AUSTRALIAN RESEARCH COLLABORATION IN ASIA

A REPORT FOR THE AUSTRALIAN COUNCIL OF LEARNED ACADEMIES (ACOLA)

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CONTENTS

SUMMARY OF KEY POINTS

1. Australian foreign policy pays little attention to the strategic significance of international research collaboration. Yet nations whose intellectual communities work together are likely to improve their mutual understanding, to find pathways to common goals, and to develop strategic advantages over competing powers. These are all justifications for policymakers to take a stronger interest in the international engagement patterns currently being established by Australian researchers.

2. Australia is part of a dynamic region for research investment and output, and the members of its research community have built strong research relationships with partners across the Western Pacific, and in China particularly. Yet Australia's research engagement with Japan, India, South Korea, and Taiwan could and should be strengthened.

3. Foreign direct investment in Australian business R&D has languished over recent years, which may imply a deficiency in investment-attraction policies. Over the same period, however, foreign funding of Australian public sector R&D has surged dramatically, and investment flows in this sector are likely to have diplomatic implications. A focus on developing globally unique and leading research capabilities in Australian public institutions will be pivotal if Australia is to strengthen and exploit this particular mode of connection with foreign counterparts.

4. In aggregate, Australia attracts considerable foreign investment in its research, which may influence its patterns of overseas research engagement. Its public research system is structured quite differently from that in many Asian countries, which tend to place greater emphasis on government agencies. It is clear too that overseas students have different patterns of interest in Australian research training than is true of Australian domestic students. Any strategy that seeks to build up Australia's regional network of research collaborations needs the flexibility to accommodate these differences.

5. Relative to population and to evidence of demand for other Australian higher education services, there is considerable variation across the region in the extent to which people from different societies are receiving research training in Australia. This seems to be an issue both for high-output nations (like India) and for low-output nations (like the Philippines). A strategic approach, driven by long-term diplomatic opportunities, would seek greater balance in the research training opportunities offered to people from all countries across the region.

6. Australia's capacity to collaborate with nations of low scientific output is dependent upon the capabilities that exist in these places. In many instances, it looks currently as though the most significant opportunities for collaborating with such countries will be found in the health, medical and biological sciences, and in geosciences.

7. Responding to China's dominance of regional intellectual networks and expanding Australia's research engagement with a broader set of Asian partners may require an increase in Australian collaborative activity in the physical sciences – particularly with countries such as South Korea, Taiwan, and Singapore. But it would be a mistake if such a strategy could be implemented only at the expense of Australia's strong traditional connectivity in natural resources, medical, and social sciences fields.

8. Universities now mediate much of the research connectivity between Western Pacific nations. While Australia's ties with Japan and India particularly are constrained by a lack of collaboration with key government agencies such as Riken and CSIR India (a deficiency that probably warrants response), the ongoing promotion of Australian diplomatic interests through university research networks is likely to have a bigger impact in the long run.

9. Specialised government agencies may play a role in shaping national and regional policies that is disproportionate with their scale and impact on the scientific literature. Unfortunately, Australia does not currently feature as a pivotal player in research networks involving such agencies. Making specialised Australian agencies more open to regional engagement and seeking to nurture Australian partnerships with equivalent agencies in Asian societies would strongly enhance Australia's capacity to engage in research diplomacy across the region.

10. Finally, across nearly all subjects, Australian researchers have obvious weak links to other Asian societies compared with their level of connection to China. Australians also have weak links to Asian researchers in some specific areas of potential relevance for international policymaking. This strongly indicates that there is no strategic mechanism ensuring that the Australian research system is responsive to Australia's foreign policy objectives. In the absence of such a mechanism, there is a risk that the Australian research system will ultimately prove more likely to serve China's diplomatic interests than Australia's.

1. OVERVIEW & APPROACH

The objective of this report is to provide a rigorous, data-driven analysis of Australia's collaborative research engagement with the nations of Asia and the Western Pacific.

To this end, this report seeks to map current interactions and concentrations of research activity. It provides an analysis of the strengths and vulnerabilities of the regional research system. It assesses the collaborative role being played within the region by Australian organisations, and highlights the potential for expanding the role of Australian research in regional diplomacy.

Our findings and recommendations are intended to inform a series of broader deliberations about "Asia literacy" and "research diplomacy" currently being undertaken in Australia by an expert panel for the Australian Council of Learned Academies (ACOLA).

1.1 INCENTIVES FOR COLLABORATION

Over recent decades, international collaboration has become increasingly prevalent and increasingly important across many areas of research. This reflects the growing incentives for collaborating across national boundaries – incentives that may vary slightly for individuals, institutions and governments, but which nonetheless create a shared impetus across most contemporary research communities.

For individual researchers, international collaboration may afford:

- access to expertise, equipment, datasets, research subjects or environments that are not easily accessed in any other way;
- the ability to participate in a global network of scholars, and to monitor and tap into knowledge being developed in other parts of the world;
- the potential to align one's work with high-status groups or institutions, and to increase one's likelihood of publishing in high-impact journals (and of attracting higher citations per paper for one's outputs);
- the prospect of attracting international funding streams; and
- a mechanism for establishing links to those parties that are best placed to develop or utilise the products of one's work.

These same incentives also apply to institutions. Research organisations, after all, are aggregations of the individuals who work within them, and so are subject to similar pressures and inducements for stimulating international collaboration.

However, institutions can have their own supplementary objectives, distinct from those of their employees, and consequently there are other, separate justifications prompting the leaders of organisations such as universities and government research agencies to foster international collaborations. For example, in addition to the points listed above, international collaboration may afford research institutions with:

- a cost-effective way of supporting the infrastructure needs of staff, especially in capital-intensive fields;
- an ability to respond to government or community priorities where an institution's own capabilities may have gaps or lack adequate scale;
- a mechanism for benchmarking staff and for helping to determine which researchers are doing internationally-significant and internationally-recognised work; and
- a tactic for enhancing global reputation (which is more likely from international collaboration than from purely domestic research), with consequences both for an institution's positioning in global league tables and for its capacity to attract to high-quality staff and students.

The incentives that operate at both the individual and institutional level also operate, of course, at the national level. This is why policymakers who seek to foster global leadership within a nation's research workforce and who aspire also to develop prominent research institutions will often seek to stimulate high levels of international connectivity among their nation's researchers.

It is also why the facilitation of international relationships in science has become one of the minor objectives of modern diplomacy. This is self-evidently true in the case of big science projects, such as the Square Kilometre Array, where diplomatic negotiations can determine both the extent and the cost of involvement for a nation's researchers and their institutions.

Yet governments, too, have their own particular, additional reasons for fostering international collaboration in research – or at least they should have, which brings us to the key conceptual premise for this report. In the analysis that follows, we seek to move the policy discussion about international research collaboration beyond the obvious idea that Australian governments should support international collaboration in research simply in order to bolster the standing of our institutions or the quality of our research performance.

While policymakers may have grasped the value of international collaboration in driving Australia's research agenda, in improving the productivity of Australian researchers, and in elevating the global standing of our research institutions, the data suggests that they have not yet come to appreciate the more fundamental and strategic significance of international scientific relationships. Our focus, therefore, is on the pivotal role that research collaboration can play in support of Australian foreign policy and in the pursuit of broader Australian interests.

1.2 CONCEPTUAL FRAMEWORK

Australians connect with other nations via a myriad of different processes. Our society is linked to the world through the personal interactions of friends and relatives, through trade, tourism, and professional relationships, through the dissemination of cultural goods, through the actions of our armed forces, and through the activities of Australian government officials both here and abroad.

In this context, international relationships in science and research might seem of trivial importance, representing just a minor fraction of the innumerable and complex arrangements by which Australians interact with the outside world – and perhaps it is natural, therefore, to assume that scientific collaboration doesn't matter much to Australia's international relations.

Yet, in a context where international research collaboration is growing rapidly across all nations, there are powerful reasons to ponder whether science has the potential to play a much greater role in Australian foreign relations than it does currently. Below we highlight six core objectives for Australian international foreign policy and diplomacy, and discuss in conceptual terms how these can be supported by international research collaboration.

Objective (i) – To improve the general understanding between nations

The ability to develop a general level of understanding between the people of different nations is an important objective of modern diplomacy. Over the long term, it increases the likelihood of trade, reduces the potential for international conflict, and makes it easier for different societies to resolve issues or solve common problems. Traditional diplomacy in this regard might focus on cultural exchange, the facilitation of international travel, and direct communication through normal diplomatic channels.

Yet researchers also play a growing role in this respect. Collaborative research is one of the more influential ways in which intellectual communities (and opinion leaders) in different nations can build trust and mutual affection. By working together, as members of a global community of scholars, researchers share knowledge, not only about their fields of study, but also about their respective societies. Furthermore, researchers often work in roles (e.g. as teachers in higher education establishments or as public intellectuals) where they are likely to prove effective in spreading such knowledge to other members of their society.

Strong interactions between research communities can also have an important cultural impact that improves the general understanding between nations at a much deeper level. Contemporary science is conducted according a number of established conventions, which tend to transcend parochial cultures. The scientific ethos promotes a value set based upon rationality, objectivity, and particular standards of proof. Where international research collaboration facilitates the dissemination of these values beyond our own society, it strongly improves the potential for reaching a mutual understanding with others.

Objective (ii) – To resolve issues of international disagreement

While developing a common understanding is clearly beneficial, it cannot preclude disagreements. People in all societies have different interests, and despite an on-going elevation of the scientific ethos in nearly every part of the world, no two societies are ever likely to have identical values. These differences inevitably lead to conflicts, where diplomacy will often prove critical for finding resolutions or compromises that are mutually acceptable to the opposing parties.

In this context, international research can also play a pivotal role. Consider the problem of formulating an international energy policy. In recent years, an Australian Government has sought to negotiate a global agreement to limit the burning of fossil fuels and the production of carbon-dioxide, a proposal strongly resisted by governments in developing nations for which the greater priority has been to lift people out of poverty by supplying them with cheap electricity and building materials, derived in large part from burning coal.

These divergent interests reflect different priorities and values. Yet there would be no underlying conflict if the technology existed to generate electricity or produce building materials more cheaply and with lower carbon dioxide emissions than is currently possible using fossil fuels. This is why supporting joint research into new ideas (such as fusion energy) may represent the only effective method of undertaking practical international action on this issue.

Research collaboration, in other words, can provide a mechanism for diplomatic agreement where other propositions fail. Better yet, though, if the research described in our example above were to succeed it would completely transform the terms of this particular debate. Collaborative research then may not only enable joint activities where other possibilities fail, it may also offer the longer-term prospect of removing or transcending an original cause of disagreement.

Objective (iii) – To coordinate a shared response to moments of crisis

Of course not all international crises involve disagreements among nations. Sometimes (e.g. following a national disaster) what needs to be done may seem very clear to all involved. Yet even in situations of international consensus about what is required in broad terms, implementing a course of action may entail cross-border coordination and sharing of knowledge or expertise. There is clearly an important function here for contemporary diplomacy, but this is also an area where there is a special role for science.

In recent years, for example, our region has struggled with a number of multinational disasters, including the Indian Ocean earthquake and tsunami of 2004, the catastrophic failure of the Fukushima Daiichi nuclear plant in 2011, and the mysterious disappearance of Malaysian Airlines jet MH370 in 2014. In each of these circumstances, expert opinion was pivotal in determining how to react, and often had to be applied across multiple jurisdictions. It is also arguable in each case that greater technical coordination in advance of these events could have mitigated their consequences.

This was shown very starkly in the case of the disappearance of the Malaysian Airlines jet MH370, where timely action was impeded by a lack of connectivity among technical experts in different parts of the world, all with access to different pieces of information relevant to the problem, and some of whom exhibited an apparent reluctance to share sensitive information across national boundaries. In this context, a tradition of international research collaboration is valuable since it can create trusted expert networks of a kind that can facilitate rapid transfer of information and expertise in emergency situations.

Objective (iv) – To gather information about other societies

Looking beyond global or regional issues to matters of self-interest, every nation clearly has an obligation to inform its foreign policy and military affairs using sound evidence about the economic, political, technological, and intellectual trends occurring in other countries. This is why gathering information on foreign powers has always been an important pre-occupation of governments, constituting a critical role both for expert analysts at home and for diplomats based in foreign postings.

Traditional approaches for gathering information about other societies suffer from growing limitations, however. As the global economy becomes more complex and technological, and as all societies become characterised by ever-increasing specialisation, the capacity for a relatively small group of experts to remain on top of all the important trends occurring in other parts of the world is diminishing with time. This environment certainly affords a growing role for researchers in the humanities and social sciences, working within the domain of “area studies”, and it attests to the special significance of international collaborations undertaken by this group.

But it also foreshadows a wider function for international collaboration in science and research across a broader range of fields. Researchers operate, by definition, at the frontiers of human discovery. As a consequence, those who connect personally with colleagues in other countries – whatever their field of enquiry – will often be the first to grasp those novel intellectual currents that lead to economic, political, or technological change. Sometimes researchers in one country may even help to facilitate change in another by virtue of these collaborations.

This is a development of increasing practical significance. Today, for example, China’s massive, ubiquitous, and highly educated diaspora constitutes an extremely well informed network that is perfectly placed to gather fundamental information about new trends in other societies, and to do so across technological as well as social domains. In the absence of a similar diaspora, the Australian Government’s capacity to gain information from its research community may be limited. Nonetheless, it can magnify the value of the nation’s researchers by actively fostering their engagement with colleagues in other nations and consistently surveying the most globally connected among them for advice about developments in other parts of the world.

Objective (v) – To forge strategic advantage

Much of modern foreign policy seeks to identify mutually beneficial outcomes in foreign relations. However, there will always be instances where one (or both) parties in a diplomatic relationship seek only their own strategic advantage, at the expense of others. Perhaps intelligence gathering can be seen in this light, but there are other instances where instruments of foreign policy are used to derive a more overt advantage over other powers. In forging military and trade alliances, for example, diplomacy invariably seeks to include some countries but exclude others.

While not usually fundamental, international scientific collaboration can form a key component of such efforts. In the military sphere, allies will often work together very closely on joint research initiatives in order to derive a joint technological advantage over other countries. In trade policy, too, international research collaborations may be used to justify the creation or the elimination of trade barriers. International research collaboration may also be a useful way to establish objectivity in international arbitration around sensitive issues (such as whaling or controlling the proliferation of weapons of mass destruction).

In all these cases, the quest for strategic advantage may lead certain nations to work together on particular research initiatives, excluding others, in order to derive a technological or political advantage. But there is another possibility too – that a country might use its international research collaborations specifically to derive a strategic advantage, even at the expense of its collaborators. This may be a particular feature, for instance, of scientific relations where one party is much larger and better resourced than the other, and is thus able to enforce its research priorities upon the other. In this situation, two nations may work together, ostensibly for mutual advantage, but their activity ultimately serves one power much more effectively than it does the other.

Objective (vi) – To provide humanitarian or development aid

Finally, we come to the humanitarian objectives of foreign policy. The provision of humanitarian aid and development support has become a significant function for foreign affairs departments across the developed world. Yet this is also an area of considerable political tension. In most countries there are diverse views across the political spectrum about how much should be spent on foreign aid and development and on the effectiveness of such programmes.

Research can be critical in this capacity since it can help to ensure that aid investments are used effectively. Collaborative research involving both donors and recipients of humanitarian or development support may be especially significant since it is likely to lead to understanding and agreement on both sides about how to improve the effectiveness of common initiatives in future.

But collaborative research between donors and recipients can be valuable in a more profound respect too. A community with a strong spirit of enquiry and openness to ideas may be better placed to solve problems and to find ways of improving their lot than a community that lacks such a spirit. As the adage goes: "Give a man a fish, and you feed him for a day; show him how to catch fish, and you feed him for a lifetime; but show him how to continuously improve the fishing process, and you set him on the path to economic development."

Over the long term, international research collaboration with developed nations (which might entail a joint project, on-site capacity building, advice about the development or governance of research institutions, or traditional research training) may help to instil a spirit of enquiry and a desire for continuous improvement in poorly developed regions; and it is possible that the cultural consequences of such activities will ultimately prove more important than many other, more direct forms of aid.

Table 1.2a – A role for research collaboration in international affairs

Diplomatic objective	Role for international research collaboration
i. To improve general relations between nations	- Enables intellectual communities to build trust, mutual affection and understanding - Helps to spread the scientific values of rationality, objectivity, and belief in evidence
ii. To resolve issues of international disagreement	- May provide the only mechanism for joint work to address a contentious issue - Can change the nature of a policy debate and expand the options available for policymakers
iii. To coordinate a response in a moment of crisis	- Enables rapid transfer of information and expertise in emergency situations - Mitigates the consequences of terrible events
iv. To gather information on other societies	- Provides access to knowledge (and beliefs) being developed in other parts of the world - Affords excellent opportunities for information gathering in a non-confrontational way.
v. To forge strategic advantage	- Has become an essential feature of the world's closest military alliances. - May prove critical in international arbitration on trade or disarmament
vi. To provide humanitarian and development aid	- Can ensure that aid money is well spent, and brings lasting benefit. - Helps to instil a culture of enquiry in developing societies.

These various functions of contemporary diplomacy, and the various ways in which they can be strengthened by international research collaborations, are summarised above in table 1.2a.

These functions form the conceptual basis for this report. Thus, in assessing the nature of Australia's research collaborations and the relationship between science and diplomacy in Asia and the Western Pacific, we are not simply going to re-iterate the view that nations whose intellectual communities work together are more likely to reach the frontiers of knowledge more rapidly, or to foster better researchers or higher-profile research institutions. On the contrary, our focus will be to study collaboration through a broader prism.

Our intention is to ask what Australia's current patterns of regional collaboration signify, if one accepts the premise that nations that collaborate in research are more likely to understand one another, or to find pathways to common goals, or to develop strategic advantages over competing powers. We will ponder, too, certain implications of the gaps in Australia's patterns of research collaboration, on the assumption that there is a link between research collaboration and the dissemination of scientific values – notably the belief in empirical knowledge and the view that authority comes from an objective evaluation of reality, not from convention, or through the manipulation of others, or from propaganda.

By doing this, we hope above all to show that the beneficiaries of any international policy for Australian research are not merely the people doing the work or the organisations that employ them, and that Australian policymakers actually have a broader set of incentives for facilitating strategic regional collaborations in science and research than is currently accepted.

1.3 METHODOLOGY & LIMITATIONS

Our analysis of collaboration across Asia and the Western Pacific begins with an overview of research scale and international linkage among public research organisations across the region. This analysis draws upon data sourced from the Organisation for Economic Cooperation and Development (OECD MSTI & OECD RDS), from the National Science Foundation (NSF SEI) in the US, and from the Australian Bureau of Statistics (ABS 8111 and ABS 8109).

Subsequently, we analyse two customised bibliometric datasets provided by Thomson Reuters (TR DATA). These data enable comparisons of research publications and international co-authorships between 2010 and 2012 by field or subject area, and some of these data have been previously used for an extensive benchmarking of universities across the region (BR 2014).

These datasets provide excellent indications of key trends across the region. However, their use imposes some limitations upon our analysis. These are explained as follows.

(i) Business research collaborations

An analysis focused upon traditional academic outputs will provide little insight into the relationships being forged by researchers in commercial organisations. Industry researchers do not share the incentives that currently exist in public research institutes to publicise the outcomes of their research via research publications. In certain fields some related insights might be gleaned from patent datasets or from trade and investment data. However, we take the view that businesses ought to be left to pursue their own interests in Asia in their own way.

Thus, while we do make some observations about overseas investment in Australian business research and development, this is considered a secondary issue. The explicit focus of this report is to draw observations about how research engagement across public-sector networks (rather than private-sector organisations) can assist a broader diplomatic agenda.

(ii) Collaborations that do not lead to publications

Within any research system, collaboration will not always lead to research publications. In particular, our approach does not evaluate research that generates important outcomes but no academic publications. This can be an important issue for research that is not focused upon the discovery of new knowledge, but is more commercially oriented, more applied or developmental in nature, or intended to facilitate certain social, political or environmental outcomes.

On this basis, it should be recognised that our analysis will underestimate the level of activities occurring in certain significant areas – for example in some areas of research that overlap with the delivery of foreign aid, or in areas of social science where outputs may take the form of a policy document rather than a research publication. It can be a significant issue where sharing of infrastructure or data or software, say, leads to strong outputs but not to co-authorships. It is also an issue in several foundational forms of collaboration, such as in conference organisation and attendance, in peer review activities, in scholarly editorial work, and in joint research student supervision.

(iii) Collaborations in the humanities

Our bibliometric datasets do not include any information on the humanities, and even if they did one would need to be cautious about what the data on outputs and co-authorships signified. The relationship between volume and productivity is not strong in the humanities, and compared with the situation in the sciences collaboration may be more likely to occur without recognition via co-authorships.

Despite this, the humanities do encompass some of the most important fields through which our public research base builds an understanding of other societies. For this reason, it should be understood that the humanities fields represent a gap in our analysis – although the nature and intensity of specific regional relationships in these fields may well follow similar patterns as are observed in the sciences and social sciences.

(iv) Collaborations with countries of low research activity

The other limitation in our data is that we do not analyse joint outputs involving Australian researchers and researchers based in countries with low research activity. In the interests of simplicity, we focus most of our analysis upon those nations across Asia and the Western Pacific that are already very actively involved in research. The key countries in this respect are Australia, China, India, Japan, New Zealand, Singapore, South Korea, and Taiwan. These are the places on which we concentrate, although we do include commentary on the extent to which other nations in the region are building their own research capabilities.

(v) Collaborations in research training

Perhaps the most important form of research collaboration that is not canvassed using bibliometric datasets is that which occurs between research supervisors and their graduate students. When an Australian travels overseas to join a foreign research group, or when a foreign student comes to Australia to do a PhD or accept a position as a postdoctoral researcher, he or she will typically publish the findings of his or her work according to their institution of employment rather than their country of origin.

Yet the relationships formed under these circumstances are among the most important in establishing long-term personal networks across the research community. Because of this, as a part of our analysis, we do provide a short commentary on recent trends in overseas student migration to Australia for research training. This is a critical form of international collaboration. However, it should be recognised that our subsequent analysis of co-authorships does not cover this form of activity and thus provides an under-estimate of the actual level of collaboration within the scientific literature between Australian and non-Australian researchers.

In summary, the datasets we analyse focus upon public-sector interactions. They do not include information on collaboration in the humanities or in the commercial sphere. They omit research collaborations that fail to generate co-authored publications, and they provide limited data on low-output nations. Co-publication data also cannot capture the number of foreigners working in Australian research groups, or the number of Australians working in research groups overseas. Given these caveats, we do not pretend to provide a comprehensive representation of the complete state of research interactions between Australia and its neighbours to the north.

Our goal is subtler. By presenting the structure of the research system in the region, by highlighting the nature of its dominant research networks across a range of fields, and by revealing the broader patterns of current Australian collaborations, we show how Australia might benefit from a more strategic policy of international research engagement and we are able to make some simple suggestions about what form such a policy might take.

Key Point 1

Australian foreign policy pays little attention to the strategic significance of international research collaboration. Yet nations whose intellectual communities work together are likely to improve their mutual understanding, to find pathways to common goals, and to develop strategic advantages over competing powers. These are all justifications for policymakers to take a stronger interest in the international engagement patterns currently being established by Australian researchers.

2. RESEARCH IN ASIA & THE PACIFIC

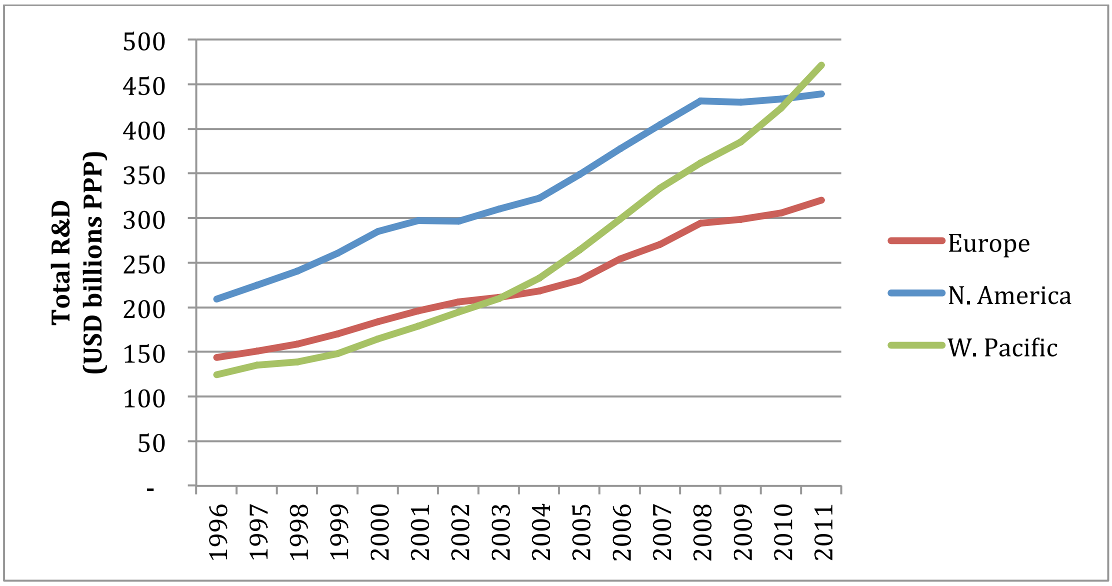
Australians have historically turned to Europe and North America for their international research collaborations. This is not surprising – it reflects the overwhelming importance of these two regions in global research and development (R&D).

In recent years, though, several nations in Asia and the Western Pacific have experienced a boom in R&D investment, which has changed the geographic distribution of knowledge-creation around the world, and produced new opportunities and powerful incentives for Australians to collaborate with the expanding research communities situated in countries like China, India, and South Korea.

2.1 REBALANCING GLOBAL R&D

Asia has emerged in recent years as the dominant region globally for R&D investment. Figure 2.1a summarises total R&D expenditure across all sectors (i.e. business, universities, government agencies, and private non-profit research institutes) and reveals that the amount of R&D activity in the Western Pacific (adjusted for purchasing power parity) exceeded that in North America for the first time in 2011.

Figure 2.1a – Trends in R&D investment

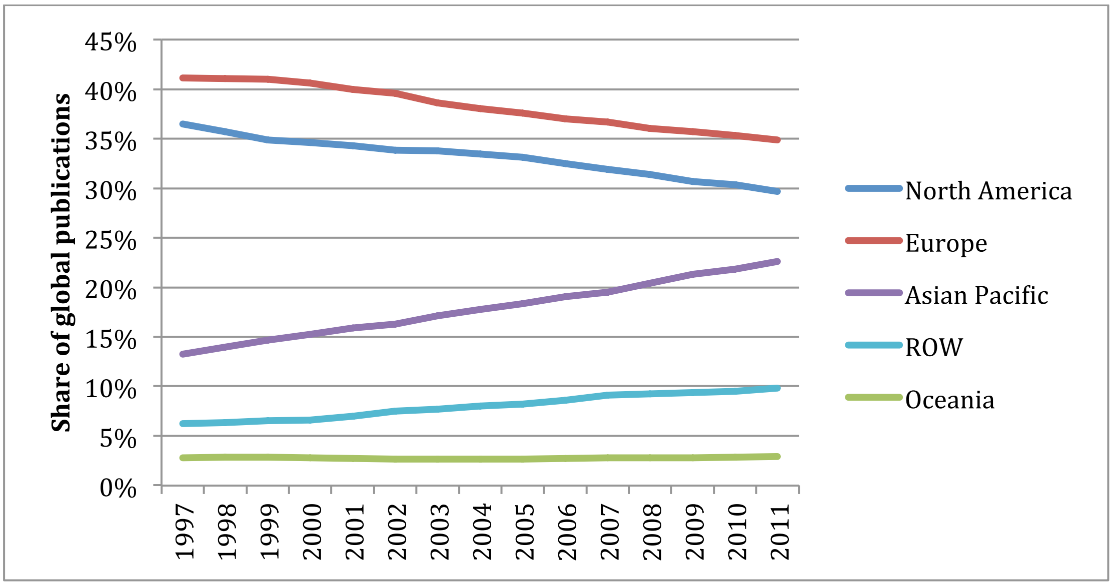


Note: Derived from OECD MSTI. Current dollars are adjusted for purchasing power parity. N. America in this case combines only the USA and Canada. The Western Pacific in this case combines data only for Australia, China, Japan, NZ, Singapore, South Korea, and Taiwan.

The main driver for this transition has been business R&D spending. However, research investments in government agencies and universities have also been rising across the region, which in turn has led to a dramatic increase in the publication of scientific articles involving authors who are not based in either Europe or North America.

Figure 2.1b shows the recent trend in publication outputs, where authors are categorised by region and where publication counts are allocated to countries on a fractional basis according to the residence of each author on a paper. This figure highlights the remarkable growth in the relative importance of the Asian Pacific region in the global economy of ideas.

Figure 2.1b – Regional share of global publication outputs



Note: Derived from NSF SEI. Data are fractionated by author residence. North America includes USA, Canada, and Mexico. Asian Pacific includes all East Asian, South-East Asian, and Western Pacific nations. ROW includes Central & South America, Africa, the Middle East, and South Asia.

It also indicates that while other parts of the developing world have been increasing their contribution to global knowledge outputs, they have been doing so at a slower rate than is true for the Asian Pacific.

This extraordinary growth in the Asian Pacific is largely due to the dramatic surge in scientific outputs from China. For the decade from 2001 to 2011, China increased its publication count more than four-fold. As a consequence, nearly a quarter of the world's global scientific output now occurs in this region – within a group of countries with which Australia shares a time zone and in which Australia has obvious economic and strategic interests.

Perhaps even more interesting, though, is what happens when you aggregate some of these regions together. If one combines the 2011 publication outputs of the Asian Pacific, Oceania, and India (which was classified under 'ROW' in figure 2.1b) one can account for over 28% of the world's fractionated outputs – not far off the combined North American share, which stood at 30%.

The inclusion of India will be useful for our analysis. Between 2001 and 2011, Indian research did not grow at Chinese rates, but it more than doubled its publication count, and exceeded Australia's total volume of scientific outputs in

2007. India is also significant as it now accounts for over 90% of all scientific publications generated in South Asia, and it too is a nation of particular strategic and economic importance to Australia.

In table 2.1c, we summarise the scientific publication outputs for China, India, Australia, and other key nations in the Asian Pacific and Oceania. Given our interest in the interplay between international research collaboration and diplomacy within our region, these are the nations upon which we will focus our analysis.

