Australian Academy of Science

INTERNATIONAL SCIENTIFIC COLLABORATIONS IN A CONTESTED WORLD

Monday 13 and Tuesday 14 November 2023

Discussion paper

INTERNATIONAL SCIENTIFIC COLLABORATIONS IN A CONTESTED WORLD

The Australian Academy of Science's 2023 national symposium will facilitate a dialogue on the role of international scientific collaboration in providing benefits to the nation and the globe in our fragmented, contested, and uncertain world.

Australia and our science system benefit from the values of the research enterprise—openness, accountability, objectivity, and integrity in our collaborations regionally and globally. Scientific collaboration benefits all partners, and the Australian government has recognised that the exchange of ideas and people is a net positive economically and socially.[1,2]

The adoption of science and technology is essential for Australia to compete, innovate, grow, and drive further improvements in productivity and sustainability. Emerging technologies—such as generative artificial intelligence (AI)—offer new ways to generate economic value and solve social problems. However, new knowledge also brings new risks. Dealing with these risks can inadvertently act as a barrier to the way Australian scientists collaborate globally.

Australian science has a crucial part to play in securing the prosperity of the nation and the Indo-Pacific region. This paper provides relevant background, data, and questions to stimulate thinking around scientific collaborations in a contested world.

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Tuesday 14 November
9.00am—5.00pm AEDT
The Shine Dome, Canberra or online

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SCIENCE AND TECHNOLOGY IN TODAY'S COMPETITIVE LANDSCAPE: A NEW ERA?

Scientific capacity is a powerful asset that nations are keen to possess. Scientific discoveries are vital for success in the global economy and for addressing societal challenges such as health, environment, and national security.

During the Cold War, the United States of America (USA) established itself as a science and technology leader, bolstering the economic and military competitiveness of its allies.[3,4] International scientific collaboration expanded after the Cold War, driven by easing political tensions, advances in communication technology, and growing recognition of the advantages of global scientific cooperation. Geopolitical dynamics allowed and enabled scientists to collaborate more freely, access global funding sources, build big science infrastructure,[5,6] and share knowledge through digitalisation and more accessible scientific publications globally.

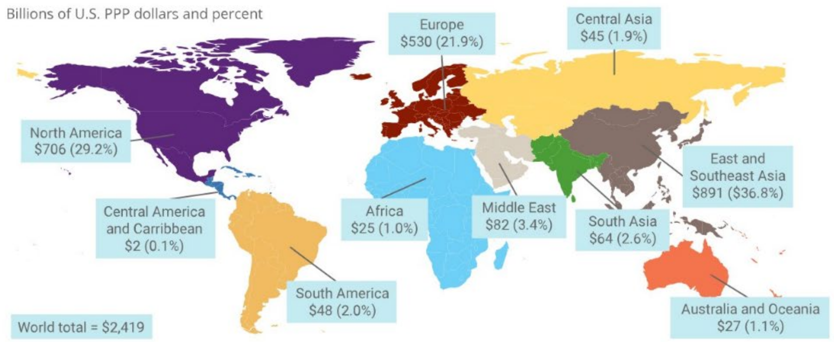
Today, four megatrends characterise the global science system, namely:

- Rapid expansion in papers, publications and means of scholarly communication;
- Spread of scientific capacity and output to a growing number of countries;
- Expansion of the number and proportion of international collaborations; and
- Changing geopolitics of science.

The well-being of nations and their citizens depends on solutions that only global scientific collaboration can secure.

Nation-states are positioning themselves in a changing international system by increasing their scientific and technological sovereignty. Consequentially, many nations have significantly increased their research and development (R&D) investments and have become major contributors to global research efforts.

Global science has evolved into three main centres of activity, workforce, and funding: the USA, Europe and China. Other players exist, however, particularly in East and South Asia and South America.[4]



PPP = purchasing power parity.

Note(s):
Foreign currencies are converted to dollars through PPPs. Some country data are estimated. Countries are grouped according to the regions described by *The World Factbook* (CIA 2021).

Source(s):
National Center for Science and Engineering Statistics, estimates as of December 2021. Based on data from Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (September 2021 edition), and United Nations Educational, Scientific and Cultural Organization, Institute for Statistics, Science Technology and Innovation data set (March 2021 release).

Figure 1: Global R&D expenditures by region

Source: Science and Engineering Indicators 2022, National Centre for Science and Engineering Statistics[7]

China is seeking to consolidate its place as a scientific and technological power– leveraging access to international scientific research for strategic advantage, increasing R&D expenditure, prioritising its domestic technology markets, and developing strategically important industries such as energy, biotechnology and telecommunications.[8] As a result of almost 20 years of consistent, patient and at-scale investment, China has developed seven universities ranked amongst the world's top 100, up from three in 2011.[9]

Governments in democratic countries are increasingly aware of China's policy focus on building strategic advantage through advanced science and technology capability. This awareness is driving geopolitical competitiveness and a focus on national security.[10] In this context, balancing risk management with open and effective international scientific research collaboration is becoming an important issue.

