National Innovation Systems Contributing to Global Innovation: The Case of Australia

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In the context of the increasing globalization of innovation, this chapter explores ways in which Australia is drawing on global experience in the design of national innovation systems, while at the same time recognizing that many of the benefits from national innovation systems spill across national borders. The chapter provides examples of Australian engagement in worldwide innovation through the globalization of 'big science', with outcomes in fields such as aerospace and pharmaceuticals. It also provides examples of ways in which Australia is drawing on the experiences of other countries in developing new policies and programmes. And just as Australia is learning from other countries, others can also learn from the Australian experience. In both policy development and big science projects, advances made in Australia build on and will contribute to global innovation benefits.

Global science cooperation and national innovation

Well-designed national innovation systems recognize the value of international linkages and collaboration. Global collaboration harnesses the best talent and resources to address world challenges, with participating countries sharing the costs, through:

- international research collaboration to address issues such as the Ebola virus;
- big science collaborations such as the Square Kilometre Array (SKA; see below) and the Laser Interferometer Gravitational-Wave Object (LIGO);[1] and
- shared access to major facilities such as synchrotrons.

The Global Science Forum (GSF) of the Organisation for Economic Co-operation and Development (OECD) was established in 1992.[2] Originally known as the 'Mega-Science Forum', it is a forum in which OECD members and other countries can discuss scientific issues. Through this forum, the GSF has also been providing analysis and advice to governments on international science collaborations; the name was changed to the Global Science Forum in 1999 to more accurately reflect this broader role. The GSF includes 33 member countries that are either OECD members or other countries (as Key Partners).

In the area of international scientific cooperation, the GSF provides a venue for consultation among the senior science policy officials. It produces findings and action recommendations on high-priority science policy issues that require international cooperation, and identifies opportunities for collaboration on major scientific undertakings.[3]

Challenges to which the GSF seeks to respond include:

- the tension between the fiscally constrained environment on science, technology, and innovation (STI) in most jurisdictions, along with a need to demonstrate the impact and benefits of public investment in science;
- the growing complexity of science and technology, which requires greater international and inter-disciplinary cooperation;
- the rapid development of information and communication technologies and associated 'open science' and 'big data' developments;
- the growing societal engagement with science and the need to ensure public trust; and
- the increasing importance of emerging economies in global STI, which is expanding the global competition for talent and requiring new approaches to international cooperation and its governance.

The GSF serves its members in the formulation and implementation of their science policies by exploring opportunities for new or enhanced international cooperation in selected scientific areas, defining international frameworks for vital national or regional science policy decisions, and addressing the scientific dimensions of issues of global concern.[4] The GSF's current activities include a scoping exercise to help determine upcoming priorities for research infrastructure.

The globalization of science and innovation: Examples

This section provides an example of an international project based, in part, in Australia, and an example of a policy programme that underpins the big science environment in the country. They can both be seen as efforts bringing together scientists and engineers from around the world in a way that can serve as a roadmap for other international efforts.

The Square Kilometre Array

The SKA project is an international attempt to construct a radio telescope capability many times more powerful than any currently in existence. The project involves international collaboration and funding. The SKA project plans to locate a facility in both Australia and South Africa and to build it in two phases. The indicative capital budget for Phase 1 is about $A1 billion. The purpose of the SKA is to probe key questions about the nature and origins of the universe and the laws of physics.

Australia has long been a leading player in radio astronomy. It has been a strong proponent of this project and offers an exceptionally good site for locating some of its most exciting elements. The country has taken a leadership role and brings world-class radio astronomy capabilities to the project. Australia and other SKA partners will gain benefits from the exchange of top scientists and engineers and the SKA will inspire young people to develop an interest in science.

Construction and operation of the low-frequency SKA in Australia offers the potential for substantial tangible economic benefits through demands for local supply of goods and services that will feed into employment, wage rates, and an overall boost to real incomes and economic welfare.

