochlear has established a 'rest of life' brand commitment that encourages client loyalty. Says Roberts, "The value proposition

of Cochlear's product involves a two-part system: the implant lasts a lifetime, but a great deal of intelligence sits external to the ear and essentially sends power and sound data to the implant. We don't have anything in the implant to wear out, but as the technology advances patients can replace the external piece." But the company has encountered and survived controversy. Roberts notes that although the early years of the company saw protest from deafness advocates over offering hearing where it was not wanted, "in countries like Australia and the US, the majority of new recipients getting Cochlear implants are not children. More people over the age of 65 are getting an implant than children. Increasingly there is an order of magnitude more deafness in adults than there is in children – the adults actually had speech and language; they heard, and then they went deaf."

Cochlear maintains their brand integrity – in particular, with potential clients – and retains their market share by building communities, and using volunteer networks, social media and events. In the US – and to a smaller extent in other regions around the world – the company coordinates 'Celebration', an event that allows implant recipients and those considering the process to gather and exchange stories and experiences. This 'Cochlear Community' and Cochlear's associated volunteer networks offer a living example of the value of *peer-to-peer* consultation in marketing a product, rather than relying solely on the *expert-to-user* experience. Roberts notes, however, that these methods are chosen on a "country to country" basis – a technique that might be successful in Germany may not work in China. A key example of the success of peer-to-peer (and even *user-to-expert*) marketing can be found in the work of Mike Noble, who received an implant as a child after going deaf. He won a Graeme Clark Scholarship as an adult, and now works with clinicians, implant recipients and new clients to promote and disseminate the positive message of Cochlear. As a *digital native* and having a lifetime of experience with the company's products, Noble acts as a powerful social media ambassador for Cochlear.

Since its establishment in 1978, Cochlear has gained more than 70 per cent of the global

market, with operations extending to the United States, Europe, India, Korea and Japan. Through innovation, internationalisation, and an appreciation of cultural diversity, the company offers autonomy to regional operations, and encourages locally developed engagement programs. Each region has dedicated country managers who address cultural and regulatory diversity, and coordinate multi-disciplinary teams that can handle local issues. At the clinical coalface, Cochlear works closely with surgeons and clinicians who have self-selected a very specific career in managing hearing disability. Through careful clinical and patient diplomacy and management, the company has established a powerful and loyal lobby that allows it to maintain its market share. Cochlear currently employs more than 2600 staff globally, with 75 per cent of its AU\$120-million R&D program based in Australia, and the balance in Belgium, Gothenburg and Colorado.

Technological innovation is at the core of Cochlear, which prizes technical expertise. Roberts believes that with the quantum of medical knowledge doubling every two to three years, the role of the company “is on the side of technological innovation, to scan the horizon for what technologies can be applied in combination with developing trends in clinical and medical knowledge so that innovation may change intervention.” However, a diverse range of disciplines and collaborations are vital to Cochlear’s success. For example, key non-technical skill sets include design thinking, social science (studies on social isolation), communication, understanding cultural diversity, marketing and community engagement. To foster interdisciplinary collaboration and gain access to a wider range of skills and expertise, Cochlear recently relocated to Macquarie University to form part of the world’s first precinct dedicated to hearing and related speech and language disorders. A key element of this collaboration focuses on trend analysis and prediction, but the scope for innovation is widened by nurturing relationships with all faculties, regardless of their ‘technical’ status.