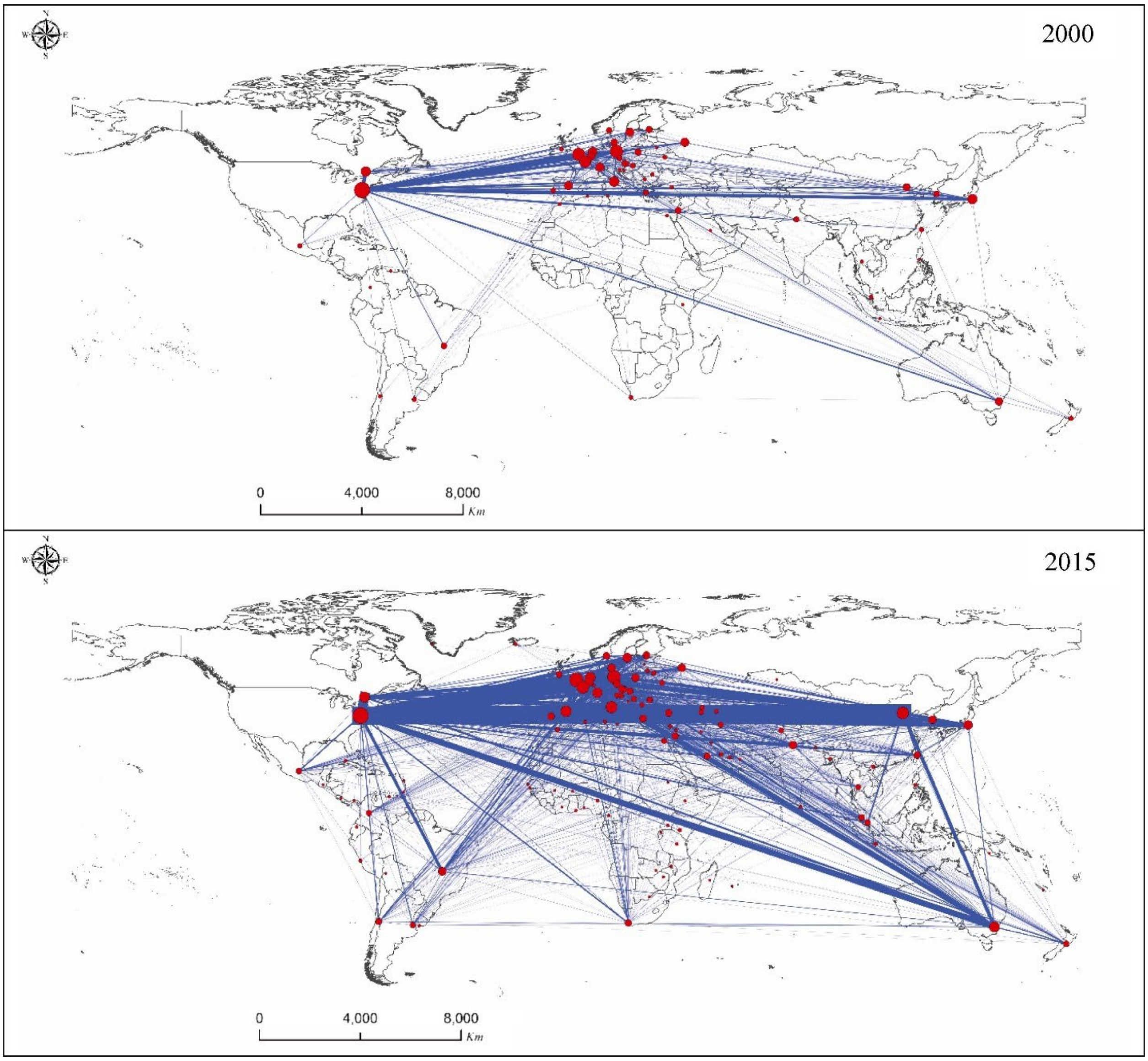


Figure 2: Spatial patterns of international scientific collaboration network (2000 and 2015)

Source: Qinchang Gui, Chengliang Liu, Debin Du, *Globalization of science and international scientific collaboration: A network perspective*, Geoforum, Volume 105, 2019, Pages 1-12[11]

ISSUES TO CONSIDER

- How might the evolving competition between China and the USA influence Australia's international scientific collaborations and strategic partnerships into the future?
- What do we need to create a robust science system in the face of new conflicts or security threats?

THE GLOBAL SCIENCE SYSTEM – NEW OPPORTUNITIES AND NEW RISKS?

The development of this multipolar science system presents complex challenges but also a new role for the Australian science sector.

Australian scientists and science have a long and rich history of international collaboration, exemplified by the role of Prof Frank Fenner in the eradication of smallpox and Australia's contribution to establishing and sustaining the Antarctic Treaty System.

The occurrence of worldwide crises necessitates active international science diplomacy and robust multilateralism. While the response to COVID-19 (SARS-CoV-2) showed that international collaboration can produce swift results, it also revealed its limitations, especially in the unequal distribution of vaccines and treatments across different countries. Vaccine nationalism and diplomacy exemplify the competing yet cooperative dynamics that are expected to shape the response to future crises.

Institutions—including academies of science and international organisations such as the International Science Council and United Nations technical organisations—provide important conduits for collaboration. International scientific bodies and networks build bridges between nations and communities to address matters of common concern and make global progress.

Yet not all nations or sets of nations view international scientific collaboration through the same lens. In the USA, Europe and China, collaboration is motivated by strategic competition. In other nations, scientific collaboration is viewed with an economic development lens or a lens that emphasises the United Nations Sustainable Development Goals.

In the Australian context, geopolitical competition is driving renewed recognition of a security dimension to international research collaboration. This is exemplified through evolving defence strategic policy settings and responses to counter foreign interference in the research sector.

RISKS TO SCIENCE IN A CONTESTED WORLD

Advances in science and technology have transformed R&D processes, with increased investment in fields like information technology, biotechnology, nanotechnology, quantum computing, and artificial intelligence.

The development and deployment of advanced technology platforms—as distinct from individual technologies—is a crucial element in strategic competition and defence innovation, which makes their regulation and control more difficult than in the past. [12]

While international protocols and national governments regulate research on chemical, biological, radiological, nuclear, and explosive technologies through conventional export controls to prevent knowledge transfer, it is less easy to control the transfer of data, information and expertise from fundamental scientific research, which has traditionally been exempt from defence-related regulations but can arguably be considered as potentially dual-use. For instance, AI and quantum computing may have the potential for both civilian and military use, in addition to being the focus of intense economic competition between companies, countries and regions.

The changing geopolitics of great power rivalry is impacting the organisation and evolution of global science and international scientific collaborations. Competition between the USA and China has impacted collaborations between scientists in those countries.[13] War in Ukraine has also had a dramatic, though not wholly unexpected, impact on Russian and Ukrainian scientific collaborations.[14]

Communication tools alter how the public receives scientific information and makes informed decisions, and influence the spread of mis- or disinformation. The polarisation and oversimplification of scientific knowledge often presented through traditional and social media compel the public into a binary agreement; yes or no, agree or disagree.

WHAT IS A PLATFORM?

A platform is a system or stack of technologies, processes, information, or services that enables the operation or development of other end-use technologies, applications, or processes. Examples of platforms are operating systems, the internet, cloud computing, big data platforms, telecommunications platforms, genome editing or artificial intelligence.

Platforms can be interoperable, codependent, widely used, and governed by shared standards.

WHY EMPHASISE PLATFORMS?

It's not possible to handle platform vulnerability or threats in the same way as stand-alone technology systems or products. Segmenting a platform into sub platforms, like data segmentation, can hinder the platform's ability to share functionality or features. Making security modifications to the platform can affect all users and applications, affecting interoperability. Altering the platform's features can also have far-reaching consequences for many dependent end-use technologies. Sharing information can create legal, regulatory, and societal ambiguity and pose difficult questions on jurisdiction for national and international governance policies.

Platforms are often developed by the private sector but have applications in other areas such as research and defence, so traditional approaches to protection can cause problems with other technologies that share the same platform.

Technology platforms controlled by private actors can present challenges for national security and foreign policy. For example, Elon Musk's SpaceX has become a major US defence contractor, launching satellites and operating the Starlink network, but SpaceX also supplies the technology to other countries. The US Senate Armed Services Committee is probing national security issues raised by decisions made by Musk regarding Starlink operations in Ukraine.[30] This has created a scramble among nations on how they can secure Starlink and similar technologies.