Table 2.1c – Publication outputs for key regional cohort of nations

Country	2001		2011	
	Outputs	As % of cohort total	Outputs	As % of cohort total
China	21,134	16.4%	89,894	38.4%
Japan	56,082	43.6%	47,106	20.1%
South Korea	11,008	8.6%	25,593	10.9%
India	10,801	8.4%	22,481	9.6%
Australia	14,484	11.3%	20,603	8.8%
Taiwan	7,912	6.2%	14,809	6.3%
Singapore	2,434	1.9%	4,543	1.9%
New Zealand	2,851	2.2%	3,472	1.5%
Thailand	727	0.6%	2,304	1.0%
Malaysia	472	0.4%	2,092	0.9%
Vietnam	155	0.1%	432	0.2%
Indonesia	189	0.1%	270	0.1%
Philippines	141	0.1%	241	0.1%
Sri Lanka	73	0.1%	130	0.1%
Cambodia	7	0.0%	33	< 0.1%
Fiji	16	0.0%	23	< 0.1%
Laos	5	0.0%	21	< 0.1%
Papua New Guinea	32	0.0%	21	< 0.1%
Other Pacific Island	7	0.0%	13	< 0.1%
North Korea	-	0.0%	4	< 0.1%
COHORT TOTAL	128,529	100.0%	234,084	100%

Note: Derived from NSF SEI. Counts are fractionated based upon author's place of residence.

The table presents each country's volume of scientific outputs in 2001 and 2011, as well as their share of total research outputs across all countries in the cohort. There are two important points that should be made here.

First, it should be observed that Australia, Japan, and NZ all accounted for a reduced share of the cohort total in 2011 compared with the situation in 2001. This implies a strong rationale within each of these countries for building good relationships with research communities in many of the other countries shown.

The decline in Japan's share of output across the cohort is especially striking as it implies serious diminution of Japan's relative importance in the generation of knowledge within Asia – although its total contribution still remains very large.

Second, one should note the vast disparity in output between China and Japan at the top of the table and North Korea and Papua New Guinea at the bottom. In 2011, China and Japan together accounted for over half the outputs across the cohort, while the top eight nations shown in the table were responsible for 98% of total outputs across the cohort.

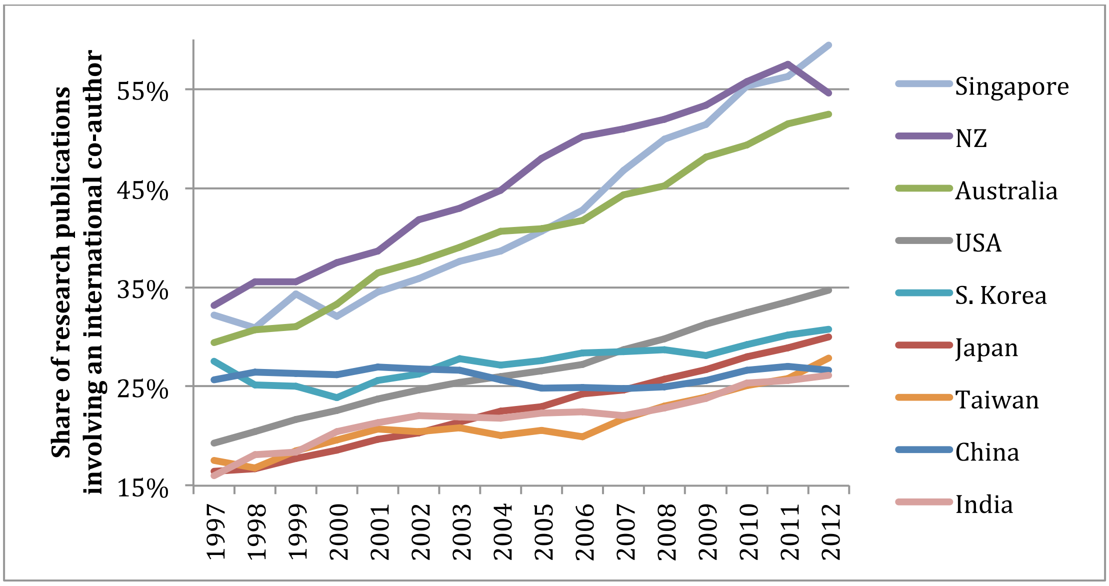
The scale of research being conducted in different countries obviously has a serious impact upon the potential for collaboration. Consequently, the bulk of our analysis in this report will concentrate upon the nations at the top of this list. However, this does not diminish the importance of research collaboration as an instrument of foreign policy in the other nations shown. It just means that the opportunities for connecting will be fewer and less diverse in nature.

2.2 GROWING INTERNATIONALISATION

An expansion in research investment and output in any country sets the scene for an expansion of international collaboration, but it does not necessitate it. Nonetheless, over recent years there has been a dramatic increase globally in international research collaboration.

This is illustrated in figure 2.2a, which shows for the lead nations in our cohort what proportion of scientific publications have involved an international co-author. Data are also include in this figure on the USA which, given its size, has historically been able to support a relatively insular research system.

Figure 2.2a – Scientific articles involving international co-authors



Note: Derived from NSF SEI. Whole counting is used in this instance.

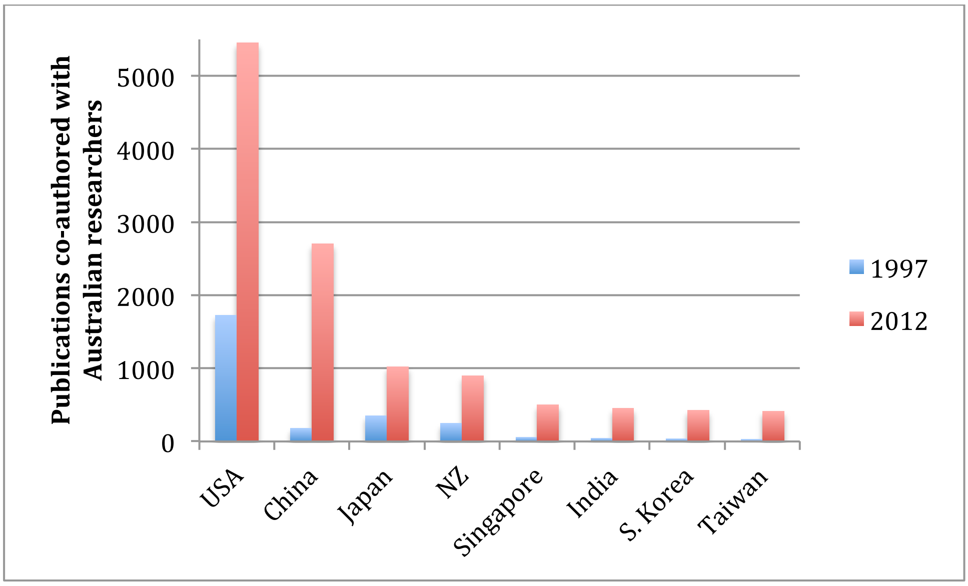
The increase in international co-authorship of research publications reflects a long-term trend dating back at least to the early 1980s. It strongly suggests that researchers and their institutions have perceived growing advantages in working with peers in other countries. Indeed, researchers in Australia, NZ, and Singapore are now more likely to co-publish with an international partner than without one.

Even in the case of China, where internationally co-authored papers have remained fixed at around 26% to 27% of total national output, there has still been a more than four-fold increase in the volume of this country's internationally co-authored papers over the past decade, in line with its overall expansion in national output.

The picture on all fronts is of a regional research community that is increasingly interconnected across national borders and where such activity is no longer an occasional event, but a mainstream occurrence.

Despite this, there is evidence that Australian research is not as engaged with parts of our region as it could be. Figure 2.2b shows the number of papers co-authored with partners in key Asian nations as well as with the USA in 1997 and 2012.

Figure 2.2b – Partners on Australia's internationally co-authored papers



Note: Derived from NSF SEI.

It reveals an extraordinary growth in joint outputs between Australia and China over the period. This is clearly a significant development, though one should be cautious in interpreting it, for one can see here that the increase in co-authored papers between Australia and the US was actually greater than that between China and Australia in absolute terms.

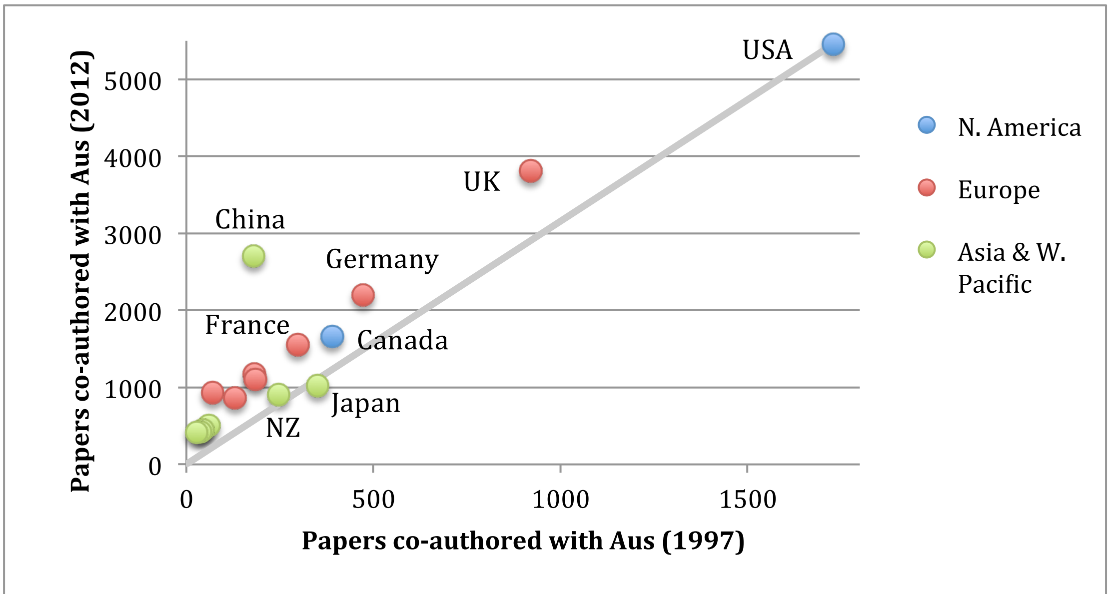
What is most striking about the figure, however, is the very low level of ongoing collaboration between Australian researchers and researchers based in Japan, India, South Korea, and Taiwan. In 2012, Australians co-published scarcely more frequently with Japanese researchers as they did with New Zealanders – this with a nation that has 13 times New Zealand's volume of scientific output.

A similar point can be made about Australian partnerships with the Singaporeans, Indians, South Koreas and Taiwanese. It does seem remarkable that Australian researchers should be collaborating less than half as often with Indians or South Koreas as they are with New Zealanders – even though India's scientific output is 7 times larger and South Korea's is 6 times larger than New Zealand's.

This is not to diminish the importance of our research relationships with New Zealand, or the cultural, political, and linguistic ties that facilitate collaboration with this country. It does provide perspective though, and strongly suggests that Australia is not maximising the strategic advantages of having a research workforce that is internationally engaged.

Figure 2.2c strengthens this argument. It shows Australia's bilateral co-authorships with a subset of European, North American, and Asian countries, plotting co-authored papers in 1997 against co-authored papers in 2012. With the exception of China, this figure shows that there have been no dramatic movements in the relative patterns of Australia's international collaborations.

Figure 2.2c – Papers co-authored with Australia



Note: Derived from NSF SEI. Papers are counted on a whole-count basis – i.e. any co-authorship with an Australian researcher counts as 1 paper regardless of the number of authors involved. Countries not marked are Netherlands, Italy, Spain, Switzerland, Singapore, India, South Korea, and Taiwan. The grey line indicates the growth rate for Australia-USA co-authorships.

Of particular note is the relatively limited scale of collaboration between Australia and India, South Korea, and Taiwan, which are clustered down in the bottom left-hand corner of the figure. It can be seen that Australia has grown its joint outputs with these countries slightly faster than it has grown its joint outputs with the USA or Japan. Yet these countries still represent a very modest proportion of Australia's internationally collaborative research.

The idea that Australia might be underweight in its international collaborations with South Korea and India is accentuated in Table 2.2d, which shows for several countries how their share of the world's internationally co-authored papers compares with their share of Australia's internationally co-authored papers.

It is clear from these data that Australia has strong research relationships with China and New Zealand. China accounts for 15% of the world's internationally co-authored papers, but for 16% of Australia's internationally co-authored papers. While New Zealand accounts for less than 2% of the world's internationally co-authored papers, but for more than 5% of Australia's internationally co-authored papers

Table 2.2d – Australia's joint international outputs with Asia, 2012

Country	% of the world's internationally co-authored papers	% of Australia's internationally co-authored papers
USA	43	33
China	15	16
Japan	7.8	6.2
NZ	1.5	5.4
Singapore	2.1	3.0
India	3.5	2.7
S. Korea	4.8	2.6
Taiwan	2.2	2.5

Note: Derived from NSF SEI. Papers are counted on a whole-count basis – i.e. any co-authorship with an Australian researcher counts as 1 paper regardless of the number of authors involved. Percentages do not add to 100% due to the existence of multiple authors from multiple jurisdictions on papers.

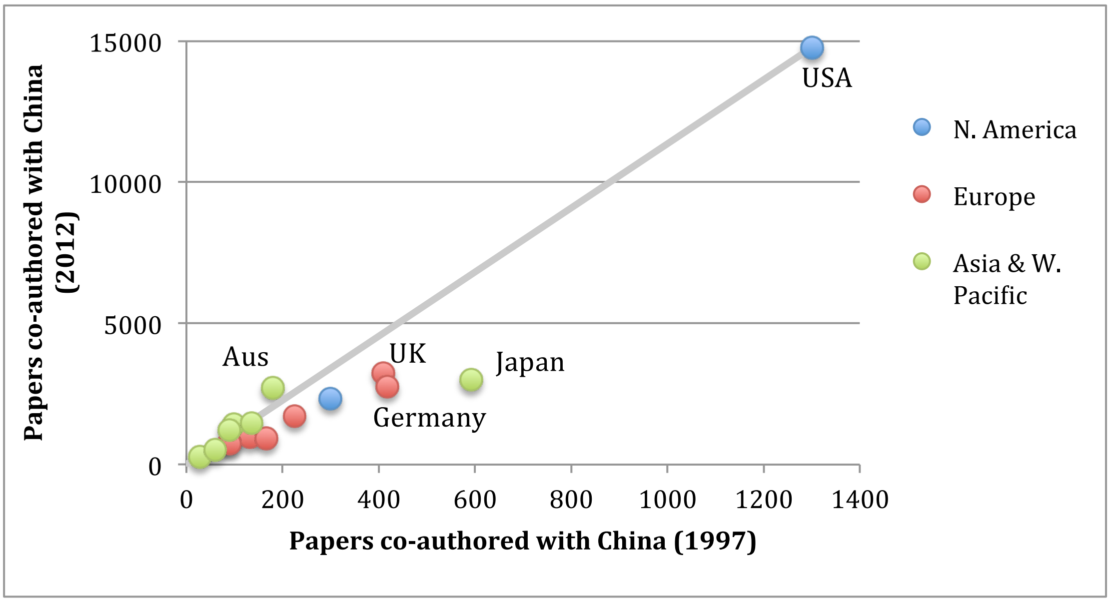
In South Korea and India, on the other hand, these ratios are reversed. South Korea is especially interesting, accounting as it does for nearly 5% of the world's internationally co-authored papers, but for less than 3% of Australia's internationally co-authored outputs.

Given that Australia appears to have developed relatively strong research ties with China, it is useful to analyse Chinese co-authorships more broadly. In particular, it is important to see whether other countries have also experienced similar growth in Chinese collaborations.

Figure 2.2e shows the trend in collaborations with China for the same set of countries. It can be seen from this figure that there has been a dramatic increase in co-authored papers between the US and China. Interestingly, only three countries experienced faster growth rates in co-authored papers, albeit off a lower base: Australia, Singapore, and Taiwan.

The really remarkable thing about these data, however, is the relatively low growth in Chinese collaborations with European countries, and with Japan. In 1997, Chinese researchers were three times more likely to co-publish with a Japanese and twice as likely to co-publish with a German than with an Australian researcher. Yet in 2012, Chinese researchers were co-authoring a similar number of scientific articles with collaborators in all three countries.

Figure 2.2e – Papers co-authored with China



Note: Derived from NSF SEI. Papers are counted on a whole-count basis – i.e. any co-authorship with a Chinese researcher counts as 1 paper regardless of the number of authors involved. Countries not marked are Canada, France, South Korea, Singapore, Taiwan, Netherlands, Italy, Spain, Switzerland, India, and NZ. The grey line indicates the growth rate for China-USA co-authorships.

All of this suggests that the escalation in Australian collaboration with China is not just a function of the growth in the Chinese research system, but reflects something deeper about the relationship between these two countries – as well as that between China and the USA, Singapore, and Taiwan.

Interestingly, these are all countries where ethnic Chinese and Chinese-born researchers play a significant role in the public research system. This is consistent with a view that the Chinese diaspora has been a critical factor in driving elevated levels of collaboration between China and Australia.

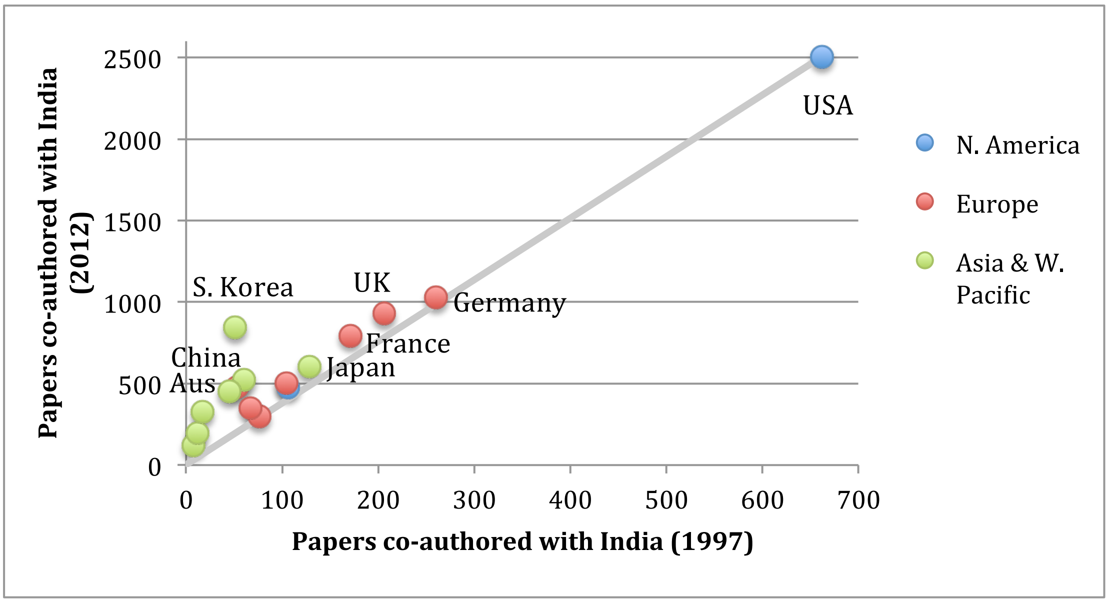
Australia, of course, also has a large number of Indian migrants in its research workforce. The growth in Indian research collaboration, however, has been lower than that with China, and as we saw above in table 2.2d joint outputs remain low compared with India's total volume of internationally co-authored outputs.

Figure 2.2f provides some perspective on this issue, by showing the recent trends in Indian collaborations with this same group of Asian, European, and North American countries. These data reveal that Indian co-authorships with Australia are not low relative to the scale of India's co-authorships with China or Japan.

Remarkably, India has a fairly similar level of co-authorship with Australia as it does with China. Moreover, the figure shows that China, Australia and Singapore have all expanded their collaborations with India strongly over recent years – at least compared with the situation in North America or Europe.

The really striking development, though, is the growth of the relationship between India and South Korea. In 1997, Indian researchers co-authored roughly the same number of publications with Australian collaborators as they did with South Koreans. Yet by 2012, Indian researchers were co-authoring far more papers with South Korean collaborators than Chinese, Australian, or Japanese collaborators.

Figure 2.2f – Papers co-authored with India



Note: Derived from NSF SEI. Papers are counted on a whole-count basis – i.e. any co-authorship with a Chinese researcher counts as 1 paper regardless of the number of authors involved. Countries not marked are Italy, Spain, Canada, Switzerland, Taiwan, Netherlands Singapore, Taiwan, and NZ. The grey line indicates the growth rate for India-USA co-authorships.

This may reflect a particularly engaged Indian diaspora in South Korea, or strong policies for bilateral engagement between the two nations, or perhaps just a fortuitous alignment of technological interests. Whatever the explanation, it implies that while Australia may have experienced decisive growth in its research collaborations with China, it is clearly not maximising its prospects for collaborating with other countries in the region.

The strength of the bilateral relationship between Indian and South Korea (both nations where the scale of total output is similar to Australia) suggests that Australia could strive at least to double its scale of research collaborations with either of these powers.

A similar commentary, incidentally, could be made about Taiwan. The data in figure 2.2c above showed that in 2012, Australians were authors on more scientific publications jointly with researchers based in Singapore than with researchers based in Taiwan. Yet Taiwan's total research outputs that year were equivalent to roughly three times the number of outputs generated by Singaporean researchers.

All of this this may or may not present an issue for the quality or outcomes of Australian research. But it is indicative of a community that has, for the most part, been building its international relationships out from where they were fifteen years ago. It suggests, too, a high dependence on the personal networks of its migrant workforce, rather than the deliberate targeting of partner countries through a more strategic process.

Above all, it implies that Australia is not as well positioned to generate regional diplomatic advantage from its research community as it perhaps might have been – or as it has the potential to be.

Key Point 2

Australia is part of a dynamic region for research investment and output, and the members of its research community have built strong research relationships with partners across the Western Pacific, and in China particularly. Yet, Australia's research engagement with Japan, India, South Korea, and Taiwan could and should be strengthened.

3. MODES OF CONNECTION

Researchers connect with one another across national boundaries through a wide range of different mechanisms and out of a diverse set of motivations. Therefore, while Australia has experienced an expansion in co-authorship of scientific outputs with researchers based in Asian countries over recent times, its international research engagement should also be understood in a wider context.

Over recent years, Australia has experienced a remarkable growth in international funding for its public-sector research. It has also come to depend upon international students to sustain recent growth in PhD student numbers. Furthermore, its capacity to engage with some countries within the region may be constrained by variations in national support given to different forms of public institutions.

Before going into our discipline-based bibliometric analysis, we explore these issues briefly, as they too have implications for international research strategy.

3.1 GLOBAL INVESTMENT

One of the key ways in which research has been globalised over recent decades, is via cross-border investment. This is an important theme for Australia. Overseas funding of Australian R&D now accounts for over $500 million per annum. This amounts to a small fraction of Australia's total R&D activity, yet it still represents a significant investment, and can be regarded as an external endorsement of the calibre of Australian research.

Table 3.1a summarises the scale of international resourcing for Australian R&D by sector of performance. It can be seen from this table that Australian universities sourced $180 million in R&D investment from international sources in 2010, while in 2011-12 Australian businesses sourced $212 million in foreign R&D investment and Commonwealth Government agencies derived more than $130 million in R&D investment from overseas.

Table 3.1a – International R&D investment in Australia by sector

Sector	R&D funds sourced overseas	As % of sector R&D	Year of data collection
Business	$212 million	1.2%	2011-12
Universities	$179 million	2.2%	2010
Commonwealth Government agencies	$134 million	6.4%	2011-12
State Government agencies	$12 million	1.1%	2011-12
Private Non-Profit	$58 million	6.9%	2011-12

Note: Derived from ABS 8111, ABS 8104, and ABS 8109. R&D funds are in current Australian dollars.

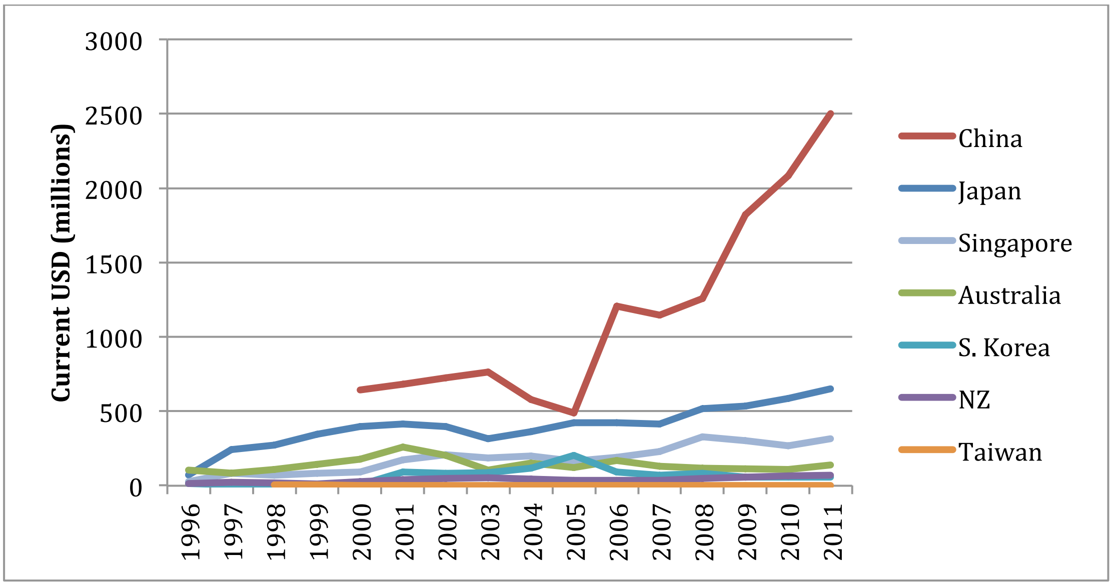
It should be noted here that international funding specifically for Commonwealth Government agencies has increased substantially over recent years, probably reflecting the impact of the Wireless LAN royalties now flowing to the CSIRO from overseas and channelled back into research. Prior to this, international investment accounted for a lower proportion of total sector outlays on research.

For most of the past decade, international funding averaged 2.4% of total Commonwealth Government agency research expenditures, a proportion fairly similar to that received by universities.

It is natural enough to presume that these research funds sourced offshore represent an economic benefit for Australia. What may be less well appreciated, though, is that they also represent a particular sort of relationship: one in which key decision-makers in other parts of the world recognise Australian technical or intellectual leadership.

This is especially significant in the case of public-sector (as opposed to private-sector) research. Figure 3.1b shows the trend since the mid-1990s in the volume of industry research and development funds sourced abroad. One can observe from this figure that Australian industry is fourth in the region (behind China, Japan, and Singapore) for its capacity to attract foreign R&D funds.

Figure 3.1b – Business R&D investment sourced abroad



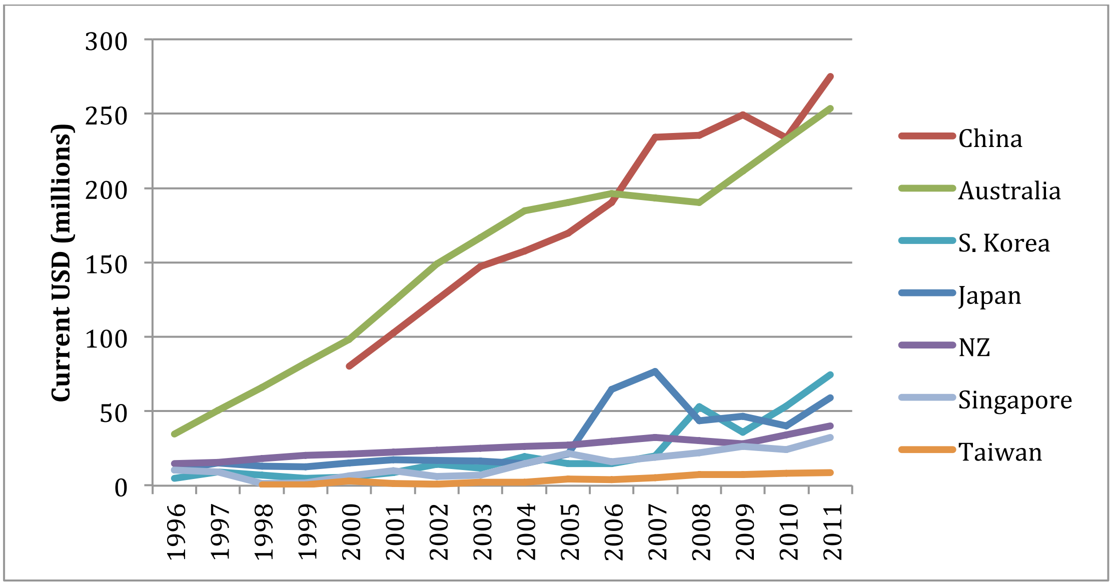
Note: Derived from OECD MSTI. Figures are shown in millions of current US dollars, adjusted for purchasing power parity.

The sharp growth in spending on Chinese R&D shown in the figure obviously reflects a broader context of foreign investment in Chinese innovation. But Australia's position looks weak, even independent of the comparison with China. In Australia, in 2011, overseas investment in Australian business R&D was yet to regain its 2001 peak, and Australian business was apparently a less desirable location for direct international R&D investment than the much smaller city-state of Singapore.

This reflects, in part, the enduring importance of the dotcom bust in 2001, which produced a rapid decline in foreign direct investment flowing to multinational R&D subsidiaries based in Australia. The disparity between Australia and Singapore might also be understood as a function of the differing policy incentives that have been provided within these countries to attract foreign investment for commercial R&D. It should be recognised, however, that total business R&D investment (i.e. including R&D funds sourced domestically as well as abroad) actually grew more quickly in Australia than in Singapore over the period 2001 to 2011. So whether the data presented above in figure 3.1b implies a genuine issue for Australian foreign investment policy is open to debate.

On the other hand, there is a very different and much more positive story to be told about Australia's public-sector institutions (which we define here as government agencies, universities, and private non-profit research institutes combined). Figure 3.1c presents the trend in the total volume of R&D funds sourced abroad by universities, government agencies, and private non-profit organisations. It illustrates that Australia is a very desirable location indeed for this kind of investment – as desirable, in fact, as China, even though Australia's economy is very much smaller than China's.

Figure 3.1c – Public-sector R&D funds sourced abroad



Note: Derived from OECD MSTI and OECD RDS. Figures are shown in millions of current US dollars, adjusted for purchasing power parity. "Public-sector" in this instance includes private non-profit research institutes. Australian data in 2011 is an estimate based upon 2011 data for government agencies and private non-profit institutions combined with university data from 2010.

The fact that international funders give Australian public institutions disproportionate research funding relative to other nations across East Asia and the Western Pacific may indicate an English language bias or Anglo-Saxon cultural bias. Certainly one would expect a significant proportion of these funds to be derived from American or British funding bodies.

Whether this is true or not, however, the pattern certainly underlines the economic importance of international connections in research. It highlights the competitive, global marketplace in which Australian institutions now operate. And since funding bodies are often linked to policy-making institutions (as is certainly the case with defence funding bodies and health funding bodies in the US) it suggests an additional diplomatic incentive to foster these sorts of connections.

It also implies a reason to consider whether some financial relationships are more desirable than others. In a subtle way, these global investments reflect a system of global incentives that encourage Australian researchers to seek out research partnerships with some countries ahead of others.

In key strategic or commercial areas (and one thinks here especially of defence-related research or near-to-market commercial activities), it may well be true that receiving R&D funding from an organisation in one country essentially prevents a researcher from connecting with researchers in another country. In some fields, in other words, international research investments may have strategic implications of relevance to Australian foreign policy.