## Westpac

Westpac are one of the few companies globally that have a team dedicated to using a *customer-centred design* approach. The company’s Digital Customer Experience Team consists of 20 people from varying and remarkably eclectic backgrounds – including fashion designer, anthropology, pure web design, product and technology design, and French philosophy – and is supplemented by external contractors depending on workload or project-specific specialist skill sets requirements. The team’s Chief Experience Officer is Ian Muir, formerly a mechanical engineer, who initially was employed by Westpac in the mid-1990s to design and market one of Australia’s first Internet banking programs using Windows diskettes mailed to customers, before being reassigned to develop Australia’s first banking website. Muir explains, “We followed a customer-centred design approach, which essentially involved customers in helping to resolve some of the fundamental flaws in the web design. There was a very tight correlation between that customer perspective – the business perspective of what we’re trying to achieve –and the technological capability that we had at the time.” Given the significant evolution in customer expectations over the following decades, Muir observes that the team’s practice and methodology, “has evolved into *collaborative design*, *customer experience design* and a more *service design* approach, which asks, ‘What are the services that customers might be wanting to achieve? How do we look at this from an end-to-end perspective? And, What is the journey that they might go on?’”

Like all of the ‘Big Four’ Australian banks, Westpac presented the Digital Customer Experience Team with many “conservative, complex and legacy-based systems and processes” associated with customers and the manner in which they needed service. But the team soon established that a style of *open innovation* was the most effective strategy in addressing fundamental issues and targeting the appropriate audience. One of Muir’s first innovative acts was to engage the services of Stephen Cox, a *design anthropologist* who initially consulted to Westpac in 2000, but now works full-time with the team. Cox’s background in anthropology and archaeology informed a radical new line of enquiry that sought to find the right solution for customers

by identifying what they actually 'needed'. The accolades and awards showered on Westpac's team by consumer groups led to subsequent research into business – and eventually corporate – Internet banking. This dedicated internal design practice has seen Westpac become the leading institution in the field, a feat maintained for more than a decade. While Westpac's competitors undoubtedly use similar techniques in small, distributed pockets of their banking practice, and invariably rely on externally sourced practitioners, Westpac remains one of the few financial institutions nurturing a dedicated creative team that can service such a magnitude of customer experience design practice.

In addition to customer-focused design practice, Muir's team has tailored a *design principles group* that specialises in disseminating successful initiatives throughout the organisation. Muir credits Cox and his colleagues with being able to, "identify and learn best practice, keep pace with appropriate levels of technique, and establish best practice in applying these techniques." For example, the group trains more than 500 people annually in developing a "more customer-centred approach", encouraging an understanding of customer mind-set in a variety of ways, including the development of competencies in data analysis and synthesis, prototype development, and app design. The design group has been lauded for its ability to use reflexive practices to inform and develop techniques and tools that can be used across the organisation. The Digital Customer Experience Team also conducts R&D that incorporates the use of ethnographic approaches that include cultural probes, contextual enquiry and observational research. While the team's core researchers come from such diverse fields as archaeology, mechanical engineering and philosophy, the rapid pace of technical change often means that state-of-the-art technical capabilities like app development and HTML5 programming are outsourced on a project-specific basis.

The Westpac team has recently liaised with academic institutions – in particular, collaborating with Roy Green at the University of Technology Sydney and University of Newcastle – to create a new, triangular design discipline that incorporates business and design thinking with university teaching. Muir explains, "There

is a higher order interest as to how we can complete this triangle back to the institutions and bridge back to the educational level. Language, philosophies and other disciplines may help bridge the divide that seems to exist between business thinking and design thinking." Currently, the customer- and service-centred design industry is fragmented within Australia, and predominantly involves SMEs that have a symbiotic relationship with larger companies, parlaying specialist services in exchange for the contracting abilities of the latter.

Westpac's Internet and mobile banking team is arguably unique among Australian companies in that its in-house development and cross-disciplinary composition – supplemented externally where necessary – has attracted favourable comparisons with the global design units of corporations like Google.

## ResMed

ResMed – a medical innovation company created in 1989 – specialises in commercialising devices for sleep breathing disorders such as *obstructive sleep apnoea* (OSA), and services a global market: 54 per cent of sales are in the US; 36 per cent in Europe; and 10 per cent in Asia. The company employs over 4,000 staff with core skills of systems thinking, communications and teamwork. In addition to technical prowess, ResMed values emotional intelligence and actively nurtures cross-functional teams that interact domestically and globally across the organisation. These strategies ensure cross-pollination of knowledge, and an appreciation of each other's expertise.