Other risks to science and national science systems in a contested world include:

- **Foreign interference**. The open nature of global science makes Australian research institutions vulnerable to exploitation by foreign actors through both soft power mechanisms (exchanges, funding) and more direct interference to obtain privileged information, access a national competitive advantage, or shape public opinion. Policymakers are concerned that such activities can compromise valuable research or sensitive data and cause damage to national security, economic, and military interests.[15]
- **Global competition for scientists**. This remains a concern for many nations given the global nature of many science domains.[3] Nations have established programs to attract talent—including targeting foreign diaspora—such as China's 1000 Talents program, and other programs that operate in western nations, including Australia.[16,17]
- **Data, cybersecurity, and intellectual property protection.** An ongoing concern globally, as protective legislation and regulations race with the technology.

International research collaborations provide an opportunity for state and non-state actors to obtain sensitive information, technology, and cybersecurity techniques. From 2021-2022, 76,000 cybercrimes were reported in Australia (approximately one every seven minutes). Cybersecurity and intellectual property (IP) protection are of particular concern as Australia has access to sensitive and classified information from the USA and other Five Eyes partners.

- **Regulation of scientific collaborations.** Regulation has become the norm, as governments take steps to reduce risks of interdependent science, technology, and innovation, and limit international technology transfers through increasing oversight, regulation, and restrictions on scientific exchanges.
- **Over-reliance on international collaborations.** Increased dependence on international partners and external support for research, infrastructure, and talent can compromise national sovereignty over its intellectual property and research outputs, particularly if domestic R&D is minimal.

These risks are disrupting interconnected global science value chains and the extensive international science partnerships that have been established over the last three

REGULATION AND ITS IMPACT ON COLLABORATION

International scientific collaboration is crucial for success in Australia's competitive landscape, but the risks associated with it are increasing, including foreign interference, data privacy, and technology control. While some limits are reasonable, overstating risks or creating uncertainty harms beneficial collaboration.

Emerging technologies like generative AI offer new possibilities for economic value, productivity, and social solutions, but also bring new risks that are difficult to manage. Traditional methods of listing specific 'critical technologies' are not sufficient for platforms that have a range of uses and users. Policymakers need to support international research collaborations and technology use while managing risks effectively.

Australian researchers and research organisations (universities, medical research institutes, business, and science agencies) must comply with an array of economy-wide and sector-specific regulatory requirements that apply to international research collaboration. Legislation and regulations such as the *Defence Trade Controls Act 2012* can both hinder and stimulate international research collaboration in a range of ways.

However, Australian scientists also face regulatory barriers due to increased nationalism and securitisation from other countries, including export controls that affect scientific equipment and supplies.

POLICY OPTIONS

Policymakers must consider how their regulations affect collaboration, as poorly designed regulations can limit access to goods and services, increase costs, and discourage research and investment. Conflicting or complex regulations can create confusion and administrative burdens, damaging productivity and competitiveness.

Policymakers should balance national security while supporting trade, research, and international collaboration.

Policymakers should consider the utility of export controls alongside other levers such as investment controls, IP protection, and diplomatic levers. Some policymakers suggest like-minded techno-democracies are needed to address the national security threat posed by China's objective of obtaining national strategic advantage, securing allied supply chain resilience, preventing the misuse of commercial technologies, and addressing military-civil fusion science systems.

decades. The growing emphasis on "shared values" in technology development and research may lead to a separation of science, technology, and innovation activities.

OPPORTUNITIES FOR SCIENCE

Presenting science as a competition among nations ignores the reality of a global science system and its international networks. The path from science to innovation is complex and involves many players. Since science is shared globally, many national industries benefit from foreign research. Private companies now invest heavily in research and development, and partnerships between public and private sectors are becoming more common. Additionally, research and production arms of private companies can be situated across many countries.

The path from science to innovation is complex and involves many players. Since science is shared globally, many national industries benefit from foreign research.

These suggest opportunities and imperatives for nations from the multipolar science system:

- **Access to knowledge is democratised by digitalisation.** Scientists from smaller nations and the Global South—while still underrepresented—have greater access to the stock of knowledge and capacity to participate in scientific dialogue than at any other time in human history.[18] New modes of scholarly communication and publishing (including social media) are further disrupting the old science order. Nevertheless, integrating scholars from nations outside of the USA, Europe, and China remains challenging.
- **International collaboration can support and strengthen domestic research ecosystems.** It is rare for a single nation to have all the talent and infrastructure required to foster a thriving research and innovation environment. By tapping into knowledge, innovation, and human resources from abroad, nations can leverage resources through international collaboration that may not be available domestically.
- **Global challenges require scientific evidence**. The big challenges of our time—climate change, pandemics, environment protection, regulation of the seas, and space—are all multilateral issues where no one nation can impose its will. These challenges require scientists to come together and provide evidence.
- **Role of science in diplomacy and international relations**. International exchange promotes cooperation and shared understanding between nations and directly supports diplomatic processes through providing evidence and advice to inform decision-making.

This makes for a more complex global science system and public policy conundrum—how to reap the benefits of internationalisation while having a clear eye on the risks?

ISSUES TO CONSIDER

- What barriers to collaboration do scientists face because of limitations placed on the research sector in the interest of national security?
- Are current measures proportional to the risks of international scientific engagement? Can they be made more effective to encourage productive engagement?
- As a middle-power, can Australia follow its own path or be a leader in technology regulation, or will we always “follow the leader” (e.g., USA and Europe)?

AUSTRALIA'S PLACE IN THE GLOBAL SCIENCE SYSTEM

Australia has significant global influence for its size, but often overestimates its scientific capabilities despite being a middle-power science nation. Australia and Oceania together account for 1.1% of the world's investment in research and innovation, a level that is dwarfed by the world's science superpowers—the USA, China and Europe. Australian scientists, however, are amongst the best in the OECD in terms of research output.

Australia is also above average in the OECD in international scientific collaborations. Australia's share of top 10% of cited publications has risen sharply since the early 2000s. Additionally, Australian scientists' proportion of top 10% of cited publications involving international collaboration has risen more sharply than the OECD average.

