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Between the LEVIATHANS

The United States has been Australia's closest scientific partner for nearly a century. But with the globalization of science and the rise of China, Australia may need to rethink the science policies that have guided this partnership.

When Australian Prime Minister Scott Morrison visited Washington, DC, in September 2019, he made one of his major policy announcements at the National Aeronautics and Space Administration's headquarters. Citing NASA's "inspirational campaign to return to the Moon and travel to Mars," Morrison announced new funding of $150 million (in Australian currency) for his country's researchers and businesses to engage with NASA, to reinforce Australia's position as a "partner of choice."

The prime minister remarked, "We've partnered with the US in almost all of their missions to space for the last 60 years and this investment paves the way for the next 60." The White House marked the visit with a statement citing the two countries' history of joint space efforts and setting out plans to "enhance cooperation between our scientific, engineering and education communities," particularly in critical technology areas for the future.

Given this history, it might be surprising for many people outside Australia to learn that the country had only just established its own national space agency, in July 2018. NASA was created in July 1958, after the Soviet Union launched the Sputnik satellite in 1957 and as part of the postwar US science policy boom shaped by Vannevar Bush's *Science, the Endless Frontier.* The new Australian Space Agency's stated aim is to be different from other space agencies, with a focus on tripling the size of the Australian space industry by 2030, leveraging existing strengths in science and industry to increase the country's share of the "expanding global space economy."

The story of Australian science is one of steady development of national capability and policy over the past century, intertwined with increasing international connectedness. Based on available data on coauthorship and international collaboration, the United States has been Australia's most important partner for joint research since the 1930s, even before formal diplomatic relations were established in 1940. The Australian National University, where I work, was established in 1946 during Australia's own postwar institution-building boom, and the United States has been its leading research partner for that entire time. The university has an office in Washington because of this, and because of the quality and scale of American science. In 2017, total US investment in research and development was the highest in the world, and over twenty times Australia's total.

But the global science landscape is shifting dramatically, most notably in the rise of China. How America responds to this shifting landscape will have huge implications for longtime scientific partners such as Australia, and, by

extension, for the global science enterprise. These shifts mean that Australian science policy, after three decades of relative stability, is starting to experiment with new models. For the first time in Australia's history, its leading international partner for science and technology may soon be a country other than one of its Western military allies.

Growing up with science

In the *Web of Science* database, the first Australian scientific publications date back to 1900. There are four for that year, two in journals published in the United Kingdom and two reporting on the "Plague situation in Sydney," by the US Consul Colonel George W. Bell. The oldest example of Australia–US science collaboration appearing in the database is a 1929 study on colloidal platinum, involving the University of Adelaide and the University of California, Berkeley, and published in the UK *Journal of the Chemical Society*. Australian science grew steadily in the century since, with over one hundred thousand papers in the database published in 2018.

After Federation in 1901, the new national government in Australia quickly came to see supporting science and technology as among its key functions, with the first national defense scientist appointed in 1907 and the foundations of the country's national laboratories—the Commonwealth Scientific and Industrial Research Organisation (CSIRO)—laid between 1916 and 1920. But it was right after World War II when the national research effort really took off, with growing defense laboratories, CSIRO expanding into new sectors, and the establishment of the National Bureau of Geological Sciences, the Commonwealth Universities Research Grants Committee, and the new national university. In this same period, the country signed the Australia, New Zealand, United States (ANZUS) Security Treaty in 1951 and became a formal partner in the "Five Eyes" intelligence sharing alliance in the 1950s, with the United States, the United Kingdom, Canada, and New Zealand.

In the decades since, science cooperation between Australia and the United States—both civilian and defense—has continued to grow. Australia didn't create its own NASA or Defense Advanced Research Projects Agency (DARPA) in the 1950s because it didn't need to. As the Australian science system developed, with its strengths in fundamental research and in areas of national priority such as agriculture, mining, medicine, astronomy, and the environment, individual researchers collaborated with the best in their fields worldwide, driving productivity, reputation, and impact. More often than with anyone else, this was with American scientists and this collaboration was built into the Australian system.