Key Point 3

Foreign direct investment in Australian business R&D has languished over recent years, which may imply a deficiency in investment-attraction policies. Over the same period, however, foreign funding of Australian public sector R&D has surged dramatically, and investment flows in this sector are likely to have diplomatic implications. A focus on developing globally unique and leading research capabilities in Australian public institutions will be pivotal if Australia is to strengthen and exploit this particular mode of connection with foreign counterparts.

3.2 SECTORAL ANALYSIS

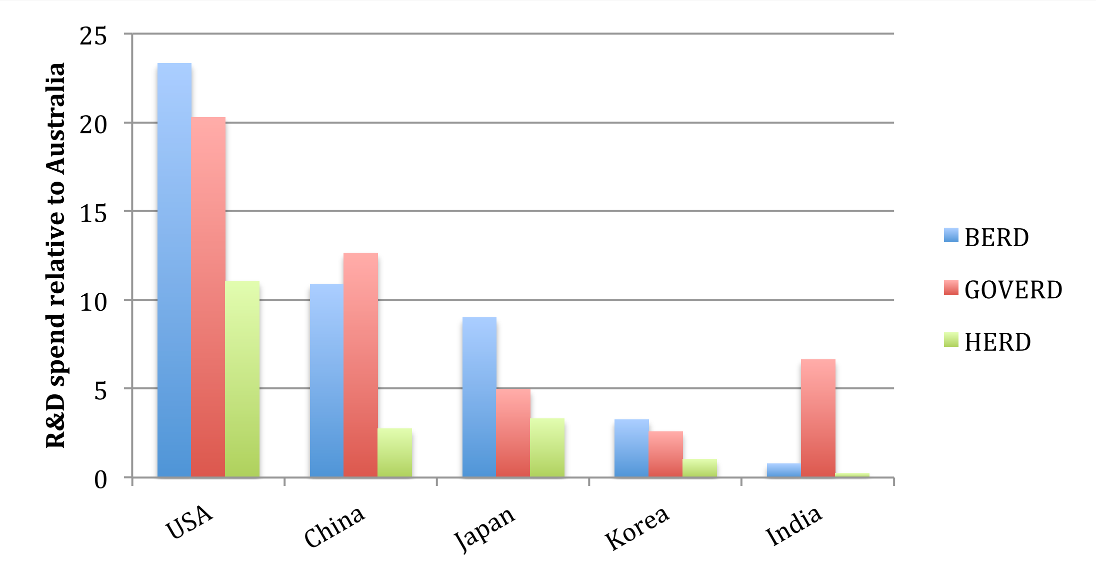
The above being noted, the differing levels of international investment by sector also point to another issue that may be significant to Australia in its research collaborations within Asia.

In all the major Western Pacific countries, including Australia, there is now more R&D spending in the business sector than in the public sector. As we noted at the outset, however, there is much less scope for steering or exploiting private-sector relationships in support of foreign policy goals than is true in the public sector.

Yet even in connecting public-sector researchers across international boundaries, there may be underappreciated constraints reflecting the cultures of the organisations in which researchers operate. And the different emphasis that different societies place upon various different models for public-sector research is potentially significant in this respect.

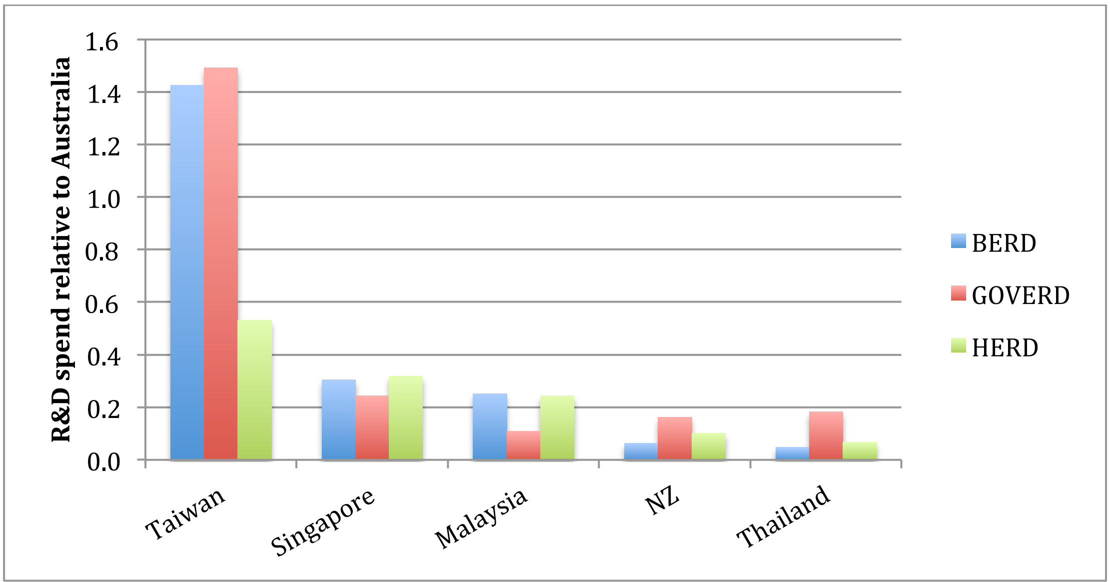
We illustrate this by looking at the extent to which different societies within the region invest in businesses, government agencies, and universities. For a range of Asian and Pacific countries, plus the USA as a point of reference, figures 3.2a, 3.2b, and 3.2c show R&D spending by sector normalised for the scale of equivalent spending within Australian institutions.

Figure 3.2a – R&D spend by sector relative to Australia, larger nations



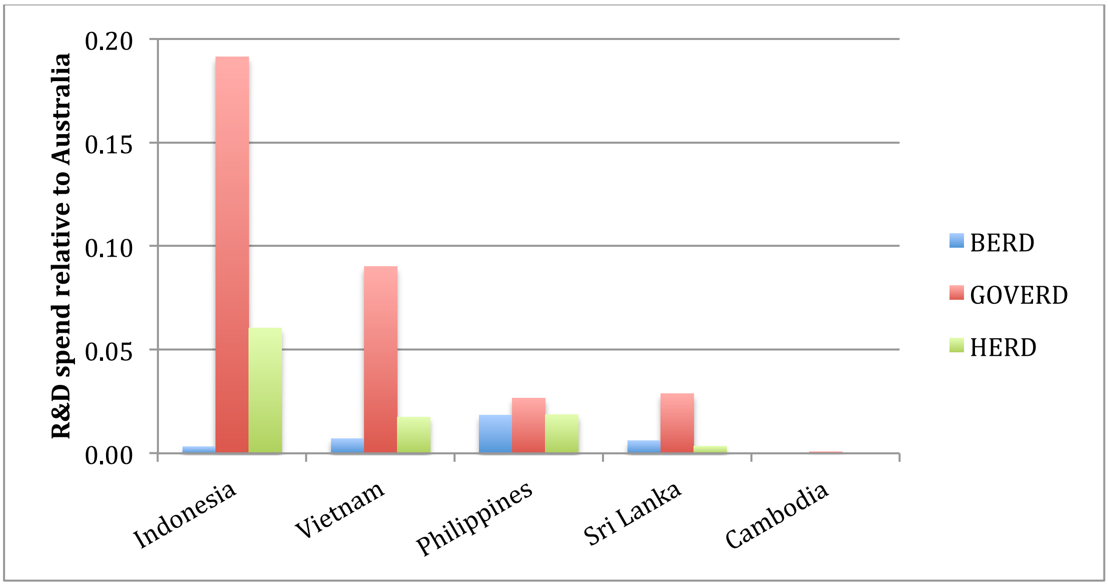
Note: Derived from OECD MSTI & UNESCO 2013. Each country's R&D spend in business (BERD), government agencies (GOVERD), and universities (HERD) is normalised with respect to Australia's equivalent spend with data adjusted for purchasing power parity.

Figure 3.2b – R&D spend by sector relative to Australia, middle nations



Note: Derived from OECD MSTI & UNESCO 2013. Each country's R&D spend in business (BERD), government agencies (GOVERD), and universities (HERD) is normalised with respect to Australia's equivalent spend with data adjusted for purchasing power parity.

Figure 3.2c – R&D spend by sector relative to Australia, small nations



Note: Derived from OECD MSTI & UNESCO 2013. Each country's R&D spend in business (BERD), government agencies (GOVERD), and universities (HERD) is normalised with respect to Australia's equivalent spend with data adjusted for purchasing power parity.

From the first of these figures, it can be seen that business R&D spending in the US is nearly 25 times greater than in Australia and R&D spending in government agencies is nearly 20 times greater than in Australia, while spending in universities is only 10 times greater than in Australia.

In other words, relative to the US, Australia has a much stronger weighting of investment in its universities than in its government agencies or in its business sector. In all three sectors though, US investments dwarf those in their Australian counterparts.

Something similar is true of China and Japan. In these countries, each of the three R&D-performing sectors is much larger than in Australia. The implication is that there are likely to be many opportunities, across all three sectors, for Australians to find research partnerships in each of these societies.

In the other countries, however, total R&D investment is lower and the situation is more complicated. To begin with, compared with the practice in Australia, most Asian societies strongly emphasise government agency research as opposed to university research. For example:

- government agencies in India operate at six times the scale of those in Australia, while Indian universities spend only a quarter of what Australian universities spend on research;

- in South Korea, research spending in government agencies sits at more than twice the level in similar organisations in Australia, while there is roughly an equivalent amount spent on university R&D in both countries;

- Taiwan spends 40% more on research in government agencies than Australia does, but only half as much as Australia does on university research; while

- Thailand, Indonesia, Vietnam, and Sri Lanka, small investors as they are in research, nonetheless have their greatest sectoral scale relative to Australia within the government agency space.

The implication is that it may be easier for Australians to identify research partners in these nations' government laboratories than in their universities.

Furthermore, based upon the assumption that researchers will typically find it easier to build relationships with partners in similar kinds of institutions, it may also be the true that Australians in government agencies will find it easier than Australians based in universities to build partnerships with public-sector colleagues in some of these countries.

In Singapore and Malaysia, on the other hand, the pattern is reversed. In these countries the ratio of R&D investment between universities and government agencies is skewed even more towards universities than is true in Australia. As a consequence, these may be countries where Australians are more likely to connect with the local universities than they are with government research agencies.

All of this has implications for policymaking. It implies that it may be useful to adopt a different investment model when trying to build research ties, say, with Malaysia than with Thailand. It also suggests that there may be a particular role for researchers in Australian government agencies, as opposed to universities, when governments seek to establish research relationships with countries like Vietnam or India.

This is not to suggest, of course, that any Australian government should be prescriptive about which kinds of organisations should be involved in research partnerships with different countries. But it does highlight the need for flexibility, and for mechanisms that can support collaboration in different ways. Research cultures do vary across sectors, and one should assume that this influences the way in which different national research communities connect with one another.

3.3 RESEARCH TRAINING

One obvious consequence of the balance in investment between government agencies and universities is the implication for research training. All other things being equal, countries with high relative investment in universities will tend to offer proportionally more opportunities for research training than countries with high relative investment in government agencies.

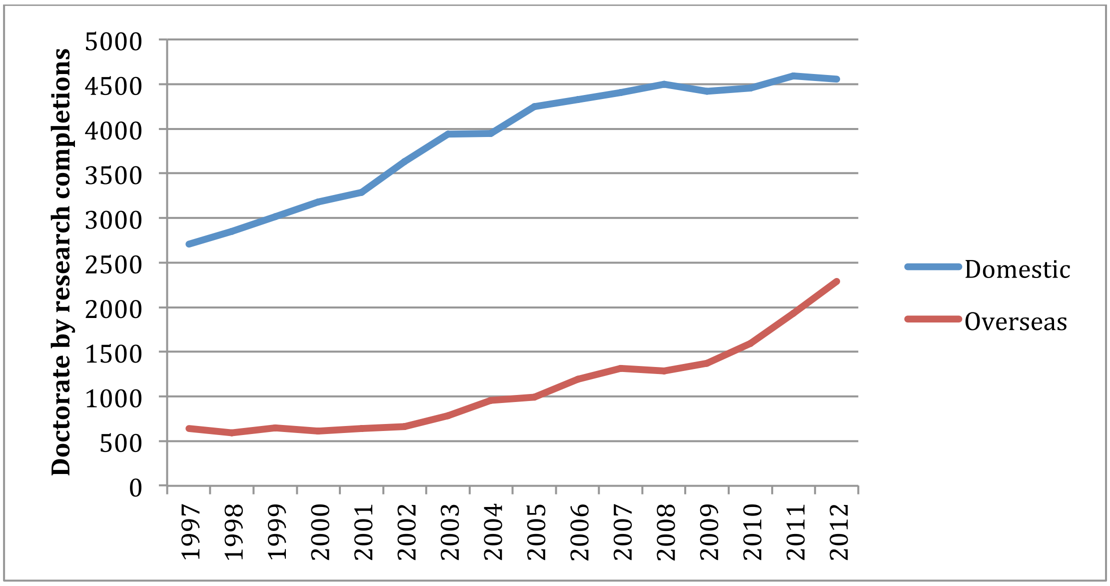
This is an important theme for Australia. Asian nations that have emphasised government agencies rather than universities, may discover that they have inadequate capacity to train their domestic students who are interested in pursuing PhDs, thus augmenting the demand for students to travel in order to receive research training elsewhere. These same countries, moreover, may have limited opportunities to support Australian PhD candidates who are keen to pursue their own doctoral studies overseas.

This is a significant issue because travelling to undertake doctoral training is an important form of international collaboration – one that often creates long-term personal relationships. If our premise is correct, the structure of institutional investment across Asia makes it much more likely for Asian students to travel to Australia for this purpose than for Australian students to travel to Asia, and it seems likely that this imbalance will continue for many years to come.

We do not have the data here on Australians undertaking doctoral training in Asian countries, and the main focus of this report is on co-authorships rather than research training. Nonetheless, there is evidence of strong growth in the number of overseas students (many of whom are Asian) coming to Australia in recent years to complete their PhDs.

Figure 3.3a, for instance, summarises trends in Australian completion rates for doctoral students by numbers of domestic and overseas students. These data reveal that the number of overseas students completing PhDs in Australia has nearly quadrupled over the past decade. They also show that the number of domestic students completing PhDs has remained constant for about five years, arguably indicating a growing dependence upon international students within the Australian system.

Figure 3.3a – Doctorate by research completions



Note: Derived from DE 2014.

In the short-term, this growing cohort of overseas PhD students enhances the research output from the Australian higher education system – a tangible benefit. Each member of this group also represents a potential skilled migrant, who may subsequently join the Australian workforce and contribute in broader ways to the Australian economy.

In the longer term, though, this group should also be seen as a community of future significance for Australian diplomacy within the region, since many of these individuals will return to their countries of origin and pursue careers within public institutions, some rising to positions of influence.

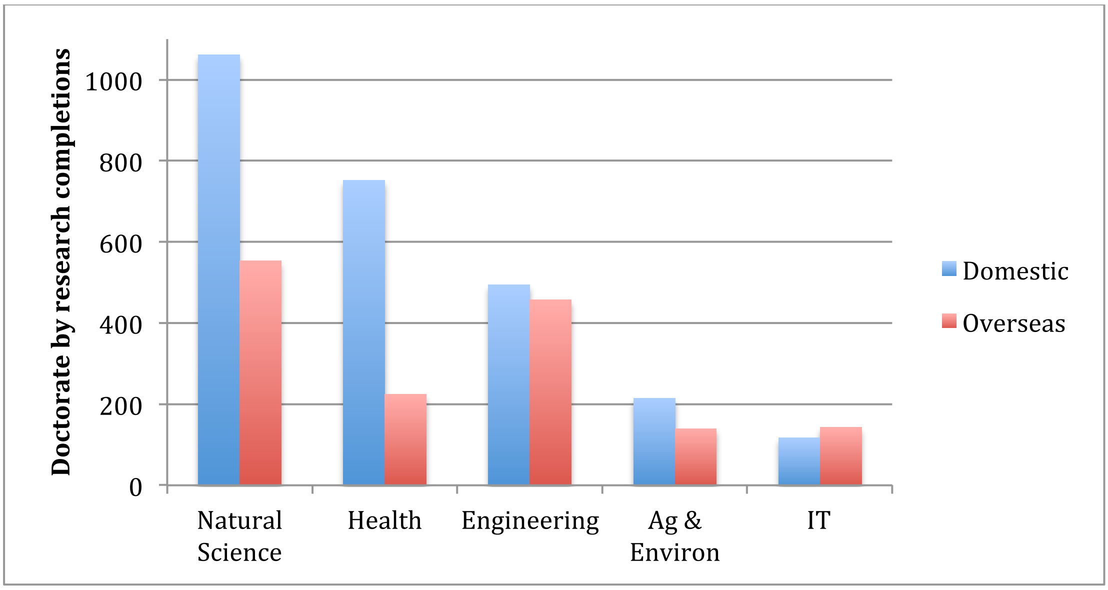
Whatever the consequences for Australia, it is interesting to note that foreign doctoral students are not equally interested in pursuing Australian degrees across all fields.

Figure 3.3b below shows total Australian doctorate by research completions in 2012 for both domestic and foreign students in broad scientific and technological fields, while figure 3.3c shows the same data for the social sciences and humanities.

These figures indicate that Australia attracts its greatest numbers of overseas PhD candidates in natural & physical sciences, in engineering & related technologies, and in the broad social sciences and humanities (the society & culture category). However, the more interesting observations here are those that relate to the ratio between domestic demand and overseas demand for PhD positions.

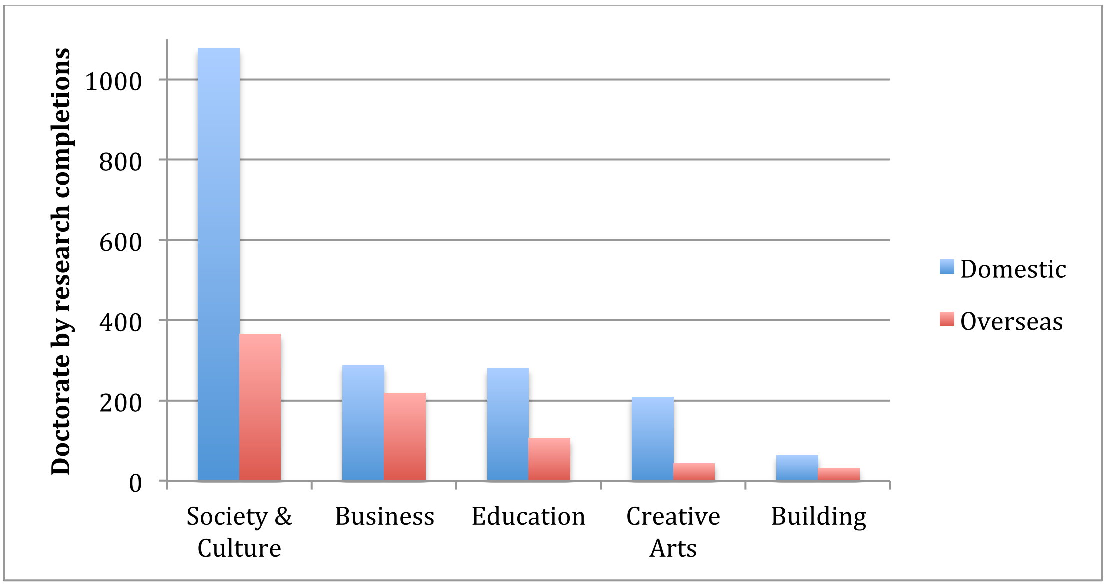
In certain fields, Australian universities graduate as many (or nearly as many) foreign PhD students as they do domestic students. The areas that stand out in this respect are engineering, information technology, agriculture & environmental studies, and business.

Figure 3.3b – Doctoral completions in the sciences



Note: Derived from DE 2014. Natural Science encompasses 'natural & physical sciences'; Engineering encompasses 'engineering & related technologies'; Ag & Environ encompasses 'agriculture, environmental & related studies'; while IT stands for 'information technology'.

Figure 3.3c – Doctoral completions in the social sciences & humanities



Note: Derived from DE 2014. Business encompasses 'management & commerce'; while Building encompasses 'Architecture & building'.

These are fields, presumably, where the incentives for overseas students to travel to Australia are strongest relative to the incentives currently experienced by domestic Australian students. These can be seen, too, as domains where the student experience (for domestic students as well as foreign ones) is most likely to feel international by virtue of the student cohort.

In some other domains, by comparison, the number of foreign students completing PhDs is low relative to the number of domestic students. Here the incentives for domestic students to undertake Australian PhDs would seem much stronger relative to the incentives that exist for foreign students.

Broad areas that stand out in this respect are health, society & culture, education, and the creative arts. In general, doing a PhD in these fields might be expected to feel less international in Australia than is true, say, for engineering – though obviously the experience within specific groups could vary enormously.

The implications in all this are quite interesting. Overseas students apparently have very different patterns of interest in Australian research training compared with domestic students. This implies that maximising Australia's ongoing capacity to benefit from the desire of Asian students to travel in order to undertake research training may require either:

- a more overt focus upon a particular sub-set of disciplines with proven appeal to overseas students; or
- a new strategy to strengthen international interest in fields like health and social sciences.

Either way, the implication is consistent with what we have proposed elsewhere in this section – namely that a serious policy aligning Australian research collaboration with diplomatic objectives would need to be nuanced to account for the interests and choices of people and organisations in other parts of the world, which may differ in substantial ways from similar groups or organisations in Australia.

Key Point 4

In aggregate, Australia attracts considerable foreign investment in its research, which may influence its patterns of overseas research engagement. Its public research system is structured quite differently from that in many Asian countries, which tend to place greater emphasis on government agencies. It is clear too that overseas students have different patterns of interest in Australian research training than is true of Australian domestic students. Any strategy that seeks to build up Australia's regional network of research collaborations needs the flexibility to accommodate these differences.

4. COUNTRIES WITH LOW RESEARCH OUTPUT

In section 2, in table 2.1c, we provided a list of key nations across Asia and Oceania, ranked by volume of publication outputs. Among these countries, the most prolific were China, Japan, South Korea, India, Australia, Taiwan, Singapore, and New Zealand.

These nations (along with Malaysia, which has had one of the highest growth trajectories in the region) form the basis of our analysis in subsequent sections of this report.

Before moving on to this, however, it is worth including a short commentary about those nations with lower levels of output: Thailand, Vietnam, Indonesia, the Philippines, Sri Lanka, Cambodia, Fiji, Laos, Papua New Guinea, various other Pacific Islands, and North Korea.

4.1 PHD TRAINING FOR LOW-OUTPUT NATIONS

In our conceptual framework, we identified six broad diplomatic objectives where there is a potential role for international research collaboration. When dealing with countries of low research intensity and low research output, three of these objectives are arguably more significant than the others.

- First, in order to strengthen our foreign relations across the region, it is clearly in Australia's interest to spread scientific values into low-output nations and to build trust within their intellectual communities.

- Second, it is surely useful for Australia to establish expert relationships in order to enable rapid coordination of knowledge and expertise in emergency situations.

- And third, research relationships can help to ensure that our humanitarian and development aid budgets in countries of low scientific intensity are well spent and bring lasting benefit.

Investment in bilateral relationships in any area of science will support the first of these objectives, so long as such relationships are built around rigorous research methodologies. Such methodologies are more likely to be found in a country of high scientific intensity than in one of low scientific intensity, which reinforces the long-term value in bringing doctoral students from countries of low scientific output to study in Australia.

Yet as table 4.1a shows below, Australia is currently much more successful in attracting research students from some countries than others. In absolute terms, the leading recipients of postgraduate research training visas in Australia in 2012-13 were Chinese (1,520 visas granted), Malaysian (805 visas granted), Indonesian (687 visas granted), Bangladeshi (600 visas granted), Indian (479 visas granted), and Vietnamese (423 visas granted).

Table 4.1a – Postgrad Research Sector visa applications granted, 2012-13

Country	Postgrad Research Training (574) visas granted	Higher Education Sector (573) visas granted	AusAID or Defence sponsored (576) visa granted	Ratio of 573 to 574	Population per Australian 574 visa granted
Singapore	153	3,148	0	20.6	34,722
Malaysia	805	5,897	92	7.3	36,323
Fiji	23	125	99	5.4	38,032
Sri Lanka	312	2,061	123	6.6	65,154
Vietnam	423	7,849	649	18.6	209,865
Nepal	127	5,387	100	42.4	216,334
PNG	29	233	536	8.0	247,138
Bangladesh	600	1,787	157	3.0	257,826
Taiwan	84	1,227	0	14.6	277,571
Thailand	186	3,416	108	18.4	359,059
Indonesia	687	3,793	1,241	5.5	359,337
S. Korea	97	3,641	2	37.5	515,510
Pakistan	240	4,352	328	18.1	746,500
Cambodia	17	229	181	13.5	874,391
China	1,520	44,809	26	29.5	888,615
Philippines	70	2,039	331	29.1	1,381,525
Japan	60	930	5	15.5	2,126,025
India	479	11,648	57	24.3	2,581,809

Note: Visa data is derived from DIC 2013, while population data used to calculate the values for the final column were obtained from WB 2014. The 573 visas are for university undergraduate courses and exclude those involving research training, which are covered via the 574 visas. AUSAID or defence-sponsored 576 visas are used to bring international students to Australia to study courses of any kind.

However, these data can be normalised, and a different picture emerges if one compares the volume of visas granted for postgraduate research training in Australia in 2012-13 with either the population of country of origin or the number of undergraduate (573) visas granted.

The final column in table 4.1a above suggests that, relative to population, a disproportionate number of 574 visas for postgraduate research training in Australia were granted to Singaporean, Malaysian, Fijian, Sri Lankan, Vietnamese, Nepalese, Papua New Guinean, and Bangladeshi citizens in 2012-13.

This may imply that the capacity for dramatically increasing the number of students undertaking research training from these countries is limited – even though these are all countries of low research output.

On the other hand, these same data suggest that there may be quite good capacity to increase the number of Indian, Philippine, Cambodian, Pakistani, Indonesian, and Thai students undertaking research training in Australia.

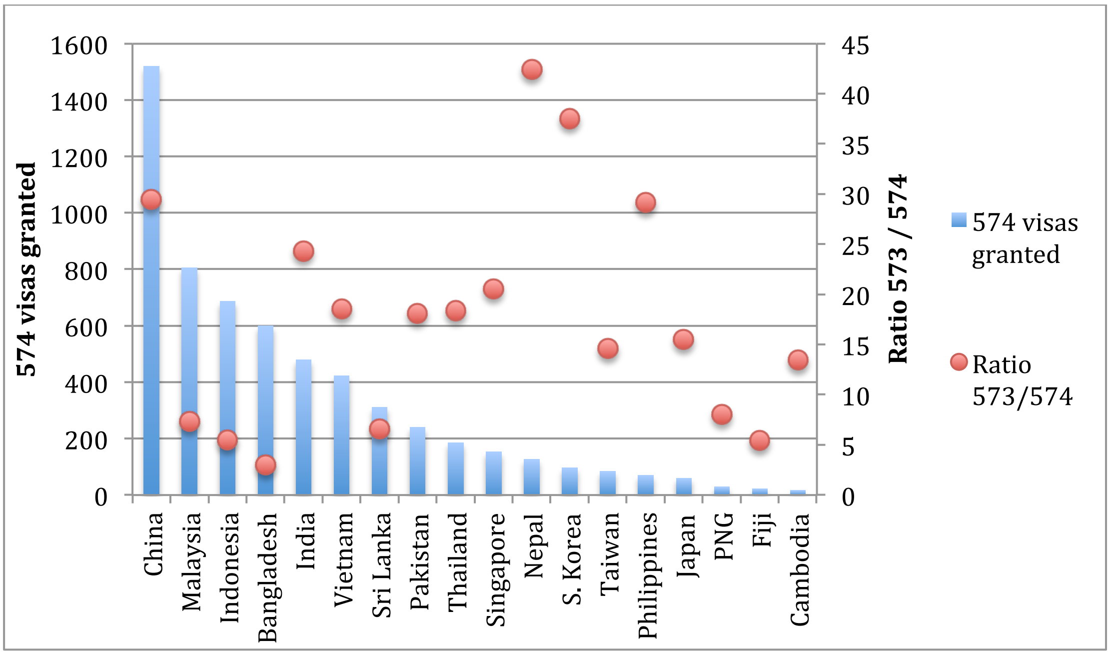
Of course, there are many factors at play here, including the level of opportunity to pursue research training locally or in other foreign countries apart from Australia. Perhaps most significant of all, though, is the level of education and particularly of higher education across each of these populations.

This is where it is useful to study the ratio of 573 visas to 574 visas granted, since this provides an indicator of each country's demand for Australian research training relative to its demand for other Australian higher education services.

Figure 4.1b is instructive in this regard, as it plots total research training (574) visas granted, together with the ratio of 573 visas / 574 visas. It reveals that China, India, Nepal, South Korea, and the Philippines all have relatively high ratios of 573 visas granted compared with their numbers of 574 visas granted.

Judging from their demand for other Australian higher education services, Australia arguably has additional scope to attract a much greater number of candidates for research training from these societies.

Figure 4.1b – Education versus research training visas granted, 2012-13



Note: Derived from DIBP 2014. Shows total grants during 2012-13, combining grants from both onshore and offshore applications.

On the other hand, the ratio of 573 / 574 visa grants is low in Malaysia, Indonesia, Bangladesh, Sri Lanka, Papua New Guinea, and Fiji. The implication here would seem to be that expanding links through research training may be a lesser priority at the current time than building connections through higher education at the undergraduate level or developing bilateral research projects involving these countries directly.

All these data are indicative only, but putting them together may be useful in determining allocations of AUSAID (576) visas and whether it makes sense to expand elements of that programme.

Certainly the evidence from current visa allocations is that Australia is not building the same sorts of relationships with the future research workforce in the Philippines, India, and Cambodia as it is in most other emerging economies across the region. There may be scope too, in relative terms, for expanding the emphasis on research training for students from Pakistan and Thailand.

This raises a key issue for Australia. A strategic approach, driven by long-term diplomatic objectives, would surely seek greater balance in the research training opportunities offered to citizens from different countries across the region.

Key Point 5

Relative to population and to evidence of demand for other Australian higher education services, there is considerable variation across the region in the extent to which people from different societies are receiving research training in Australia. This seems to be an issue both for high-output nations (like India) and for low-output nations (like the Philippines). A strategic approach, driven by long-term diplomatic opportunities, would seek greater balance in the research training opportunities offered to people from all countries across the region.

4.2 FOCI FOR LOW-OUTPUT NATIONS

While research training is important for spreading scientific values and for building trust with intellectual communities that are currently emerging across our region, there are additional reasons to foster direct collaborative partnerships with researchers based in low-output countries.

As we have previously observed, establishing expert relationships around research themes can underpin rapid coordination in emergency situations. It can also increase the odds that Australia's humanitarian and development aid is well spent and brings lasting benefit.

Research partnerships in the health and medical sciences, in earth sciences, and in natural resource management seem most likely to be important in implementing of these objectives. But collaboration in engineering and social sciences may prove significant, too, in ensuring a high impact from Australian aid.