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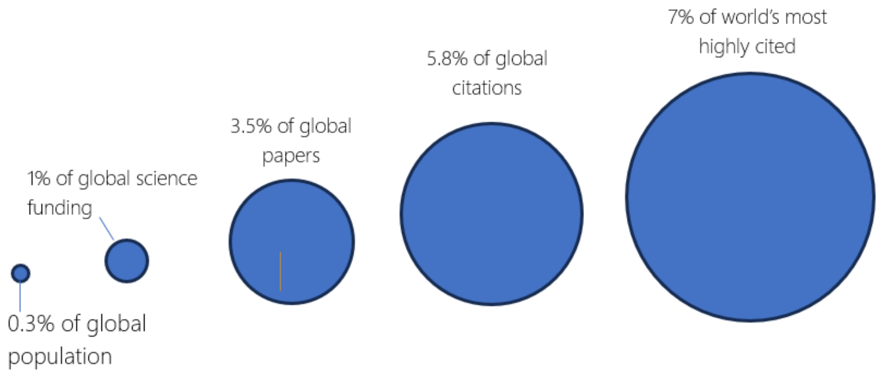

Figure 3: Australia's share of global science

Source: Clarivate InCites

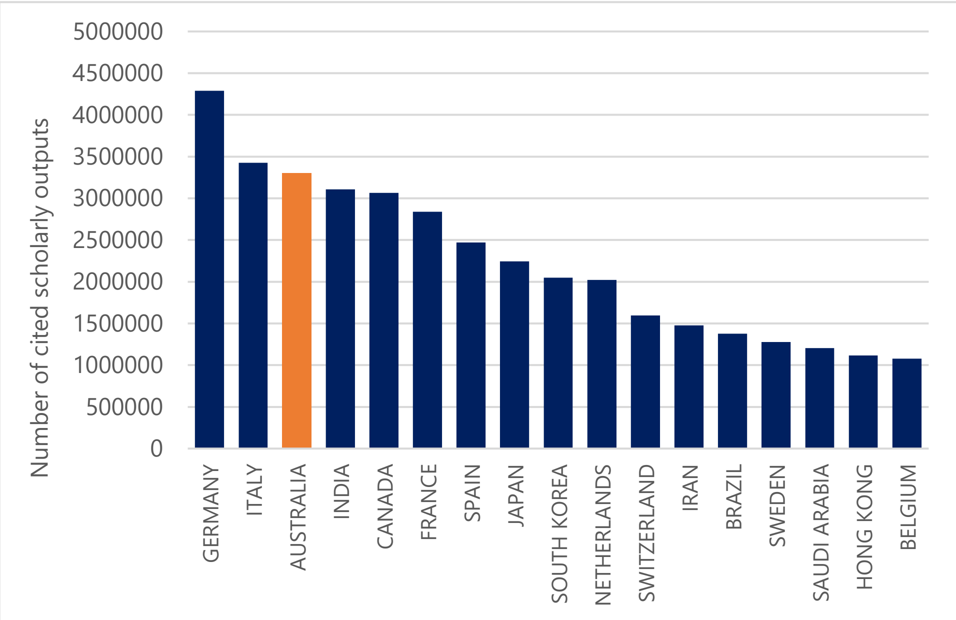

Figure 4: Top countries in cited scholarly outputs, 2020-22, excludes the US, China and the UK

Source: Clarivate InCites

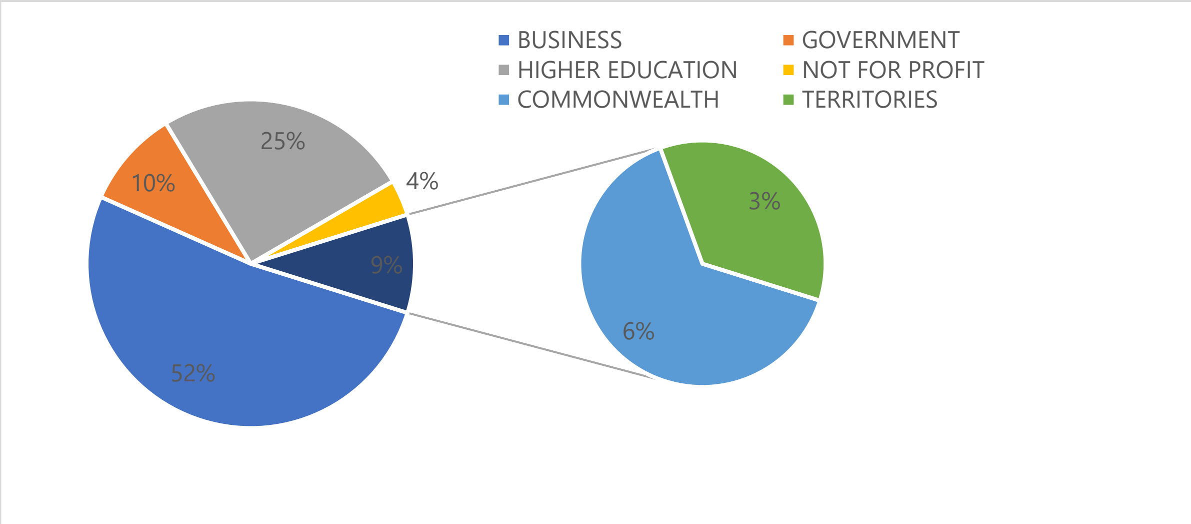

Figure 5: Research Intensity: Proportion of R&D investment for science-related fields of research, by sector, 2020-21

Source: OECD Main Science and Technology Indicators

Understanding what this means for the health of the Australian economy is difficult. Investment in science stands at 1.68% of gross domestic product (GDP), but this number underplays the role of science in underpinning industries and how we work and live.

A 2016 national study looking at the role of science in the national economy suggested that the advanced physical, mathematical, and biological sciences make a direct contribution of around $185 billion a year to the Australian economy, or about 14% of GDP[19]:

- When the flow-on impacts of these sciences are included, the economic benefit of these scientific fields expands to about $330 billion a year, or 26% of the nation's economic activity.
- 10% of total Australian employment (about 1.172 million jobs) was directly related to the advanced physical, mathematical, and biological sciences.
- Exports associated with the advanced physical, mathematical, and biological sciences activities are worth around $84 billion a year. This is 32% of Australia's goods exports and equivalent to 25% of total Australian exports of goods and services.

However, despite these contributions to the economy, investment in science in Australia as a proportion of GDP has been falling for several years and is now well below the OECD average, as noted above.

