Australian Academy of Science

SUBMISSION TO THE

JOINT COMMITTEE ON TRADE AND INVESTMENT GROWTH - INQUIRY INTO AUSTRALIA'S FUTURE IN RESEARCH AND INNOVATION

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Australian Academy of Science submission to the Joint Select Committee on Trade and Investment Growth

Summary

Science, research and innovation will underpin a large part Australia's future trade and investment growth. A strong and diverse science and research sector will create knowledge that can be embodied in new and improved goods and services, produced by Australian workers. The Australian Academy of Science welcomes the Australian Government's National Innovation and Science Agenda (NISA), which recognises the importance of science and research to Australia's future prosperity. NISA contains a number of welcome initiatives to improve Australia's competitiveness in research and innovation, including a long-term, $1.5 billion commitment to the National Collaborative Research Infrastructure Strategy.

NISA is an excellent foundation from which to improve Australia's science, research and innovation capability. However, a number of challenges remain to ensure Australia's scientists and researchers can compete with European and American peers. These include:

- maintaining a strong, secure and productive research sector with a long-term resourcing strategy
- creating an integrated innovation chain, by improving the ability and capacity of business to capitalise on Australian research and development
- recognising the importance of basic research to Australia
- increasing our international scientific engagement
- improving science and mathematics education for school students, to reverse the relative decline in Australia's performance in these areas compared to our neighbours.

Addressing these challenges remains vital to enhancing our global competitiveness. Australian science and research must remain a central part of trade and investment policy to ensure that Australia can continue to export innovative goods and services to our region and the world.

Recommendations

- **The Academy recommends that the Government commits to a national research investment strategy, with a view to long-term investment growth.**

- **The Academy recommends that support for commercialisation of research in Australia, including business innovation incentives, is coupled to policy certainty. Additionally, the Academy recommends that the Government gives consideration to expanding direct support for commercialisation on a long-term basis.**

- **The Academy recommends that the emphasis on commercially-oriented research be accompanied by an explicit commitment and strategy to sustain and improve high-quality fundamental and public-good research in Australia.**

- **The Academy recommends that the Government implements and fully funds all of the international engagement recommendations made by the Chief Scientist.**

- **The Academy recommends that the Government develops a set of targets and policies aimed at improving Australian students' performance in science and mathematics.**

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Science, research and innovation for trade and investment

The National Innovation and Science Agenda (NISA) places science and innovation at the centre of government policy. The Australian Academy of Science welcomes this renewed focus on the importance of science, and the recognition that Australia's future prosperity in a competitive world will rely on the development and implementation of new knowledge, skills, products and services.

In a globalised economy, maintaining and improving living standards relies on maintaining competitive advantages through productivity improvements. Science and research are crucial to this, as illustrated in a report by the Australian Council of Learned Academies (ACOLA):

> *"To stay competitive, firms need to be continuously innovating. Science, research and technology make a critical contribution to such competitiveness. Research and development (R&D) leads to the creation of new knowledge. This is used by firms to increase the efficiency with which inputs to production are translated into outputs in the form of new goods and services. Thus R&D is a key driver of increases in productivity over the longer term."*[1]

New knowledge, goods and services developed or adapted in Australia will provide the basis of future trade and investment. Even trade in commodities that rely on Australian natural resources must embody science, research and innovation to remain globally competitive. Indeed, recent advances in the physical and biological sciences underpin 26% of Australian economic activity.[2] Success in a competitive global environment depends on resource, labour and capital productivity, which is realised through research and development. Trade and investment growth therefore relies on Australia maintaining strong capabilities in science and research. A concerted and long-term focus on the priorities outlined in Box 1 are essential to lay the basis for Australia's future prosperity and improvements to health and the environment.

Box 1: ***Science Priorities for Australian Innovation – Australian Academy of Science***

The Australian Academy of Science has adopted three priority areas to support science and innovation in Australia. These priorities are the necessary enablers of Australia's future prosperity, and the Academy has suggested a number of objectives and practical solutions. See more at https://www.science.org.au/science-priorities

Priority 1:	A society with the understanding and skills to use and apply science, technology, engineering and mathematics in their lives and careers.
Priority 2:	The best and brightest scientists solving Australia's current and future challenges.
Priority 3:	A strong, secure and globally connected research capability.

