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Boosting productivity with innovation and new technologies

There is an urgent need for Australia to look at measures to increase innovation. Current measures are inadequate and Australia is lagging behind key international competitors, many of whom are rapidly growing their investment in research and innovation.

Dr John Bell, co-author of SAF04
The Role of Science, Research and Technology in Lifting Australian Productivity

Golden thread

Building the industries of the future will enhance productivity and ensure resilience. Adapting to change and creating new opportunities for all Australians in the future require increased investment in research and development, a commitment to innovation, better links between business and research, and the training and use of an innovation-capable workforce that effectively combines humanities, arts and social sciences (HASS) and science, technology, engineering and mathematics (STEM) capabilities for creative problem solving.

Key findings

Here are six key findings designed to support productivity growth:

1. Increases in research and development lead to productivity growth. Australia needs to raise the levels of research and development in the medium term to at least the OECD average.
2. Institutional reforms coupled with increased government spending on infrastructure, on labour force participation, and on education and training would dramatically raise national productivity.

3. Countries that do better than Australia in innovation feature policy setting and programs that encourage a culture of innovation and collaboration.
4. Research translation and application need to be a key element of Australian innovation strategy.
5. A skilled and productive workforce is essential for economic growth, with innovation requiring excellence and creativity across the range of disciplines.
6. Technology research and development support should be focused on technological areas, not on existing industry sectors.

Introduction

Productivity is critical for Australia's prosperity, economic growth and social wellbeing. Study after study reveals that increasing productivity requires research and development. But what exactly is productivity? Productivity is the efficiency with which an economy transforms inputs, such as labour and capital, into outputs, such as goods and services. Lifting productivity means producing more goods and services from the same quantity of labour, capital, land, energy and other resources. Doing so can markedly help the economy, generating higher real incomes and long-term improvements to our living standards.

The Australian Bureau of Statistics tracks economic health via a comprehensive measure known as multi-factor productivity. Multi-factor productivity is largely a measure of the effects of technical progress, improvements in the workforce, improvements in management practices and economies of scale. Over the long term, this measure represents technical progress, which is the primary source of real economic growth and higher living standards.

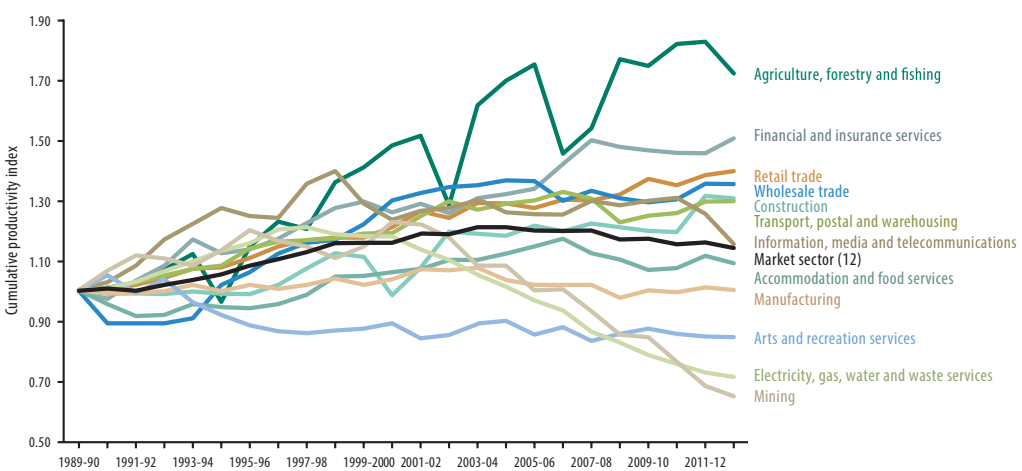

Fig. 3.1. Multi-factor productivity performance for 12 core market sectors, as well as their aggregate 'Market sector 12', from 1989–90 to 2012–13. (Source: Australian Bureau of Statistics (2013) *Estimates of Industry Multifactor Productivity*, cat. no. 5260.0.55.002, Australian Bureau of Statistics, Canberra)

Australia's performance has varied over the last decade. Up until 2003–04, multi-factor productivity grew strongly. Since 2004–05 however, multi-factor productivity has declined in most years (Fig. 3.1). Given the importance of productivity to Australians' living standards, this decline is of significant concern.

While many factors influence a country's productivity, innovation is the key.

Australian labour productivity (simply put, the amount of output produced by an hour of paid work) has also dropped. Between 1995–2004 and 2005–12 there was a reduction in all sectors except construction. Add our ageing population to the equation and it's clear that if we are to have future growth in living standards, we need productivity growth.

Sources of productivity growth

1. Changes in the quality and quantity of labour and other inputs. Examples include skills, improvements through education, and improvements in physical capital such as computing.
2. Diffusion of ideas: new knowledge spreads through training and adoption of new equipment.
3. Technological improvements, including new techniques, inputs and products.
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, including improvements in management and workplace organisation.
6. Changes in the functioning of markets, namely regulatory change that removes barriers to efficient market operations.
7. Returns to scale: large markets justify the establishment costs for the large-scale production of standardised goods, provide an outlet for specialised goods, and allow firms to produce multiple products for diverse consumers using the same machinery.
8. Changes in incentives, due to changes in the regulatory environment, taxes and trade opportunities.

Increases in research and development lead to productivity growth.

What is the relationship between research and development and productivity? While many factors influence a country's productivity, innovation is the key. A study in 2001 of 16 countries spanning nearly 20 years found that increases in research and development lead to productivity growth. A 1 per cent increase in business research and development creates a long-run increase in productivity of 0.11 per cent. Even more impressively, a 1 per cent increase in public research created a 0.28 per cent productivity increase. These numbers are significant compared with the average annual rate of growth of Australian multi-factor productivity of around 0.8 per cent.