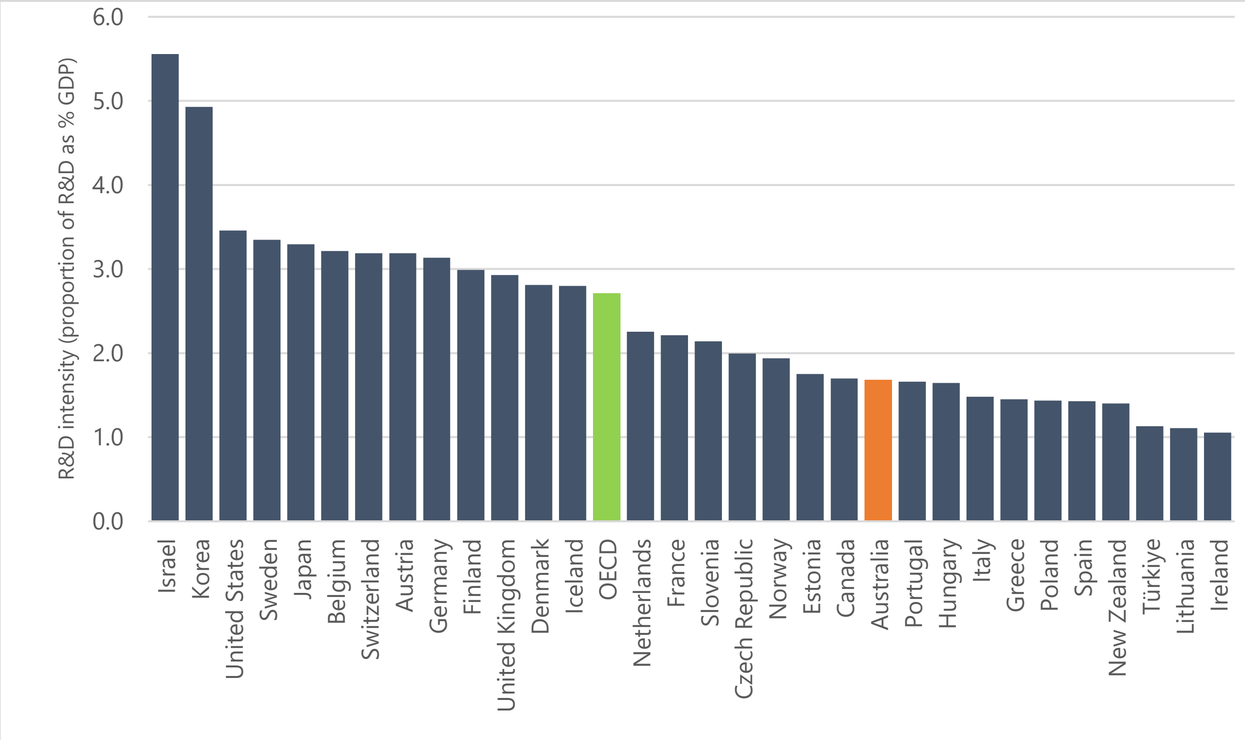

Figure 6: Research Intensity: Proportion of R&D as a percent of GDP, 2020-21

Source: OECD Main Science and Technology Indicators

The biannual statistical collection on Australia's expenditure on R&D is a useful—though inadequate—proxy for our investment. Australia's expenditure on R&D in science-related fields is dominated by the private and higher education sectors, which is not unusual across the OECD. However, compared to other OECD nations, Australia's business sector performs a relatively low level of R&D.

Across the economy, much of Australian science expenditure is in information and communications technology (ICT), biomedical sciences, engineering, and agriculture. Universities dominate spending in biomedical sciences, while business is most active in ICT and engineering.

Over the last two decades, the annual number of patents granted globally has more than doubled. A large portion of this growth has been driven by a surge of patent activity in China. The annual number of patents granted in China in 2021 was nearly 43 times higher than in 2001.

Australia's patent activity is a small portion of global activity. While the number of patents granted by Australia's filing office has grown, the proportion of global patents granted in Australia has declined from 2.55% in 2001 to 0.98% in 2021.

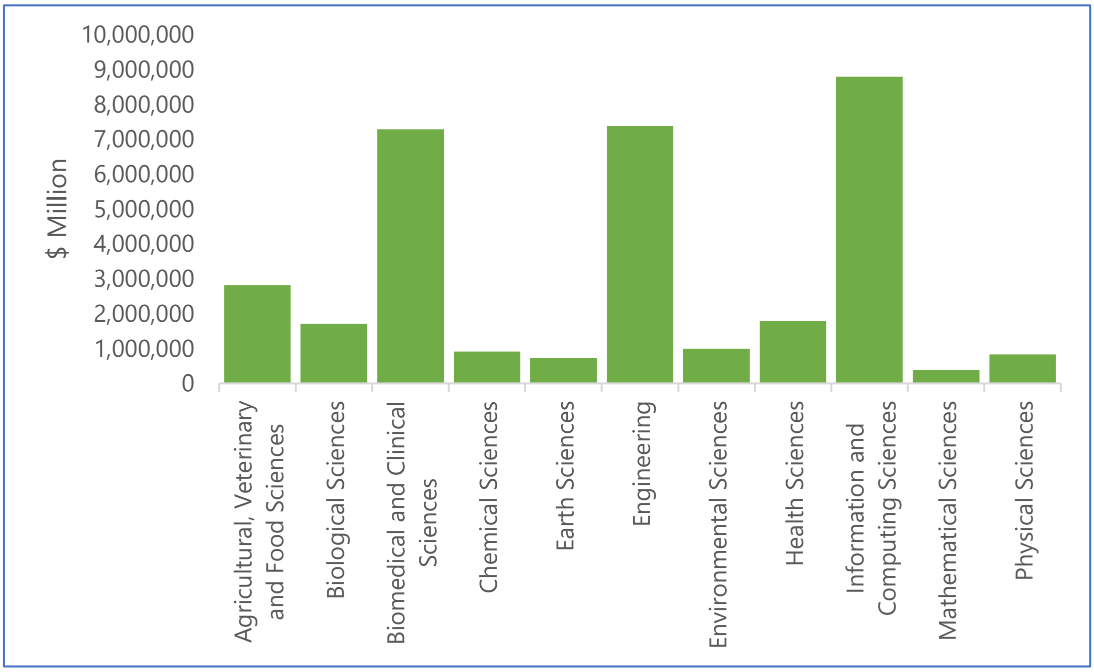

Figure 7: Total R&D investment for all sectors by science field of research, 2020-21