[1] Bell, J, Frater, B, Butterfield, L, Cunningham, S, Dodgson, M, Fox, K, Spurling, T and Webster, E (2014), *The role of science, research and technology in lifting Australian productivity*, Australian Council of Learned Academies, Melbourne, pp. 27-28. Available at: http://www.acola.org.au/PDF/SAF04Reports/SAF04%20Role%20of%20SRT%20in%20lifting%20Aus%20Productivity%20FINAL%20REPORT.pdf

[2] Centre for International Economics, *The importance of advanced physical, mathematical and biological sciences to the Australian economy*, Australian Academy of Science/Office of the Chief Scientist, January 2016. Available at: https://www.science.org.au/files/userfiles/support/reports-and-plans/2016/synthesis-report.pdf

A focus on these priorities will grow trade and investment through a productive research sector, an integrated innovation chain, international engagement and collaboration, and science and mathematics education.

A strong, secure and productive research sector

Science, research and innovation are the means for Australia to create new avenues for trade and investment in the future. As a developed economy with a relatively small domestic market, Australia will continue to prosper through exporting the products of Australian knowledge and innovation, embodied in goods and services. Mineral commodities and agricultural products will continue to be important, but science and research will make their production more efficient, increasingly sustainable and of ever-improving quality. This is reflected in the Australian Government's Science and Research Priorities, which are encouraging research in areas of strength for Australia (see Box 2).[3] Australia's important knowledge-based services will also remain an important industry. As our neighbours seek to improve their own economies, education and expertise will increasingly underpin trade between Australia and the rest of Asia and the Pacific.

At the heart of all these activities lies the science and research capability that allows continual improvements in Australia's production; critical to maintaining a competitive advantage. Considering Australia's relatively modest overall investment in research and development, Australian scientists are highly productive. Australia produces around 22 scientific publications per thousand people, trailing only Switzerland the northern European research powerhouses. Another way of looking at this: Australia produces 2.6% of the world's scientific research, despite representing only 0.32% of the world's population.[4] In addition to being productive, the best Australian scientists rank among the best in the world, with Australia contributing relatively high numbers of influential scientific publications compared with similar economies.[5]

Box 2: *The Australian Government's Science and Research Priorities*

The Australian Government has set nine science and research priorities, related to areas that the Government considers important to Australia's future. Over time, research in these areas will receive greater priority in funding support, in both fundamental and applied research. See the Science and Research Priorities overview and background.

The Government's priorities are:

- Food
- Energy
- Health
- Soil and Water
- Resources
- Transport
- Environmental change
- Advanced manufacturing
- Cybersecurity

Despite these strengths, Australian science suffers from the absence of a long-term science and research strategy and inconsistent funding, leading to an uncertain future for science and research. Federal

[3] Australian Government, *Science and research priorities*, science.gov.au website. Available at: http://www.science.gov.au/scienceGov/ScienceAndResearchPriorities/Pages/default.aspx

[4] Derived from: Organisation for Economic Co-operation and Development (OECD), *Science, technology and industry scorecard 2015*, OECD, Paris, p.106. Available at: http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard_20725345

[5] Office of the Chief Scientist (2014), *Benchmarking Australian science, technology, engineering and mathematics*, Australian Government, Canberra. Available at: http://www.chiefscientist.gov.au/wp-content/uploads/BenchmarkingAustralianSTEM_Web_Nov2014.pdf

government funding and incentives for science, research and innovation amount to $9.7 billion in 2015-16. Although Australia lags behind OECD averages for spending on higher education and research and development[6], this is still a significant public expenditure and its value must be safeguarded.

A significant challenge to maintaining value from Australia's investment in science, research and innovation is inconsistent and variable funding. Increases to funding in one year are often followed by a significant cut in the next year (see figure 1). Australia's research investment produces (and is dependent on) significant intellectual and human capital, and variable or inconsistent funding diminishes the value of this investment by causing career uncertainty and loss of key skills from important roles. Likewise, inconsistent funding does not allow researchers and institutions to plan future research with a long-term view, making it difficult to sustain effort on challenging problems.