Public sector research and development expenditure by Australian government research agencies, the Australian Research Council and the universities has wide benefits and is an important source of gains in productivity. Moreover, private sector research, innovation and other intangibles benefit the community as well as business. However, Australian investment in research and development is below the OECD standard. Countries such as Sweden, Japan, Switzerland, the United States, Germany and Singapore invest significantly more in research and development than Australia.

The institutional and capability reforms described in this chapter would lift Australia's performance to OECD best practice standards; doing so would be an important policy objective.

Investing in ourselves

> *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 (2011) *Skills for Innovation and Research*. OECD, Paris.

In Chapter 1 we saw the value of investing in education, training and research and development. ACOLA's SAF01 *Australia's Comparative Advantage* report panel commissioned detailed economic modelling that explored the impacts of the government increasing its investment in Australia's capabilities. There were two scenarios modelled: one involving broad, institutional policy change designed to improve political, legal and market structures, and the second entailed a 10 per cent increase in spending on infrastructure, on education and training, and encouraging higher labour force participation.

The forecast returns on these changes are considerable. Implementing both scenarios dramatically improves the economy, lifting gross domestic product (GDP) per capita by almost 10 per cent within years. Consumption per capita takes a little longer to improve but does so considerably. Over the long term, there are projected gains of 25 to 30 per cent

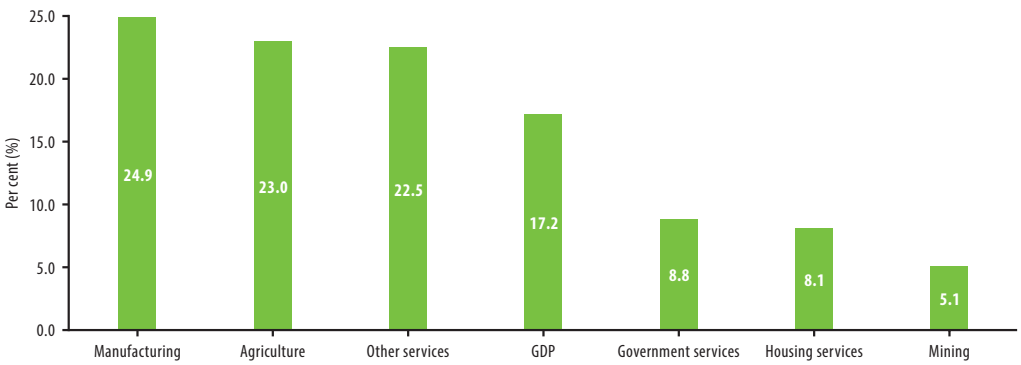

Fig. 3.2. Projected industry sector GDP gains by the year 2030 from combined institutional and investment reforms. (Source: Independent Economics (2015) *Australia's Comparative Advantage: Economic Scenarios*. A report for the Australian Council of Learned Academies, ACOLA, Melbourne, accessed from <http://acola.org.au/wp/australia-s-comparative-advantage-contributing-reports/>)

in both GDP and consumption per capita. Employment is stronger and labour productivity higher. Real after-tax wages rise, with a gain in incomes for low, middle and high skill employees.

The reforms benefit some industries more than others, although all are winners. The biggest winner from comprehensive reform is manufacturing, as economic growth increases demand for manufactured goods. Agriculture is also a bigger winner, as it is boosted by free trade agreements. Figure 3.2 shows the real GDP gains industry by industry by 2030 from the reforms. The gain in total GDP in that year is an impressive 17.2 per cent.

The reforms could represent just the beginning of lifting national productivity. Furthermore, industry-specific measures, as well as wider economic and other changes, could improve performance even more.

Policy changes that help us meet these objectives can bring major benefits.

Innovation

In 2010 the OECD identified key elements of an effective innovation strategy. These include:

- excellence in higher education;
- strong links between universities and industry;
- international mobility and cooperation for researchers;
- excellence in public research;
- ease of market entry and exit for small firms;
- access to finance by small and medium enterprises;
- well functioning venture capital markets;
- more symmetric tax treatment of profits and losses;
- research and development tax credits;
- the availability of high speed broadband internet;
- patent regimes that strike an appropriate balance between providing incentive and rewards to innovators and providing access to new knowledge for users.

Transforming research into value

ACOLA's SAF09 *Translating Research for Economic and Social Benefit: Country Comparisons* report panel sought to determine how best to convert research into applications, based on international approaches to encouraging and facilitating research translation, commercialisation and collaboration. They did this because innovation in Australia suffers from a lack of direction, short-termism and a haphazard approach. We need to urgently improve the application of publicly funded research in order to generate economic and other benefits.

The 14 nations studied were Finland, Denmark, Sweden, Germany, United Kingdom, Israel, United States, Canada, South Korea, Japan, Singapore, China, Brazil and Chile. There is a clear link between national policy on innovation and innovation performance. Countries that do better than Australia in innovation feature policy setting and programs that encourage a culture of innovation and collaboration.

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In a modern knowledge-based economy, boosting the ways in which new ideas are applied is an important priority and can be facilitated by measures such as increasing the levels of collaboration between researchers, businesses, not-for-profit sectors and government sectors. There is the opportunity for Australia to leverage the skills and knowledge in universities through sponsored research, bringing about closer collaboration between publicly funded researchers, industry, government and the community. Applying the findings here should increase the uptake of all research – in humanities, arts and social sciences disciplines, science, technology, engineering and mathematics.

Public sector research is a major part of Australia's research system. Most of Australia's researchers work in the public sector. Translation of public sector research into economic and social benefits can be difficult; this is especially so in Australia, where there are relatively few companies undertaking research and development. Researchers find it difficult to find companies with which to engage. So there is little surprise that Australian company collaboration on innovation activities with the higher education sector and public research institutions ranks lowest of the 33 countries in the ACOLA comparison.