Senior Vice-President of Global Supply Operations, Anthony Claridge attributes the global success of ResMed in part to the competitive advantage the company has gained through careful cultivation of its key resource – people – "We're anxious to learn, and that's part of where we think our success is as an organisation – we wish to not stay where we are. We want to learn more; we want to be better. We think that this provides a competitive advantage, an agility of mind, and an ability to meet changing market trends – to be constantly on the lookout for change, to be part of it, or

leading it, or weathering it. We also have an acute awareness of what we don't know, and so when people come in with backgrounds from other industries, we're delighted to have a different perspective."

Over seventy per cent of the company's R&D and a significant portion of the manufacturing base are located at the Sydney site, where a large proportion of the 1,200 employees are engineers; the others are of a non-engineering background, including administration, marketing, sales and design. Overseas staff work closely with their Australian colleagues to share their knowledge of local markets, regulations and customs and in return the Australia based staff share their in depth knowledge of the products. Claridge explains that, "Where there is a recognised need for more local knowledge, effective management acknowledges that – if you can't do it well the way you're set up, then you need to adjust to make sure you find a way to do it well. Our cross-functional thinking, the fact of being born global, and also that we are a learning organization – all stem from Dr Farrell's desire to be looking for what we need to be next. We try and get ahead of the problem rather than ignore it."

Founder and CEO of ResMed, Dr Peter Farrell came from a background in chemical engineering before working in the mechanical engineering department at the University of New South Wales, where he first began to foster what would become ResMed's intimate links with the tertiary sector. Director of Global Talent & Succession Management, Pearl Daly explains the complex skill sets required of ResMed's engineers, "Our applied research group is typically looking at blue skies, five to ten to fifteen years out."

ResMed's largest business unit manages the patient interface – or the mask that the patient wears – which requires a significant amount of applied research. Daly explains the various skills involved, "It can be mechanical or mechatronic or product design for the conceptual thinkers, and then from the applied research into mechanical engineering, software and electrical engineering. Within mechanical, we have more of a bent towards very strongly analytical engineers coupled with industrial designers and those mechanical engineers who like the conceptual, front-end side. It's extremely important to get a

good balance in the design engineering team. Depending on where they're at in the product development life-cycle, we might change that mix accordingly." Claridge adds here that ResMed's product development is achieved using cross-functional teams, "The project leader is responsible for all of the engineering disciplines, the logistics, the manufacturing, the marketing, the quality, and the clinical factors – the whole spectrum." Overseeing the entire operation is the Sydney Leadership Team, which meets weekly and is aware of all aspects of design and production. As Claridge explains, "This is one of the areas which differentiates us from other organisations – we want to use the power of the organisation to achieve success, not the power of individuals, or a single silo's function."

Daly says that ResMed's *ACHIEVE* program, "ensures that everyone, irrespective of whether they have a science background or otherwise will know about the history of ResMed, the range of products that we make – these briefings are offered on a regular basis, and people are encouraged to up-skill."

Through their career portal, employees planning to change their position in the company can enhance their skill set by observing the overall organisational structure and key characteristics of different departments. She explains that ResMed is proactive in responding to feedback from managers about the skill sets they need, "Over the past twenty years, ResMed has continued to hire very smart people – so IQ is always very highly regarded, and these things are very important to us. We're now seeing an evolution where we still want smart people, but we also want our engineers to have better emotional intelligence, and we are including this aspect in our recruiting criteria. One of the requests from our Learning Centre saw one of our department heads asking for their engineers to be up-skilled in the art of influencing negotiations, self-awareness, being able to read a room. Also, we want our engineers and our high potential talent to be thinking about how we commercialise; at the end of the day, we are a business. We've had a very strong push towards people truly understanding that one of our key values is value consciousness and value from a financial perspective."