Since the early 1990s, there have been two consistent strands in Australian science policy that have led to the present moment. First—in strong parallel with trends in US science policy—the Australian government has placed science and technology within a broader narrative about innovation policy. The rationale for government investment in science became increasingly oriented around driving economic growth. A series of policy documents from both of Australia's major political parties—*Knowledge Nation* in 2000, *Backing Australia's Ability* in 2001 and 2004, *Powering Ideas* in 2009, and the *National Innovation and Science Agenda* in 2015—along with annual reports on the performance of the "National Innovation System" since 2010, have framed science policy in this way. Second, Australia has pursued its own economic reforms and increasing integration with the booming economies of what it now refers to as the Indo-Pacific region. As a result, it has experienced almost 30 years of uninterrupted economic growth.

With 0.3% of the world's population, Australia is a small but successful open trading economy, benefitting from the liberal international order created with US leadership after World War II. Similarly, the country's education, research, and innovation systems have succeeded by being highly internationalized, benefiting from the increasing globalization of knowledge over recent decades. According to the Institute of International Education's 2019 *Project Atlas* report, Australia has the highest rate globally (28%) of international students as a percentage of all students in higher education. And in research, Australia is second only to the United Kingdom in the proportion of research publications produced with international collaboration. According to the US National Science Board's *2020 State of US Science and Engineering* report, 60% of Australian publications involved international collaboration, compared with 39% of US papers and a global average of 23%.

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Current Australian science and innovation policy speaks directly to this globalized system and to the benefits of continued engagement with it. The two documents that set out the Australian government's latest thinking are both from 2017—the *National Science Statement* and *Australia 2030: Prosperity through Innovation*. Both highlight the importance of international collaboration and of making policy that reflects the emerging "global innovation race." The federal government also funds a number of programs to

support increased international collaboration, including the Australia–China Science and Research Fund, the Australia–India Strategic Research Fund, the Regional Collaborations Programme (for "multipartner research and innovation activities in the Asia-Pacific" to support solutions to shared regional challenges), and the Global Innovation Linkages Program and Global Connections Fund (supporting Australian researchers and businesses to partner internationally for commercialization and international research-industry links).

Getting what you wish for

What should be clear from the names of these various programs is that Australia is responding to a significantly changing map of global science and innovation. The US National Science Board's 2020 report found that "a notable trend over the past decade has been the growth in R&D spending in the regions of East-Southeast and South Asia, compared to the other major R&D-performing areas."

The science board's report also showed that since 2000, global expenditure on R&D has tripled. This is great news for anyone who believes that investment in science drives productivity and increases societal well-being. But it also represents a shock to the existing system and a challenge to the leadership of the United States. Despite the overall growth of R&D in the United States since 2000, its share of global R&D has been declining, falling from around 40% in 1995 to around 25% now. Over the same period, China's scientific publication output has risen nearly tenfold, and as a result its output in absolute quantity now exceeds that of the United States. The United States still leads in total R&D, but only slightly, with China accounting for approximately 23% of global R&D in 2017. Japan (8%), Germany (6%), and South Korea (4%) are next, followed by a heterogeneous group—comprising France, India, the United Kingdom, Russia, Brazil, Taiwan, Italy, Canada, Spain, Turkey, and Australia—that each contribute between 1% and 3% of global R&D.

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None of this should come as a surprise—governments have long pursued policies to drive economic liberalization and international education and research, and science policy scholars have been pointing to the implications of these changes for some time. At the American Association for the Advancement of Science's annual meeting in 2010, Sylvia Schwaag Serger from the Swedish innovation agency summed it up by saying that "the centre of gravity of global science and technology is shifting south and east." Schwaag Serger described "new poles of attraction in science and innovation," raising challenges for how the old poles connect to the new. The old assumptions about a single dominant player would no longer hold, she said, and new competencies and strategies would be required in Europe and elsewhere.

Writing in the Fall 2011 *Issues*, Caroline S. Wagner, in an article titled "The Shifting Landscape of Science," reviewed the implications of this trend for US policy. "Science is no longer a national race to the top of the heap", she wrote, but rather "a collaborative venture into knowledge creation and diffusion." She cited the National Academies' *Rising Above the Gathering Storm* reports (from 2005 and 2010), which flagged challenges to American competitiveness from the changing global landscape. She suggested new policy approaches were needed, to decide which areas to focus US investment in, to incentivize international collaboration, and to gather knowledge from around the world and reintegrate it locally to fuel US innovation.