In this report, we do not provide an analysis of co-authored papers between Australian researchers and those in Western Pacific countries with low research output. Yet looking briefly at these low-output nations, it is worth making a comment about the fields in which they have focused their research.

Previously, in table 2.1c, we illustrated the enormous disparity in scientific output between Australia and the developing countries in the region. In 2011, for Australia, total outputs fractionated by location of author amounted to over 20,000 publications. By comparison:

- For Thailand and Malaysia, total outputs fractionated by location of author amounted to only just over 2000 papers;

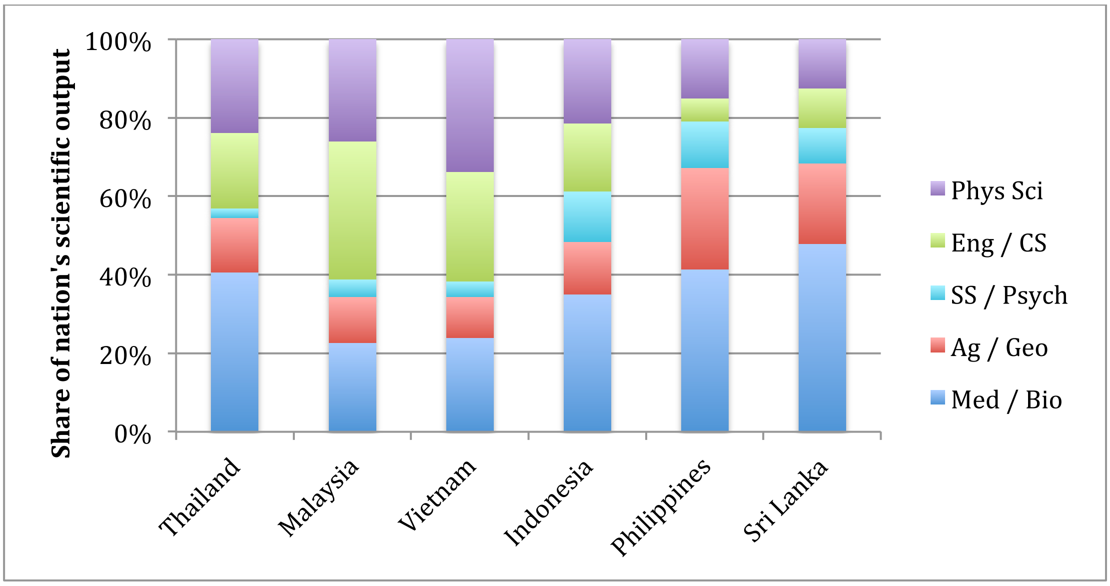
- for each of Vietnam, Indonesia, the Philippines and Sri Lanka, total outputs fractionated by location of author amounted to fewer than 500 papers; while

- for each of Cambodia, Fiji, Laos and Papua New Guinea, total outputs fractionated by location of author amounted to fewer than 50 papers in 2011 (NSF SEI).

The scope for direct collaboration between Australia and the latter countries is clearly going to be limited in this context. But scale on its own is not the only factor here.

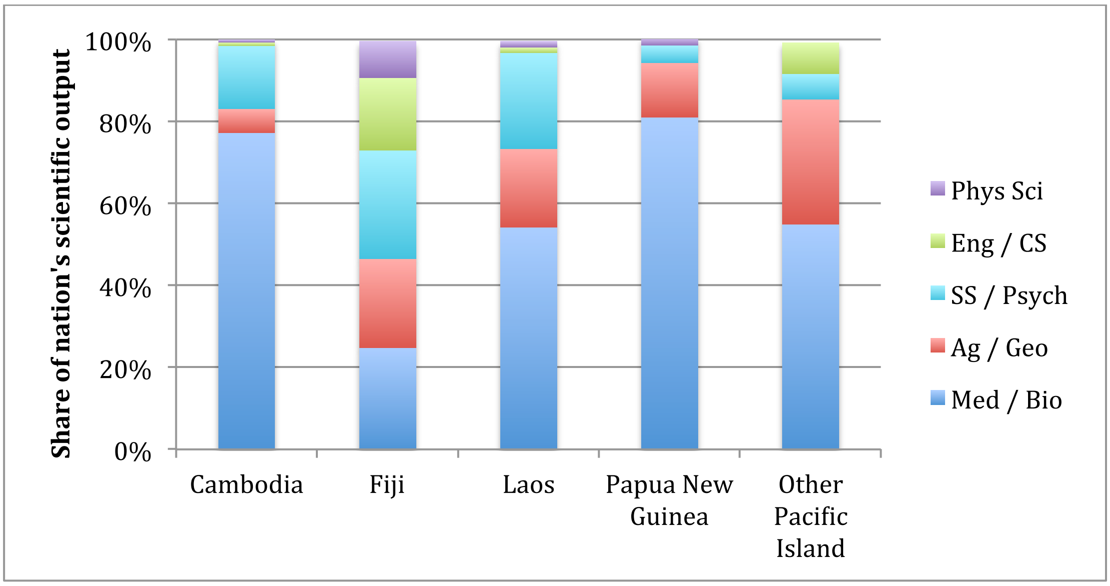
Field orientation is also important. After all, effective collaboration requires expertise on both sides of a partnership. In this respect, it is worth considering figures 4.2a and 4.2b, which show the proportion of scientific publications for these countries by broad field of focus.

Figure 4.2a – Fields of focus among nations with low output, 2011



Note: Derived from NSF SEI. Counts are fractionated based upon authors' residence. Nations are ordered left to right by decreasing volume of total outputs. "Phys Sci" stands for physics, chemistry and astronomy; "Eng/CS" for engineering, computer science and mathematics; "SS/Psych" for social sciences and psychology; "Ag/Geo" for agricultural sciences and geosciences; and "Med/Bio" for medicine, health and biology.

Figure 4.2b – Fields of focus among nations with very low output, 2011



Note: Derived from NSF SEI. Counts are fractionated based upon authors' residence. Nations are ordered left to right by decreasing volume of total outputs. "Phys Sci" stands for physics, chemistry and astronomy; "Eng/CS" for engineering, computer science and mathematics; "SS/Psych" for social sciences and psychology; "Ag/Geo" for agricultural sciences and geosciences; and "Med/Bio" for medicine, health and biology.

What is striking about these data is the emphasis on medicine, health and biological sciences, particularly among those nations of very low total output depicted in figure 4.2b.

To a significant degree, the focus afforded to social sciences, agricultural sciences, and geosciences is also fairly strong, although for the nations in figure 4.2b the absolute number of publications in each of these areas is still extremely low. The geosciences, interestingly, also tend to be much more important in these societies than the agricultural sciences.

By contrast, among these same countries, and especially those listed in figure 4.2b, there is hardly any research at all in engineering, computer science, mathematics, physics, chemistry or astronomy; and, in figure 4.2a, the same is true for the Philippines and Sri Lanka.

All this has implications for research diplomacy. Within the region, it seems that the smaller its scientific output the more likely it is for a society to prioritise medical and biological research and, to a lesser degree, geosciences and social sciences.

Therefore, in connecting with these societies through research, unless Australia is prepared to engage in substantial capacity building, it probably makes sense to emphasise collaboration across these same fields.

The situation looks different for Thailand, Malaysia, and Vietnam. In these countries, there are greater prospects for connecting also through physical sciences and engineering. So, in dealing with these countries, it probably makes sense to pursue a broader collaboration strategy.

Every nation of course can shift investment across fields and change the areas of focus within its national research portfolio over time. Currently, though, an Australian agenda to build bridges with nations of low-scientific output in the Western Pacific region would sensibly provide a special emphasis on medical and health related activities.

Key Point 6

Australia's capacity to collaborate with nations of low scientific output is dependent upon the capabilities that exist in these places. In many instances, it looks currently as though the most significant opportunities for collaborating with such countries will be found in the health, medical and biological sciences, and in geosciences.

5. REGIONAL COLLABORATION NETWORKS

In understanding whether Australia is optimising its engagement with research partners across the region it is essential to understand the nature of the collaborative networks that have evolved among the more scientifically productive countries of Asia and Oceania. To analyse these networks we:

- study co-authorships on scientific papers across several core knowledge domains;
- look at the kinds of institutions that are actively engaged in international collaboration in Australia and across the region; and
- compare the regional collaboration patterns of several government research agencies.

In this way, we highlight the dominance of Chinese networks within the region, accumulate evidence suggesting that Australia's capacities in research do not always align with other nations' strategic priorities, and imply that Australian Government Agencies in particular are not as aggressively engaged in research diplomacy as they might be.

5.1 CO-AUTHORSHIP NETWORKS BY BROAD FIELD

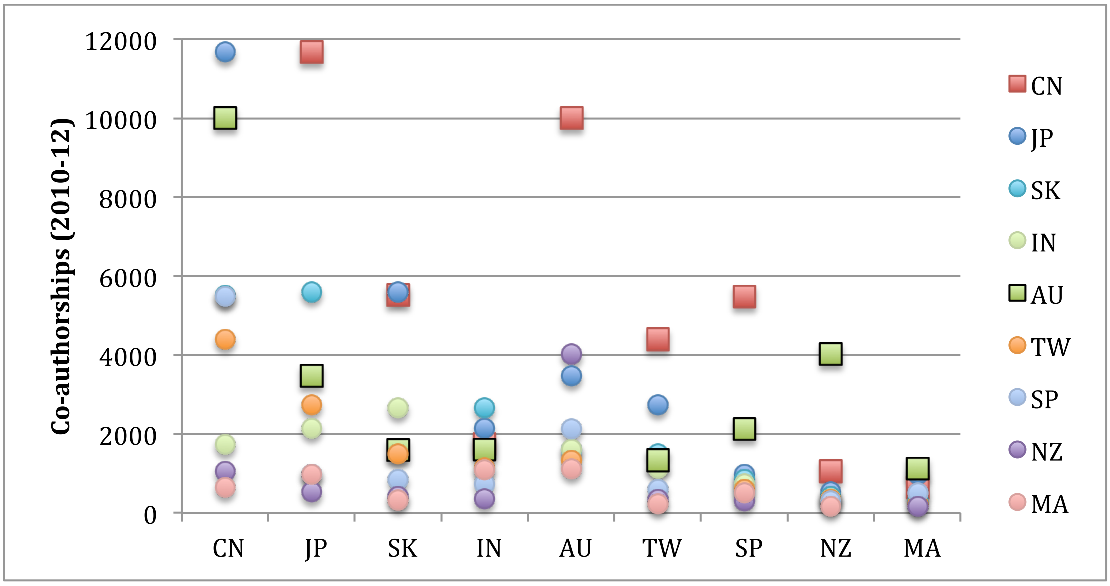
Figure 5.1a shows bilateral co-authorships by volume of papers published between 2010 and 2012. In the diagram, country pairings are identified by the x-axis delineation and the colour coding of each point.

The first thing that is noticeable from this diagram is that across the majority of countries shown, China is now the main collaborator – implying that China is beginning to dominate intellectual networks in the region. China is especially important as a collaborator for Japan, Australia, South Korea, Taiwan, and Singapore.

Exceptional among this particular set of countries, however, South Korea balances its relationship with China, with an equally strong relationship with Japan.

South Korea also stands out for having the strongest relationship in the region with India – stronger than those between China and India or between Japan and India. This may be an accident or it may reflect a deliberate strategic choice on the part of the Indians and South Koreans. It could be significant, in this respect, that both nations share a land border with China.

Figure 5.1a – Pairwise co-authored papers across all fields



Note: Derived from TR DATA. Counts papers involving co-authors from country pairs during 2010-12, where JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, and IN=India. Nations are ranked (left to right) by volume of total outputs across all fields.

India, by contrast with most other powers across the region, has a relatively weak relationship with China, co-publishing most frequently with South Korea and Japan, and co-publishing with China and Australia on a slightly lower scale.

Overall, the relationship between Japan and China is easily the strongest in the region, which is not surprising given the scale at which both powers now operate. However, this relationship appears more important to Japan than it is to China.

Japan has twice as many co-authorships with China as it does with South Korea, and more than three times as many co-authorships with China as it has with Australia, these being its next biggest partners.

China, on the other hand, has nearly the same number of co-authorships with Australia as it has with Japan – a singular testament to the strength of the Australian-Chinese relationship in research. China also has an equivalent number of co-authorships with South Korea as Japan does, plus significantly more co-authorships with Singapore and Taiwan than Japan does.

Within this regional network, Australia sits in an unusual place. As we've seen, it has strong connectivity to China. It is also the single most important research partner to New Zealand and Malaysia, and relative to scale it is closely connected with Singapore. Surprisingly, it actually has more co-authored papers with Singapore than with Japan. This is despite the fact that Japan's total research output is an order of magnitude larger than Singapore's (figure 2.1c).

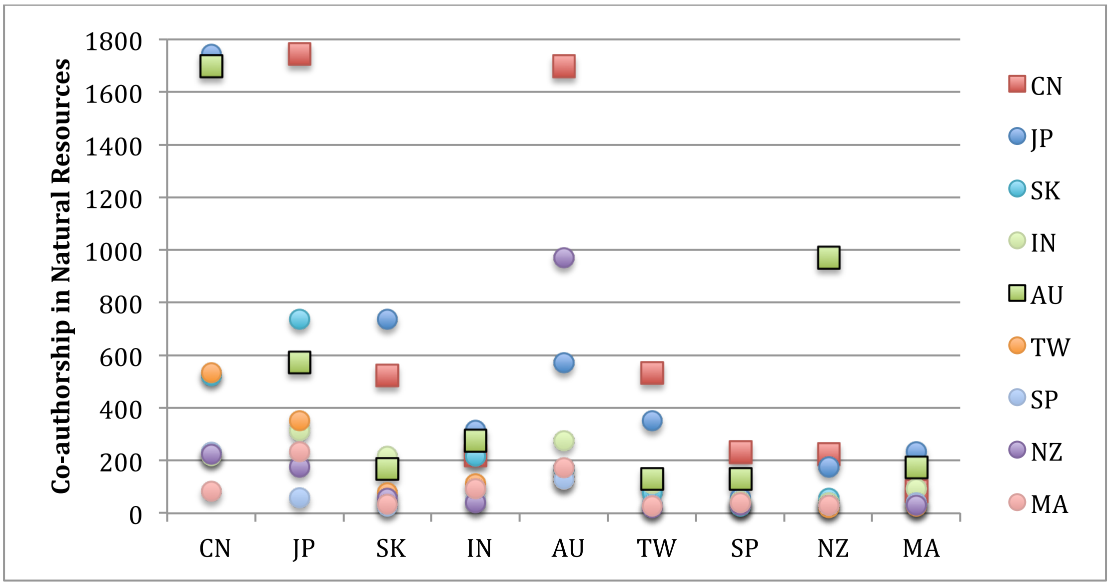
By comparison, Australian research is arguably underweight in its connectivity to Japan, Taiwan, South Korea, and India, suggesting an uneven strategic focus within the region. Indeed, its collaboration patterns are consistent with what one would expect if linkages were based predominantly upon cultural and linguistic affinity (in the case of NZ) and personal relationships built through an ethnic diaspora (in the case of China and possibly Singapore). In this context, it is plausible to argue that Australia's research linkages may not be serving a diverse set of national strategic interests.

Figures 5.1b through to 5.1g provide a similar picture, but where the data are narrowed to cover a subset of journals corresponding to six key knowledge domains. These figures show the extent to which regional research networks vary according to broad fields of activity.

To begin with, figure 5.1b makes a representation of regional co-authorships in the natural resources domain, which encompasses the fields of "agricultural sciences", "plant & animal science", "environment / ecology", and "geosciences".

In these fields, it can be seen that Australia's relationship with China intensifies. China publishes as many articles jointly with Australian researchers in these fields as it does with Japanese collaborators. Likewise, the Australian relationship strengthens slightly with partners in Japan and India, at least relative to their relationships with other countries in the region. In these fields, interestingly, the level of co-authorship between Australian and Indian researchers is greater than that between Indian and South Korean researchers.

Figure 5.1b – Pairwise co-authored papers in natural resources



Note: Derived from TR DATA. Counts papers involving co-authors from country pairs during 2010-12, where JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, and IN=India. "Natural resources" encompasses agricultural sciences, plant & animal science, environment/ecology, and geosciences. Nations are ranked (left to right) by volume of total outputs across all fields.

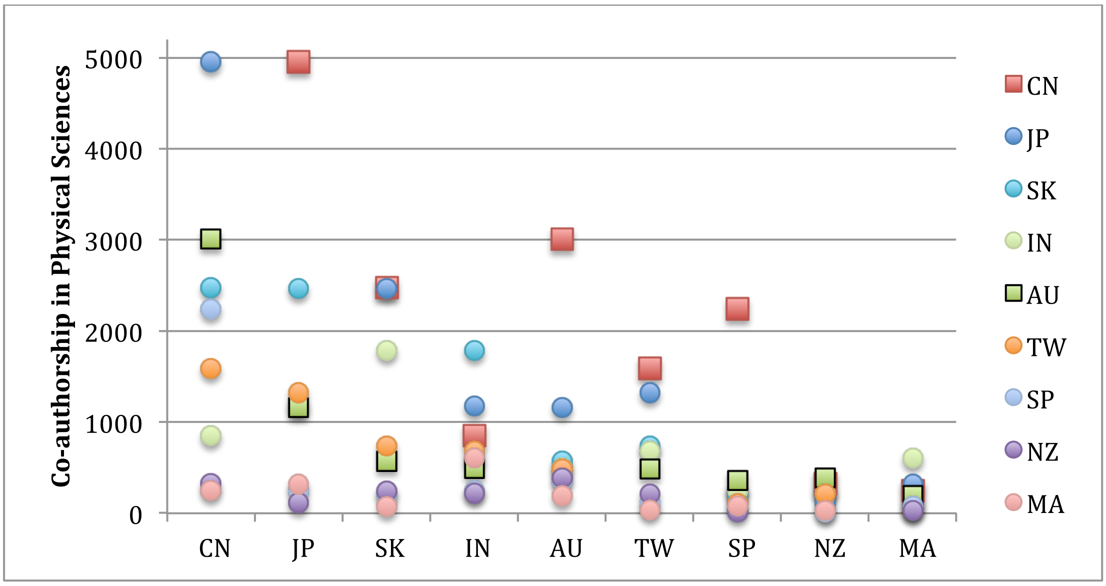
On the other hand, Australian partnerships with South Korea, Taiwan, and Singapore are not so strong in this domain. Singapore has only 6% of its collaborations with Australia in this domain, while South Korea and Taiwan have only 11% and 10% of their Australian collaborations in this domain. This compares with 24% for New Zealand, 17% for India and China, and 16% for Japan. Furthermore, while Australian relationships clearly remain important for Malaysia, this is a domain where the Malaysian relationship with Japan is slightly stronger than Australia's.

The strength of Australia's relationships with China, Japan, and India in the natural resources fields suggests that these fields should be counted among Australia's strengths, and that these are fields of some strategic priority within this particular set of nations. By contrast, the weakness of Australia's relationships with South Korea, Taiwan, and Singapore in these fields implies that these are probably not areas of strategic priority for these countries.

Figure 5.1c shows a very different pattern of collaboration in the physical sciences domain, which encompasses the fields of "physics", "chemistry", "materials science", and "space science".

In these fields, Australia remains an important collaborator for China and NZ (with which it is the lead the partner). However, in most instances it is not a highly ranked collaborator. Japan has more collaboration with Taiwan in this domain than it does with Australia, and China has nearly as many joint authorships with Singapore in these fields as it does with Australia.

Figure 5.1c – Pairwise co-authored papers in physical sciences



Note: Derived from TR DATA. Counts papers involving co-authors from country pairs during 2010-12, where JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, and IN=India. "Physical sciences" encompasses physics, chemistry, materials science, and space science. Nations are ranked (left to right) by volume of total outputs across all fields.

What is really striking, though, is the weakness of the Australian relationship with South Korea, Taiwan, Singapore, Malaysia, and India. For each of these countries, Australia is a minor partner whose level of collaboration is invariably dwarfed by that of China and Japan, and usually exceeded also by that of South Korea, India, and Taiwan.

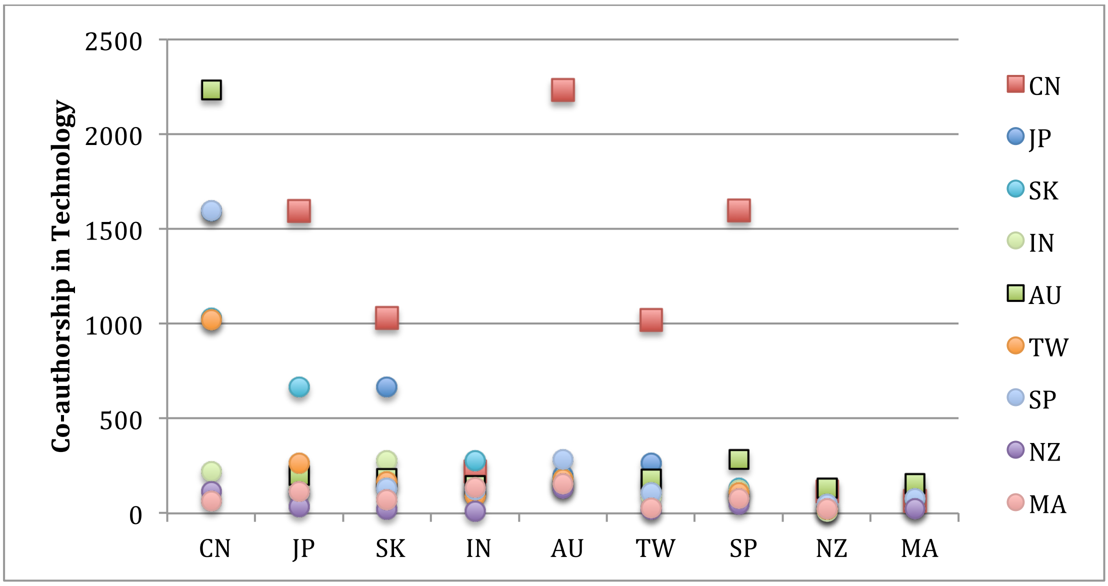
This may reflect something about the emphasis on different fields across the region. The physical sciences are very important fields for these nations. India and South Korea, for example, co-authored 1,784 joint papers across the physical sciences between 2010 and 2012 compared with just 217 papers in the natural resources domain.

Over the same period, Australians co-authored 495 papers with Indian researchers in the physical sciences – considerably more than the 275 papers Australians co-authored with Indians in the natural resources domain, but less than a third the number of co-authorships between Indians and South Koreans in the physical sciences.

Remarkably, 67% of India's total papers co-authored with South Korea, 60% of its papers co-authored with Taiwan, 49% of its papers co-authored with China, and 55% of its papers co-authored with Japan are in the physical sciences. The inescapable conclusion here is that if Australia wants to build stronger research ties in the region – and especially with countries like India, South Korea, and Taiwan – it may need a greater emphasis on research in this domain.

Figure 5.1c makes a similar representation of regional co-authorships in the technology domain, which encompasses the fields of "mathematics", "computer science", and "engineering". The patterns of collaboration in these fields are different again, and quite remarkable, being heavily dominated by the Chinese, at least if one excludes India, Malaysia and New Zealand.

Figure 5.1c – Pairwise co-authored papers in technology



Note: Derived from TR DATA. Counts papers involving co-authors from country pairs during 2010-12, where JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, and IN=India. "Technology" encompasses mathematics, computer science, and engineering. Nations are ranked (left to right) by volume of total outputs across all fields.

Australia's position in these fields is also very interesting. The volume of co-authored papers between China and Australia is extremely high. It is higher, in fact, than any other bilateral pairing in this domain. This indicates a strong relationship – but a relationship that appears to be driven by China and not by Australia.

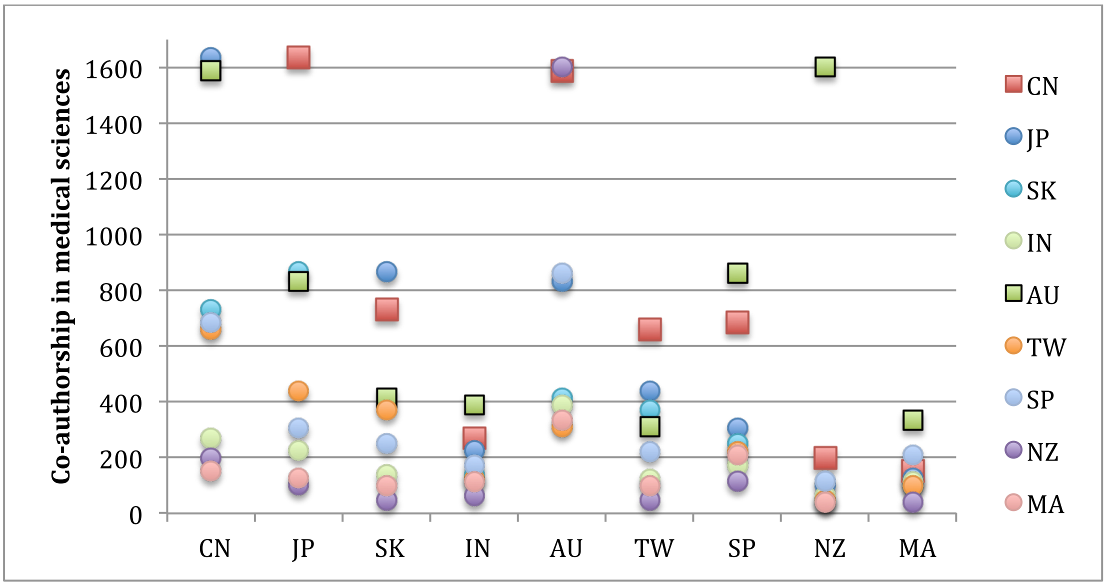
We can surmise this because China has very strong partnerships in this domain with all the countries shown (with the arguable exception of Malaysia and New Zealand), whereas Australia does not.

China, in other words, is accessing a high level of capability in Australia – as it is in Japan, South Korea, Taiwan, and Singapore – but Australians are not accessing a high level of capability anywhere else in the region outside of China. In this domain, the Chinese have internationalised across a broad base of countries, a development to which Australia has reacted by strengthening ties with China, without making any effort to forge broader links elsewhere in the region.

Of course, if Australia's strong links with China in the technology domain are a special function of the Chinese diaspora working in Australian organisations, its capacity to link on a similar scale with other societies may be quite limited. Nonetheless, the scale of the Australia-China relationship in these fields can be regarded, at least in principle, as a measure of Australia's potential for connecting with other nations in the technological fields.

This brings us to the medical sciences. Figure 5.1d presents regional co-authorships in the medical sciences domain, which encompasses the fields of "clinical medicine", "neuroscience & behaviour", and "psychiatry / psychology".

Figure 5.1d – Pairwise co-authored papers in medical sciences



Note: Derived from TR DATA. Counts papers involving co-authors from country pairs during 2010-12, where JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, and IN=India. "Medical sciences" encompasses clinical medicine, neuroscience & behaviour, and psychiatry/psychology. Nations are ranked (left to right) by volume of total outputs across all fields.

In these areas, Australia is the dominant (or equal dominant) partner for all nations shown with the exception of Japan, South Korea, and Taiwan. In the case of New Zealand, India, Malaysia, and Singapore, Australia has significantly more co-authorships even than China does. This reflects Australia's strong investment in medical research relative to other fields, and relative to the weighting that is currently given to medical research in most Asian nations.

According to National Science Foundation data, in Australia 29% of outputs are in medical and health sciences, compared with 24% in New Zealand, 21% in Japan, 20% in South Korea and Taiwan, 11% in China, and 10% in India and Malaysia (NSF SEI).

There are other observations to make, however. First, it should be noted that although New Zealand has a greater weighting in this domain than China does, China nonetheless publishes far more in absolute terms due to its tremendous scale. Yet Australia has as many co-authored publications in this domain with New Zealand as it does with China – implying, even under current circumstances, that there is greater potential to connect with China in this area.

Second, it should be recognised: (a) that Japan has twice as many co-authorships with China and as many co-authorships with South Korea as it does with Australia, (b) that South Korea has roughly twice as many co-authorships with each of Japan and China as it does with Australia; and (c) that Taiwan has more co-authorships with China, Japan, and South Korea than it does with Australia.

These latter points imply a strong East Asian network that could grow rapidly should these countries begin to increase investment in clinical research. Between 2010 and 2012, Chinese and Japanese researchers co-published around 1,600 articles in the medical sciences domain. But they co-authored roughly 5,000 articles in the physical sciences domain over the same period.

An expansion of investment in related fields in these countries could rapidly diminish Australia's potential influence on intellectual networks across the region.

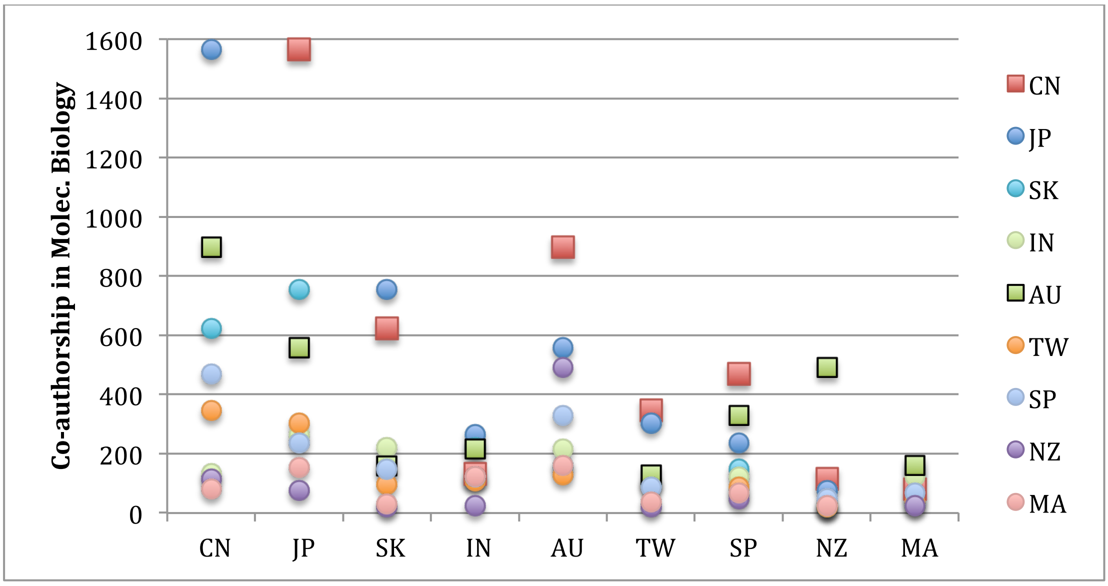
Figure 5.1e makes a similar representation of regional co-authorships in the molecular biology domain, which encompasses the related fields of "biology & biochemistry", "molecular biology & genetics", "pharmacology & toxicology", "immunology", and "microbiology".

These fields are important not only in their own right, but also in the medical context as they have often yielded fundamental advances with long-term clinical application. For Australia, which has long prided itself as a country that excels in medical research, performance in these fields is important, though their significance for diplomacy is probably lower than is true in the more applied clinical fields or in the physical sciences or in the natural resources domain.