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Reaping the rewards

Investment in public sector research generates many benefits. University research helps to ensure that students graduate with up-to-date skills that can be applied to benefit the economy and society. Research outcomes provide us with new products and processes and help industry become more efficient and competitive. More broadly, university and public sector research helps to identify and address pressing social and economic problems in areas such as health care, energy and the environment. There are strong economic benefits from publicly funded research.

The OECD economies are increasingly based on knowledge, information and technology, which drive productivity and economic growth. An important feature of a 'knowledge economy' is the strength of connections and collaboration. Publicly funded research institutes and universities employ and educate highly skilled individuals who have the capacity to deliver innovative technologies, services and knowledge to address national and global challenges. However, knowledge *per se* is of limited value: it needs be translated, communicated and applied. Recognising the importance of this flow of knowledge to application, many countries have invested in linkages that help match researchers and users. The users convey to researchers the kind of knowledge they need, and the researchers get help in finding people and businesses that may be adept at applying their ideas.

Governments play a critical role in implementing polices that can support and drive innovation. Their role in ensuring public investment in science and research, and encouraging and supporting innovation within the private sector, is vital.

The 14 countries studied in ACOLA's SAF09 *Translating Research for Economic and Social Benefit: Country Comparisons* have a mixture of policies and programs to encourage and

enhance the application of research. These include funding for start-ups, university-based incubators and technology parks, intermediaries, management and licensing of intellectual property, and training and mentoring for university student and faculty entrepreneurs. There are programs that help researchers collaborate, assistance to businesses, exchange and placement of researchers, technology transfer support and intellectual property support.

Governments play a critical role in implementing polices that can support and drive innovation. Their role in ensuring public investment in science and research, and encouraging and supporting innovation within the private sector, is vital.

There are numerous examples of stable, well-designed and funded measures in other countries that have created jobs, increased business turnover and provided other benefits. Australia would be well served by applying successful overseas incentives to encourage researchers, universities, business and other parties to work together.

Small and medium-sized enterprises (SMEs) are effective converters of public sector research. They are often able to take up and adapt new ideas quickly. SMEs are an important source of future jobs and economic growth. However, they often do not know where to go to find help, or to seek research outcomes, from universities. Supporting SMEs and start-ups with high growth potential will help to increase the translation of our public sector research.

Small and medium-sized enterprises will help to translate public sector research into practical impact. (Source: Monkey Business Images/Shutterstock)

Australia is overly reliant on indirect support for business research and development through the associated tax incentives. Greater use of direct measures such as grants, loans and procurement contracts would improve research collaboration and translation. Increasing funding for research collaboration programs and requiring rigorous engagement between the parties involved will also help. Australian research collaboration programs, such as the Australian Research Council's Linkage Program, would benefit from expansion of the program and reforms such as adoption of leading grant administration practices from overseas.

Humanities, arts and social sciences (HASS) disciplines make many contributions to social wellbeing and economic advances. For this reason, some countries have adopted specific measures to encourage HASS engagement and collaboration. HASS researchers should also be eligible for measures to encourage public sector researcher engagement with external parties.

Pathways to impact

The UK Research Councils require an acceptable Pathways to Impact statement before a research grant recipient can start work. The impact sections of grant applications must explain the following:

- Who is interested in the research?
- Why are they interested? What are their agendas?

In addition, the Pathways to Impact statement has to address the following questions:

- How is the grant recipient going to engage external stakeholders?
- What will the grant recipient do to connect with them?
- Why are the chosen channels appropriate?
- What evidence is there to indicate that this will work?
- When will these activities take place and what is the rationale?
- How much will these activities cost? (Sufficient provision has to be made in the budget.)
- Who is going to manage this part of the project and what experience do they have?

Fostering collaboration

Programs that support the placement of students and new graduates within organisations will help to transfer new creative and technical skills to the business, government and not-for-profit sectors. Work-integrated learning placements can also help build relations between universities and external agencies that can lead to future collaborations.

Australia's Cooperative Research Centres Programme represents a good model for encouraging collaboration. Projects require a joint proposal from public sector researchers and external partners (often business). The collaborating parties need to agree on their objectives and how they will work to achieve them. The external agency often brings a commercial perspective to the deal. The collaborating parties are usually expected to provide a clear indication of the outcomes that they expect to achieve and the likely value of those outcomes to business and society.

In the United Kingdom, introducing metrics for university engagement with external parties, and rewarding this engagement, has increased research translation. We could emulate this approach.

Technology transfer offices are an effective way for universities to engage with businesses and governments. Countries including Chile, Brazil, Israel and Sweden provide support for the offices, which can assist with raising funds for research and licensing and creating start-up companies.

Most of the countries reviewed assist the establishment of start-up companies from universities and, in some cases, from government laboratories. To have a chance of success, start-up companies need to have intellectual property strategies and business strategies, an analysis of market prospects, finance and other commercial inputs, and researchers willing to engage in the development process.

In Australia, CSIRO employs commercial and business development managers who help researchers establish relationships with companies. This is a sound approach because engaging with commercial partners from the early stages of research is more likely to lead to the eventual translation of the results into economic and social benefits.

Many of the countries examined, including Singapore, Japan and Germany, have adopted measures to help the outcomes of public sector research enter the market. Such measures would address a major gap in Australia's innovation system. Additionally, adequately funded intermediary organisations can assist public sector research agencies form productive linkages with small and medium-sized enterprises.

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Training researchers in translation, collaboration and entrepreneurship is a feature of leading universities in Europe. It is most important at the Master's degree and PhD stages.