# Review Panel

This report has been reviewed by an independent panel of experts. Members of this Review Panel were not asked to endorse the Report's conclusions and findings. The Review Panel members acted in a personal, not organisational, capacity and were asked to declare any conflicts of interest. ACOLA gratefully acknowledge their contribution.

## Narelle Kennedy AM

Narelle Kennedy operates her own research and consulting company, *The Kennedy Company Pty Ltd* specialising in business innovation, new models of competitiveness and productivity, industry clustering, regional development, and regulation. Previously Narelle founded and led the pioneering, business-backed research think tank, the Australian Business Foundation as CEO for over 15 years. Narelle has proven expertise not only in building a body of research work and alliances with research partners, government, corporations and sponsors, but importantly in translating and applying research intelligence in practical outreach programs for policy makers and business. Narelle is Adjunct Professor with the School of Business at the University of Technology Sydney. This affiliation continues Narelle's longstanding commitment to close collaboration, problem-solving and knowledge-sharing between the higher education sector and the business community. Narelle was made a Member (AM) of the Order of Australia in the 2014 Australia Day Honours awards for significant service to business in Australia through a range of policy development and advisory roles.

## Dean Parham

Dean Parham is an expert on Australia's productivity performance. He was long associated with Australia's Productivity Commission where he developed and led the Commission's 'flagship' program of productivity research. Since 2008, he has continued to investigate productivity trends and public policy issues in association with a number of government, academic and private-sector agencies including the Australian Treasury, the University of Adelaide, Australian National University and the Productivity Commissions of both Australia and New Zealand. He is currently a Visiting Research Fellow at the University of Adelaide, a Visiting Scholar at the New Zealand Productivity Commission and the Principal of Deepa Economics.

# About Securing Australia's Future

In June 2012 the Australian Government announced Securing Australia's Future, a \$10 million investment funded by the Australia Research Council in a series of strategic research projects for the Prime Ministers Science, Engineering and Innovation Council (PMSEIC), delivered through the Australian Council of Learned Academies (ACOLA) via the Office of the Chief Scientist and the Chief Scientist.

Securing Australia's Future is a response to global and national changes and the opportunities and challenges of an economy in transition. Productivity and economic growth will result from: an increased understanding in how to best stimulate and support creativity, innovation and adaptability; an education system that values the pursuit of knowledge across all domains, including science, technology, engineering and mathematics; and an increased willingness to support change through effective risk management.

PMSEIC identified six initial research topics:

- i. Australia's comparative advantage
- ii. STEM: Country comparisons
- iii. Asia literacy – language and beyond
- iv. The role of science, research and technology in lifting Australian productivity
- v. New technologies and their role in our security, cultural, democratic, social and economic systems
- vi. Engineering energy: unconventional gas production

The Program Steering Committee responsible for the overall quality of the program, including selection of the Expert Working Groups and the peer review process, is comprised of three Fellows from each of the four Learned Academies:

Professor Michael Barber FAA FTSE  
(Chair)

Mr Dennis Trewin AO FASSA  
(Deputy Chair – Research)

Professor James Angus AO FAA

Professor Bruce Chapman AO FASSA

Professor Ruth Fincher FASSA

Professor Mark Finnane FAHA FASSA

Professor Paul Greenfield AO FTSE

Professor Lesley Head FAHA

Professor Peter McPhee AM FAHA FASSA

Professor Stephen Powles FAA FTSE

Dr Susan Pond AM FTSE

Dr Leanna Read FAICD FTSE

[www.acola.org.au](http://www.acola.org.au)



ACADEMY OF THE SOCIAL SCIENCES  
IN AUSTRALIA



**ACOLA**



**AUSTRALIAN  
COUNCIL OF  
LEARNED  
ACADEMIES**

# 4

PROJECT