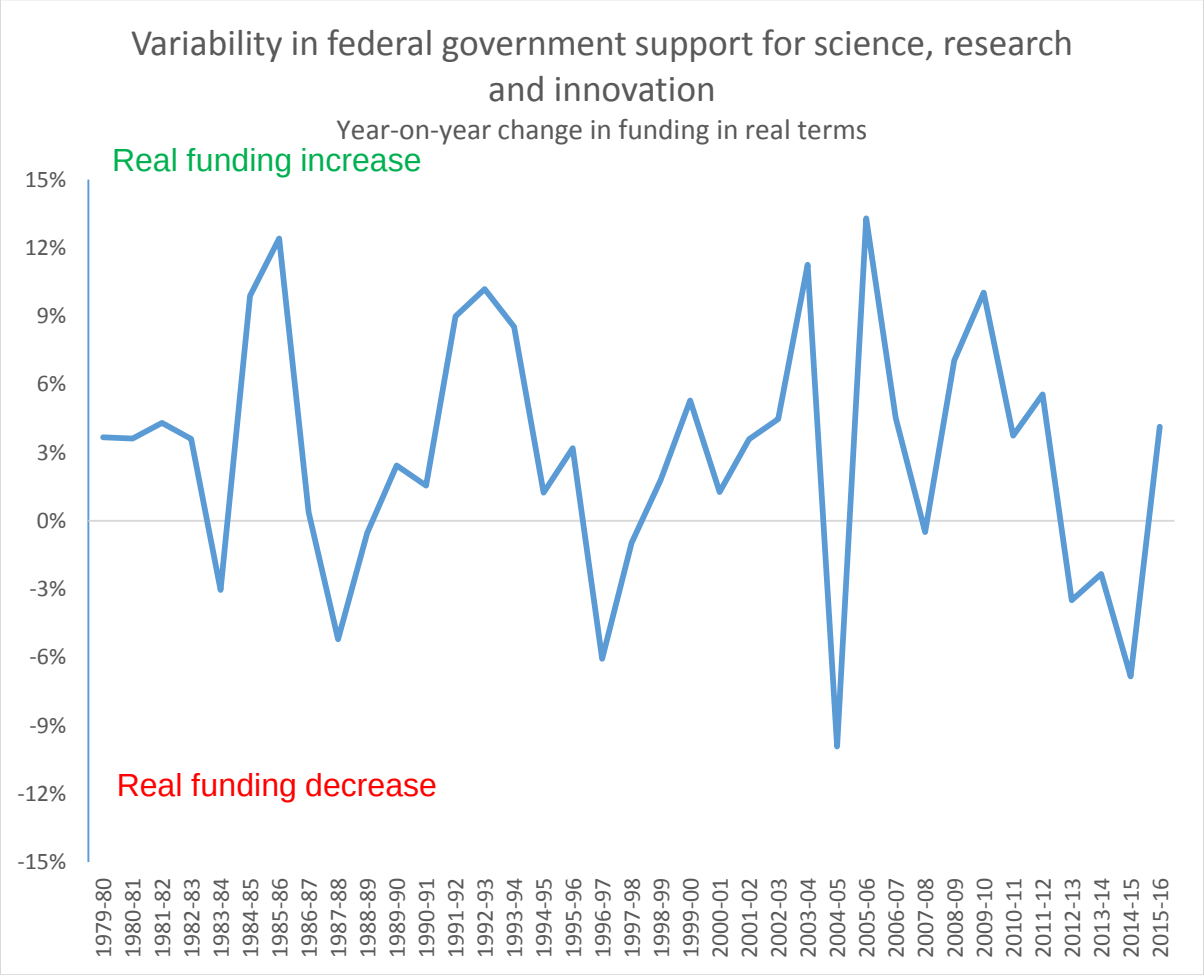

Figure 1 – Yearly percentage change in inflation-adjusted funding. Data sources: Department of Industry and Science science, research and innovation budget tables; Reserve Bank of Australia consumer price index data

Uncertainty and inconsistency is highly detrimental to the performance of science and research. The National Collaborative Research Infrastructure Strategy (NCRIS) funded 27 nationally important research facilities, but recent protracted uncertainty over the future of the program has had a considerably damaging effect. These facilities comprise not only the physical equipment, but the knowledge and expertise of specialised support staff who can help facility users make the most effective use of the sophisticated

[6] Organisation for Economic Co-operation and Development (OECD), *Science, technology and industry scorecard 2015*, OECD, Paris, pp. 96-97. Available at: http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard_20725345

equipment. In the face of an uncertain future, many of these staff have sought alternative opportunities, and some facilities lost considerable expertise and experience. The Academy congratulates the Government on making a 10-year, $1.5 billion commitment to NCRIS in the National Innovation and Science Agenda, and calls for a similar strategic approach to be extended to other areas in science and research.

The recent release of NISA is an excellent start towards taking a long-term view of science and research. The Academy commends the Government on its efforts in NISA to improve Australia's business research and development sector, and hopes that the initiatives in NISA will improve the relatively poor innovation performance of Australian business.

However, NISA is only a beginning for a science, research and innovation renaissance in Australia. It makes strategic investments in select areas and places a welcome focus on science and research. However, NISA does not entirely ameliorate the damage done to Australian science by significant funding cuts made by successive governments since 2012 (see figure 2). The Academy encourages the Government to commit to a long-term funding strategy for science and research in Australia, to maximise the value of past, current and future investments.