Source: Australian Bureau of Statistics

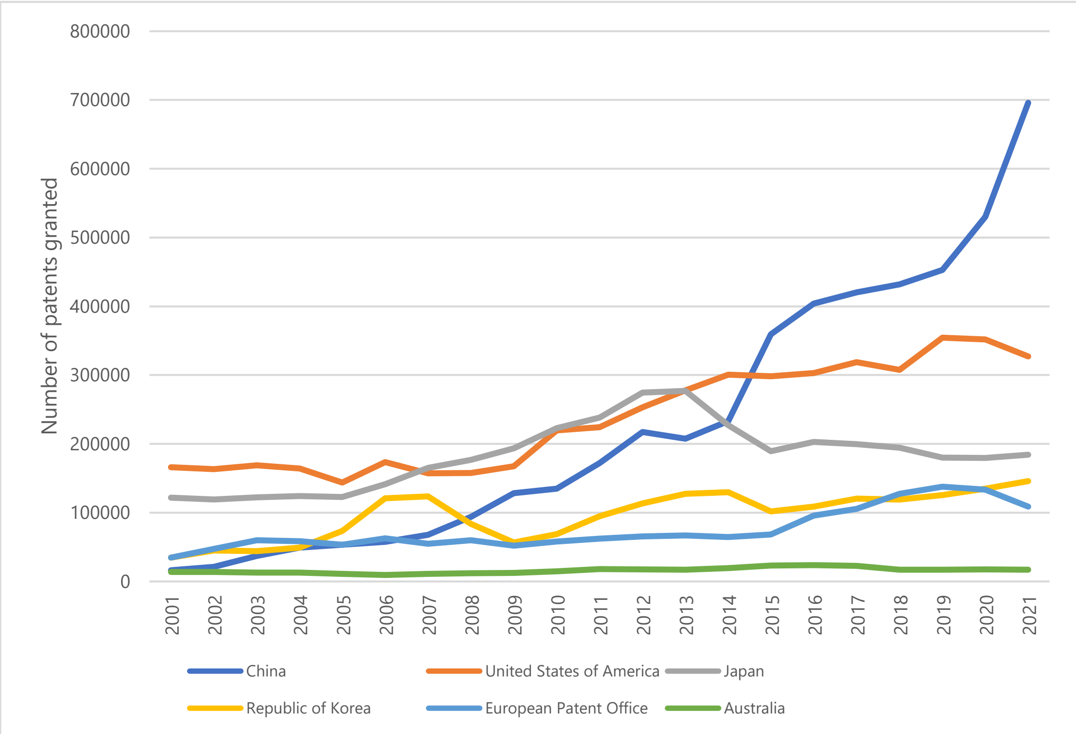

Figure 8: Top 5 patent filing offices in 2021 & Australia: total patents granted (direct and PCT national phase entries) by filing office 2001-2021

Source: WIPO statistics database

RESEARCH AND HIGHER EDUCATION MOBILITY

The size, scale, and makeup of Australia's university campuses has been transformed by the internationalisation of education. International education has also transformed Australia's research workforce.

The growth of university enrolments–enabled by growth in government and non-government funding–mirrors a broader global trend in student mobility and the mobility of scientific researchers. UNESCO calculates that worldwide, the number of scientists per million people has increased globally from 801 in 2000 to 1342 in 2021, an increase of almost 6 million.

Much of the research workforce in Australian universities is now made up of international postgraduate research students. Based on data from the Australian Bureau of Statistics, postgraduate research students represent nearly a quarter of Australia's research workforce, at 44,225 full-time equivalent (FTE) out of 181,155 FTE in 2020.[20–22] In the higher education sector, postgraduate students were 55% of the research workforce in terms of FTE in 2020.[20–22] In the same year, 36% of postgraduate research students were overseas students (23,754 overseas, 42,853 domestic).[23]

In the natural and physical sciences, the number and proportion of overseas students has grown over the last two decades. In 2021, 39% of natural and physical sciences postgraduate research student enrolments in Australia were overseas students.[23]

In 2022-23, the top five citizenship countries for postgraduate research sector student visas granted were China (18%), India (9%), Saudi Arabia (9%), Sri Lanka (7%), and Bangladesh (7%).[24] In 2016, 57% of Australia's university STEM-qualified labour force were born overseas.[25]

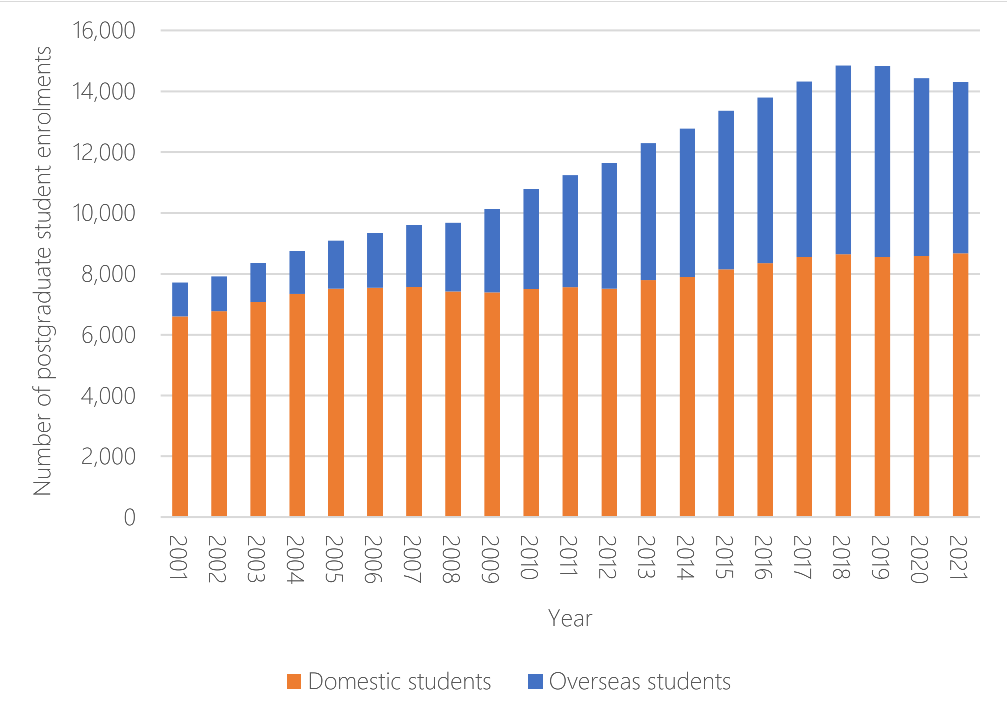

Figure 9: Natural and physical sciences postgraduate research student enrolments, Australia, 2001 to 2021

Source: Department of Education; Australian Bureau of Statistics

The ability to recruit global talent has been an important feature of the evolution of the Australian science sector for decades. The latest temporary skilled visa statistics show that the “Professional, Scientific and Technical” industry is the biggest user of these visas. In 2020-21, universities sponsored the migration of 320 “University Lecturers and Tutors”.

There is global competition for scientists and researchers. Countries like Canada, China and the United Kingdom have, in the last ten years, enacted policies and visa settings designed to attract both international students and qualified scientists. Australia has also responded with enhanced post-study work rights, including an additional four to six years for those with doctoral qualifications in health, engineering, ICT, teaching and agriculture.

Specific talent attraction schemes in science exist. In Australia, the Australian Research Council (ARC)’s Laureate Fellowship scheme is open to people born overseas, allowing universities to use it as a talent retention scheme for the world’s most distinguished scholars.

How then, is Australian science taking its place in the global science order, and what benefits does it accrue for the nation?