Checklist for encouraging research translation

ACOLA's SAF09 *Translating Research for Economic and Social Benefit: Country Comparisons* report panel's extensive international and national examinations of successful research translation activities yields the following findings:

- Business leadership of collaborative activities – as a general rule, the party that is to generate economic or social benefits from engagement or research translation should be the one to lead the project and receive and manage grant funds from government.
- Cost sharing – where business is expected to gain benefits from research translation, business should make some contribution to project costs.
- Research partnerships – effective research engagement and translation require the active involvement of both the public sector researchers and the would-be beneficiaries, working in partnerships.
- Working in industry facilities – public sector researchers engaged in research collaboration and translation should, wherever possible, spend time working in industry facilities in order to gain a better understanding of the environment in which the outcomes of the research will be applied.
- Support for commercialising research – there are several examples where researchers are supported to undertake further research in order to get their work to the point where an external party might support the project into an application phase.

- Appropriately skilled selection committees – grants for research claiming to have translation potential should be decided by committees that include business and translation experience.
- Rapid assessment of translation proposals – proposals for the support of research collaboration need to be assessed quickly and preferably continuously. Conducting calls for proposals once or twice per annum is unsatisfactory.

National innovation strategy

Our review shows how our policies and supportive programs are piecemeal, opportunistic and almost invariably short-lived.

– John Bell, co-author of SAF09 *Translating Research for Economic and Social Benefit: Country Comparisons*

Research translation needs to be a key element of a national innovation strategy. Countries achieving high levels of public sector research translation provide a sound institutional basis for this activity by making it a well-resourced, important element of a national innovation strategy. Australia can emulate overseas successes by doing the same.

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To be successful, government programs to encourage research translation should include:

- Program stability – most of the measures in use in other countries have been in place for many years. Business, in particular, dislikes frequent changes in the names and rules of support programs.
- Program continuity – businesses will not enter into discussions about research translation projects if there is any doubt over continuity of funding.
- Evaluation of measures – most countries reviewed undertake regular evaluations of their measures to encourage research translation. This often results in minor adjustments to eligibility requirements and levels of support.

Independent reviews and evaluations of research translation measures ensure that they are achieving their objectives. Leading practice countries regularly commission independent evaluations of innovation and research translation measures and make the evaluations public.

Innovation requires skilled labour and collaboration across disciplines

While STEM expertise is necessary, deep content knowledge and technical skills need to be complemented by other disciplines. Regardless of their primary qualification, all future workers will need the broader attributes to constantly reinvent their businesses and jobs.

– Stuart Cunningham, co-author of SAF10 *Skills and Capabilities for Australian Enterprise Innovation*

A skilled and productive workforce is essential for economic growth. Skilled labour is one of the main contributors to productivity gains through innovation. Skilled staff and recruits have the knowledge to improve and adopt new processes to lift business productivity. Technology-based industries need science, technology, engineering and mathematics skills to innovate and compete. However, they also need staff who understand systems, cultures and the way society uses and adopts new ideas. People skilled in humanities, arts and social sciences have a vital role in supporting innovation.

A skilled and productive workforce is essential for economic growth.

Staff need to be flexible and continue to acquire new skills. Important workplace skills include creativity, problem solving, adaptability and preparedness to continue learning. Successful organisations need people with team-building capacity, emotional intelligence, market analysis ability and cultural sensitivity. Organisations need strategic visioning skills; that is, the ability to describe the organisation's purpose and map out how it will achieve this in the coming years. Organisations whose performance is based on knowledge and its application require a combination of staff from science, technology, engineering and mathematics backgrounds collaborating closely with those with expertise in humanities, arts and social sciences.

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An Australian study by the Council for Humanities, Arts and Social Sciences titled 'Collaborating across the sectors' explored characteristics that typify a successful collaboration. The study, which involved more than 600 respondents, found that cross-sectoral collaboration leads to innovative solutions to problems, development of commercial products, collaboration with community services, and stronger engagement with clients. Teams and individuals involved in these collaborations gain from the process, which also broadens social and professional networks.

One of the study participants explained:

> *We make sure we employ people who are open, like working in teams, curious, are not really precious about their favourite method – because the sort of work we do is very applied. You have to be able to give up a lot of your adherence to the norms of your discipline – to be willing to do what it takes to help the client – to step outside what you are comfortable with. A lot is happening at the boundaries of what is already known.*

The study concluded that 'cross-sectoral collaborations will not flourish in Australia without positive actions by government, funding institutions, researchers and industry'. Collaboration can be expensive and time consuming. Hence, cross-sectoral collaboration is 'most likely to be profitable when the issues or problems being tackled cannot be dealt with by one sector alone'.

The main message from the study is that paying close attention to clients and users should help organisations develop successive waves of innovation. The information

Cochlear: hearing the need for cross-sectoral collaboration

Cochlear is a $6 billion Australian-founded company that develops electro-acoustic implants to restore hearing to the deaf. The company offers a lifelong commitment to upgrade and service its technology.

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.

Cochlear prizes technical expertise. The quantum of medical knowledge is doubling every two to three years. In an interview for ACOLA's SAF04 *The Role of Science, Research and Technology in Lifting Australian Productivity* report, then CEO Chris Roberts said that 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'.

A diverse range of disciplines and collaborations is vital to Cochlear's success. Non-technical skills 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 relocated to Macquarie University in New South Wales to form part of the world's first precinct dedicated to hearing and related speech and language disorders. The collaboration concentrates on trend analysis and prediction, but the potential for innovation is widened by nurturing relationships with all faculties.

Cochlear has demonstrated success for over 30 years in developing hearing implants.
(Source: Elsa Hoffmann/Shutterstock)

Halfbrick Studios: more than a game

Fruit Ninja and Jetpack Joyride bear witness to the power of collaboration. These globally popular titles are the products of Halfbrick, a games developer founded in Brisbane in the early 2000s.

Halfbrick began as a developer of licensed titles for platforms such as GameBoy Advance, Nintendo DS and PlayStation portable. The company then transformed into an independent games developer and publisher of its own titles for mobile devices. The business depends on high-volume sales of games via micro-purchased app downloads.