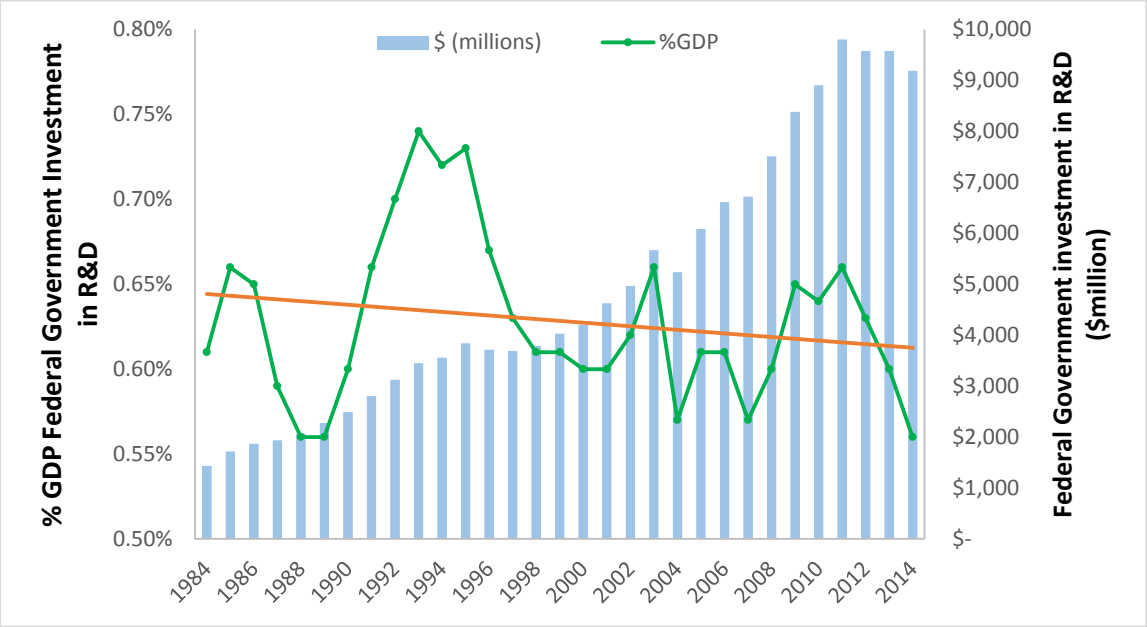

Figure 2 – Federal government support for science, research and innovation, 1984-2014. Source: Australian Parliamentary Library.[7]

Recommendation: The Academy recommends that the Government commits to a national research investment strategy, with a view to long-term investment growth.

An integrated innovation chain

New avenues of trade and investment depend on a well-functioning innovation system with the capacity to continually produce new and improved goods and services. A productive innovation ecosystem in Australia would see:

[7] Australian Parliamentary Library (2014), *Australian Government support for R&D, 1978-79 to 2014-15*. Available at: https://www.documentcloud.org/documents/1310652-parliamentary-library-australian-government.html

- a strong research sector producing important basic discoveries
- applied scientists and engineers taking those general, basic discoveries and using them to solve specific problems in diverse disciplines
- innovative investors, entrepreneurs and companies making connections between the fruits of research and development and opportunities in the market
- larger, experience-rich firms providing discipline, infrastructure and networks to scale prototypes to production.

Each of these components in the innovation chain is important; the firm that brings a world-changing innovation to market relies just as much on the basic research that underpins the innovation as the entrepreneur that developed the innovation into a marketable proposition. A successful innovation policy must support each part of the innovation chain, recognising that each part has different needs but is vital to the success of the whole.

Recent Government science, research and innovation policy initiatives have paid particular attention to improving production of commercial outputs from publicly funded research, and improving business innovation performance. These are worthy policy aims and improving business innovation performance is of particular importance. The Academy welcomes those measures in NISA directed towards promoting innovative behaviour in business; enhancing the appetite of the private sector to use Australian research discoveries to create new goods and services will provide significant benefits to the Australian community.

Business innovation and commercial outcomes from research

The policy measures in NISA will facilitate innovation in Australian business by encouraging the practice of innovation (such as through the Business Research and Innovation Initiative) and by removing barriers to companies taking risks on new ideas. However, the Academy is concerned by the implication that the Australian academic research sector is responsible to a large extent for low levels of collaboration between industry and academia, and consequent low levels of innovation.