ISSUES TO CONSIDER

- How can Australia balance competition and collaboration in research achievement and attracting talent?
- How are geopolitical tensions constraining workforce mobility and research productivity?

TRENDS IN INTERNATIONAL COLLABORATION

Australian scientists have always been international collaborators. Australia is a destination for research and study for scientists from abroad and has sought the assistance of scientists from other shores to help build capacity and solve our problems.

Successive Australian governments have encouraged international scientific collaborations, coupled with the broader internationalisation of Australian universities and the Australian economy.[2]

What was seen as an unparalleled good, requiring only limited supervision, has become more complex as governments seek to respond to an era of strategic competition with a more nuanced and cautious approach to science, viewing policy through the lens of “science sovereignty” or “strategic autonomy” and managing national security risks.

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Australia has experienced a significant level of growth in international science collaborations over the past two decades. This growth has been underpinned by the proliferation of academic research papers, the digitalisation of scholarly communication and the rise of big data alongside artificial intelligence. Collaboration is the norm for researchers in Australia—90% of the top 50 cited papers from Australian authors in Web of Science (from 2013-2023) were co-authored with overseas collaborators.

Australia provides leadership in emerging areas, for example, big-data gathering and analysis projects, such as the Global Ocean Observing System, the Square Kilometre Array radio telescope project, and the Global Bioimaging project.[26]

Outside of the Nordic countries, Switzerland and Singapore, Australia has the highest number of scholarly outputs involving international collaboration per head of population. Australia is ranked ninth globally in the volume of scholarly outputs and sixth globally in citations.

Australia's patterns of international scientific collaborations are wide and diverse. We collaborate with almost every country in the world, although across the research sector, Australia's collaborations are focused on the USA and UK, although collaborations with China have grown in recent decades and it is now among our most important international partners.[27]

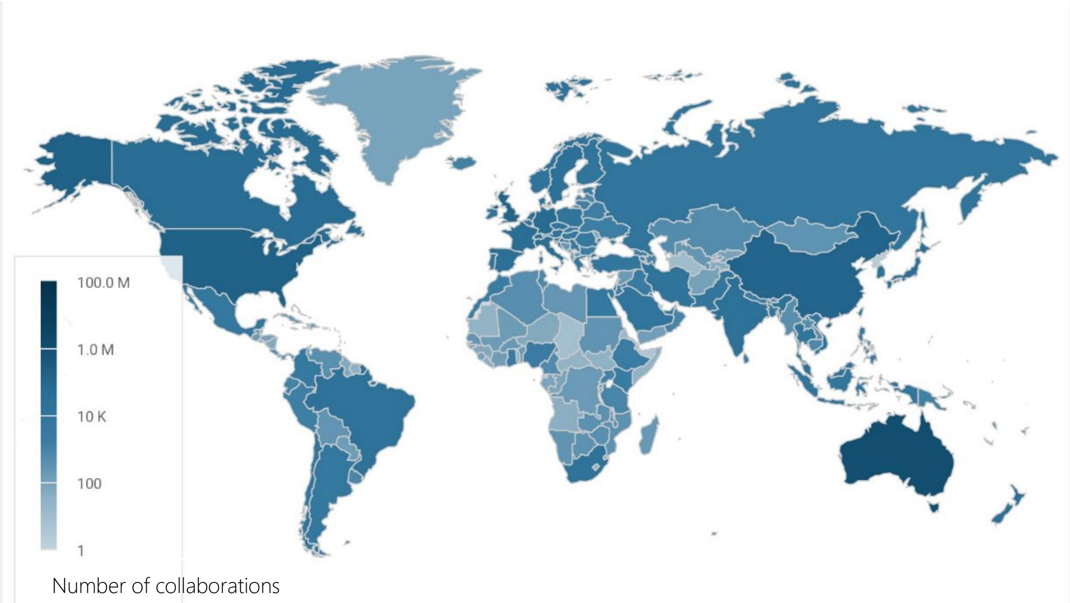

Figure 10: Australia's international collaborations, by scholarly output, 2013-2022

Source: Dimensions AI, 2023

These collaboration patterns are confirmed through the ARC grants dataset. In the STEM fields, the number of successful Discovery projects with international collaboration has risen from 58% in 2002 to 87% in 2021, though the proportion dropped back to 80% in 2022. A similar pattern is observed for the Linkage projects.

Table 1: Countries ranked by number of unique ARC-funded projects indicating collaboration, for STEM fields

Source: NCGP International Collaborations Data visualisation, ARC

Rank	2002	2012	2022
1	USA	USA	USA
2	United Kingdom	United Kingdom	United Kingdom
3	Germany	Germany	Germany
4	France	France	China
5	Japan	China	Canada

6	Canada	Canada	France
7	New Zealand	Japan	Japan
8	China	New Zealand	Singapore

Within STEM, the major trend in ARC grants with collaboration indications over the past 20 years has been the increasing prominence of China. While the USA/UK/Europe triumvirate remains dominant in ARC-funded projects, China has become a more prominent contributor.

However, there are signs this growth in collaboration has stalled. The Australia-China Relations Institute, using datasets including 2023 data, suggests that China collaborations have stalled or gone backwards in many disciplines, though remain robust in the fields of engineering and nanotechnology.[28]

There are limitations to using the datasets from the ARC, as they reflect only a proportion of research activity and generally none in the health and medical sciences. Looking at publication outputs through Clarivate InCites, there are some conflicting trends at play. There has been a clear slowing in the growth of USA-China collaborations, but no similar slowing in the growth of Australia-China scholarly collaborations. It is unclear at this point what the causes of these differing trends are, and it may be more related to a lagging effect of the pandemic than any long-term trend.

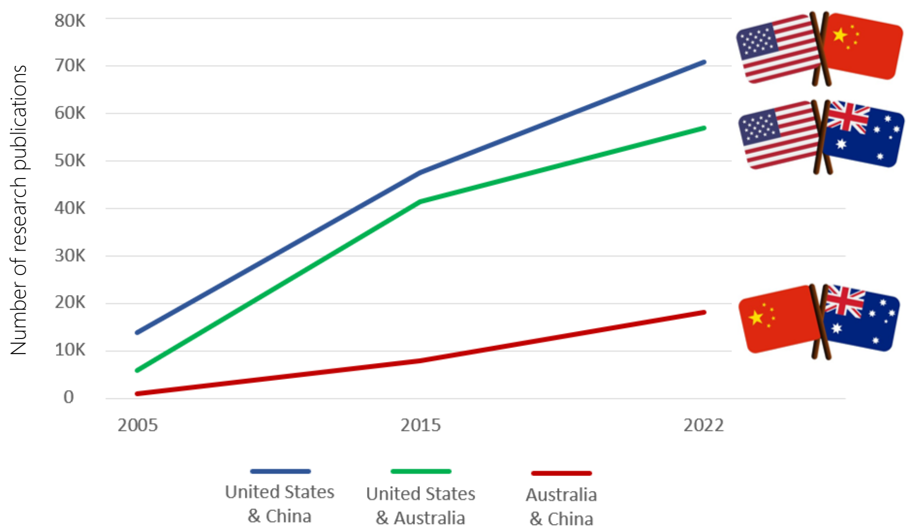

Figure 11: Collaborations between Australia, the USA and China (number of research publications) 2005-2022