Nonetheless, it is interesting to note that the collaboration patterns here are very different from those we saw above in the medical sciences. In this domain the strongest relationship is that between China and Japan, followed by those between Australia and China, and then between Japan and South Korea.

Australia is the favoured partner across these fields only in the case of New Zealand and Malaysia, but in every other instance there is at least one and sometimes three other nations with higher levels of collaboration than are observed with Australia.

Figure 5.1e – Pairwise co-authored papers in molecular biology



Note: Derived from TR DATA. Counts papers involving co-authors from country pairs during 2010-12, where JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, IN=India. "Molecular biology" encompasses biology & biochemistry, molecular biology & genetics, pharmacology & toxicology, immunology, and microbiology. Nations are ranked (left to right) by volume of total outputs across all fields.

The most striking element in this diagram, though, is the level of collaboration with Singapore. Singapore's total outputs across all fields are less than a quarter the scale of Australia's total outputs (figure 2.1c). Yet in this domain the Singaporeans "connect well above their weight", usually co-publishing at volumes far in excess of what might be expected from the relative scale of the Singaporean and Australian research systems.

For example, they have roughly twice as many connections with the Chinese and Japanese as one might expect by drawing comparisons with Australia, and they actually co-publish just as many papers with the South Koreans in molecular biology as the Australians do.

In selected fields within this broad domain, the strength of Singaporean relationships becomes even more apparent. For instance, in "molecular biology & genetics" Taiwan and India both have as many co-authored papers with small-scale Singapore as they do with Australia. In "biology & biochemistry" South Korea actually has more co-authored papers with Singapore than with Australia.

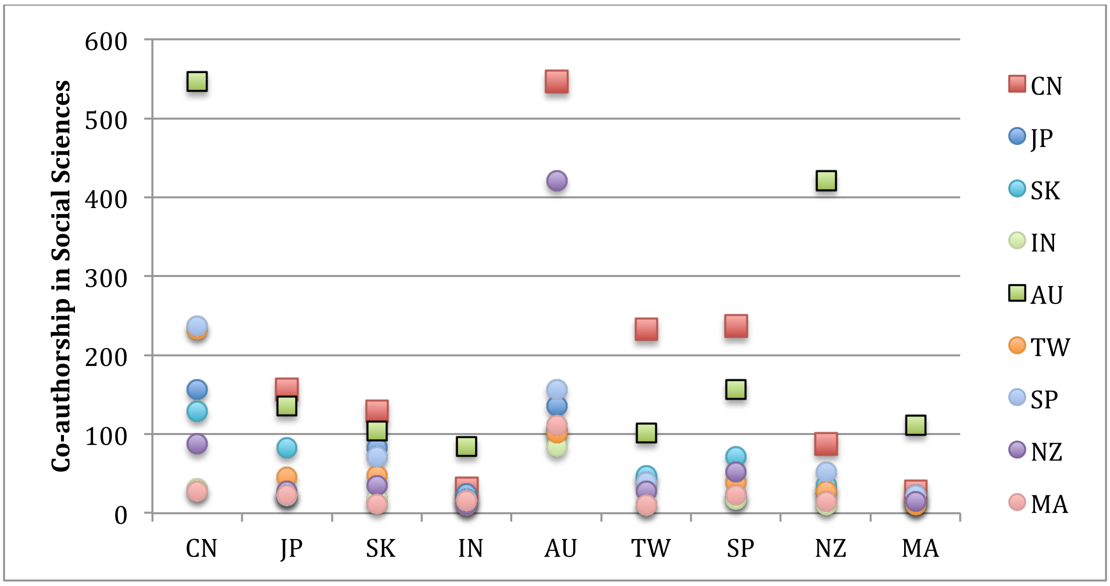
All of this suggests an area of relative underperformance for Australia within the region, the exception at the field level being in "immunology", where Australia happens to be one of the top two regional collaborating partners for almost all the countries in this set.

Finally, we consider the social sciences domain, which encompasses the fields of "economics & business", and "general social sciences". Figure 5.1g shows that collaboration across these fields takes place at a much lower scale in the region than is true across the scientific and technological domains.

This would partly reflect the lower levels of co-authorship that prevail in many areas of social science, the greater potential for parochial as oppose to universal research, as well as the greater likelihood of publication in languages other than English compared with the situation in the sciences.

Nonetheless, the social sciences are pivotal fields for Australia's broader regional relationships, and they are especially important in developing a rich understanding of cultures, economies, and societies across the region.

Figure 5.1g – Pairwise co-authored papers in social sciences



Note: Derived from TR DATA. Counts papers involving co-authors from country pairs during 2010-12, where JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, and IN=India. "Social Sciences" encompasses "economics & business", and "general social sciences". Nations are ranked left to right by total outputs across all fields.

In this context, it is surely positive that Australia is one of the top two collaborators in this domain for every nation included in the analysis. Consistent with what has been observed in other areas, Australia's connection is strongest with China and New Zealand. Yet there is a fundamental difference here compared with what was observed, say, in the technology domain.

Whereas in the technology fields, the Chinese relationship was by far the most important for almost every nation in the region, in the social sciences Australia collaborates on a similar scale as China with Japan, South Korea, and Singapore, and also maintains much stronger level of connectivity with India and Malaysia than China does.

This implies that Australian social scientists do play an important role relative to their colleagues across the region, in engaging with intellectual communities in other nations. The low absolute scale of engagement however, especially when compared with Australia's level of engagement with China, also suggests that there is room to expand this level of engagement.

With a concerted engagement strategy Australia arguably has the potential to dominate the region's intellectual networks in this domain.

Having assessed the regional collaboration patterns across six broad knowledge domains, we can now summarise Australia's collaborative strengths and make some observations about the implications for the six key diplomatic objectives we outlined at the outset of this report.

To this end, table 5.1h links diplomatic objectives with their most relevant knowledge domains. Then, within each domain, it lists the countries for which Australia ranks among their most important collaborators.

Table 5.1h – Research collaboration in different knowledge domains

Diplomatic objective	Most relevant knowledge domains	Countries for which Australia is their top / 2nd top regional collaborator
i. To improve general relations between nations	All domains	NZ, MA / CN, SP
ii. To resolve issues of international disagreement	Natural Resources Physical Sciences Social Sciences	NZ / CN, IN, SP, MA NZ / CN, SP CN, NZ, MA, IN / SP, JP, SK, TW
iii. To coordinate a response in a moment of crisis	Natural Resources Physical Sciences Medical Sciences	NZ / CN, IN, SP, MA NZ / CN, SP NZ, SP, IN, MA / CN
iv. To gather information on other societies	Physical Sciences Technology Social Sciences	NZ / CN, SP CN, MA, NZ / SP CN, NZ, SP, JP, MA, SK, TW, IN
v. To forge strategic advantage	Physical Sciences Technology Molecular Biology	NZ / CN, SP CN, MA, NZ / SP NZ, MA / CN, SP, IN
vi. To provide humanitarian and development aid	Natural Resources Technology Medical Sciences Social Sciences	NZ / CN, IN, SP, MA CN, MA, NZ / SP NZ, SP, IN, MA / CN CN, NZ, MA, IN / SP, JP, SK, TW

Note: Based upon data presented in figures 5.1a to 5.1g, which count papers involving co-authors from country pairs during 2010-12. In the right-hand column, JP=Japan, CN=China, AU=Australia, NZ=New Zealand, SK=South Korea, TW=Taiwan, SP=Singapore, MA=Malaysia, and IN=India.

This table highlights the particular importance of Australia's research links to China, New Zealand, Singapore, and Malaysia. However, it also accentuates the weakness (at least relative to other countries in the region) of Australian research ties with Japan, South Korea, India, and Taiwan.

In the case of Japan, Australia does have substantial links across a number of knowledge domains, but the relationship nonetheless often looks weak relative to the connection that exists between Japan and China, Japan and South Korea, and sometimes also between Japan and Taiwan.

Overshadowing everything else, in any event, is the fact that Chinese collaboration networks increasingly dominate the region, providing incentive for all other nations to increase their own regional engagement in research.

For Australia, this could mean expanding existing collaboration networks across a broader range of countries in domains where Australians are already well positioned, such as in natural resources, medical sciences, molecular biology, and social sciences.

But it could also mean deliberately focusing attention on building links with Japan, South Korea, India, and Taiwan, which may require a particular emphasis on physical sciences fields.

Whatever approach is taken, action along these lines would be timely. A nation's capacity to exploit research networks for diplomatic ends will always be limited if it is excessively one-sided in its patterns international engagement.

Key Point 7

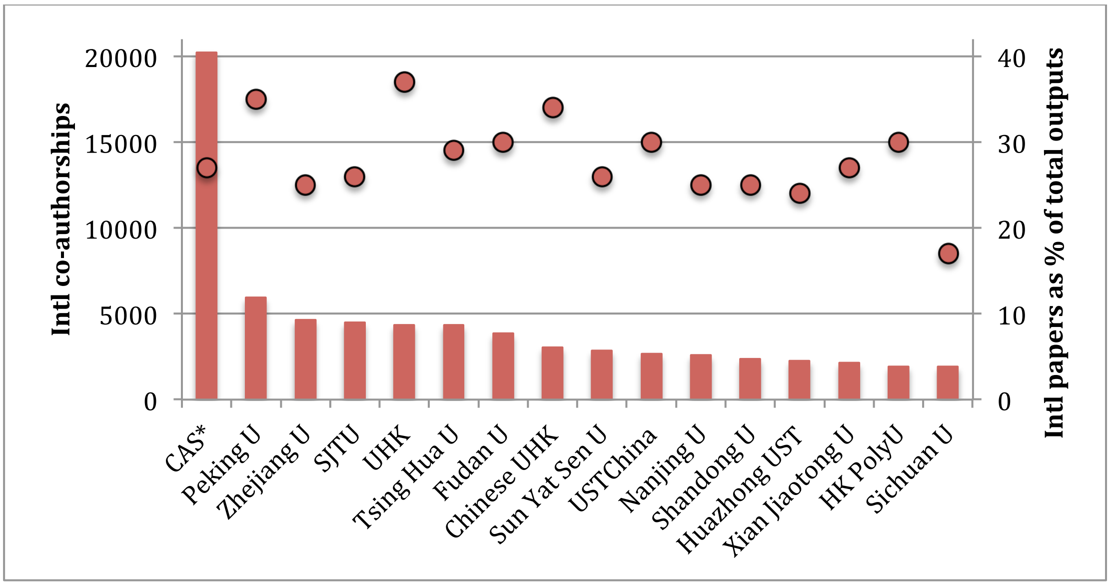
Responding to China's dominance of regional intellectual networks and expanding Australia's research engagement with a broader set of Asian partners may require an increase in Australian collaborative activity in the physical sciences – particularly with countries such as South Korea, Taiwan, and Singapore. But it would be a mistake if such a strategy could be implemented only at the expense of Australia's strong traditional connectivity in natural resources, medical, and social sciences fields.

5.2 CO-AUTHORSHIP NETWORKS BY INSTITUTION

There are several factors that are likely to influence one country's volume of bilateral outputs with another: each country's total publications in a field; perceptions of research quality and complementarity on both sides of the relationship; the ease of communication, which includes ease of travel and ability to overcome linguistic, cultural, or political barriers; and, of course, the availability of resources in order to work on common projects.

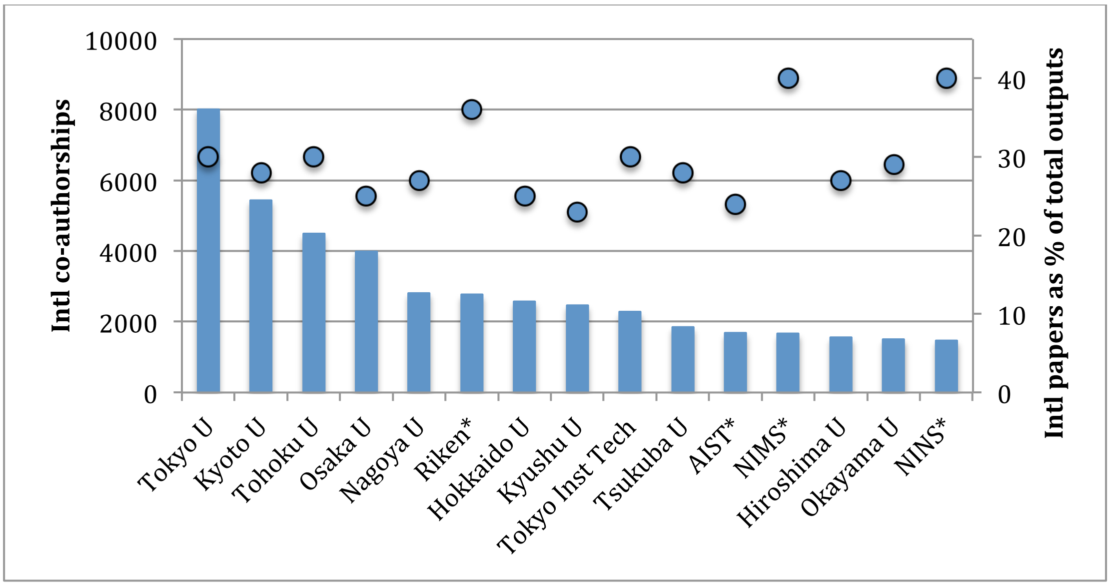
There is another factor, however, which may be important and this relates to the nature and culture of different organisations involved in research. Figures 5.2a to 5.2f show the leading institutions in China, Japan, South Korea, India, Australia, and Taiwan by volume of publications involving an international co-author.

Figure 5.2a – Top Chinese organisations by international co-authorships



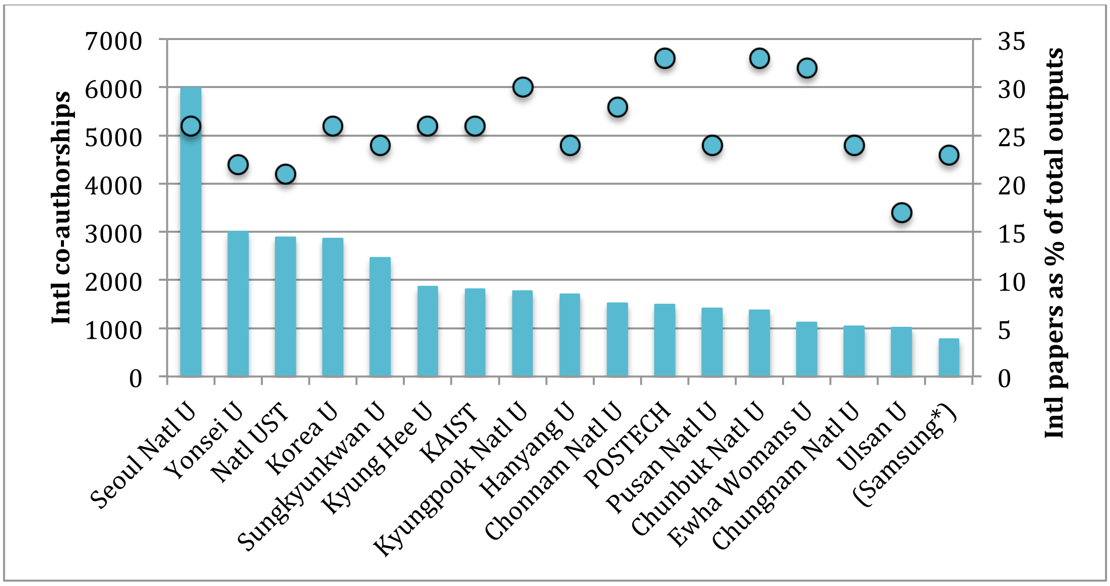
Note: Derived from TR DATA. Histogram plots publications 2010-12 with an international co-author (left axis), while dot points show these internationally co-authored outputs as a proportion of each institution's total outputs (right axis). Organisations marked with an * are not universities.

Figure 5.2b – Top Japanese organisations by international co-authorships



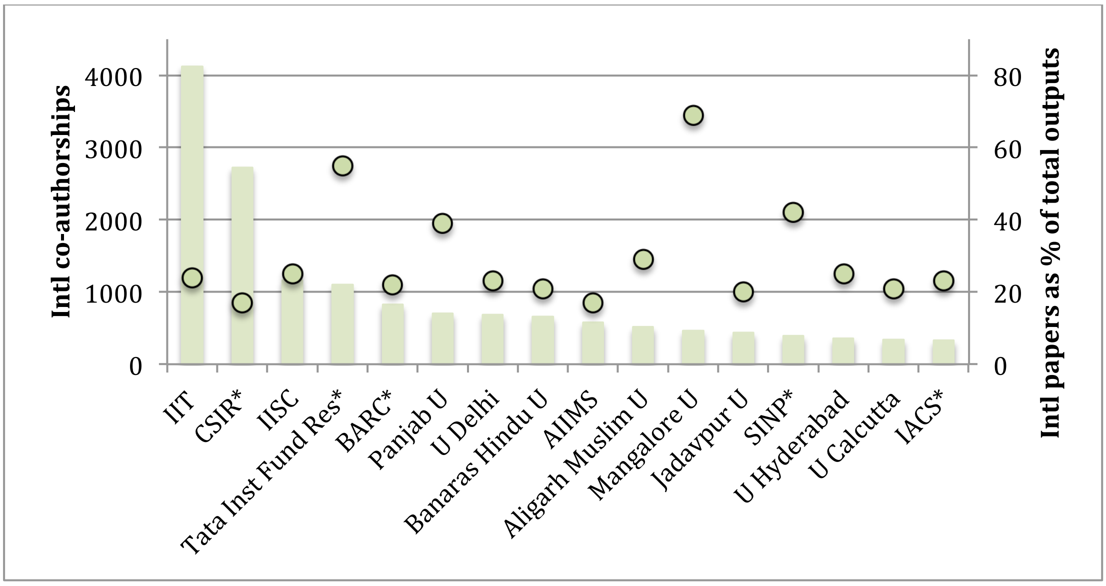
Note: Derived from TR DATA. Histogram plots publications 2010-12 with an international co-author (left axis), while dot points show these internationally co-authored outputs as a proportion of each institution's total outputs (right axis). Organisations marked with an * are not universities. AIST=Natl Institute of Advanced Industrial Science & Technology; NIMS=National Institute for Materials Science; and NINS=National Institutes of Natural Sciences.

Figure 5.2c – Top Korean organisations by international co-authorships



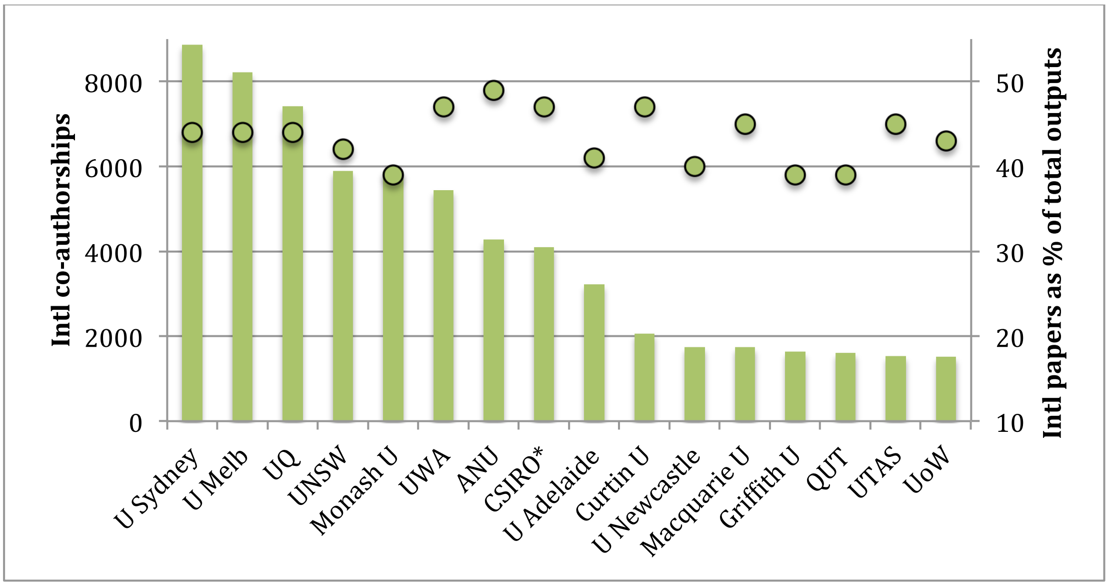
Note: Derived from TR DATA. Histogram plots publications 2010-12 with an international co-author (left axis), while dot points show these internationally co-authored outputs as a proportion of each institution's total outputs (right axis). Organisations marked with an * are not universities. Note that Samsung is actually the 20th most prolific source of internationally co-authored papers in South Korea.

Figure 5.2d – Top Indian organisations by international co-authorships



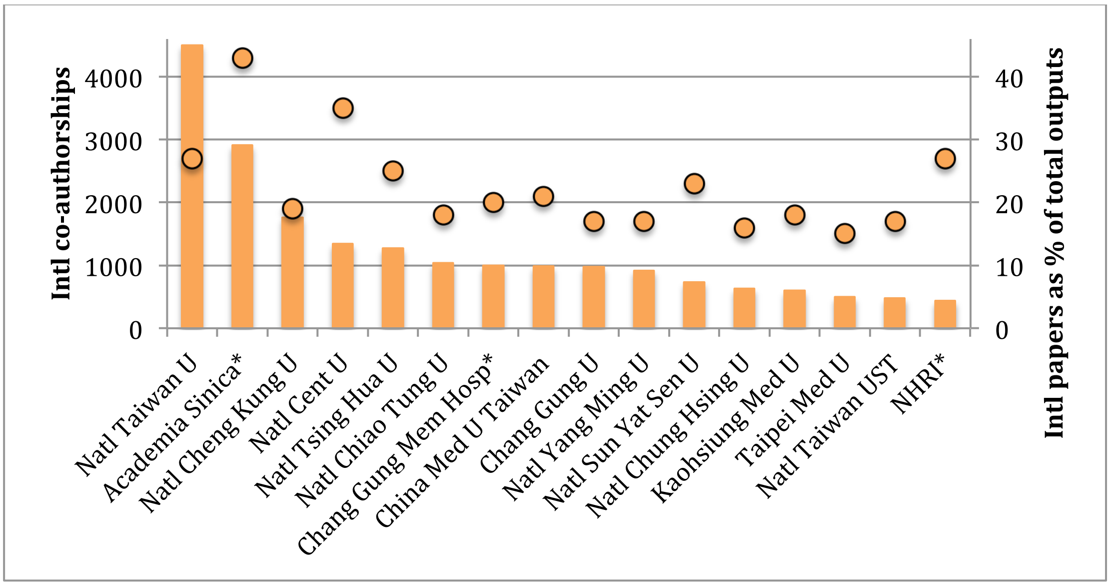
Note: Derived from TR DATA. Histogram plots publications 2010-12 with an international co-author (left axis), while dot points show these internationally co-authored outputs as a proportion of each institution's total outputs (right axis). Organisations marked with an * are not universities. IISC=Indian Institute of Science, Bangalore; BARC=Bhabha Atomic Research Centre; AIIMS=All India Institute of Medical Sciences; SINP=Saha Institute of Nuclear Physics; IACS=Indian Association for the Cultivation of Science.

Figure 5.2e – Top Australian organisations by international co-authorships



Note: Derived from TR DATA. Histogram plots publications 2010-12 with an international co-author (left axis), while dot points show these internationally co-authored outputs as a proportion of each institution's total outputs (right axis). Organisations marked with an * are not universities.

Figure 5.2f – Top Taiwanese organisations by international co-authorships



Note: Derived from TR DATA. Histogram plots publications 2010-12 with an international co-author (left axis), while dot points show these internationally co-authored outputs as a proportion of each institution's total outputs (right axis). Organisations marked with an * are not universities. NHRI=National Health Research Institutes.

There are several interesting observations to be made about these figures. First, it is evident that Australian institutions are consistently more internationally engaged than is true across the other nations shown.

In China, Japan, South Korea, and India most of the leading participants in international research have an international partner on 20-30% of outputs. In Taiwan, most have an international partner on fewer than 20% of outputs. In

Australia, by contrast, most leading institutions now have international collaborators on more than 40% of outputs.

The second point is that Australian institutions operate within a fairly narrow band in terms of the proportion of their papers with an international co-author. This means there is not much variation, compared with other countries across the region, in the extent to which leading Australian institutions are internationally engaged.

The corollary of this is that the scale of international collaboration in Australia will tend to be highly reflective simply of the scale at which Australian organisations perform research in general.

The third point to make is that in most countries across the region, universities apparently account for the vast majority of international engagements leading to publications. The notable exceptions to this rule are to be found with:

- the Chinese Academy of Sciences, which accounts for four times the number of internationally co-authored papers as the leading Chinese university (Peking University);

- Riken, the National Institute for Materials Science, and the National Institutes of Natural Sciences in Japan, all of which have higher rates of engagement with international co-authors than Japanese universities;

- Samsung, which with over 700 internationally co-authored papers between 2010 and 2012, was the only corporation in the region to publish more than 200 papers with an international partner – far exceeding Microsoft in China and Toyota, NTT and Panasonic in Japan by this measure;

- the Council of Scientific and Industrial Research, the Tata Institute of Fundamental Research, and the Bhabha Atomic Research Centre, which as government agencies were three of the top five institutions by internationally co-authored papers based in India; and

- the Academia Sinica, which is Taiwan's second most important source of internationally co-authored papers after the Taiwan National University.

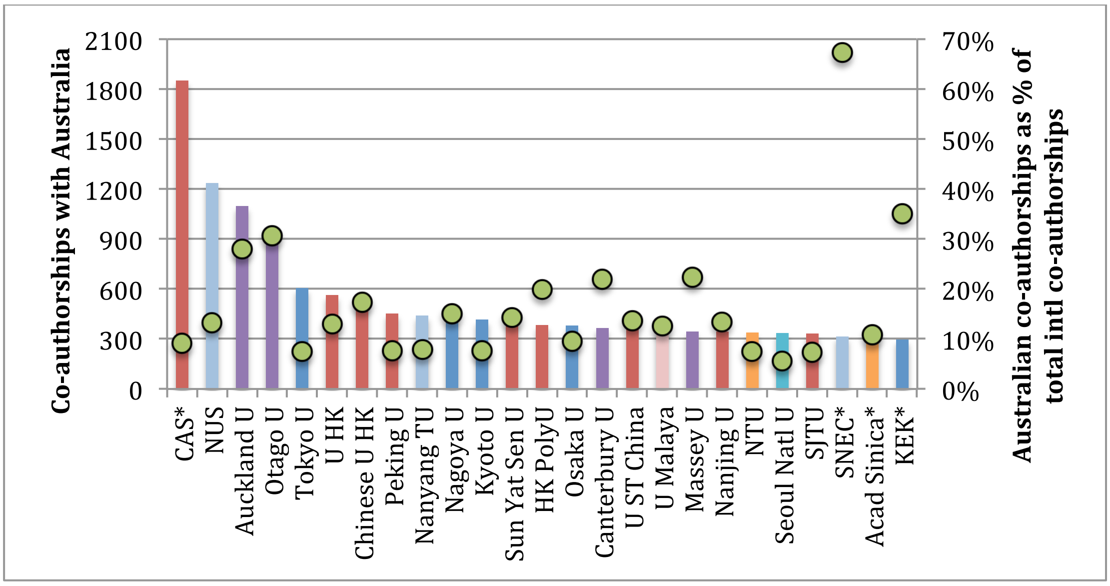
These exceptions are important. They show that in most instances (and consistent with what we saw above in section 3.2) government agencies play a more significant role in their country's total level of international research engagement than is true for Australia.

Nonetheless, the number of universities highly active in international research invariably outweighs the number of other such organisations. And this has significant implications for policymakers, not least of which is that policymakers seeking to engage in research diplomacy must find ways to utilise the capabilities that exist in universities, both nationally and regionally.

But this is not all. The preceding figures are interesting for yet another reason. Having identified the most internationally engaged institutions in each of these countries, it is now possible to ask how many are seriously connected with Australia and how many are not.

Figure 5.2g shows the top organisations across the region, ranked by volume of papers co-authored with Australian collaborators between 2010 and 2012. In this figure institutions are colour-coded by nation, and we also present each organisation's Australian co-authorships as a percentage of its total international co-authorships.

Figure 5.2g – Top regional organisations by Australian co-authorships



Note: Derived from TR DATA. Histogram plots publications 2010-12 with an Australian co-author (left axis), while dot points show these Australian co-authored outputs as a proportion of each institution's total internationally co-authored outputs (right axis). Organisations marked with an * are not universities. CAS=Chinese Academy of Sciences, SNEC=Singapore National Eye Centre, Acad Sinica=Academia Sinica, and KEK=Kasokuki Kenkyu Kiko.

This figure reveals, unsurprisingly, that many of the region's most internationally connected institutions are also Australia's leading partner institutions. It shows the overwhelming significance of the Chinese Academy of Sciences among the regional institutions with which Australian researchers collaborate.

It also highlights that Australia often accounts for fewer than 10% of these institutions' internationally co-authored outputs – the main exceptions in this regard being organisations based in New Zealand, Hong Kong, and Singapore.

What deserves our greatest attention, though, is not the list of institutions featured in this diagram but those that are absent from it. To this end, table 5.2h lists a subset of key institutions from around the region with relatively high levels of overall international engagement (as measured by volume of internationally co-authored articles) yet with relatively low levels of engagement specifically with Australian collaborators.

Table 5.2h – Research organisations with weak connections to Australia

	Organisation	Papers published (2010-12) with an international collaborator	Papers published (2010-12) with an Australian collaborator	Australian co-authored papers as % of org's total internationally co-authored papers
CHINA	Fudan Univ	3,842	209	5.4
	Huazhong Univ S&T	2,261	112	5.0
	Xian Jiaotong Univ	2,123	99	4.7
	Jilin Univ	1,885	102	5.4
	Beijing Normal Univ	1,592	79	5.0
	Wuhan Univ	1,549	84	5.4
JAPAN	Tohoku Univ	4,485	233	5.2
	Riken	2,761	131	4.7
	AIST	1,679	79	4.7
	Keio Univ	1,346	44	3.3
	Japan Atom Energy Agcy	850	17	2.0
	Tokyo Med & Dent Univ	768	39	5.1
SOUTH KOREA	Natl Univ Sci & Technol	2,882	138	4.8
	Kyung Hee Univ	1,856	47	2.5
	KAIST	1,811	35	1.9
	POSTECH	1,483	37	2.5
	Pusan Natl Univ	1,402	50	3.6
	Chonbuk Natl Univ	1,370	26	1.9
INDIA	IIT	4,123	218	5.3
	CSIR India	2,721	132	4.9
	IISC Bangalore	1,164	40	3.4
	Banaras Hindu Univ	656	29	4.4
	Aligarh Muslim Univ	512	6	1.2
	Jadavpur Univ	435	15	3.4
TAIWAN	Natl Tsing Hua Univ	1,271	52	4.1
	Natl Chiao Tung Univ	1,034	41	4.0
	China Med Univ Taiwan	982	31	3.2
	Chang Gung Univ	979	54	5.5
	Natl Yang Ming Univ	919	43	4.7
	Natl Sun Yat Sen Univ	735	31	4.2

Note: Derived from TR DATA. Lists for each region the top 6 organisations ranked by total internationally co-authored outputs where Australians are co-authors on fewer than 5.6% of such outputs (equivalent to Australia's share of Seoul National University's internationally co-authored outputs). Note that every Singaporean, Malaysian, and New Zealand organisation that published at least 100 internationally co-authored papers over the period had Australian collaborators on more than 5.6% of such outputs.