The suggestion that improving commercial outcomes from research can be fixed by encouraging universities and researchers to collaborate more with business is only a small part of the story. In fact, there are a number of systemic barriers that impede the commercialisation of Australia's research output and hinder collaboration between research institutions and industry. Engagement between industry and universities is most likely where a business wishes to innovate. This may be new to the world, new to the industry or region, or new to the firm. It is likely that the main factors impeding greater overall levels of collaboration between universities and industry are a lack of desire among business owners to engage innovative expertise available in Australian universities, or a lack of means and incentives for them to do so. This is supported by a number of observations:

- **Relatively few Australian businesses are engaged in innovation.** 2013 OECD data had Australia ranked 23rd of 33 for large firms engaged in innovation.[8] This has improved recently to 19th in the 2015 OECD data, but there is still considerable room for improvement. Australian small and medium enterprises are more likely to innovate, but overall only 42.2 per cent of Australian businesses were engaged in innovation activity in 2012–13.[9] This means that few businesses were undertaking activities in which they could be assisted by Australian researchers.

[8] Organisation for Economic Co-operation and Development (OECD) (2013), *Science, technology and industry scorecard 2013*, OECD, Paris, p.180. Available at: http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2013_sti_scoreboard-2013-en

[9] Australian Bureau of Statistics (ABS) 2014, *Innovation in Australian business, 2012–13*, cat. no. 8158.0, ABS, Canberra, http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/8158.0Main%20Features72012-13?opendocument&tabname=Summary&prodno=8158.0&issue=2012-13&num=&view

- **Business innovation in Australia lacks novelty**. ABS data show that of those Australian businesses that do introduce innovations, between 75 and 92 per cent of innovations were new-to-firm only, rather than being new to the region, industry or world.[10] Researchers are involved in the discovery of new knowledge and technologies, which is almost always new to world. Collaboration between academia and business, in those instances where a business wishes to introduce innovations that are already present in the industry or region, is unlikely to deliver significant benefits to either the innovating business or the collaborating institution.
- **Australian businesses collaborate with value chain partners.** For those businesses that do collaborate on innovation, there seems to be a clear preference to collaborate with entities in their own value chain such as clients and customers (43.8 per cent of innovation collaboration-active businesses) suppliers (42.1 per cent) or consultants (28.1 per cent).[11] This makes intuitive sense—if the predominant mode of innovation is to introduce products or processes that already exist in the industry (as in new-to-firm innovation), then the most appropriate innovation partners are those who might demand innovations already available from other firms (buyers), or those who can enable the introduction of pre-existing innovations (suppliers or consultants). If the innovation is pre-existing in the marketplace, then the expertise of researchers in creating new-to-world innovations is unnecessary. Universities would seem like a less appropriate innovation partner in these scenarios.

These observations all point to a root cause: low demand from Australian innovators for new knowledge to drive new-to-world products and services. To improve commercial output from Australian research, and improve integration in the Australian innovation chain, it is important to stimulate demand amongst Australian business for research expertise.

Unfortunately, there are a number of barriers to Australian business engaging in innovative practices which could lead to higher utilisation of Australian research expertise. These are also barriers that inhibit commercialisation:

- **Australia has a relative lack of venture capital investment**. A report from ACOLA has highlighted that venture capital investment in Australia is declining sharply. Furthermore, the level of venture capital investment in Australia as a percentage of gross domestic product is low compared to other OECD countries.[12] Venture capital and other forms of finance that accept higher levels of risk compared to conventional financial institution debt instruments are essential for bridging the gap between research outcomes and commercial goods or services.

  The Academy of Science welcomes the Government's initiatives in creating new investment vehicles to provide capital for commercialisation—the Biomedical Translation Fund and the CSIRO Innovation Fund. Together with the Clean Energy Finance Corporation, investment by government in commercialisation activities has the potential to significantly improve prospects for commercialisation of Australian breakthroughs in Australia. Should these initiatives succeed after a reasonable trial period, consideration could be given to expanding this approach to stimulate commercialisation across all of Australia's research priorities.

[10] ABS 2014, *Innovation in Australian business*.
[11] ABS 2014, *Innovation in Australian business*.
[12] Bell, J, Frater, B, Butterfield, L, Cunningham, S, Dodgson, M, Fox, K, Spurling, T and Webster, E (2014), *Securing Australia's future 4: the role of science, research and technology in lifting Australian productivity*, Australian Council of Learned Academies, Melbourne, http://www.acola.org.au/PDF/SAF04Reports/SAF04%20Role%20of%20SRT%20in%20lifting%20Aus%20Productivity%20FINAL%20REPORT.pdf

- **Incentives for business research and development favour larger companies.** Australia's support for business research and development is mostly indirect, relying heavily on the R&D tax incentive. By its nature, this support favours those companies with sufficient existing capital to establish or undertake new research and development activities. However, commercialisation of research outcomes is frequently undertaken by small start-up or spin-out companies that can lack such capital. Similarly, because the incentive is a tax offset (albeit partially refundable), it can be of limited use unless there is a strong expectation that the company will incur a tax liability from concurrent or future profit. This means that indirect support through a tax offset is of little use to a start-up company engaged in commercialisation of a novel technology, which may be wanting in capital to conduct its R&D program.