Investment in the SKA project creates options for Australia to secure a competitive position in supercomputing and the management of massive datasets. Successful implementation of the SKA will require major progress in this area. The data-handling demands of the SKA will be well ahead of current commercial drivers of progress, working with huge data streams needing to be managed. The largest data volumes will originate in Western Australia, and it will be necessary to have major, highly innovative data processing performed within that region.

A key feature of the data-handling requirements of the SKA lies in the ability to identify rare, weak signals in a background of massive noise. This type of problem arises in a number of other settings as well. It was the stimulus for the Australian development in the 1980s of fast Wi-Fi capabilities, which subsequently proved highly successful commercially. Such data handling also underpins the emerging use of computer modelling of geological structures as an input to resource exploration. Locating this type of data-processing capability in Western Australia supports strong synergies with resource exploration and development.

Australia's National Collaborative Research Infrastructure Strategy

In Australia, the drivers for big science projects such as the SKA are also reflected in national decisions about investment in shared research infrastructure. These facilities provide the tools for Australian researchers to contribute to global science and innovation, and highlight:

- the increasing importance of major research infrastructure to research and innovation;
- the changing nature of research—which now places more emphasis on collaboration and the importance of systemic infrastructure (broadband, high-performance computing, data repositories, etc.);
- the limited capacity of a 'small' nation to meet major infrastructure needs; and
- the increasing cost and complexity of research infrastructure.

Some expensive research equipment needs to be used around the clock in order to get value from it before it is no longer leading-edge equipment (for example, the life expectancy of state-of-the-art sequencing machines is about five years). Experience shows that sharing access to leading-edge research equipment and facilities can result in new beneficial collaborations between users both within and between public and private sectors.

Since Australia's National Collaborative Research Infrastructure Strategy (NCRIS) programme began in 2004, it has resulted in the investment of around $A3.7 billion to develop and fund national research infrastructure projects. NCRIS involves a strategic and collaborative approach to investment in world-class research facilities, networks, and infrastructure that are accessible to researchers and meet long-term needs. Many high-priority, medium-scale research facilities are too large or complex to be supported by any single research institution, but are nevertheless necessary to leading-edge research. NCRIS provides funds in the range of $A5 to $A60 million, supporting facilities that are too large to be funded through other Australian programmes but are less than 'landmark' investments such as the SKA, which require separate case-by-case consideration. NCRIS also seeks to avoid wasting limited resources that would result from competitive or uncoordinated duplication of key research facilities.

The key requirements of NCRIS include:

- Major infrastructure should be developed on a collaborative, national, non-exclusive basis. Funding and eligibility rules should encourage collaboration and co-investment.
- Access is a critical issue in the drive to optimize Australia's research infrastructure. In terms of NCRIS funding, there should be as few barriers as possible to accessing major infrastructure for those undertaking meritorious research.
- Due regard must be given to the whole-of-life costs of major infrastructure, with funding available for operational costs where appropriate.
- NCRIS should seek to enable the fuller participation of Australian researchers in the international research system.

Participants in NCRIS facilities include institutions of higher education, the Australian federal government as well as state and territory research agencies and institutions, independent research institutions, private-sector research organizations, and industry. Researchers from other countries access these facilities through collaborations with Australian researchers. NCRIS funds have supported access for Australian research to international infrastructure such as the European Molecular Biology Labs and the Giant Magellan Telescope.

Australia is currently planning the next stage of national-scale research infrastructure. The evolving roadmap will be shared with the international community through the country's participation in the Group of Senior Officials on Global Research Infrastructures, whose most recent meeting was hosted in Sydney in February 2016.[5] Countries such as New Zealand and Singapore have been invited to follow Australia's progress and participate where they wish.

The global search of big corporations for research from public-sector inputs

Corporations that previously employed large numbers of researchers in their own laboratories are increasingly building alliances with leading-edge public-sector research groups around the world to access skills, expertise, and equipment. These alliances provide corporations with low-cost access to new ideas emerging from public-sector research facilities—yet another example of how the global innovation system integrates and builds on national systems.

This trend provides opportunities for different groups:

- for countries such as Australia to get 'on the radar' of multinational corporations and attract research investment;
- for public-sector researchers to develop entirely new approaches to addressing major challenges and solving industry problems; and
- for research students involved in these activities to enjoy greater employment prospects.