The company has grown from a predominantly engineering background into one that includes software engineering, creative design, user-centred design, art design, storytelling, community relations management and advanced technical skills in cloud computing and social media analytics. Forty per cent of staff have an engineering background, while 20 per cent have training in art and 10–15 per cent in design, with the remainder a mix of sound specialists, quality assurance, community managers and administration.

gleaned from the clients will also help dictate the right skills mix for an organisation. Getting the relationship right between technical staff and those with humanities and social sciences skills is a critical factor for efficiency and productivity. The balance will play a major role in achieving alignment between production inputs, the production process and uptake in the market.

Building effective and productive multidisciplinary teams is not easy, but it is vital.

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Bringing it all together

Unsurprisingly, given all the evidence provided by ACOLA's multidisciplinary research, countries investing more in skills report higher rates of innovation activity.

Improving cross-sectoral collaboration entails far more than increasing the supply and diversity of skills at the individual level. Rather it is about how skills can be combined within organisations, industries and innovation 'ecosystems'. It is also about how these skills can be combined with physical capital and effective organisational systems to yield new ideas that generate new products or services, new applications of technologies in production and new ways of marketing and distributing those goods and services.

The way in which Australian enterprises use and manage skills and capabilities is a critical component of the broader strategy needed to enhance our innovation performance. We need to improve the way we turn knowledge into products to become more efficient and successful innovators.

ACOLA's SAF10 *Skills and Capabilities for Australian Enterprise Innovation* report panel has undertaken the first in-depth investigation of how Australia's best-known innovative enterprises build and combine technical and non-technical skills to develop new products and services and to capture new markets and consumers.

Westpac: banking on collaboration

Westpac has a team dedicated to customer-centred design. The company's Digital Customer Experience Team consists of 20 people from varying and remarkably eclectic backgrounds – including fashion design, anthropology, web design, product and technology design, and French philosophy. The team is supplemented by external contractors depending on workload or project-specific specialist skill sets requirements.

Chief Experience Officer, Ian Muir, says that the team's practice '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?'

The team dealt with many 'conservative, complex and legacy based systems and processes' associated with customers and the manner in which they needed service. However, the team soon established that a style of open innovation was the most effective strategy in addressing fundamental issues and targeting the appropriate audience. A design anthropologist applied his skills to help develop a radical new approach that sought to find the right solution for customers by identifying what they actually 'needed'.

Westpac has a design principles group that specialises in disseminating successful initiatives throughout the organisation. The approach, according to Muir, is 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 (critical analysis of everyday working practices to improve competence and promote professional development) to develop techniques and tools that can be used across the organisation.

The 2015 Global Innovation Index reveals that Australia is a relatively inefficient innovator. Our overall ranking for innovation inputs is a reasonable 10th. However, our ranking for innovation outputs is 24th. The index shows that Australia has the relevant skills but lacks the capacity to manage and use these skills and other inputs for innovation. This issue should be a considerable concern to any government seeking to support and sustain innovation.

The Australian Bureau of Statistics's Business Characteristics Survey identifies barriers for applying innovation. The single most often stated barrier is the lack of access to the funds needed to develop and implement innovation: almost one-third of all innovation active businesses reported the problem. However, the single most significant barrier overall was a lack of access to skills. The skills shortages include those within businesses, in the catchment area and, more generally, in the labour market.

ACOLA's SAF10 *Skills and Capabilities for Australian Enterprise Innovation* report panel commissioned Swinburne University of Technology to undertake a statistical

analysis of the factors associated with innovation performance among Australian businesses. The analysis confirms that different types of skills are more important for different types of innovation. Science, technology, engineering and mathematics skills are more strongly associated with innovation in products and processes, while business skills are associated with process, organisational and marketing innovation.

Many Australian enterprises need to develop a different type of workforce with a different skills profile. For example, engineers not only need to know how to construct a sound apartment building – they also need to understand market conditions and customer preferences and how these might change in the future. They need to understand design and aesthetic aspects, and they require the communication and negotiation skills to 'sell' their idea to superiors.

Our future workforce needs to combine technological expertise with the ability to effectively and efficiently integrate various knowledge bases and skill sets, and deploy 'soft skills' including team-building capacity, emotional intelligence, strategic visioning, market analysis and cultural sensitivity.

Skills for innovation

- Basic skills – covering numeracy, reading and comprehension, written expression (literacy), active learning, oral expression, problem solving, critical thinking, self-awareness and digital literacy.
- Knowledge skills – knowledge drawn from science, technology, engineering and mathematics and the humanities, arts and social sciences. Knowledge skills lie at the foundation of 'knowledge organisations' (that is, organisations that create, manage, use and transfer knowledge-based products/services). These skills are now essential features of businesses in manufacturing and in the mining, agricultural and service industries.
- Technical and technician skills – areas such as equipment maintenance, installation, repair, operation and control, machine programming and software maintenance, quality control, technology and user experience design, and troubleshooting.
- Creativity, design and cross-cultural skills – idea and opportunity creation (which may or may not be sourced from science and technology), problem solving, integrative thinking, ingenuity, and customer orientation including cross-cultural understanding within and across multiple global markets.
- Entrepreneurial skills – abilities related to starting a business, whether as a start-up company or as a new venture in an established organisation, including an ability to focus on satisfying customer needs and wants.
- Business skills – implementation and administration of critical business systems and processes, including sales and marketing, accounting and finance, materials procurement and supply, project delivery, recruitment and motivation of employees and contractors, and management of time.
- Management and leadership skills – judgment and decision making, communicating and coordinating with others, emotional intelligence, negotiation, persuasion, organisation culture, training and teaching others.