Indeed, since the late 1980s, research has become increasingly internationally networked. Wagner described a positive "network effect" where knowledge gains value by being shared in an open system. But Jonathan Adams, writing in *Nature* in 2013, cautioned about the risk of a growing divide between those researchers, institutions, and countries that are connected to the cutting-edge of the global network, and those that aren't. Maintaining these connections is crucial for Australia's prospects, as it is for other smaller nations that benefited so greatly from the scientific and economic openness of the postwar era.

More recently, Melissa Flagg and Ivy Estabrook have written about the contemporary challenges to US science policy from the "emerging R&D landscape." When total global R&D has tripled since 2000, when 75% of science is being produced outside America, and when 75% of American science funding comes from outside government, what are the right policy settings? Flagg and Estabrook argue that global change has rendered obsolete the Vannevar Bush model and its focus on individual university scientists in a national context—with implications for everything including science advice to government, knowledge transfer for industry innovation, and national security.

Openness challenged

For an Australian prime minister, visiting Washington and the White House is a big deal. After all, the Australia–

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United States alliance underpins Australia's national security, and the United States is the largest foreign investor in its economy. Given the importance of the United States in global research and innovation, it is no surprise that the science policy community feels the same way, with representatives from around the world coming to Washington and the major American science conferences every year to keep an eye on what is happening there.

At the annual AAAS Science and Technology Policy Forum in June 2018, the list of speakers was a who's who of the American system—the head of the National Science Foundation and senior executives from the US National Laboratories, NASA, and Microsoft. But it was the speaker from DARPA who made the observation that most caught my attention. "For decades," he said, "the US government has pumped billions of dollars each year into a research system that is relatively open. At DARPA for example, we fund research in universities and we accept some international partners.

"We're funding cutting-edge science and technology on behalf of the Department of Defense," he added. "Because of the size and technological leadership of the US system, we have bet that we could put funding into this open system and still capture almost all of the best ideas for America and its national security.

"But," he concluded, "with the rise of China and its huge investments in science and technology, it is not at all clear that this system—that has served America and its allies so well—will work anymore." He made this statement just months after FBI Director Christopher Wray testified to the US Congress in February 2018 that American universities were naïve about the risks of engaging with China, and that Chinese researchers and students were being used to collect information and steal intellectual property.

Only a decade ago, the prevailing theory was that the continuing internationalization of science and technology—though requiring some adjustments on the part of the existing global leaders and their partners—had the potential to deliver benefits to all countries. The ever-increasing mobility of human talent, knowledge, and innovation would help everyone deal with the biggest global challenges, such as climate change and global health.

How quickly the paradigm has changed. 2019 was when this change really hit home in the US science system, prompting a plethora of reports, including the Taskforce on American Innovation's *Second Place America?* and the Council on Foreign Relations' *Innovation and National Security: Keeping Our Edge*. At the government level, the reports have so far prompted two policy responses. The first was a clampdown on international engagement (primarily but not exclusively focused on China) amid concerns about research security and integrity, the theft of intellectual property, and foreign interference. The second was a call at the 2019 AAAS Science and Technology Policy Forum from the director of the White House Office of Science and Technology Policy, Kelvin Droegemeier, for a "second bold era of American science and technology." The White House's budget priorities for fiscal year 2021 include a strong focus on "dominating the industries of the future" and key technology areas such as space, quantum science, artificial intelligence, and advanced manufacturing. Already the Trump administration has started to channel funding to agencies such as the National Science Foundation, DARPA, and NASA for these fields.

The Australian system is also grappling with the changes in the global landscape. If the center of gravity of global science and technology keeps moving east and south, that should be good for Australia—after all, that is Australia's part of the world. But it cannot be assumed that as the shift continues, the rules and institutions will automatically remain the same. As Australia seeks to balance the opportunities and risks, key concerns include overreliance on one country (China) for international students, foreign interference on campuses, participation of Chinese government-controlled companies in critical infrastructure such as the 5G cellular network, and research collaboration being diverted to support foreign militaries or human rights violations. To help address such concerns, in late 2019 the Australian government and university community codeveloped *Guidelines to Counter Foreign Interference in the Australian University Sector*.