  Direct support for business R&D, particularly for small companies, could increase the ability of companies to conduct novel innovation and engage with new research and knowledge produced by Australian institutions. OECD data rank Australia 33 of 36 OECD countries for direct support to business research and development as a percentage of GDP. A strong and stable commercialisation program could be an effective vehicle for supporting early-stage commercialisation endeavours to help bridge the gap between the outputs of research and commercial goods and services. Although NISA contains welcome initiatives to provide some support for commercialisation and venture capital, consideration should be given to expanding direct government support for business innovation as occurs in a number of other countries.

- **Lack of stability in policy settings for supporting commercialisation.** ACOLA has pointed out that Australia's schemes to support business R&D, and commercialisation, have not inspired confidence in the business community*:*

  > *Commonwealth Government measures to assist firms are fragmented and lack scale and continuity. Unlike most other OECD countries, Australia has a history of frequent changes to assistance measures. This makes it difficult for business to plan for or rely on government assistance.*[13]

  A long-term, well-resourced commercialisation support program would provide confidence to business to invest in novel innovation and R&D, and assist in fostering a broader innovation culture among Australian business. ACOLA argues that policies that focus on enhancing demand for research and innovation services have been shown to be an effective way of capturing benefits from publicly funded research.[14]

A broadening of Australian businesses conducting novel innovation would drive greater collaboration between researchers and industry. However, given the current barriers outlined above, measures in NISA to improve business innovation will be most effective if they are built on and expanded in the future, and remain available for an extended period of time.

Recommendation: The Academy recommends that support for commercialisation of research in Australia, including business innovation incentives, is coupled to policy certainty. Additionally,

[13] Bell et al. (2014), *Securing Australia's future 4: the role of science, research and technology in lifting Australian productivity*, p. 56

[14] Bell et al. (2014), *Securing Australia's future 4: the role of science, research and technology in lifting Australian productivity*, p. 56.

the Academy recommends that the Government gives consideration to expanding direct support for commercialisation on a long-term basis.

Recognising the importance of basic research

While recognising the importance of prioritising limited resources and ensuring return on investment, the Academy is committed to ensuring that the importance of basic, curiosity-driven research is not overlooked. Basic research is the genesis of all innovation in that it is the new discoveries and leaps in understanding that provide the human and knowledge capital to drive innovative solutions to current and future challenges. Unless Australia maintains its capacity to undertake world-class basic research across diverse fields of science, there will be a diminished capacity to engage in and enjoy the benefits of innovation in the future.

It must also be recognised that publicly funded research returns numerous benefits to society, of which commercial output is just one. Just a few examples include:

- improvements in public health through new or improved methods of clinical practice, based on advances in biomedical knowledge
- advances in management of land and the environment through improved knowledge of natural processes
- production of graduates trained in research techniques and methods, who use their skills in the public and private sectors to solve difficult problems that face the community.

The Academy is concerned that:

- **changes to university funding to incentivise industry-focused research may inadvertently disadvantage basic research.** The Government's implementation of changes to university research block grant funding, as recommended by the Review of Research Funding and Policy (the Watt review), places significant incentives on attracting funding from industry and other sources. While providing incentives for universities to attract commercial funding is unobjectionable in and of itself, the proposed new funding allocations no longer provide any incentive to improve the quality of research conducted by universities. The Academy is also concerned that academics will be discouraged by their institutions from undertaking research that may have a social or environmental rather than commercial focus.
- **the proposed assessment of research engagement with industry will create bias against basic research**. The Academy is concerned that the Government's proposal to implement a system of measuring 'research engagement' to sit alongside the current Excellence in Research for Australia (ERA) system will create a damaging and unnecessary bias against basic and public-good research. Although the proposed research metric is yet to be developed, it is likely to be based on existing work which uses research income as a proxy for engagement[15], so that engagement is only considered where money changes hands. This cannot take into account those situations where academic researchers work with other organisations collaboratively to solve problems which may not have an immediate commercial aspect. In addition, should the research engagement metric be tied to incentives, it is likely that non-commercial but publicly beneficial research would be discouraged. These arrangements are also likely to place a significant additional administrative burden on universities without a clear articulation of the expected benefits.