Global corporations seek to locate those public-sector researchers who can best meet their needs. Of these alliances, of which there are many in Australia, two—Boeing with Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Monash University with GlaxoSmithKline (GSK)—illustrate this trend.

Boeing Australia has worked with its parent company in Seattle to be the sole Australian supplier of flight control surfaces such as ailerons, spoilers, and rudders for a number of Boeing commercial aircraft, including the new 787 Dreamliner. These are manufactured in Melbourne and exported to the United States of America (USA) for assembly. Boeing has collaborated with the Australian government research agency called CSIRO for over 23 years; in recognition of this collaboration, in 2011 Boeing named CSIRO the 'Supplier of the Year' 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, $A25 million research programme in space sciences, advanced materials, energy, and direct manufacturing. In the past decade, Boeing has transferred an estimated $A100 million in technological knowledge (including the cost of licences, know-how transfer, and so on) to Australia and has invested more than $A500 million in plant, equipment, training, and research laboratories.[6]

Monash University's Institute of Pharmaceutical Sciences (MIPS) collaboration with GSK was established in 2009 with $A3.3 million in initial funding from the Government of the State of Victoria and GSK. It leverages the unique skills of MIPS in drug delivery and formulation with the industrial know-how and world-class medicine development capabilities of GSK Australia. This project funded the creation of a centre to support the development of next-generation formulations and platform technologies for new medicines.

GSK has continued to make significant investments in Australia, creating new high-skilled jobs while continuing to support the successful MIPS-GSK collaboration. GSK's advanced manufacturing facility in Victoria is its largest sterile facility in the southern hemisphere, where it manufactures medicines and vaccines that utilize blow-fill seal technology, developed in partnership with MIPS. This technology, which is an advanced antiseptic process, produces a range of container sizes suitable for the delivery of unpreserved, sterile products. GSK and MIPS have collaborated on more than 20 other projects since 2010. The partners have a strategy to underpin an ongoing 10-year sustainability and growth target for enhanced pharmaceutical manufacturing in Australia that embraces a range of partners and communicates knowledge to a broader audience.[7]

Melbourne's world-class concentration of bioscience and medical research includes MIPS, BIO21,[8] CSL Ltd,[9] the Walter and Eliza Hall Institute of Medical Research, and NCRIS platforms such as the Australian Genome Research Facility. Australian Prime Minister Malcom Turnbull recently announced a major expansion of BIO21 to house CSL's Global Research and Translational Medicine Hub. Melbourne's research institutes are well connected to other global centres of bioscience and their innovations have an impact around the world.

Enhancing national contributions to global innovation

National innovation systems are increasingly making greater use of demand-side policy and programme measures (see also Edler in Chapter 5).[10] In doing so, they are drawing on the experiences of other countries and adapting them where necessary. This sharing of policy ideas and experience raises the performance of the global innovation system. One example is the US Small Business Innovation Research (SBIR) Program, established in 1982. It currently distributes around US$2.5 billion in contracts and grants. US agencies with external R&D budgets of more than US$100 million per annum are required to spend 3.0% 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 or that support innovation aimed at public good outcomes (which are generally diffused globally, contributing to global innovation). Individual agencies are responsible for selecting awardees. One project, led by Alan Finkel, received SBIR funding in 1986 in support of a transformational technology development that underpinned company sales and reputation growth for the next two decades.

Evaluations of the US SBIR 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 10-year period.[11] He found that the awardee firms had a five times greater increase in employment and a 2.5 times increase in sales than the control firms. In recent years, other countries—including Finland, the Netherlands, Sweden, and the United Kingdom (UK)—have copied or adapted the SBIR Program to accelerate the growth of new technology-based businesses. Australia is planning to start a pilot SBIR-type programme at the federal level this year.