Meanwhile, the numbers of international students in Australia and the levels of international research collaboration have continued to rise. James Laurenceson and colleagues at the University of Technology Sydney have mapped this for Australia along with possible future implications, including new national security concerns. As Laurenceson recently wrote, "By one measure, China is on the cusp of becoming Australia's leading international partner in knowledge creation, an endeavour vital to Australia's prosperity."

Multipolar explorations

These trends mirror more profound underlying shifts. China has become Australia's largest two-way trading partner. And Australia's demographics are changing—in 2018, when its population reached 25 million, Australia passed the point where more than half of all residents were either born overseas or have at least one migrant parent. Writing in *The Monthly* in December 2019, the Australian journalist George Megalogenis described the coming "identity shocks" for Australia: "No other rich country we compare ourselves to has Australia's ethnic face, almost equal parts Asian, Anglo and European."

According to the US National Science Board report, China is already America's leading partner for international collaboration in science, with Chinese researchers accounting for 26% of US internationally coauthored papers in 2018. But in the context of rising great power competition, science and technology are increasingly caught up in concerns about economic competitiveness, trade, and national security.

Opinions are divided about the right policy response. Writing in the Winter 2020 *Issues* about China and 5G, Carolyn Bartholomew rightly pointed to the risks of cutting-edge technologies being used by an authoritarian state—risks that now go well beyond the borders of any one nation—and called for the United States to "push to win the race for 5G" by rethinking industrial policy, investing in R&D, and working more closely with its allies. With useful insight into Chinese policy thinking, Richard P. Suttmeier in the same *Issues* described "40 years of increasingly intimate scientific and technological cooperation" between the United States and China and the risks of a "de-coupling" agenda increasing costs in a globalized innovation system, undermining global responses to major challenges and eroding norms of universalism in science.

At the AAAS annual meeting in Washington in 2019, Caroline Wagner noted that China "has networked well," and that its rise has happened in a very different international science system than that which existed in the middle of the twentieth century. "They're working with everyone," she said, and if the United States were to try to "cut them off, or cut them out, they can just come through another part of the network."

This new world is multipolar, as highlighted by recent discussions in the European Union about what European "technological sovereignty" might look like. The United States and China will remain the two dominant players, but framing everything as a race between only them misses the full picture of twenty-first century science and technology. Perhaps Europe can work as a block of a similar size, but no other individual country accounts for more than a few percent of global R&D. Are smaller nations destined to be buffeted by forces beyond their control, or might they now actually be able to have more influence in shaping global science and technology?

Australia has never faced a situation like this before. The stakes for education, research, and innovation are high—and just as they have globalized, they have also been more tightly tied to national security and competitiveness. Each country will respond to this new world order in its own way. Australia—as exemplified by its new space agency and the prime minister's announcement at NASA—is working hard to strengthen collaboration and dialogue with the United States in key areas of mutual priority. It is also clear that Australia's success over recent decades has been through high levels of international engagement—particularly within its geographic region—driving science quality, impact, and growth. And both the Australian government and the country's scientific community know that the expanding global space economy will have many more players in it in 2030 than it did in the past.

The DARPA representative speaking at the 2018 AAAS forum summed it up when he said that the old system won't work anymore. The question for governments, institutions, and scientists now is how to remain connected to the cutting-edge of the global knowledge network—wherever it might be—without compromising national values and sovereignty. This will require new thinking at the national level, and also across borders. As Australia experiments with its science policies and institutions, its leaders will also be watching the United States very closely, just as everybody else will be doing. One thing is clear: the old models for science and innovation are poor guides to the future for any nation, large or small. International science helped create the current technologically networked world, and now everyone will have to figure out how to live in it.

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Recommended reading

Australian Government, "Australia's National Science Statement" (2017).

Melissa Flagg and Ivy Estabrook, "The Emerging R&D Landscape: A Tale of Scale and Saturation," *The American Interest* 14, no. 5 (November 26, 2018).

James Laurenceson and Michael Zhou, "Partners in Knowledge Creation: Trends in Australia-China Research Collaboration and Future Challenges," University of Technology Sydney: Australia-China Relations Institute working paper (July 19, 2019).

Caroline S. Wagner, "The Shifting Landscape of Science", *Issues in Science and Technology* 28, no. 1 (Fall 2011): 77–81.