[15] Cahill, T (2015), *Research engagement for Australia – measuring engagement between universities and end users,* Australian Academy of Technological Sciences and Engineering, Melbourne. Available at: http://atse.uberflip.com/i/499806-research-engagement-for-australia-measuring-research-and-engagement-between-universities-and-end-users

The most appropriate assessment of university research is its quality. The ERA process remains the most suitable way to evaluate Australian research effort, and policy decisions should be based on these data. Importantly, the ERA is an appropriate way to assess both basic and applied research.

Recommendation: The Academy recommends that the emphasis on commercially-oriented research be accompanied by an explicit commitment and strategy to sustain and improve high-quality fundamental and public-good research in Australia.

International engagement and collaboration

The Chief Scientist's report, *Science, Technology, Engineering and Mathematics: Australia's Future*, identified international engagement as a significant priority for Australian science and research, and highlighted the benefits that international engagement in STEM can bring to Australia:

> *STEM can bridge cultural divides through its absence of ideology and shared intellectual tradition. It also showcases Australia's advantages as a destination for international students, R&D investment and business partnerships. Inward investment from multinational companies and access to global supply chains must flow from these relationships.*[16]

In other words, science, research and innovation is increasingly a global activity and Australia's efforts do not exist in isolation. Rather, ideas, expertise and technology from abroad are used to improve life and productivity for Australians, just as Australian inventions and know-how has impact around the world. Although Australia produces more than its share of scientific knowledge on a per-capita basis, the reality remains that Australia will continue to rely on accessing ideas and knowledge from overseas as well as creating and exporting home-grown innovations.

This makes international links between researchers and businesses integral to Australia's science and innovation system.

For example, the Gardasil vaccine that protects against viruses that cause cervical cancer has its genesis in international collaboration. The researchers who developed the knowledge and technology behind the vaccine, Professors Ian Frazer and Jian Zhou, met when they were both visiting the University of Cambridge in the United Kingdom, away from their respective homes in Australia and China. They subsequently collaborated in Australia on the research that enabled the development of Gardasil. This demonstrates how international engagement and collaboration in science can be an important stone in the path to discovery.

International collaboration and engagement is of greater importance in smaller countries such as Australia which have do not have the thriving domestic networks of researchers with similar interests. International data indicates that collaboration and engagement between researchers acts as a vital means to overcome the limited scale available in smaller economies.[17]

The Academy's position papers, *Internationalisation of Australian science* and *Australian science in a changing world: innovation requires engagement*, show that relatively minor investments in international scientific engagement can leverage funding and commercial outcomes totalling up to 21 times the value of

[16] Office of the Chief Scientist (2014), *Science, Technology, Engineering and Mathematics: Australia's Future,* Australian Government, Canberra, p.30. Available at: http://www.chiefscientist.gov.au/wp-content/uploads/STEM_AustraliasFuture_Sept2014_Web.pdf

[17] Organisation for Economic Co-operation and Development (OECD), *Science, technology and industry scorecard 2015*, OECD, Paris, p.130. Available at: http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard_20725345

the original funding. These papers also set out that international engagement can have implications for education, national security, diplomacy and the evidence base for policy making.[18]

Australia's distance from other countries means that international collaboration and engagement is more difficult and expensive for Australian scientists than those in Europe and America. However, because of our relative isolation from comparable research centres, international engagement and collaboration is critical to ensure that Australian researchers are abreast of the latest developments in their fields.

In this context, the Academy welcomes the Government's inclusion of funding in NISA to encourage international collaboration for researchers and business.[19] Although final details are still to be determined, it is clear that additional support for international science engagement will be provided along with support to help business to form links with international research clusters.

However, even with this new investment, Australia's international science and research engagement activity will remain ad-hoc and underfunded.

The Chief Scientist's report outlines a number of strategies to enhance Australia's international science engagement, including improving science diplomacy and enhancing government-to-government linkages as a basis for collaboration. It is not yet clear that NISA will adequately implement these recommendations.

Recommendation: The Academy recommends that the Government implements and fully funds all of the international engagement recommendations made by the Chief Scientist.

Science and mathematics education

For Australia to remain a prosperous nation in a globalised world, the focus of Australia's economy must become the development of advanced goods and services that embody cutting-edge knowledge. To successfully create, acquire and implement these advanced goods and services, it is important to create a workforce with expertise in science, technology, engineering and mathematics.