Several pioneering features of SBIR, maintained since its inception 34 years ago, have contributed to its success. First, there is no federal government budget impact because the funding is set aside from existing expenditure. This approach has helped to secure bipartisan support. Second, SBIR is generous in its encouragement of innovative firms and projects—the government takes no equity position, requires no matching funds, and expects no payback. Risk mitigation is managed through the two-phase awards process, and societal benefit comes from its contribution to the economy through jobs and taxes. Third, because each agency administers its own programme within the guidelines established by Congress, agencies are empowered and motivated. Fourth, SBIR provides funding for early-stage innovation ideas that are too high risk for private investors, including venture capital firms, so that these ideas have a chance to come to fruition.[12]

SBIR-type programmes are seen as addressing needs that are not being met by market mechanisms alone. The success of demand-side innovation measures such as SBIR contracts depends on a number of factors. The SBIR contracts approach, where an invitation is issued to develop a solution to an identified problem, requires programme administrators who are lateral thinkers able to identify issues that are amenable to this type of approach. These administrators also need a solid, working knowledge of related research activities. SBIR-type programmes differ from conventional public-sector procurement and require a different mindset. For example, some health ministries may not see investment in innovation as part of their responsibility, even though such investments may reduce hospital costs or improve patient well-being. SBIR-type schemes also require a capability on the part of research suppliers, who must have the necessary agility and business skills.

Creating pathways to employment for research graduates

Research graduates have global employment opportunities and are important contributors to global innovation. In Australia only about one-third of PhD-trained researchers are employed in the business sector, compared with two-thirds in the USA. This makes it harder to establish research collaboration projects between business and the public sector in Australia, which in turn has an impact on the innovation capacity of this sector. Increasing the numbers of researchers in business is therefore of some importance. Again, Australia is seeking to learn from the experience of other countries such as France, where companies that employ new PhD graduates receive a quadruple tax deduction on their salaries for two years.[13]

In the UK, Knowledge Transfer Partnerships (KTPs) create demand for recent graduates while also encouraging their supervisors to become involved in knowledge transfer. KTPs aim to help businesses improve their productivity and competitiveness through the better use of technology, knowledge, and skills. Each KTP is a three-way partnership between a business, an academic institution, and a graduate. The academic institution receives a grant to partially subsidize the cost of employing a recently qualified graduate to work at the company; the average company contribution to KTP projects is around £20,000. Typical KTPs last between six months and two years, depending on the project and the needs of the business. KTP opportunities are advertised online.[14]

KTPs are delivered through Innovate UK. A wide range of knowledge-exchange activities—spanning management; marketing, business administration and policy; engineering technology; and information technology, computer science, and computation—are undertaken. Associates are jointly supervised by staff in the company and in the faculty at the university concerned.

The costs of the partnerships are partly funded by government and partly by the participating business. A review in 2010 reported that 62% of company partners subsequently offered the associate a permanent position, and 82% of associates accepted those offers.[15] A recent independent study evaluating the economic impacts of the KTP Associates and participating universities found that, in the period 2001–08, the return on public investment was £7.5–7.9 per £1 of KTP grant funding, with £1.6–1.8 billion gross value-added and between 5,530 and 6,090 jobs created.[16]

Australia has a small programme called Innovation Connections that provides financial support to place a publicly funded researcher in a business or a business researcher in a publicly funded research organization to work collaboratively on a specified project.[17] An EU-wide KTP Program, currently understood to be under consideration, would have impact beyond national innovation systems.

Increasing the contribution of public-sector research to innovation

Measuring engagement between public-sector researchers and external parties is an important step towards providing incentives to increase the translation of public-sector research for economic and social benefit.[18] The Australian Academy of Technology and Engineering (ATSE) has taken the initiative of exploring options for metrics to measure Australian universities' research engagement with external partners. These partners may be Australian or based overseas. This work is intended to ensure that research engagement is appropriately recognized and rewarded alongside research excellence.[19]

The proposed metrics are derived from existing data collections of Australian university research. These metrics are based on external dollars attracted to support research from industry and other users of university research, as a direct measure of research engagement. Research engagement with industry is seen as a forward-looking proxy for impact. Building on the ATSE's initiative, in December 2015 the Australian government announced its intention of introducing, for the first time, clear and transparent measures of non-academic impact and industry engagement when assessing university research performance. Built on the work of the ATSE, the new metrics will be piloted through the Australian Research Council in 2017 and fully implemented by 2018.