In this table, Seoul National University is used to establish a benchmark for engagement with Australian research. Over the years of our analysis, Australia accounted for just 5.6% of Seoul National University's internationally co-authored outputs, which was the lowest of proportion of any institution among Australia's top 25 research partners as listed in figure 5.2g.

Of the organisations listed in table 5.2h, i.e. of those that are highly connected internationally but which have not developed comparatively strong research relationships with Australia, some noteworthy features would be:

- the low engagement with Australian research by three key Japanese government agencies (Riken, AIST, and the Japan Atomic Energy Research Agency);
- the extremely low levels of engagement with Australian research among a number of South Korean universities (Kyung Hee University, KAIST, POSTECH, and Chonbuk National University); and
- the low levels of engagement with Australian research among leading Indian institutions (IIT, CSIR India, and IISC Bangalore), which also provides an explanation for the surprising absence of Indian institutions in figure 5.2g.

The data here on Indian and South Korean institutions is especially significant, given Australia's weakness in connecting with the research systems of these countries.

If Australian policymakers were to aspire for Australia to maintain a high level of access to and influence within regional knowledge networks, targeting some of these organisations – or understanding why Australians are not connecting with them – may prove valuable.

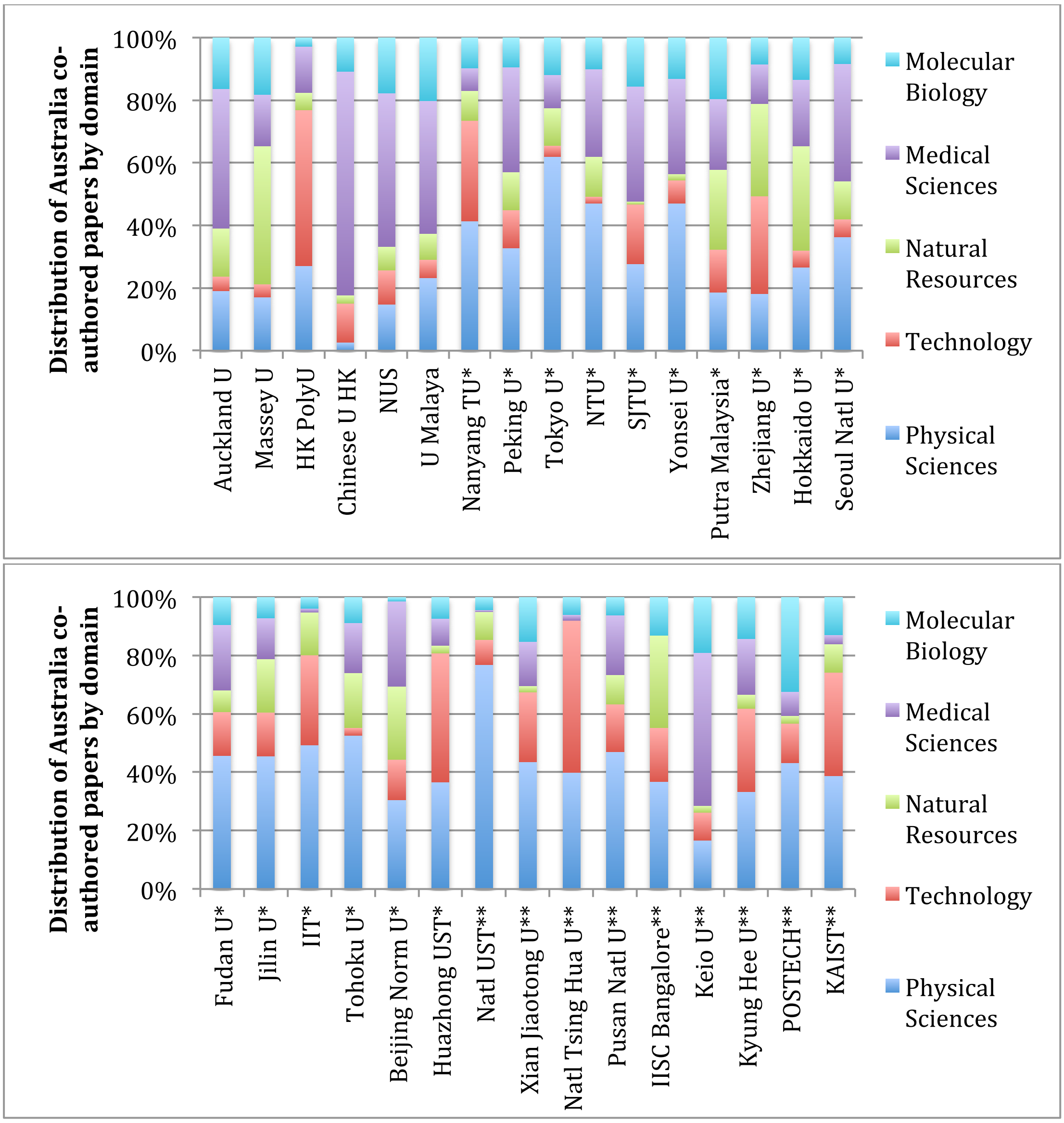
To this end, it is interesting to compare the domains in which Australian researchers are collaborating with colleagues across these institutions. Figures 5.2i and 5.2j do this by showing the distribution of selected institutions' joint outputs with Australia across five broad knowledge domains.

In these figures, institutions are also ranked by the proportion of their internationally co-authored papers with an Australian collaborator, enabling a comparison of field bias among organisations with quite different levels of engagement with Australian partners.

It is evident from these figures that institutions with very similar rates of connectivity to Australian research can have a very different domain focus in their Australian collaborations. For example, compare Hong Kong Polytechnic University and the Chinese University of Hong Kong in figure 5.2i.

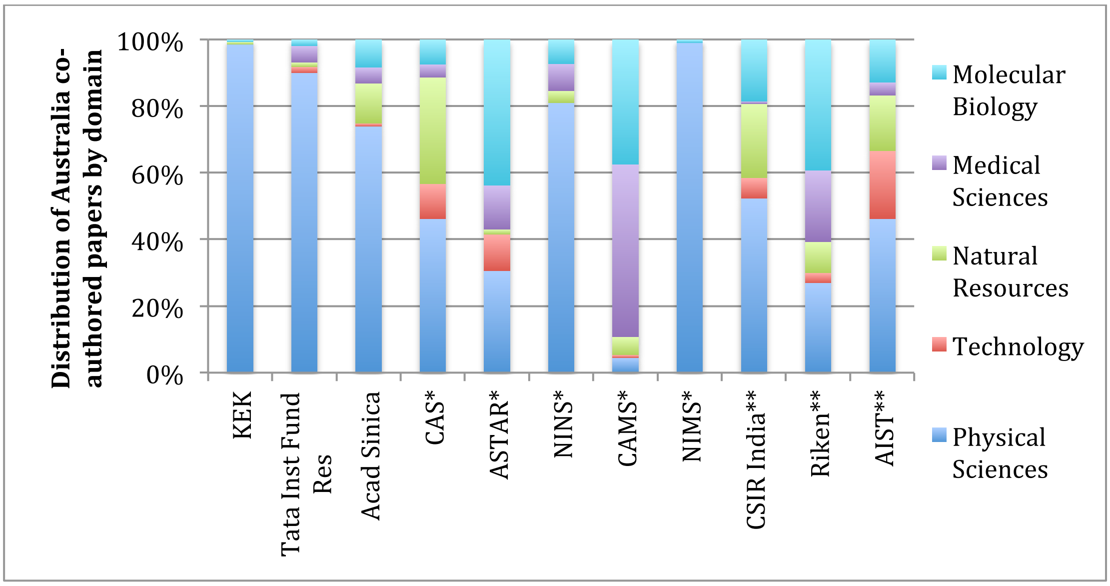
The inverse is also true. It turns out that different institutions, with quite different rates of connectivity to Australian research, can also have very similar distributions in the domain focus of their joint outputs with Australian collaborators. In this instance, compare the Chinese Academy of Sciences with India's Council for Scientific and Industrial Research in figure 5.2j.

Figure 5.2i – Australian co-authored papers by domain, selected universities, 2010-12



Note: Derived from TR DATA. Organisations are ranked (left to right) by proportion of internationally co-authored outputs involving an Australian collaborator. Those marked with * have Australian collaborators on fewer than 10% of internationally co-authored articles, while those marked with ** have Australian collaborators on fewer than 5% of such articles. NUS=National University of Singapore; NTU=National Taiwan University; SJTU=Shanghai Jiao Tong University; ITT=Indian Institutes of Technology; Natl UST=National University of Science and Technology, Korea; IISC Bangalore=Indian Institute of Science, Bangalore; and KAIST=Korea Advanced Institute of Science and Technology.

Figure 5.2j – Australian co-authored papers by domain, selected government agencies, 2010-12



Note: Derived from TR DATA. Organisations are ranked (left to right) by proportion of internationally co-authored outputs involving an Australian collaborator. Those marked with * have Australian collaborators on fewer than 10% of internationally co-authored articles, while those marked with ** have Australian collaborators on fewer than 5% of such articles. CAS=Chinese Academy of Sciences; ASTAR=Agency for Science, Technology and Research; NINS=National Istitutes of Natural Sciences; CAMS=Chinese Academy of Medical Sciences; NIMS=National Institute for Materials Science; CSIR India=Council fo Scientific and Industrial Research, India; AIST=National Institute for Advanced Industrial Science and Technology.

The significance in these points is that, at the institutional level at least, factors besides field mix are clearly critical in determining rates of collaboration. Nonetheless, in broad terms, field mix does seem to have an underlying impact.

Consider the universities' data in figure 5.2i. It can be seen here that universities with high rates of connectivity to Australia (such as Auckland University, Chinese University of Hong Kong, and the University of Malaya) tend to have a high proportion of collaborations in the medical sciences.

This is not to say that there aren't exceptions, since there are also universities in this category with collaborations focused around natural resources (Massey University) and technology (Hong Kong Polytechnic University). But universities in this group are certainly more likely to have a high proportion of their Australian collaborations in the medical sciences than is true of institutions in the other categories.

It can be seen, likewise, that universities with intermediate rates of connectivity to Australia (such as Peking University, Putra Malaysia University, and Hokkaido University) tend to collaborate with Australia across a somewhat more diverse spread of domains.

Of course there are universities in this category, too, with a high proportion of their Australian co-authored outputs focused in a narrow set of fields, such as in the physical sciences and technology (like Nanyang Technological University) or in the physical sciences (like Tokyo University). However there does seem, on the whole, to be some increased diversity in the range of domains by which universities in this set connect with Australia.

By contrast, universities with low rates of connectivity to Australia (such as Korea's National University of Science and Technology and KAIST) mostly have their Australian collaborations heavily focused in the physical sciences and technology.

Again there are exceptions, where the emphasis is on medical sciences (Keio University), or where there is at least a sizeable degree of collaboration also in natural resources (Indian Institute of Science, Bangalore) or in molecular biology (POSTECH).

Yet overall, the pattern seems broadly consistent with a view that universities with Australian collaborations strongly focused in the medical sciences are more likely to be strongly connected with Australia than those that have their Australian collaborations more heavily focused in the physical sciences.

On the other hand, among government agencies shown in figure 5.2j a slightly different picture emerges. In this instance, the sample is smaller and government agencies of course are often quite different from universities – for one thing, they are usually far more specialised.

What this figure indicates, though, is that there are institutions in Asia that have a strong focus on the physical sciences in their Australian collaborations, yet which also have Australian collaborators on a very high proportion of their internationally co-authored papers. (See KEK, the Tata Institute of Fundamental Research, and Academia Sinica.)

Understanding what is going on in these organisations may provide some insights into what would drive a deeper connection between Australian institutions and Asian universities with a particular focus on the physical sciences.

Looking across both figures it is also interesting to observe something about the molecular sciences. In general, outputs in this branch of knowledge do not feature strongly among these institutions' Australian collaborations, and where they do it is usually for institutions that are only loosely affiliated with Australian research.

Of the few organisations that have roughly a third or more of their joint outputs with Australians in the molecular biology domain, two have very low rates of connectivity to Australian research (Riken and POSTECH), while the other two have only intermediate rates of connectivity to Australian research (the Chinese Academy of Medical Sciences and Singapore's Agency of Science, Technology and Research).

This could imply that East Asian organisations strongly oriented towards molecular biology do not currently see it as an area for intensive engagement with Australia. Perhaps Asian researchers in this space are currently more focused upon linking to American or European partners, who have long dominated global discovery within this domain.

In any event, it does look as though the appetite for connecting with Australia in research at the institutional level is currently strongest in the physical sciences and in the medical sciences – in all likelihood because Australia's neighbours have prioritised research in the one domain, while Australia has prioritised investment in the other.

To a certain extent, however, all of this is peripheral. The most important evidence we have highlighted here shows that Australian universities are already highly internationally orientated, which means that expanding Australia's regional research networks may depend as much upon expanding the size of Australia's research system as it does upon developing policies to promote specific forms or domains of research engagement.

It is also apparent that researchers based in universities rather than government agencies are increasingly dominating regional public-sector research networks, a fact that should be seen as very important should Australian policymakers wish to exploit these networks in Australia's diplomatic interests.

Key Point 8

Universities now mediate much of the research connectivity between Western Pacific nations. While Australia's ties with Japan and India particularly are constrained by a lack of collaboration with key government agencies such as Riken and CSIR India (a deficiency that warrants response), the ongoing promotion of Australian diplomatic interests through university research networks is likely to have a bigger impact in the long run.

5.3 THE ROLE OF GOVERNMENT AGENCIES

Although universities and large, generalist government agencies like CSIRO are now the most prominent organisations involved in regional research networks, small and specialised government agencies also remain important in fostering international relationships in research.

This is especially true in research relating to politically contentious themes such as national defence, environmental resource management, climate monitoring, public health, and nuclear science.

Analysis of the collaboration patterns of specialised government agencies are usually not indicative of whole-of-nation interactions since research to address a particular topic may be conducted across multiple agencies. In Australia, for example, there is climate research not only in the Bureau of Meteorology, but also in CSIRO and in a number of universities.

For this reason, an assessment of the collaboration patterns of researchers solely within the Bureau of Meteorology cannot provide much indication about the foreign interactions of Australian climate scientists in their totality.

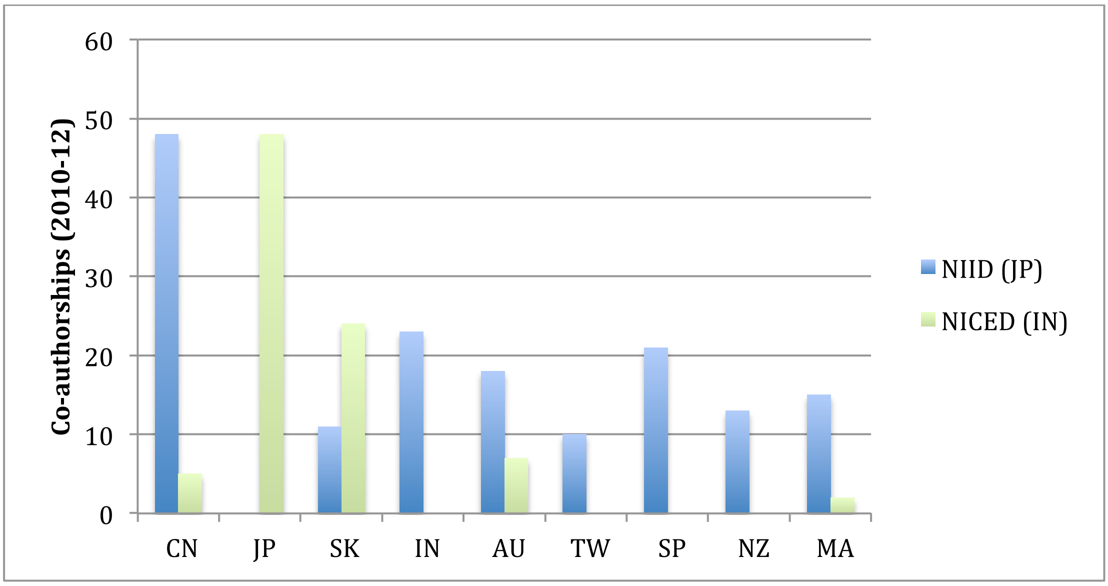
But, such an analysis can show something about the Bureau of Meteorology's own openness to the outside world and its likely patterns of influence in foreign circles. This form of analysis can also shed light on the extent to which specialised government agencies elsewhere in the region are connected with counterparts in Australia.

It is in this spirit, that figure 5.3a presents data on the regional collaboration patterns of two key agencies involved in surveillance, control and research relating to infectious diseases.

It can be seen from this figure that that National Institute for Cholera Enteric Disease in India has much stronger collaborations with Japan and South Korea than it does with Australia. Likewise, it can be observed that the National Institute for Infectious Disease in Japan has much stronger connections with China than with Australia, and stronger connections with India and even Singapore than it does with Australia.

This begs the question as to whether Australia is maximising its regional influence among the disease control community in these two countries.

Figure 5.3a – A comparison of disease control agencies



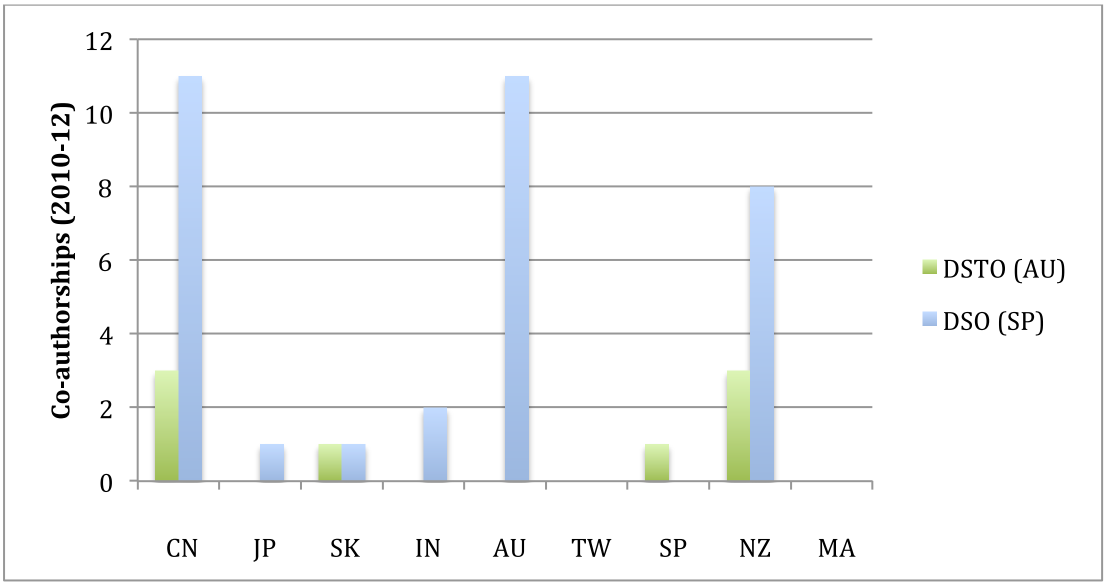
Note: Derived from TR DATA. Shows two specialist agencies' co-authored research papers with partners in countries across the region. NIID = National Institute for Infectious Disease; and NICED = National Institute for Cholera Enteric Disease.

Likewise, figure 5.3b contrasts the regional collaboration leading to scientific publication for the Defence Science and Technology Organisation (DSTO) in Australia and the Defence Science Organisation (DSO) in Singapore.

One must be cautious in interpreting this diagram, since the imperative to publish research in the scientific literature is typically fairly low for defence research agencies. It is noteworthy, however, that the DSO in Singapore appears to be collaborating with more countries in Asia – or, at least, is generating more joint papers than DSTO in Australia.

Significantly, too, the DSO in Singapore appears to be collaborating at a similar scale with researchers both in China and Australia – and could, in fact, be acting as a conduit for the flow of knowledge between these two nations. All of this raises the question as to whether these patterns of collaboration are merely a consequence of happenstance or whether they reflect a level of regional engagement that serves Australia's strategic interests.

Figure 5.3b – A comparison of defence agencies



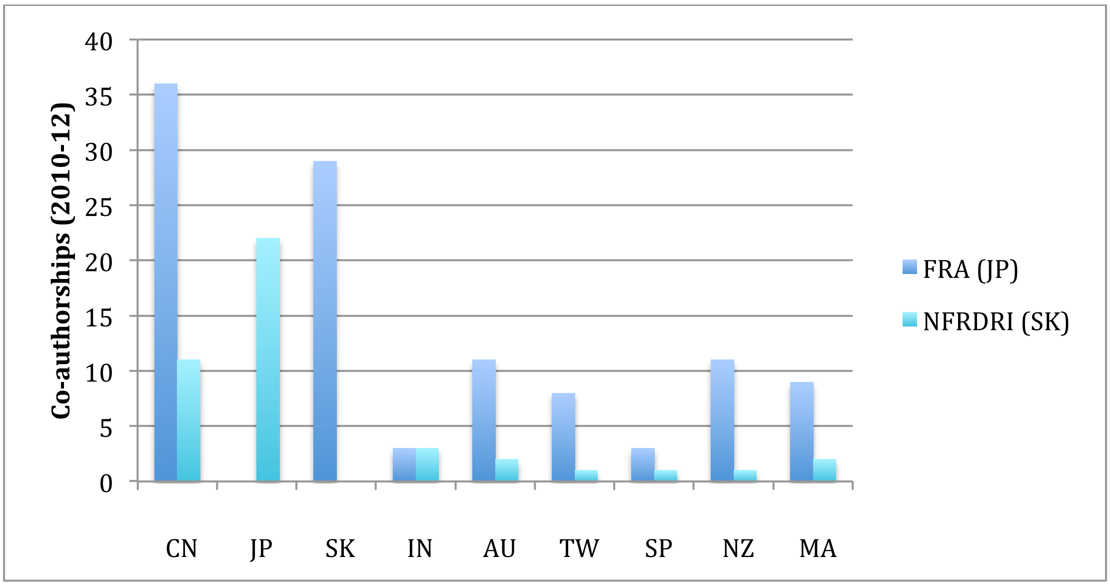
Note: Derived from TR DATA. Shows two specialist agencies' co-authored research papers with partners in countries across the region. DSTO=Defence Science & Technology Organisation; and DSO=Defence Science Organisation.

In similar vein, figure 5.3c suggests that the Fisheries Research Agency in Japan has three times the collaborative outputs with South Korea as it does with Australia, while the National Fisheries Research and Development Institute in South Korea has more collaborative outputs with India and ten times the collaborative outputs with Japan as it does with Australia.

At the same time, figure 5.3d suggests that the Forestry and Forest Products Research Institute in Japan has twice as many collaborative outputs with South Korea and five times as many with Malaysia as it does with Australia.

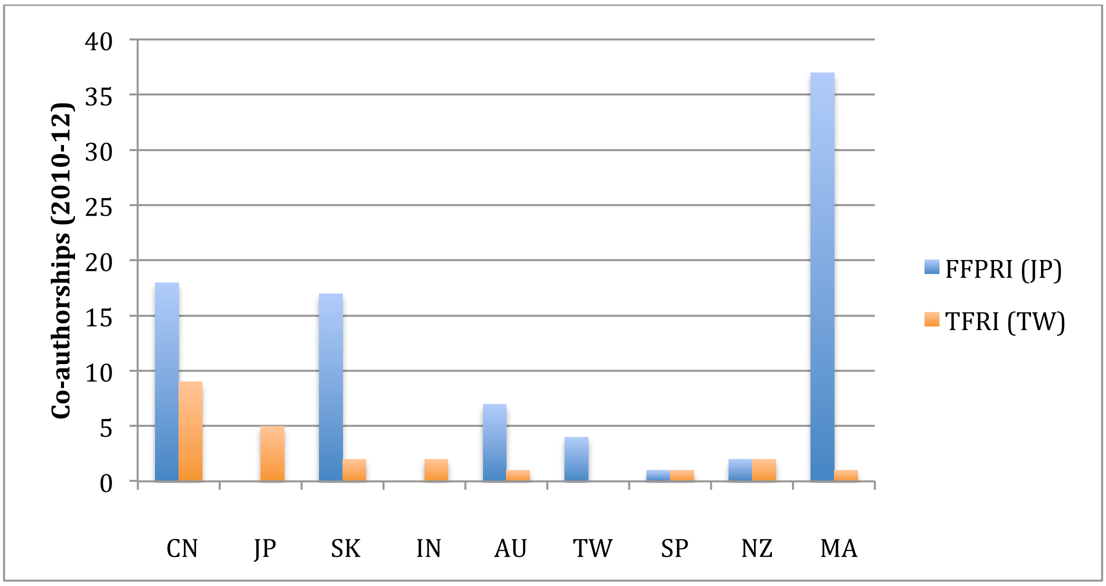
Given that fishing and forestry periodically throw up contentious issues, which sometimes cause tensions in Australia's international relations, and that Japan is often a key player in both respects, it seems logical to suggest that there might be benefits in fostering closer ties between Australian researchers and these particular agencies.

Figure 5.3c – A comparison of fisheries research agencies



Note: Derived from TR DATA. Shows two specialist agencies' co-authored research papers with partners in countries across the region. FRA=Fisheries Research Agency; and NFRDRI=National Fisheries Research and Development Institute.

Figure 5.3d – A comparison of forestry agencies



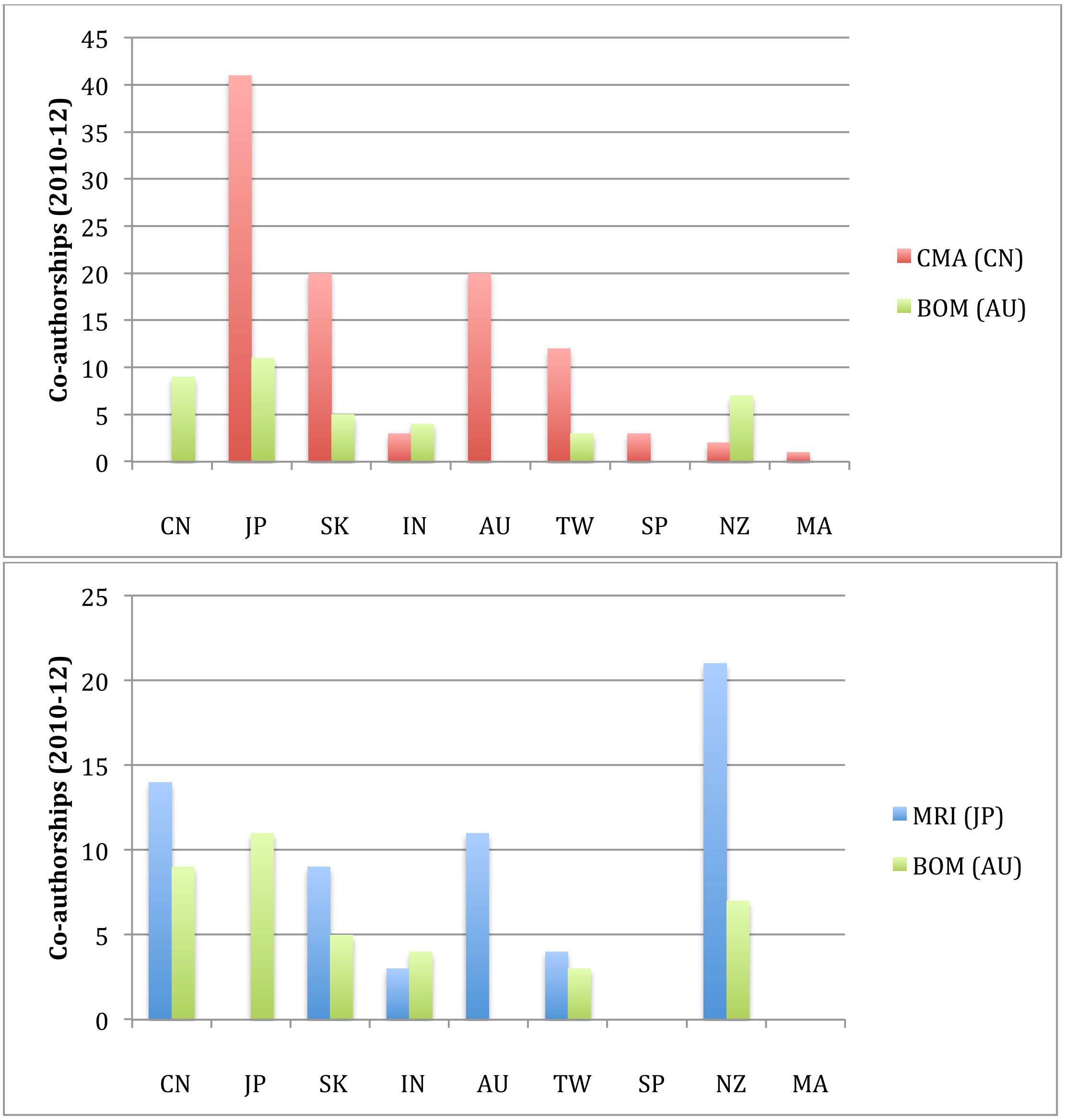
Note: Derived from TR DATA. Shows two specialist agencies' co-authored research papers with partners in countries across the region. FFPRI=Forestry & Forest Products Research Institute; and TFRI=Taiwan Forestry Research Institute.

Then there is the situation with meteorological agencies. Based upon co-publication volumes, figure 5.3e implies that the China Meteorological Administration is three times more likely to turn to a Japanese partner than the Meteorological Research Institute (MRI) in Japan is to turn to a Chinese partner.

At the same time, the MRI researchers are publishing more with New Zealand collaborators than they are with the Chinese, and twice as much with New Zealanders as they are with Australians. This suggests a possibility that the New Zealanders may have a special degree of influence with Japanese colleagues that Australians lack.

Furthermore, given the significance of climate research in international affairs, and the frequency with which the public discourse demands affirmations of international consensus on climate science, the absolute number of co-authored papers involving all three agencies seems remarkably low.

Figure 5.3e – A comparison of meteorological agencies



Note: Derived from TR DATA. Shows two specialist agencies' co-authored research papers with partners in countries across the region. CMA=China Meteorological Administration; BOM=Bureau of Meteorology; and MRI=Meteorological Research Institute.

To give some perspective on this, the Australian Bureau of Meteorology published a total of 289 papers between 2010 and 2012, of which 102 (or 35%) involved an international co-author, and of which only 9 involved a Chinese co-author and only 4 involved an Indian co-author.