ACOLA's SAF10 *Skills and Capabilities for Australian Enterprise Innovation* report panel has examined the role of government, industry, and education and research institutions in developing innovation skills and capabilities. Drawing on prior studies and extensive interviews with industry leaders and innovation experts, the commissioned work identified sets of skills for innovation (see the box, 'Skills for innovation'). Innovation requires a wide range of technical and non-technical skills. Most of the skills relate to managing oneself and others (for example, leadership, collaboration and organisation) and combine knowledge and skills from different disciplines.

Innovation requires a wide range of technical and non-technical skills.

Thankfully, an organisation does not need to have all of the skills and competencies to initiate and sustain innovation. Organisations can profit from working cooperatively and in competition, developing and even sharing capabilities relating to new innovations.

Tinkering, failing and adapting: working with new technology

All new technologies disrupt the current way of doing things; this brings both benefits and disadvantages. The challenge is to leverage and share as many of the rewards while limiting any damage.

– Robert Williamson, co-author of SAF05 *Technology and Australia's Future*

3D printing is one new technology that is already driving innovation in health, manufacturing and other sectors. (Source: CSIRO)

Technology is all around us. Every home, every school, every workplace and every entertainment venue incorporates technology, much of which would have been unimaginable a generation ago.

We intuitively understand what the term 'technology' means, although producing a succinct definition is no simple task. ACOLA defines technology as 'knowledge of everything – products, processes, and forms of organisation – that can create economic value'. Listing examples of technology is an easier task than trying to robustly define the term.

'Technology' includes a broad selection of processes, products, materials, structures, information and practices. The word can encompass groups of similar things such as furniture, clothing, genetically modified organisms or calculators. It may be captured by sector-specific terms, such as biotechnology, transport infrastructure, public health and mining technology. It might describe collective needs or uses such as information and communication, energy generation and storage, fabrication, transport or sanitation.

Technological development has been the prime driver of economic transformation and a major force for social change throughout much of human history. Economic, social and cultural activities drive technology diffusion, adoption and innovation, all of which take place in an environment of change and uncertainty.

A history of invention

> *The outstanding characteristic of our civilization is its complete dependence on invention. We are entirely surrounded by inventions and their resulting products. Our very existence, our comfort, and happiness are at the mercy of invention. Every fiber of our social system is permeated with invention. It is the cornerstone of our civilization and a very life-blood of its existence.*
>
> *It is now universally acknowledged that the tremendous progress of this country … is due to invention.*

These words apply just as much today as when Joseph Rossman, a patent examiner based in Washington DC, wrote them almost 100 years ago. Rossman wanted to know why inventors invent. He surveyed 710 inventors and described the findings in his 1931 book, *The Psychology of the Inventor: a Study of the Patentee*.

The number one response that inventors gave in answer to Rossman's question, 'What motives or incentives cause you to invent?' was a love of inventing.

The patent examiner concluded: 'The sheer joy of inventing, resulting from an irrepressible urge to invent, has been felt as the greatest urge by the inventors of this study. The pleasure resulting from manipulation and experimentation, the satisfaction of solving problems and the desire to create, were considered sufficient in themselves as objectives by the inventors.'

Later studies on independent inventors and professional research scientists found that both score abnormally high on aesthetic personality values. They value beauty and elegance for its own sake. In other words, creativity is central to technological change.

Technology reports

ACOLA's SAF05 *Technology and Australia's Future: New Technologies and their Role in Australia's Security, Cultural, Democratic, Social and Economic Systems* report panel commissioned 13 reports on various aspects of technology. The reports, available online, are part of a detailed investigation of how technology changes, whether these changes can be predicted, what the consequences or impacts of those changes might be, what technology means to people, and ways to evaluate and make technological interventions.

The reports include:

- Bottling sunlight: using energy storage technology as a lens to view the factors affecting technological change in the electricity supply industry;
- Collective technologies: autonomous vehicles;
- Digital computing, modelling and simulation;
- From Frankenstein to the Roomba: The changing nature and sociocultural meanings of robots and automation;
- Genetically modified crops: how attitudes to new technology influence adoption;
- Printing the future? An analysis of the hype and hope of rapid prototyping technology;
- Technology and work;
- Performance-based research funding – an overly simplistic technological intervention.

Australia's technology capacity

Technological change supports long-term economic growth. It is an intrinsically uncertain process. Nations have differing capacities to adapt to it, and skills underpin this difference.

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Technological innovation and progress result from trial and error, mistakes and unexpected successes. Technology is developed and improved by trial and error: no new technology product or artefact is perfect. Technologies fall in and out of favour. Australia's capacity to adopt emerging technology will, in part, depend on the approach of the public, governments, industries and businesses to uncertainty and failure (see Chapter 5).

Australians are just as entrepreneurial and risk taking as citizens of equivalent OECD countries. The RAND Corporation, a US global policy think tank, published *The Global Technology Revolution 2020*, which concluded that Australia has an excellent capacity to acquire a broad range of technologies. The report assessed 29 countries on their capacity to adopt selected emerging technologies to promote economic and social progress, ranking Australia as having the capacity to acquire all 16 of the report's chosen technologies. Factors important to the uptake of technology by Australian business and industry include cost; policies, regulations and laws; collaboration; open data; and privacy and security.

It is better to focus on the desired goal rather than trying to pick a technology winner. For example, a policy goal of decreasing carbon emissions is best achieved by allowing innovative solutions to emerge. Policy stability will encourage long-term investment in

most industries. Collaboration between research, university, business and industry sectors is crucial to solving major problems and creating a highly skilled workforce.

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A consistent message throughout this book is the importance of skills. Skills are needed to develop, adapt and apply new technologies. A study of technology adoption internationally by Comin and Hobjin in 2004 stated that 'the most important determinants of the speed at which a country adopts technologies are the country's human capital endowment, type of government, degree of openness to trade, and adoption of predecessor technologies' (*Journal of Monetary Economics* **51**, 39).