A database of international scope developed in Australia is in the process of integrating patents from most countries alongside academic publications and business data. Known as 'The Lens', among other capabilities it will enable the measurement of impact by tracking the number of times academic publications have been cited in the patent literature. It is conceivable—and probably desirable—that such impact data will become a component of national and international rankings of research institution performance.

Managing intellectual property to provide global opportunities for innovation

Government agencies responsible for the administration of intellectual property (IP) rights systems are becoming more pro-active in making their information available to potential users. In December 2014, a discussion paper announced that the government would put in place arrangements to provide industry and other end-users with better access to research.[20] To achieve this outcome the government would seek to:

- establish an online point of access to commercially relevant research for business, and
- develop a whole-of-government policy to open up access for business and the community to publicly funded research.

The Australian IP rights agency, IP Australia, has implemented the first of these objectives. IP Australia recognizes that knowledge created by research organizations is rarely in a form that can be immediately applied commercially. Potential small- and medium-sized company research users often lack the resources and experience to find such knowledge. This is a particular problem in Australia, where the percentage of Australian researchers employed in business is relatively low. Add to this a researcher 'reward system' that is not set up to encourage research commercialization, and the challenge of helping potential users of IP becomes that much harder.

IP Australia operates an Australian patent database. In addition, it has established an in-house analytics group of experts, the Patent Analytics Hub, to help Australian innovators make the most of their IP. The Hub provides analysis, visualization, and interpretation of data included in patent documents.

IP Australia has also developed:

- an IP Toolkit to facilitate, simplify, and improve collaboration between researchers and industry; and
- Source IP—a digital marketplace for sharing information, indicating licensing preferences, and facilitating contact for IP generated by the public research sector in Australia. This is similar to other globally available databases, including those of the Danish Patent and Trademark Office and the Malaysian Patent Office.

Source IP's focus is on connecting rather than buying or selling IP. It provides a single point for information and making contact, and because it is a primary database it can be trusted. It provides 'translated' patent listings with usage suggestions. It also provides some information on provisional patent applications, as well as those in Patent Cooperation Treaty (PCT) and national phases (a PCT application, which establishes a filing date in all contracting states, must be followed up with the step of entering into national or regional phases to proceed towards the granting of one or more patents). IP Australia's work is connecting Australian researchers and IP owners with potential users around the world.

In addition, WIPO's PATENTSCOPE allows more than 60 million patent documents to be searched, including patent applications filed under the PCT.[21] Through the Access to Specialized Patent Information programme, patent offices and academic institutions in developing countries can receive free or low-cost access to sophisticated tools and services for retrieving and analysing patent data.

Conclusions

This chapter has shown that Australia's science base is strong and contributes to innovation both nationally and internationally through its engagement in worldwide innovative programs. Although by population Australia is a small country, it takes advantage of the globalization of big science, finding a place on the international stage in cooperative ventures with other countries and opening itself up to interaction with scientists from around the world. In doing so, it draws on the experiences of other countries in developing new policies and programmes.

Australia, through its national innovation policies, recognizes the value of international linkages and global collaboration. It aims to harness the best talent and resources to address global challenges and to share costs of providing and maintaining leading-edge facilities and equipment, which would otherwise be prohibitive, with other participating countries.

Australia's innovation system is in transition. It is learning from international best practice, both in policy development and in big science projects. As these evolve, Australia's experiences with finding workplace connections for research graduates, with managing IP, and with fostering the engagement of the public sector in translational research can contribute to the societal benefits to be reaped from global innovation. And in this way, too, Australia can participate by providing lessons to other countries that want to be part of the global innovative effort.

Notes

1 See https://www.skatelescope.org/ for information about the SKA project; See https://www.ligo.caltech.edu/ for information about LIGO.