One might question here the low level of overall international engagement relative to other Australian research organisations. But the really significant point for Australian diplomacy is that China and India are both countries with which previous Australian Governments have sought unsuccessfully to establish international agreements relating to climate change.

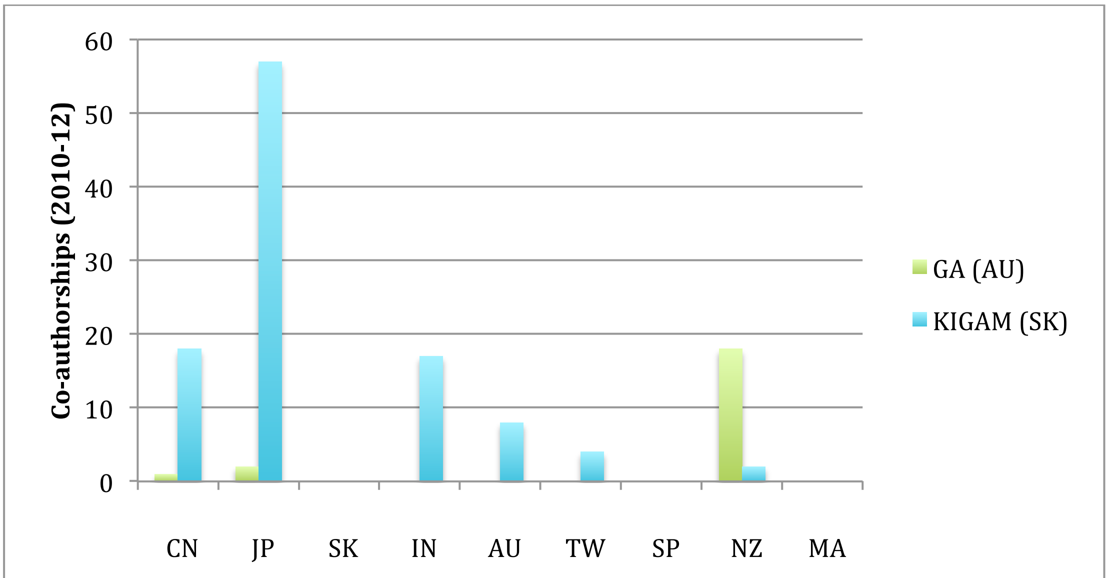
It is possible that a stronger connection between these research agencies might have been advantageous in seeking common positions for international policy.

Geoscience has a less obvious significance for foreign affairs than meteorology. Yet figure 5.3f affords another interesting comparison. It contrasts the regional collaboration patterns of Geoscience Australia with those of the Korea Institute of Geoscience and Mineral Resources (KIGAM).

Both bodies published a similar number of scientific outputs between 2010 and 2012, of which roughly the same proportion (around 40%) involved a foreign partner. Yet whereas researchers at Geosciences Australia remain heavily oriented towards the North American and European research systems, those at KIGAM have been co-publishing very extensively with partners in Japan.

This difference may not matter to Australia's foreign policy at the present, but if it is suggestive of the regional collaboration patterns that persist across a number of other specialist agencies, then Australian government research may not be properly serving Australia's long-term foreign policy interests.

Figure 5.3f – A comparison of geoscience agencies

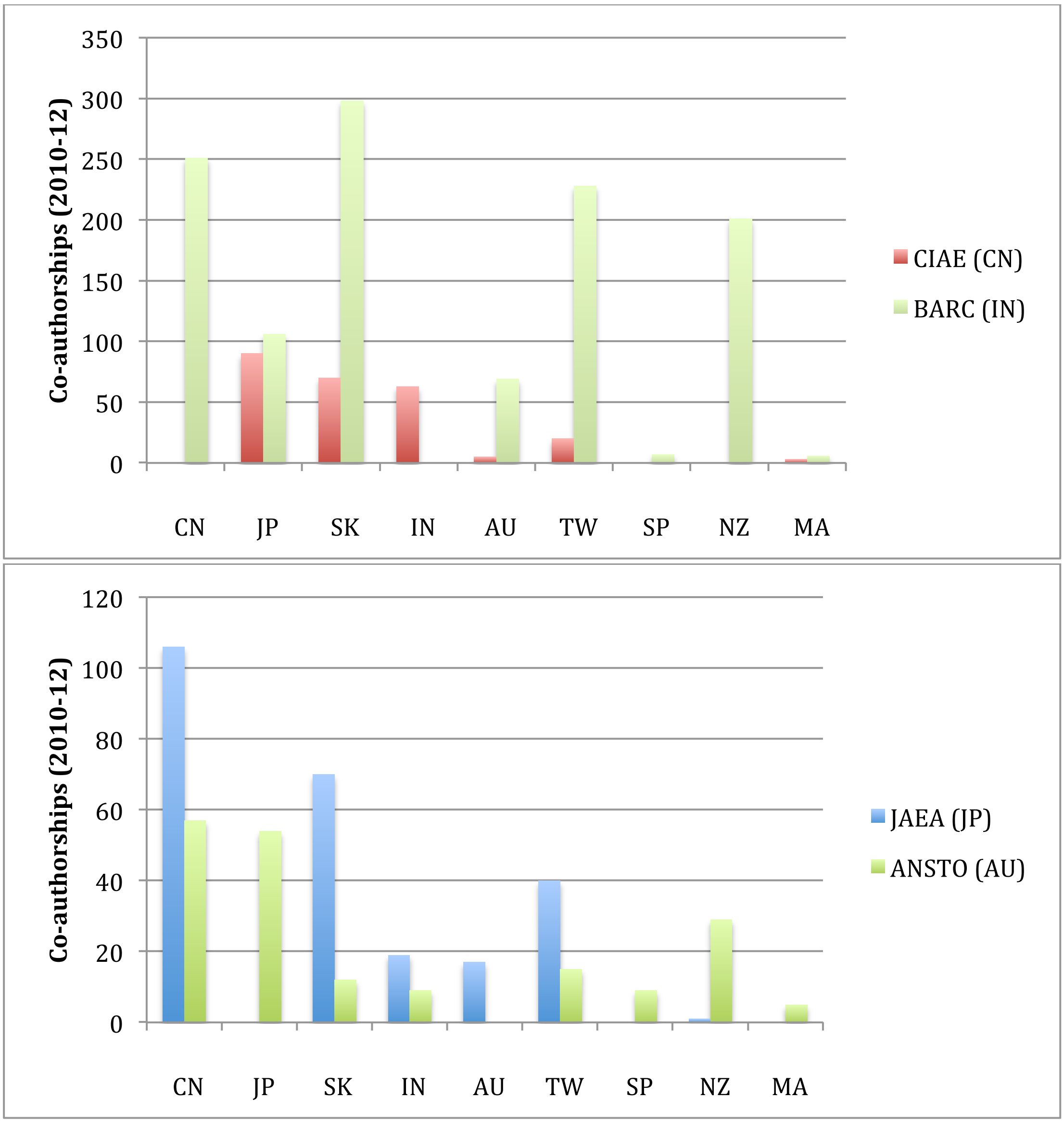


Note: Derived from TR DATA. Shows two specialist agencies' co-authored research papers with partners in countries across the region. GA=Geoscience Australia; and KIGAM=Korea Institute of Geoscience and Mineral Resources.

This brings us, finally, to figure 5.3g, which highlights the astonishing scale at which Indian, Chinese and South Korean nuclear research agencies are now publishing together – and the relative lack of engagement by such agencies with Australian collaborators.

In the absence of a local nuclear industry in Australia, ANSTO affords Australia with only a modest capability in nuclear science. At the same time, nuclear technology is proliferating across the region. In this context, strong research links with Asian nuclear science become very important, and expanding research connections with India may prove especially valuable.

Figure 5.3g – A comparison of nuclear agencies



Note: Derived from TR DATA. Shows two specialist agencies' co-authored research papers with partners in countries across the region. CIAE=China Institute of Atomic Energy; Bhabha Atomic Research Centre (BARC); JAEA=Japan Atomic Energy Agency; and ANSTO=Australian Nuclear Science and Technology Organisation.

All countries and all governments have their own priorities, and occasionally these become manifest in government research agencies. Such agencies will sometimes fulfil influential roles beyond that of simply advancing the frontiers of knowledge. These might include the provision of advice within government and the development of government policies.

All of this means that small, specialist research agencies can be particularly effective institutions to target for research diplomacy. Yet from this brief survey, it would seem that some foreign agencies in this category are not especially well connected with Australian research, and that several similar Australian agencies are not especially well integrated either into Asian research systems.

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Key Point 9

Specialised government agencies may play a role in shaping national and regional policies that is disproportionate with their scale and impact on the scientific literature. Unfortunately, Australia does not currently feature as a pivotal player in research networks involving such agencies. Making specialised Australian agencies more open to regional engagement and seeking to nurture Australian partnerships with equivalent agencies in Asian societies would strongly enhance Australia's capacity to engage in research diplomacy across the region.

6. COLLABORATION BY SUB-FIELD

In our analysis so far, we have shown that Australian research relationships in Asia are unlikely to be maximising Australian diplomatic objectives, and we have highlighted the differing extent of regional research collaboration by broad domains of knowledge.

From a study of 250 subject categories, we now identify those specific sub-fields in which Australian organisations are collaborating most strongly with partners based across the region. We organise these subjects by field. Within each field, we rank subjects by Australia's total volume of outputs. Then, for each subject, we compare the extent to which researchers in leading Asian nations are co-publishing with Australian collaborators.

In this way, we reveal that the dominance of Australia's collaborative relationship with China extents not just across all fields, but also across the majority of subfields. We also highlight several areas of relevance to Australian international relationships where the level of regional engagement looks low.

6.1 AGRICULTURAL & ENVIRONMENTAL SCIENCES

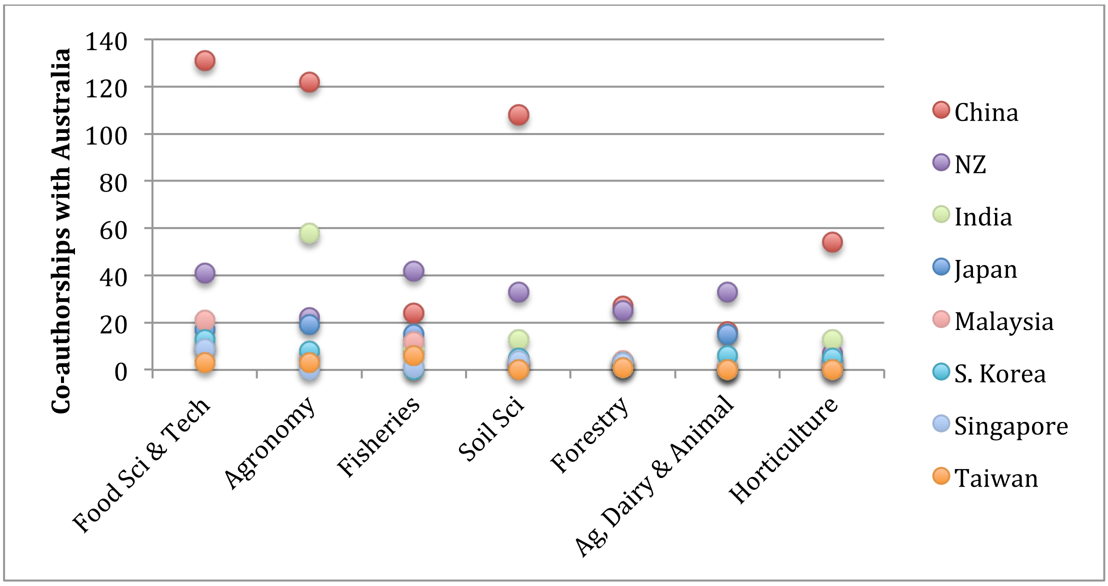
Figures 6.1a to 6.1d show Australia's regional collaboration in food science and agricultural sciences, in fundamental biology, in environmental science, and in geosciences. Australia's co-authorships in these fields appear strong for:

- China in environmental sciences (364), multidisciplinary geosciences (348), plant sciences (254), geochemistry & geophysics (195), water resources (160), food science & technology (131), agronomy (122), soil science (108), ecology (108), and horticulture (54);
- Japan in plant sciences (97), environmental sciences (94), multidisciplinary geosciences (84), ecology (70), meteorology & atmospheric sciences (61), oceanography (55), and geochemistry & geophysics (55);
- India in environmental sciences (72), multidisciplinary geosciences (65), agronomy (58), and plant sciences (52);
- Singapore in ecology (50);
- NZ in ecology (196), multidisciplinary geosciences (156), marine & freshwater biology (116), plant sciences (112), environmental sciences (107), zoology (85), evolutionary biology (72), oceanography (70), geochemistry & geophysics (65), physical geography (56), and biology (50); and

- Malaysia in environmental sciences (55).

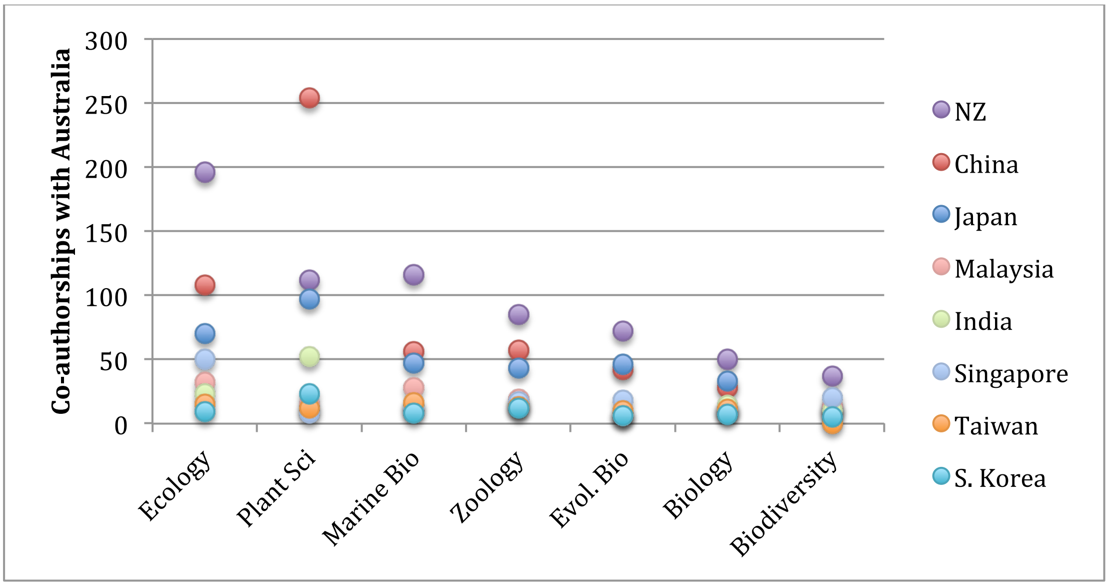
These listings are derived using a threshold of 100 co-authored articles per subject for China (except in the case of "horticulture" where China didn't make this threshold but was by far Australia's leading partner). A threshold of 50 co-authored articles per subject was employed for other nations.

Figure 6.1a – Australian collaborations in food and agricultural sciences



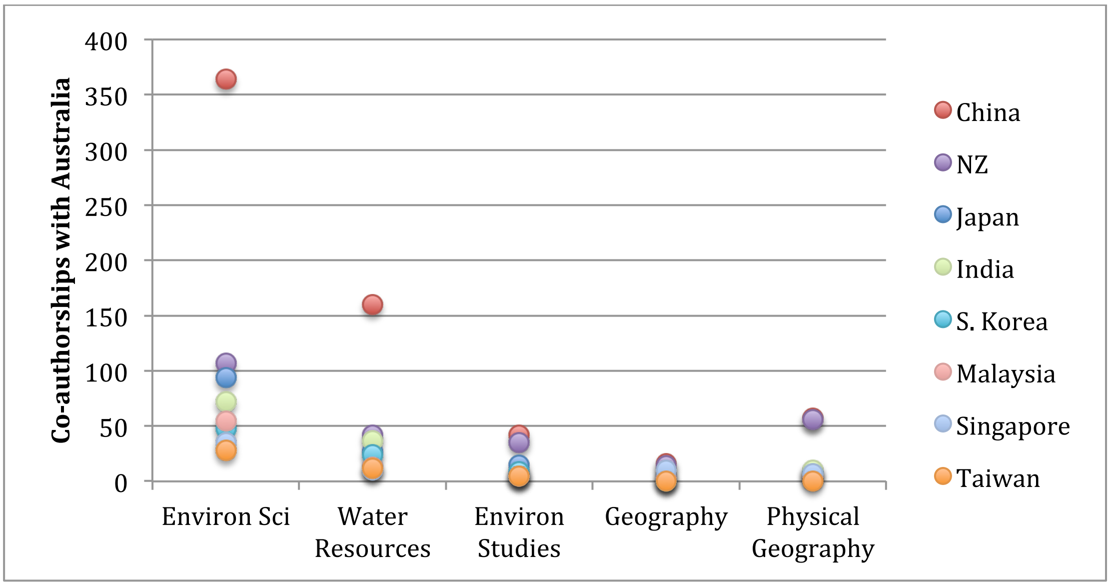
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined.

Figure 6.1b – Australian collaborations in biology



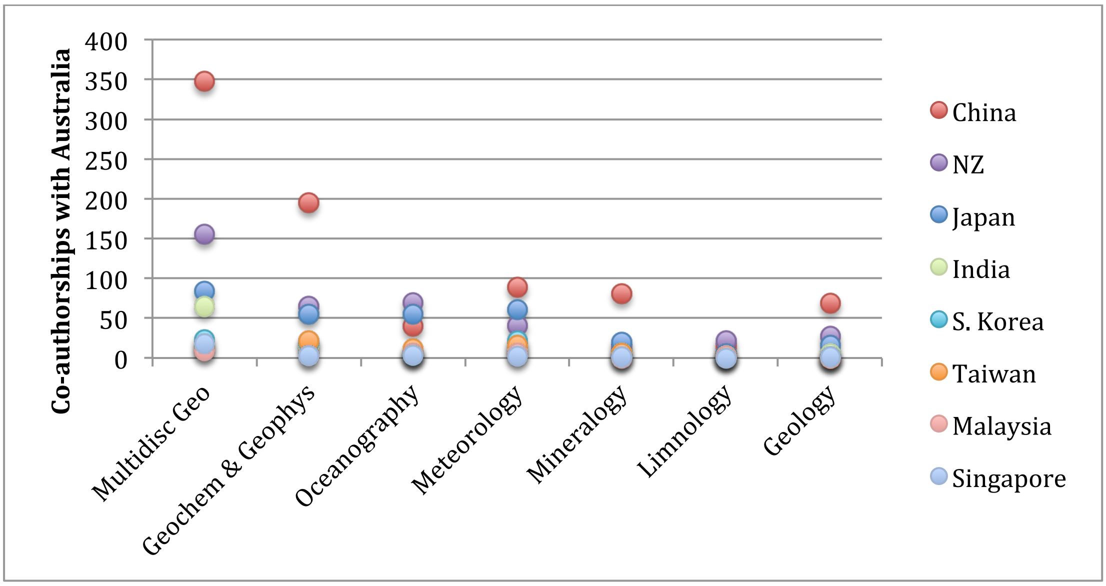
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined.

Figure 6.1c – Australian collaborations in environmental science



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined.

Figure 6.1d – Australian collaborations in geosciences



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined.

Interestingly, no Asian nation reaches the threshold of 50 joint papers with Australia in the subject categories of fisheries, forestry, agriculture, dairy & animal science, biodiversity conservation, environmental studies, geography, or limnology.

6.2 MOLECULAR LIFE SCIENCES & MEDICINE

Figures 7.2a to 7.2f show Australia's regional collaboration in molecular biology, in biomedicine, in selected clinical sciences, in allied clinical sciences, and in public health. Australia's co-authorships in these fields appear especially strong for:

- China in biochemistry & molecular biology (259), biotechnology & applied microbiology (188), oncology (188), pharmacology & pharmacy (170), genetics & heredity (169), neurosciences (148), clinical neurology (145), ophthalmology (133), endocrinology & metabolism (108), cell biology (104), and general & internal medicine (101);

- Japan in biochemistry & molecular biology (172), genetics & heredity (125), oncology (123), immunology (105), cell biology (94), neurosciences (93), pharmacology & pharmacy (83), clinical neurology (78), endocrinology & metabolism (66), hematology (63), and gastroenterology & hepatology (60);

- South Korea in oncology (106);

- India in ophthalmology (113), public, environmental & occupational health (62), biochemistry & molecular biology (60), infectious diseases (52), and general & internal medicine (50);

- Singapore in ophthalmology (206), biochemistry & molecular biology (84), genetics & heredity (87), oncology (85), clinical neurology (76), peripheral vascular disease (72), and nursing (69);

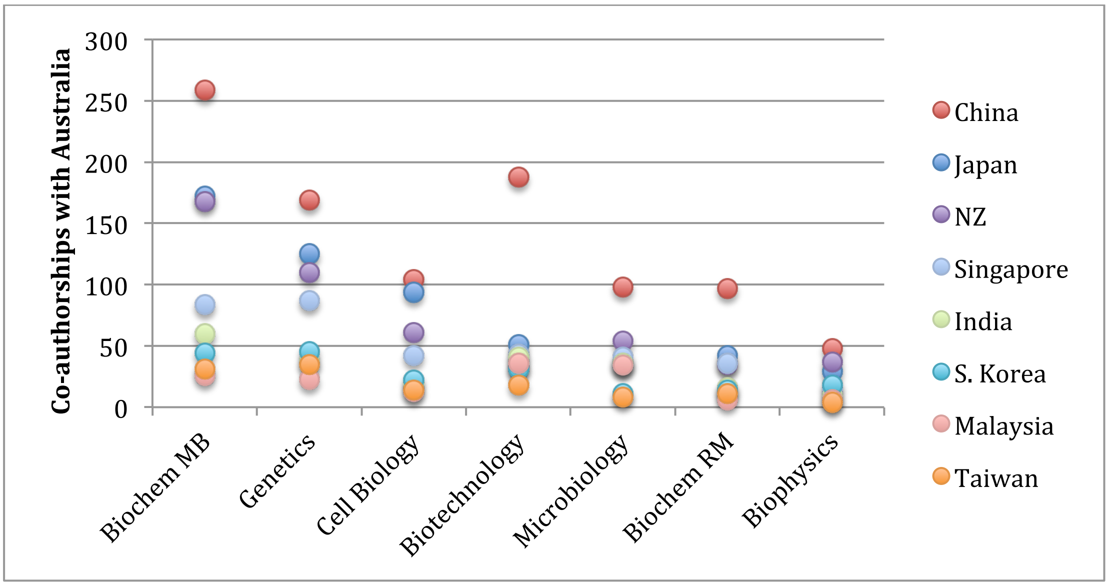
- NZ in sport sciences (203), biochemistry & molecular biology (168), general & internal medicine (150), cardiac & cardiovascular systems (131), clinical neurology (123), oncology (111), genetics & heredity (110), neurosciences (104), physiology (98), endocrinology & metabolism (90), veterinary sciences (68), hematology (68), pharmacology & pharmacy (66), and cell biology (61); and

- Malaysia in public, environmental & occupational health (62).

These listings are derived using a threshold of 100 co-authored articles per subject for China, and of 60 co-authored articles per subject for Japan, Singapore, and NZ. A threshold of 50 co-authored articles per subject was employed for other nations.

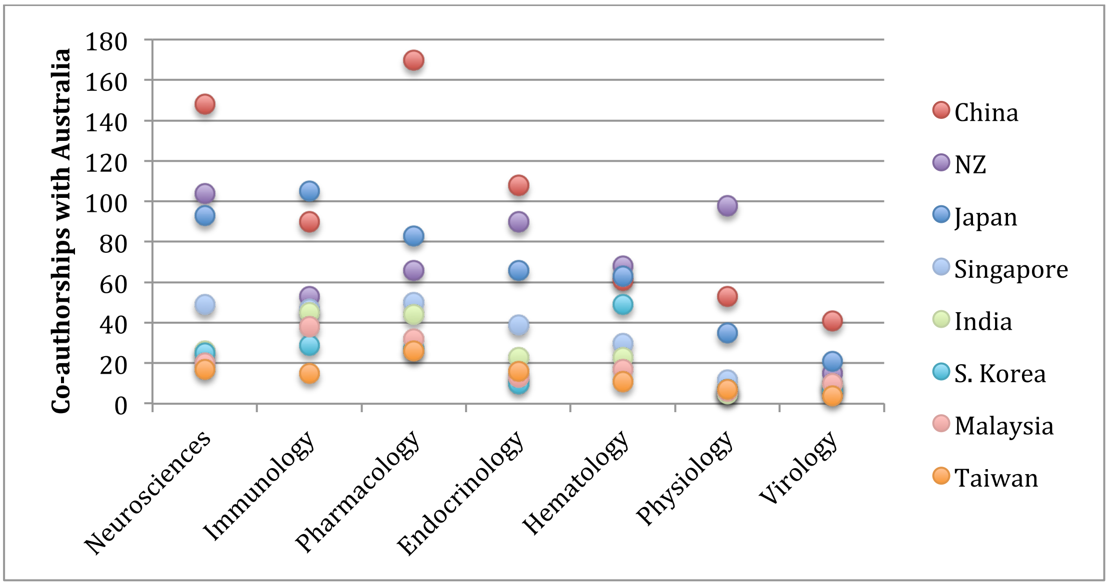
Interestingly, no Asian nation reaches the threshold of 50 joint papers with Australia in the subject categories of biophysics, virology, substance abuse, health care sciences & services, health policy, pathology, parasitology, or tropical medicine.

Figure 6.2a – Australian collaborations in molecular biology



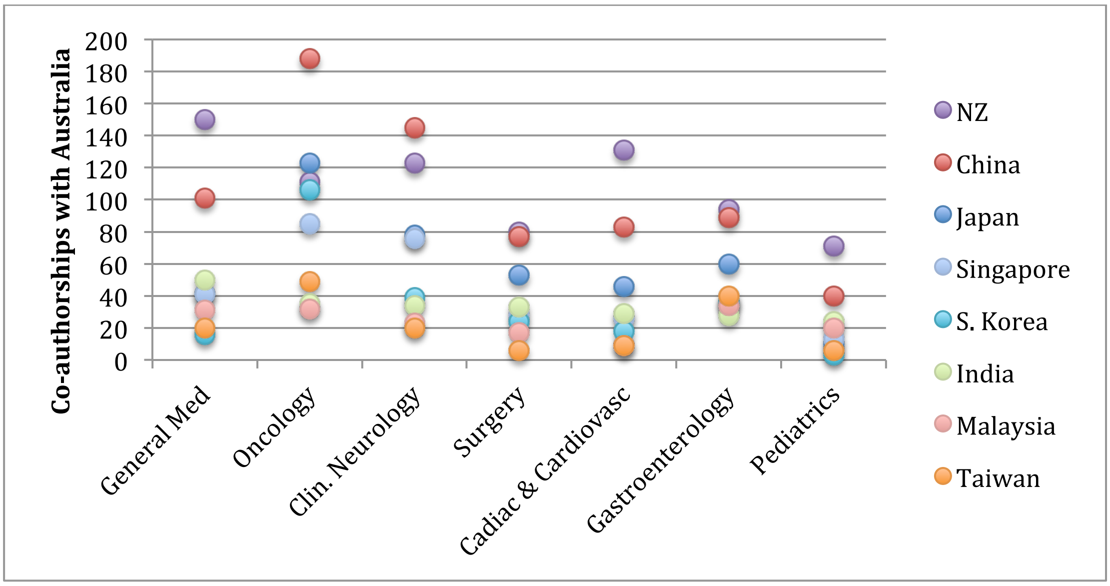
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Biochem MB=Biochemistry & Molecular Biology; Genetics=Genetics & Heredity; Biotechnology=Biotechnology & Applied Microbiology; and Biochem RM=Biochemical Research Methods.

Figure 6.2b – Australian collaborations in biomedicine



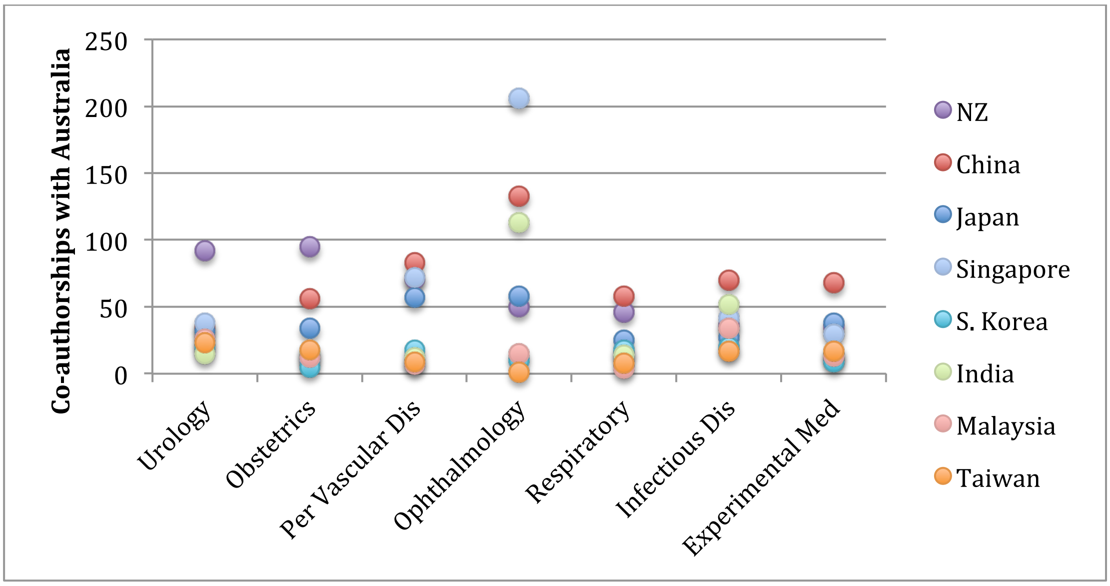
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Pharmacology=Pharmacology & Pharmacy; and Endocrinology=Endocrinology & Metabolism.