Source: Clarivate InCites

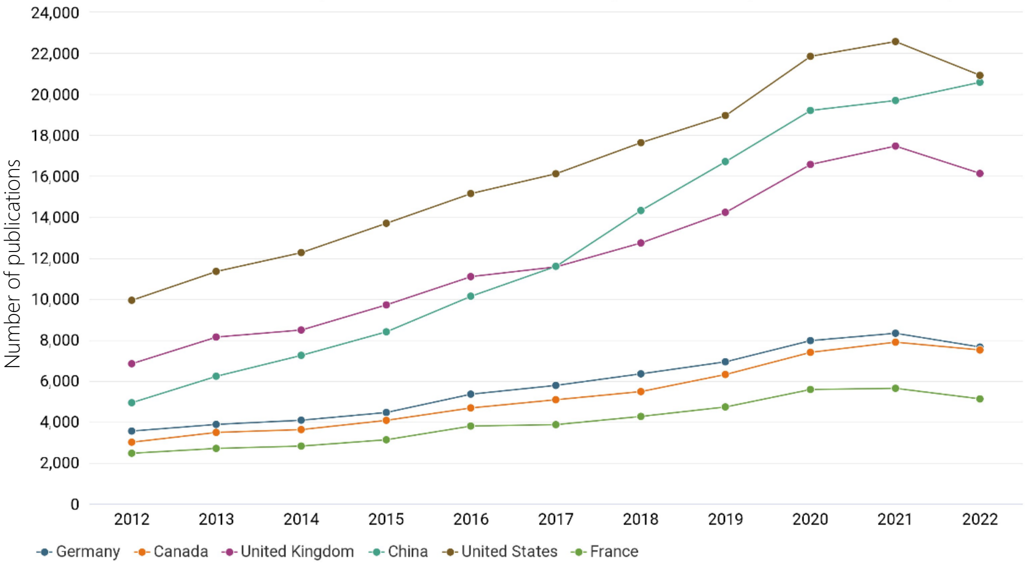

Figure 12: Australia's international collaborations outputs (number of publications), 2017-2022, Web of Science

Source: Clarivate InCites

Australia's patterns of collaborations with major powers also differ. The largest fields of science in which we collaborate with the USA, and Europe/UK are in biomedical and biological sciences. Whereas, in our collaborations with China, engineering, ICT, and the chemical sciences are more prominent.

ISSUES TO CONSIDER

- How are changing geopolitical dynamics and emerging players influencing who Australia collaborates with, and in which fields/technologies?
- Are there areas of science that Australia does not have capability or capacity to research without international collaboration?

BRAIN GAIN - HOW AUSTRALIA BENEFITS FROM GLOBAL SCIENCE

Science and grand strategy are converging—not for the first time.

The world of science has changed dramatically in the past twenty years. The rise of Asia—and China in particular, —the empowerment of Global South countries, digitalisation, and the extraordinary growth in scholarly outputs have scientists in 2023 looking at a vastly different world of science than we did in 2003.

Science has become a new and defining force in international politics. In the words of Eric Schmidt, science—which he defines as innovation:

"…is the ability to invent, adopt, and adapt new technologies. It contributes to both hard and soft power. High-tech weapons systems increase military might, new platforms and the standards that govern them provide economic leverage, and cutting-edge research and technologies enhance global appeal…"

The phenomenon of states seeking to leverage science in the pursuit of power is nothing new. The establishment of learned academies in the 17th century—whether in England, France, or Russia—was part of the pursuit of national economic and military advantage.

What has changed, however, is that science is now a truly global enterprise. Moreso, the pace of change is unprecedented. While individual states may not be able to control the self-perpetuating advance of science, the science system is vulnerable to the decisions and actions taken by states as they seek to manage risks in response to geopolitical competition. As the war in Ukraine and the way in which Russia was divorced from the global science system has shown, geopolitical events shape science as much as science shapes the world. Yet, science is no longer an optional extra for states—it is rapidly becoming central to state power.

Science is no longer an optional extra for states—it is rapidly becoming central to state power.

So, what is the role of Australia in this emerging science and technology-shaped world order?

- Invest in ourselves. For all our small size in terms of population, Australia has been, and remains an advanced industrial nation and a middle-power in science. But such a role is forged—not assumed. To stay a middle science power, Australia needs to invest in our science capability.
- Reformation. Australia lives with a thirty-year-old science system architecture. Renovation has been done along the way, but the essential features remain. The Academy has long argued that the system is showing its age and requires reform.[29]
- Collaborate more, collaborate smarter. Australia cannot do everything; we need international collaboration for knowledge exchange, research productivity, and access to technologies developed overseas.

  Exchanging science talent enhances our scientific research capability and impact, provides access to global networks, supports skilled migration, delivers economic benefits, and promotes understanding between countries.

  Challenges such as climate change, pandemics, biodiversity loss, food security, and energy transitions transcend borders and are too big and complex for closed research communities. These need functional multilateral collaboration and pooled resources and knowledge.

> Given how important international collaborations are to Australia's science system and addressing global challenges, Australia needs to continue participating actively in the global scientific endeavour. But we also need to be smarter and do so with greater strategic intent. Moreso than in the past, scientists will need to navigate a web of regulations, restrictions, and barriers. We will need to understand that there will be types of collaborations possible with some countries that will not be possible with others.
>
> To do this, we must create an environment that supports international scientific collaborations and manages the risks. Policy shapes and supports research and innovation—we must use it effectively to strike a balance between security and openness.

If Australian scientists are strongly discouraged from collaborating with nations outside of our alliance relationships, it would hinder their ability to accelerate progress on global challenges by sharing ideas and resources with other scientists. Moreover, it would prevent them from developing themselves through collaboration and competition and from attracting top talent. Most importantly, Australia would stand to lose out on a deeper understanding of other nations, not just in terms of technological development and military modernisation but also in terms of their people's aspirations and goals.

There are significant national interest consequences of both maintaining and decoupling our research alliances. International science collaboration will provide challenges to national security as well as contribute to maintaining it. How we strike a balance, and on which principles and what evidence, demands careful analysis and discourse by all impacted.

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