A better understanding of basic scientific knowledge and quantitative skills can help people to deal with, and apply, technology. Preparing students in science, technology, engineering and mathematics courses will improve their understanding of basic scientific and technological knowledge. Technology, of course, involves far more than science and maths, and often entails value decisions. Many emerging technologies trigger debate about ethical, legal and social implications from invention to use. The humanities disciplines are vital in helping us decide when, how and in what circumstances it is appropriate to use new technologies.

The context in which technology is deployed affects its impacts. Technology and human nature are closely related: just as we change technology, using technology changes us. Technology changes the way we act, think, learn and socialise.

We are part of an increasingly connected international system. Globalisation is an impact of technology, with implications for security, culture, democracy, governance, society and the economy. Information and communications technology and transport technologies, in particular, facilitate globalisation. Globalisation and technology have differentially affected Australians, producing costs and benefits to the nation. Some people have benefited and some have been disadvantaged, both domestically and internationally.

Technology and economic policy are inextricably linked. Government needs to explicitly consider the benefits as well as the risks of new technology. Saying 'no' is often an easier choice for government than permitting innovation. However, blocking or delaying new technology due to excessive fear of the risks relative to the benefits (such as with new medical drugs) can slow economic growth and lower living standards.

The role of education

To tinker is to test, experiment, make mistakes and keep trying. As such, it is a valuable skill for innovation. Tinkering entails trying to improve or repair something in a casual way. Making things and then making them better is what we and our ancestors have been doing for millennia.

Schools and universities can encourage creativity by providing greater opportunities for hands-on tinkering and building. We don't need to be able to build a mobile phone in order to use one. But for a country to embrace mobile telephony, it needs people who have the skills to design, install and maintain the requisite infrastructure. These skills turn out to be little different from those needed to develop mobile telephony in the first place.

The skills needed for technological creation and engineering include deep scientific knowledge, understanding of business and entrepreneurship and, perhaps most importantly, the ability to deal with uncertainty and open-ended design problems through

'optimism and resilience in problem solving'. 'Resilience in problem solving' is code for failing, but jumping up again. As the maxim says, 'Failure is the stepping stone to success'.

Engineering education should make creativity a deliberate focus and complement scientific facts-based education with hands-on 'tinkering', recognising the 'craft' component of engineering. A greater focus on the creative and tinkering aspects of engineering (technology creation), without diminishing scientific rigour, would not only attract more students to the field, but would also create better technologists and thus eventually better technologies.

New technologies require professional engineers and technologists for their creation, as well as a technologically skilled workforce for their adoption. Educating for skills in creativity and tinkering is crucial.

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Technology is constantly changing the nature of our work. Old jobs disappear and new ones arise. The workforce needs to thrive with tomorrow's technologies; it needs to be adaptable. A 1988 report from the US Office of Technology Assessment considered the employment impacts of new technology and concluded that:

> *People most likely to prosper in these networks are … able to change, adapt to unfamiliar work, and learn new trades as a continuous part of working experience. The talents needed are not clever hands or a strong back but rather the ability to understand instructions and poorly written manuals, ask questions, assimilate unfamiliar information, and work with unfamiliar teams. In short, the new networks require the skills provided by a solid basic education.*
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> *An educated population is the most critical infrastructure of the emerging economy. It is critical for both the economic growth of the nation as whole, and the success of individuals acting as either consumers or employees.*

Educated workers are more adept at implementing new technologies. Technological change favours the more highly skilled workers. Although a traditional university degree provides no guarantee of being able to adapt to technological change, the ability to think in a non-routine manner is likely to be most helpful.

The importance of being wrong

Failure is an ever-present partner of inventing, of new technology, and of trying out a new policy. But rarely should it be an excuse not to try. Acknowledging the possibility of failure, and dealing with it in an effective manner, is often a recipe for success.

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To quote JK Rowling, the creator of the Harry Potter series: 'Failure is so important. We speak about success all the time. It is the ability to resist failure or use failure that often leads to greater success. I've met people who don't want to try for fear of failing.' JK Rowling

speaks from experience. UK's best-selling living author received many rejections from book publishers when she first sent out her *Harry Potter and the Philosopher's Stone* manuscript.

New technologies are born imperfect. Their improvement takes time and many failures. Such failures are often simply inevitable steps along a path that ends in a mature, polished and functioning technology. Engineers can learn from technological failures just as scientists accumulate knowledge through undertaking experiments that falsify a theory.

Fear of failure also manifests itself in business and government. Changing any aspect of an existing policy approach or innovation always carries with it a risk of failure. Risk-averse leaders and governments are often more content to do nothing or little rather than initiate an action that might see them blamed for a failure. Media reports on technological failures can reinforce the idea that 'playing it safe' may be more desirable than being bold and taking a risk.

There are processes and practices that can be adopted to improve the response to failures. If failures arising from the development and adoption of new technologies were viewed as system flaws (to be fixed) rather than flaws in the characters of those involved, it could encourage people to try out new, and even risky, technologies.

Governments can play a central role in encouraging experimentation and entrepreneurship. Additionally, there's a place for education systems to present the 'journey' of discovery and the often associated failures on the road to seeking ultimate success.

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Investing in our future

The Australian Government's 2015 innovation agenda was developed by examining the industries that were excelling in their trade performance. Maintaining competitiveness in these industry sectors is crucial, and requires improving their efficiency and productivity through the effective application of technology and innovation. The major problem with using existing industry sectors as a way of focusing technology research effort is that today's sectors are a poor guide for future large-scale industry developments. This is especially true when it comes to fundamental transformations, which can create entirely new industries.

Governments that insist upon neutrality of interventions tend to favour existing industries, which are typically least able to adapt.

Technology is complex and dynamic. Technologies and industries that have performed well in the past will not necessarily perform well in the future, at least without substantial adaptation and transformation. Adaptation involves innovation, change, and new technologies.