2 OECD, no date.

3 OECD, no date.

4 OECD, no date.

5 Department of Education and Training, Australia, 2016.

6 Bell et al., 2014.

7 Monash University, 2012.

8 BIO21 is one of Australia's largest biotechnology research institutes, with more than 500 researchers.

9 CSL Ltd is a Melbourne-based leading global biotherapeutics company that operates in more than 30 countries.

10 See Chapter 5 of this report.

11 Lerner, 1996.

12 Lerner, 1996.

13 BusinessFrance, no date.

14 Innovate UK, 2016.

15 Regeneris Consulting, 2010.

16 WECD, 2015.

17 Department of Industry, Innovation and Science, Australia, 2016.

18 Bell et al., 2015

19 ATSE, 2015, 206.

20 Department of Education and Department of Industry, Australia, 2014.

21 See http://www.wipo.int/patentscope/en/ for information about WIPO's PATENTSCOPE.

References

ATSE (Australian Academy of Technology and Engineering). 2015. *Research Engagement for Australia: Measuring Research Engagement between Universities and End Users.* Melbourne: ATSE. Available at https://www.atse.org.au/content/publications/reports/industry-innovation/research-engagement-for-australia.aspx.

———. 2016. *Research Engagement for Australia: Measuring Research Engagement between Universities and End Users. Report of a Pilot Study.* Melbourne: ATSE. Available at https://www.atse.org.au/content/publications/reports/industry-innovation/research-engagement-for-australia.aspx.

Bell, J., M. Dodgson, L. Field, P. Gough, and T. Spurling. 2015. *Translating Research for Economic and Social Benefit: Country Comparisons.* Final Report. Melbourne: ACOLA (Australian Council of Learned Academies). Available at http://www.acola.org.au/PDF/SAF09/SAF09%20Full%20report.pdf.

Bell, J., B. Frater, L. Butterfield, S. Cunningham, M. Dodgson, K. Fox, T. Spurling, and E. Webster. 2014. *The Role of Science, Research and Technology in Lifting Australian Productivity.* Report for the Australian Council of Learned Academies. Available at www.acola.org.au.

BusinessFrance. No date. 'France's Research Tax Credit: Benefits and Advantages for Your Company'. Paris: BusinessFrance. Available at http://sayouitofrance-innovation.com/wp-content/uploads/2015/01/UK_CIR_1901.pdf.

Department of Education and Department of Industry, Australia. 2014. *Boosting the Commercial Returns from Research,* December. Canberra. Available at http://www.industry.gov.au/industry/Documents/Boosting-Commercial-Returns-from-Research.pdf.

Department of Education and Training, Australia. 2016. 'Department Hosts Major International Research Infrastructure Meeting'. News release, 17 February. Available at https://www.education.gov.au/news/department-hosts-major-international-research-infrastructure-meeting.

Department of Industry, Innovation and Science, Australia. 2016. Innovation Connections, an interactive website. Available at http://www.business.gov.au/advice-and-support/EIP/Innovation-Connections/Documents/Customer-Information-Guide.pdf.

Innovate UK. 2016. 'Graduate Vacancies with a Difference: Classic KTP Vacancy Advertisements'. Available at http://info.ktponline.org.uk/action/search/partnership_vac.aspx.

Lerner, J. 1996. 'The Government as Venture Capitalist: The Long-Run Effects of the SBIR Program'. NBER Working Paper No. 5753. Cambridge, MA: National Bureau of Economic Research. Available at http://www.nber.org/papers/w5753.pdf.

Monash University. 2012. 'MIPS Welcomes $60M Investment by GSK in New Manufacturing Capability in Melbourne'. Press release, 3 February. Available at https://www.monash.edu/pharm/about/news/2012/gsk-investment-boronia.

OECD (Organisation for Economic Co-operation and Development). No date. *The OECD Global Science Forum: Strategic Directions 2015–2019.* Paris: OECD Publishing. Available at http://www.oecd.org/sti/sci-tech/STI-GSF-brochure.pdf.

Regeneris Consulting. 2010. *Knowledge Transfer Partnerships Strategic Review.* Cheshire, UK: Regeneris Consulting.

WECD (Warwick Economics & Development). 2015. 'The Impacts of KTP Associates and Knowledge Base on the UK Economy'. Birmingham, UK: WECD.