Australia's performance in international benchmarking exercises of science and mathematics skills of students shows that Australian students are being overtaken by many of our near neighbours. The Australian Council for Educational Research notes that:

- Australian students' scientific literacy has remained relatively stable, but has been overtaken by a number of countries and now lags behind some of our neighbours including China, Korea, Singapore and Japan.
- Australian students' scores for mathematical literacy have declined significantly between 2003 and 2012. Alarmingly, one in five Australian students tested in 2012 failed to demonstrate a baseline level of mathematical literacy.[20]

[18] Australian Academy of Science (AAS) (2010), *Internationalisation of Australian science*, AAS, Canberra, pp.11-14. Available at https://www.science.org.au/files/userfiles/support/reports-and-plans/2015/internationalisation-of-australian-science.pdf; AAS (2011), *Australian science in a changing world: innovation requires engagement*, AAS, Canberra, pp. 10-14. Available at: https://www.science.org.au/files/userfiles/support/reports-and-plans/2015/innovation-requires-global-engagement.pdf

[19] Australian Government (2015), 'Global Innovation Strategy', *National Innovation and Science Agenda*, Australian Government, Canberra. Available at: http://www.innovation.gov.au/system/files/case-study/Factsheet%2012%20-%20Australia%E2%80%99s%20Global%20Innovation%20Strategy.pdf

[20] Thornton, S, De Bortoli, L and Buckley, S (2013), *PISA 2012: How Australia measures up*, Australian Council for Educational Research, Melbourne, pp.ix-xv. Available at: https://www.acer.edu.au/documents/PISA-2012-Report.pdf

In addition, the number of secondary students studying science subjects has been in decline over several decades.[21] The number of STEM-qualified tertiary graduates has declined from 22 per cent of total graduates in 2002 to 16 per cent in 2012.[22] Similarly, in 2012, the Office of the Chief Scientist undertook a systematic review of the health of Australian science.[23] The report found that student participation at secondary schools in the enabling science subjects of mathematics, chemistry and physics has been declining. Furthermore, student participation in the enabling sciences at tertiary level has been in long-term decline, with continuing science undergraduate participation in mathematics, physics and chemistry all declining during the 1990s and not recovering during the 2000s.

The relative and absolute declines in Australian science and mathematics is alarming. Should this continue, Australia's workforce will not have the STEM skills to adequately deal with increasingly technical avenues of global trade and investment.

A recent report by ACOLA—*Securing Australia's Future 5: Technology and Australia's Future*—highlighted that education must produce workers with the ability to adapt to new technologies and the capacity for life-long learning as it is difficult to predict future technological change.[24] In this context, science and mathematics are important core skills that enhance and encourage creative inquiry and experimentation, which will be increasingly important for workers of the future.

It is likely that future trade and investment will be in (and enabled by) goods, services and knowledge which may not exist or be conceived of today. STEM-literate workers will be required to invent, develop, acquire and manage these new technologies. Without an understanding of STEM concepts and skills, Australian students risk becoming workers who are left behind by technological advances.

The Academy welcomes the efforts that the Australian Government is making to improve science and mathematics for school students, notably by funding a number of programs that are making high-quality educational resources available to all Australian students—in particular Primary Connections, Science by Doing and Mathematics by Inquiry that are led by the Academy.

However, further reform is needed to ensure that all students are provided with a satisfactory grounding in science and mathematics. Important actions that will improve Australia's performance in school science and mathematics include:

- ensuring each student in every Australian school is taught by **appropriately qualified teachers** with access to the best resources and support, regardless of postcode
- teaching **science as a core subject in primary school**, in the same way as maths and English
- Having **specialist teachers lead high school science and maths** programs in core curriculum areas
- Embracing the principles of **inquiry-based learning** that foster curiosity and innovative thinking from an early age
- **supporting science and maths teachers** to provide the best possible education to students.

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[21] Goodrum, D, Druhan, A and Abbs, J (2011), *The status and quality of year 11 and 12 science in Australian schools*, Australian Academy of Science/Office of the Chief Scientist, Canberra, https://www.science.org.au/sites/default/files/user-content/year-1112-report-final.pdf

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Similarly, university STEM teaching can be significantly improved, and the Academy encourages government and universities to work together to recognise excellence in university STEM teaching and create appropriate incentives for university teaching staff to improve their teaching methods and materials.

A STEM-literate, innovation-capable Australia depends on excellent education at all levels. Australia must be vigilant to ensure our performance in science and mathematics does not fall further behind our neighbours, with the result that we are left behind by technological change.

Recommendation: The Academy recommends that the Government develops a set of targets and policies aimed at improving Australian students' performance in science and mathematics.