Governments that insist upon neutrality of interventions tend to favour existing industries, which are typically least able to adapt. Acknowledging that the world is changing, and embracing that change as a valuable business opportunity, can lead to growth and prosperity. We are competing with other high-performing countries that are prioritising their research and innovation support for future growth areas such as green technologies and health and to help address global challenges.

Technology research and development support should be focused on technological areas, such as information and communications technology, advanced materials, biotechnology and nanotechnology, not on existing industry sectors. To achieve advances in human health, government cannot just invest in the medical sector; to achieve advances in transport, government cannot just invest in roads. If large economic impact is desired, the underpinning sources are likely to come from a wide range of disciplines.

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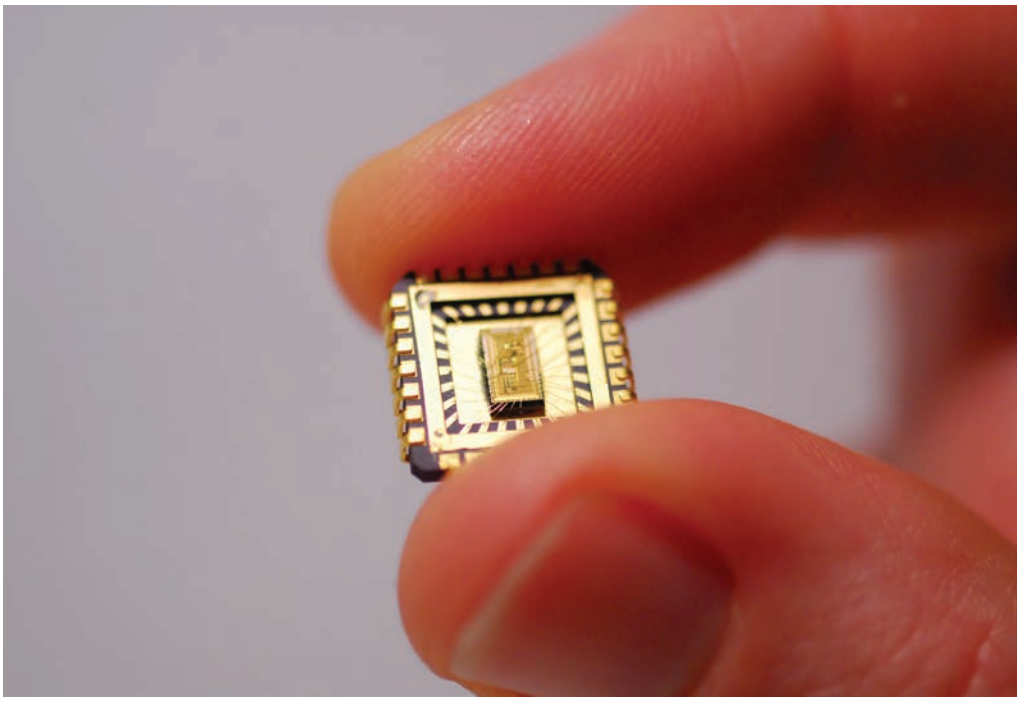
We don't need to try the impossible and pick specific technology winners. The largest economic impacts are likely to come from general-purpose technologies, which can transform all industry sectors. So government support of technology research and development for this, especially information and communications technology, is valuable. Other important general-purpose technologies are advanced materials, biotechnology and nanotechnology.

In 2016, the Australian Government commissioned the 2016 National Research Infrastructure Roadmap to support future investment decisions in research infrastructure. The Chief Scientist for Australia will lead the project.



A prototype chip that incorporates nanotechnology to detect disease. Nanotechnology is one area likely to be a major driver of innovation in multiple sectors. (Source: EPSRC IRC in Early-Warning Sensing Systems for Infectious Diseases, CC BY 2.0)

Conclusion

Innovation lies at the heart of securing Australia's future. Properly nurtured, innovation (meaning far more than simply commercialisation of new technologies and products) can help Australia considerably improve its overall productivity, with benefits to us all. That nurturing would include increased government investment and a series of institutional policy changes.

Commentators – especially those promoting a particular agenda – often use the term 'investment' as a synonym for 'spending'. But in the case of priming the economy for improvements to Australia's productivity, the findings from ACOLA's Securing Australia's Future reports really do represent a solid investment, one with a profound return on outlay. There are projected gains over the long-term of up to 30 per cent in both gross domestic product and consumption per capita. The dividends include more jobs and wage rises for all workers.

We can learn much from other countries, such as policies and programs that encourage and enhance the application of research. Drawing research agencies closer to businesses is an essential step in enhancing the take-up of discoveries. There are domestic models – in addition to those from overseas – that show how this can be done well.

Skilled labour is vital. Organisations need to employ and develop staff with broad knowledge bases and strong integrative skills; our education system needs to support the development of these suites of skills. Technical skills alone will never be sufficient.

Collaboration, nationally and internationally, is important. Strengthening management and leadership capabilities is also crucial.

Australia needs to adapt to the shifting foundations. We need to change our strategy from focusing upon what worked well in the past, or on business sectors that in the past have been strong. Instead, we should create and sustain the capacity, skills, culture and the will to adopt, adapt and develop our future source of prosperity and wellbeing. Australia's bright future can be envisaged, created and achieved through innovation and new technology.

This chapter on lifting national productivity draws on key ACOLA reports (SAF01 *Australia's Comparative Advantage*; SAF04 *The Role of Science, Research and Technology in Lifting Australian Productivity*; SAF05 *Technology and Australia's Future*; SAF09 *Translating Research for Economic and Social Benefit: Country Comparisons*; SAF10 *Skills and Capabilities for Australian Enterprise Innovation*) as well as incorporating cross-cutting themes that appear in the other ACOLA reports.