Figure 6.2c – Australian collaborations in high-volume clinical sciences



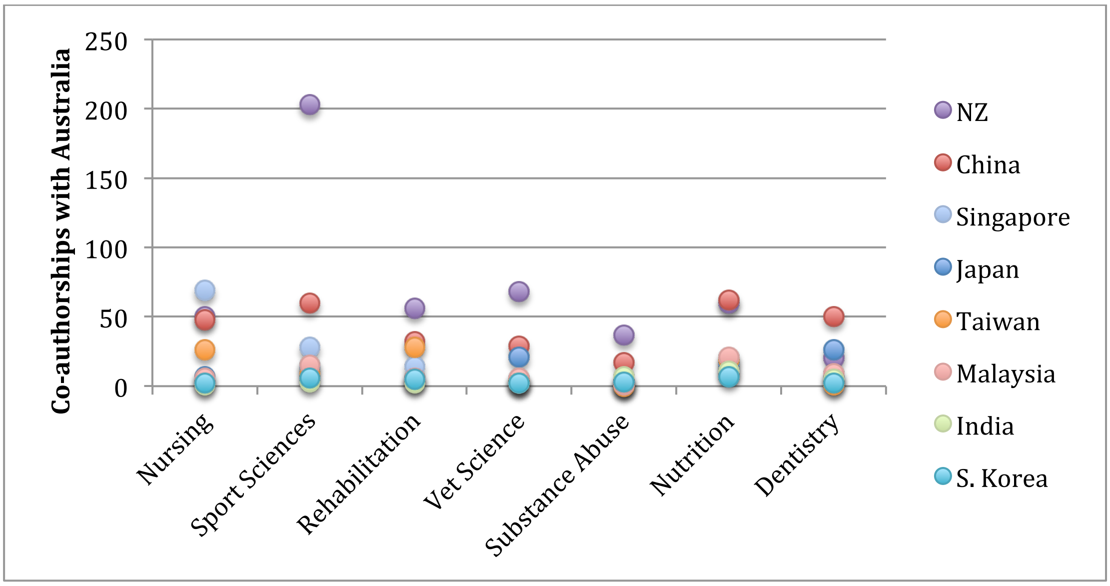
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, General Med=General & Internal Medicine; Cardiac & Cardiovasc=Cardiac & Cardiovascular Systems; and Gastroenterology=Gastroenterology & Hepatology.

Figure 6.2d – Australian collaborations in selected other clinical sciences



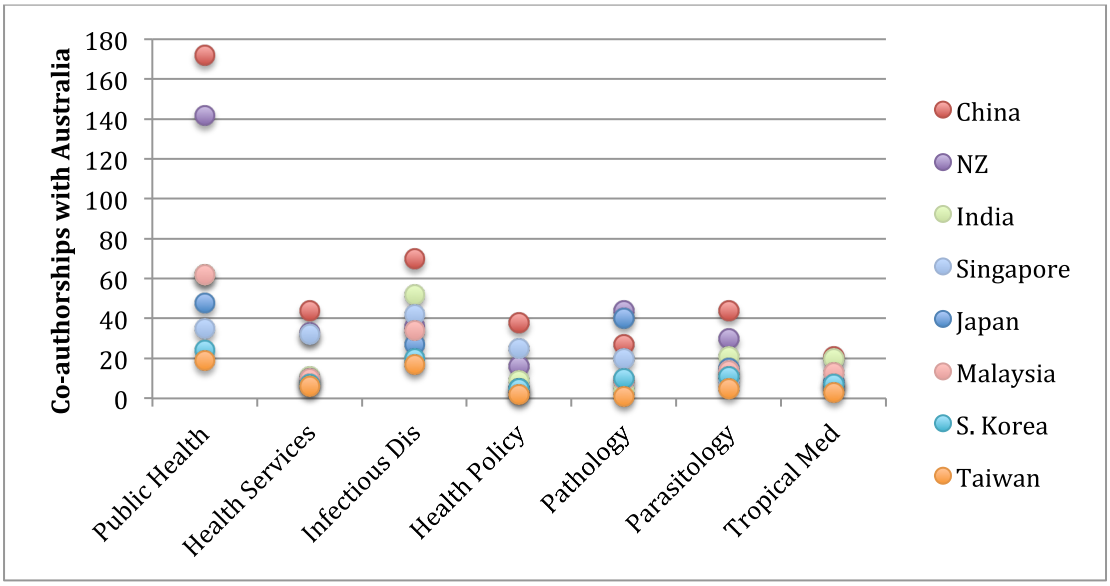
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Urology=Urology & Nephrology; Obstetrics=Obstetrics & Gynecology; Per Vascular Dis=Peripheral Vascular Disease; Respiratory=Respiratory System; and Experimental Med=Research & Experimental Medicine.

Figure 6.2e – Australian collaborations in allied clinical sciences



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Nutrition=Nutrition & Dietetics; and Dentistry=Dentistry, Oral Surgery & Medicine.

Figure 6.2f – Australian collaborations in public health & related areas



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Public Health=Public, Environmental & Occupational Health; Health Services=Health Care Sciences & Services; and Health Policy=Health Policy & Services. Note also that Infectious Diseases is included here as well as in figure 7.2d, by way of comparison with Parasitology and Tropical Medicine, both of which might be presumed key themes for the developing world.

6.3 ENGINEERING & TECHNOLOGY

Figures 6.3a to 6.3e show Australia's regional collaboration in mathematics, in computer science, in engineering, and in technology fields. Australia's co-authorships in these fields appear especially strong for:

- China in electrical & electronic engineering (720), nanoscience & nanotechnology (312), automation & control systems (291), chemical engineering (290), artificial intelligence (290), applied mathematics (284), metallurgy & metallurgical engineering (233), energy & fuels (232), civil engineering (200), information systems (191), mechanics (179), interdisciplinary applications of computer science (160), mathematics (159), mathematics (159), theory & methods of computer science (156), multidisciplinary engineering (148), software engineering (147), environmental engineering (140), telecommunications (133), instruments & instrumentation (128), mechanical engineering (127), and interdisciplinary applications of mathematics (116);

- Japan in nanoscience & nanotechnology (64), and energy & fuels (51), instruments & instrumentation (48), electrical & electronic engineering (42), and metallurgy & metallurgical engineering (42);

- South Korea in chemical engineering (72), nanoscience & nanotechnology (68), and chemical engineering (61);

- India in electrical & electronic engineering (43);

- Taiwan in electrical & electronic engineering (53);

- Singapore in nanoscience & nanotechnology (54); and

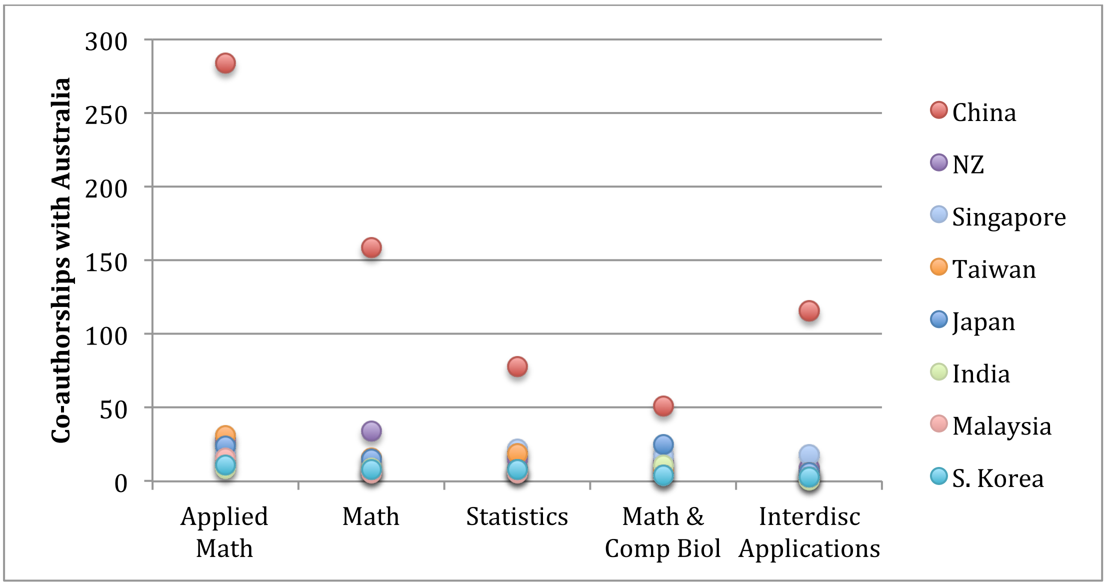
- Malaysia in electrical & electronic engineering (49).

These listings are derived using a threshold of 100 co-authored articles per subject for China. A threshold of only 40 co-authored articles per subject was employed for other nations.

Interestingly, no Asian nation outside China reaches the threshold of 40 joint papers with Australia in any sub-field of mathematics or computer science. This is extraordinary given the scale of the relationship that is now sustained between China and Australia across these fields.

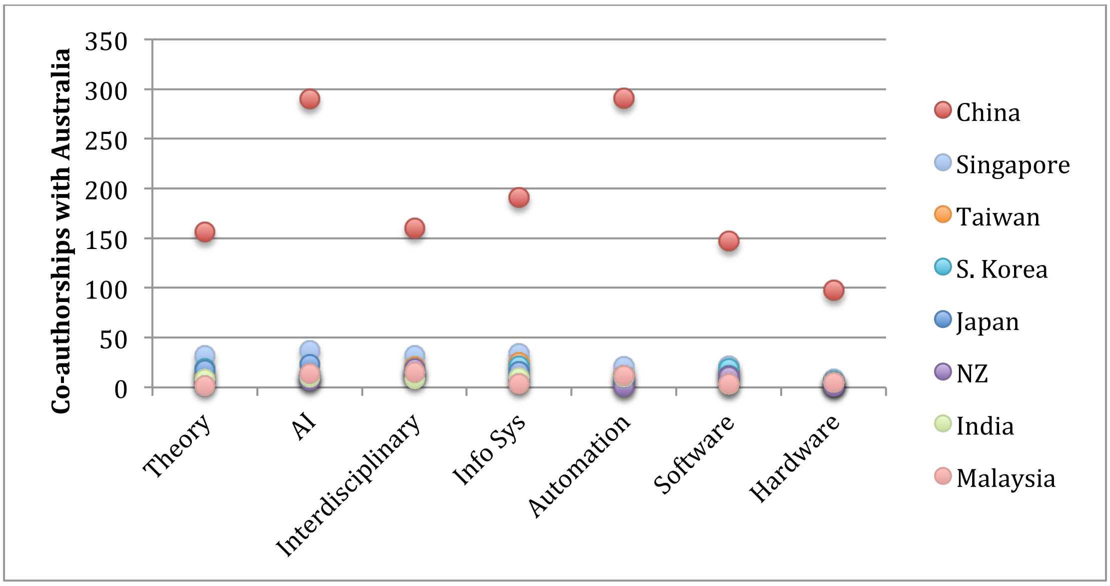
A similar argument can be made for most fields of engineering (civil, biomedical, mechanical, environmental, multidisciplinary, geological, manufacturing, ocean, aerospace, and petroleum engineering) as well as in the technology categories of mechanics, telecommunications, construction & building technology, and mining & mineral processing.

Figure 6.3a – Australian collaborations in mathematics



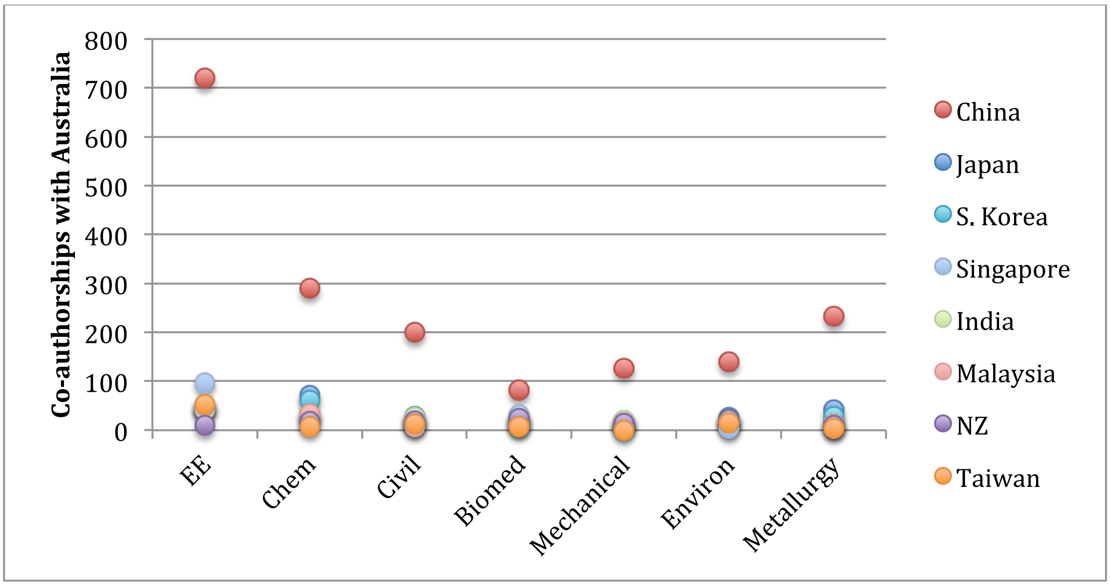
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Math & Comp Biol=Mathematical & Computational Biology; and Interdisc Applications=Interdisciplinary Applications of Mathematics.

Figure 6.3b – Australian collaborations in computer science



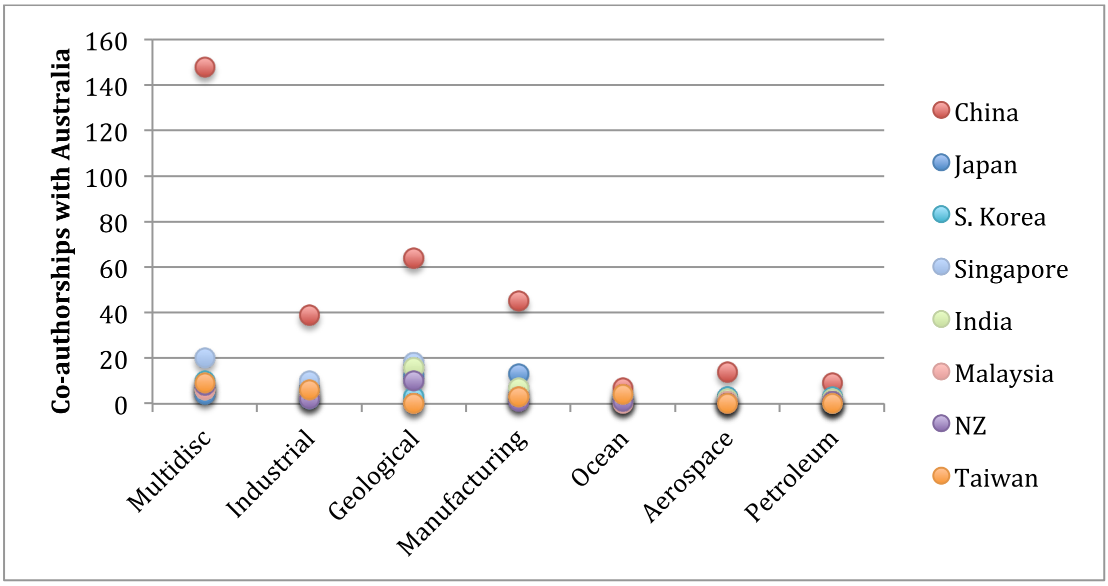
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Theory=Theory & Methods of Computer Science; AI=Artificial Intelligence; Interdisciplinary=Interdisciplinary Applications; Info Sys=Information Systems; Software=Software Engineering; and Hardware=Hardware & Architecture.

Figure 6.3c – Australian collaborations in high-volume engineering fields



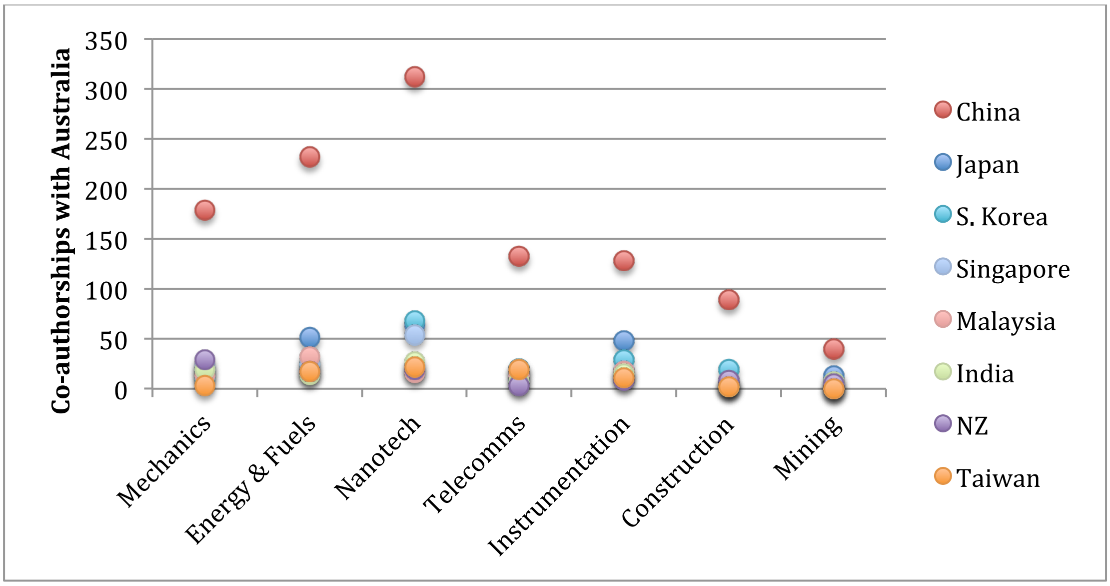
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, EE=Electrical & Electronic Engineering; Chem=Chemical Engineering; Civil=Civil Engineering; Biomed=Biomedical Engineering; Mechanical=Mechanical Engineering; Environmental=Environmental Engineering; Metallurgy=Metallurgy & Metallurgical Engineering.

Figure 6.3d – Australian collaborations in lower-volume engineering fields



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Multidisc=Multidisciplinary Engineering.

Figure 6.3e – Australian collaborations in technology



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined.

6.4 PHYSICAL SCIENCES

Figures 6.4a to 6.4c show Australia's regional collaboration in physics (including astronomy), in chemistry, and in materials science. Australia's co-authorships in these fields appear especially strong for:

- China in multidisciplinary materials science (898), physical chemistry (552), applied physics (522), multidisciplinary chemistry (371), multidisciplinary physics (283), astronomy & astrophysics (226), physics, particles & fields (215), optics (200), condensed matter physics (195), analytical chemistry (136), electrochemistry (131), polymer science (126), and atomic, molecular & chemical physics (107);

- Japan in astronomy & astrophysics (310), physics, particles & fields (182), multidisciplinary physics (178), multidisciplinary materials science (170), applied physics (159), multidisciplinary chemistry (106), physical chemistry (118), condensed matter physics (72), optics (65), atomic, molecular & chemical physics (58);

- South Korea in multidisciplinary physics (155), multidisciplinary materials science (137), astronomy & astrophysics (120), applied physics (98), multidisciplinary chemistry (88), physics, particles & fields (87), multidisciplinary physics (69), and physical chemistry (53);

- India in astronomy & astrophysics (151), physics, particles & fields (95), multidisciplinary physics (65), multidisciplinary materials science (64);

- Taiwan in physics, particles & fields (175), multidisciplinary physics (155), and astronomy & astrophysics (114);

- Singapore in multidisciplinary materials science (118), physical chemistry (103), multidisciplinary chemistry (77), and applied physics (70); and

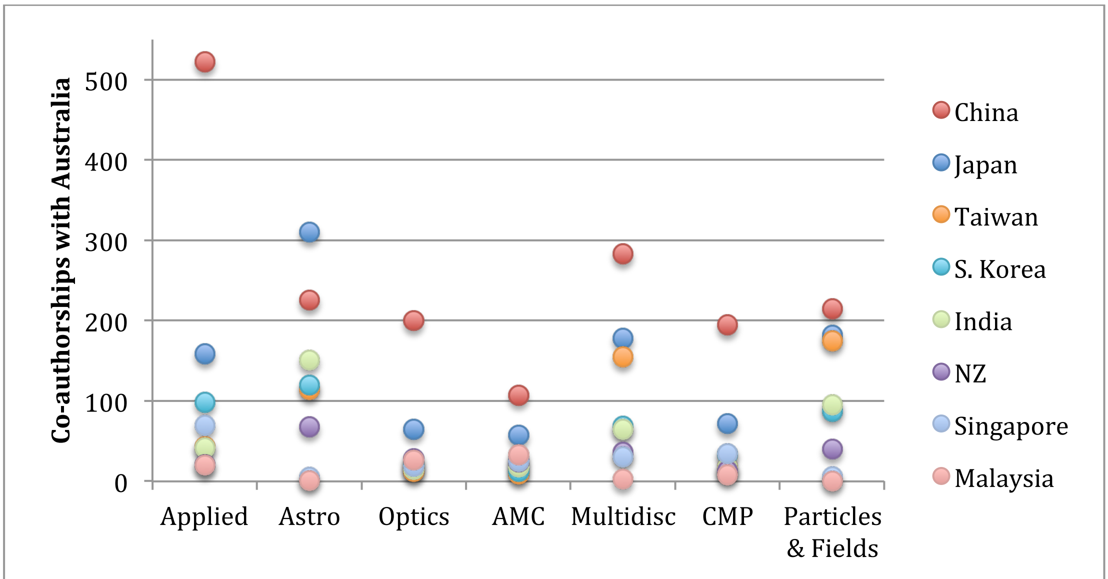
- NZ in astronomy & astrophysics (68) and multidisciplinary materials science (58).

These listings are derived using a threshold of 100 co-authored articles per subject for China. A threshold of only 50 co-authored articles per subject was employed for other nations.

Interestingly, no Asian nation outside China reaches the threshold of 50 joint papers with Australia in any field of chemistry or materials science, outside the particular subjects of physical chemistry, multidisciplinary chemistry, or multidisciplinary materials science.

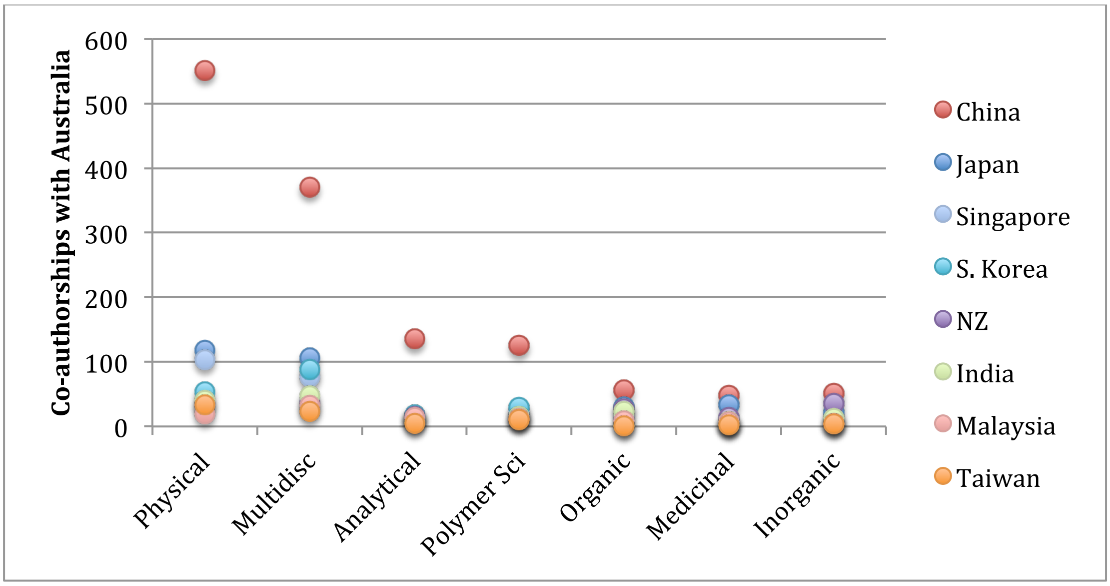
This suggests that where collaborations with Australia occur in these broad fields they tend to result in publication within multidisciplinary rather than specialist journals.

Figure 6.4a – Australian collaborations in physics



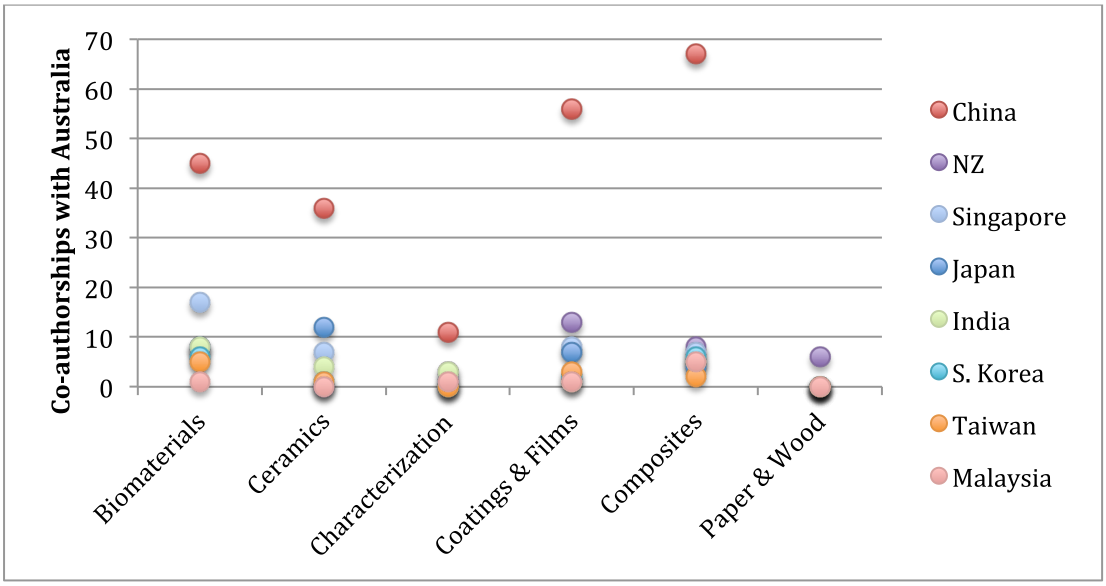
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Applied=Applied Physics; Astro=Astronomy & Astrophysics; AMC=Atomic, Molecular & Chemical Physics; Multidisc=Multidisciplinary Physics; CMP=Condensed Matter Physics; and Particles & Fields=Physics, Particles & Fields.

Figure 6.4b – Australian collaborations in chemistry



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Multidisc=Multidisciplinary Chemistry.

Figure 6.4c – Australian collaborations in materials science



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance Characterization=Characterization & Testing. Note also that due to scaling issues, data is not included here for Multidisciplinary Materials Science, where co-authorships were China (898), Japan (170), South Korea (137), Singapore (118), India (64), NZ (58), Malaysia (44), and Taiwan (37).

6.5 BEHAVIOURAL & SOCIAL SCIENCES

Figures 6.5a to 6.5c show Australia's regional collaboration in psychology, business, and selected social sciences. Australia's co-authorships in these fields appear especially strong for:

- China in psychiatry (145), operations research & management science (132), economics (128), management (89), hospitality, leisure, sport & tourism (42), education & educational research (42), business (41), psychology (41), business & finance (35);

- Japan in psychiatry (59) and economics (50);

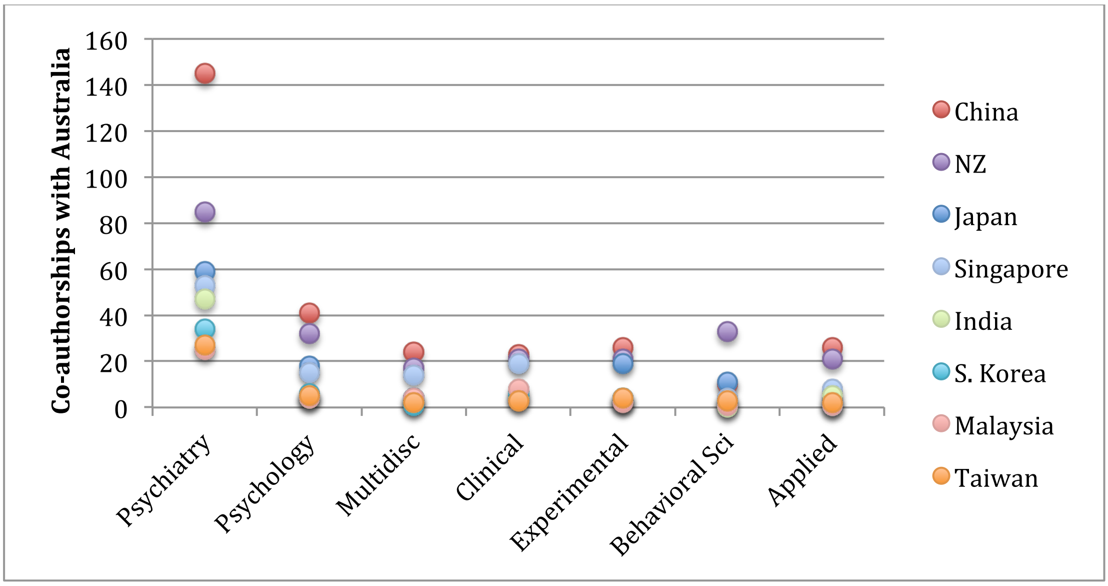
- India in psychiatry (47);

- Singapore in psychiatry (53) and economics (48); and

- NZ in psychiatry (85), economics (58), management (49), education & educational research (41), business (34), hospitality, leisure, sport & tourism (34), psychology (32), behavioural sciences (33).

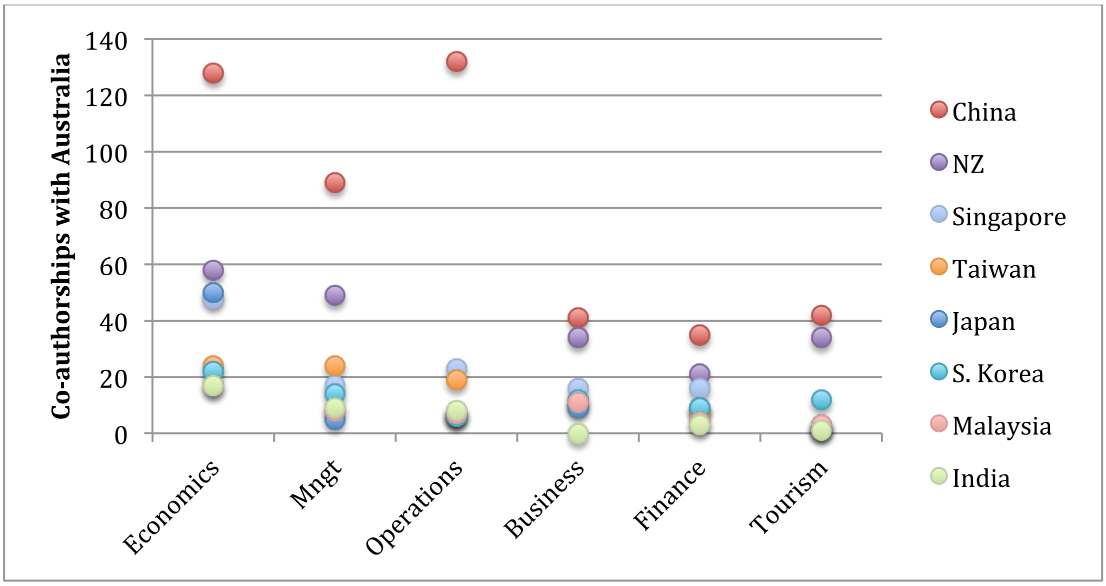
These listings are derived using a threshold of 30 co-authored articles with Australia per subject between 2010 and 2012. No Asian nation reaches this threshold in the subject categories of multidisciplinary, clinical, experimental, or applied psychology, or in any of the social sciences shown in figure 6.5c, with the exception of education & educational research.

Figure 6.5a – Australian collaborations in psychology



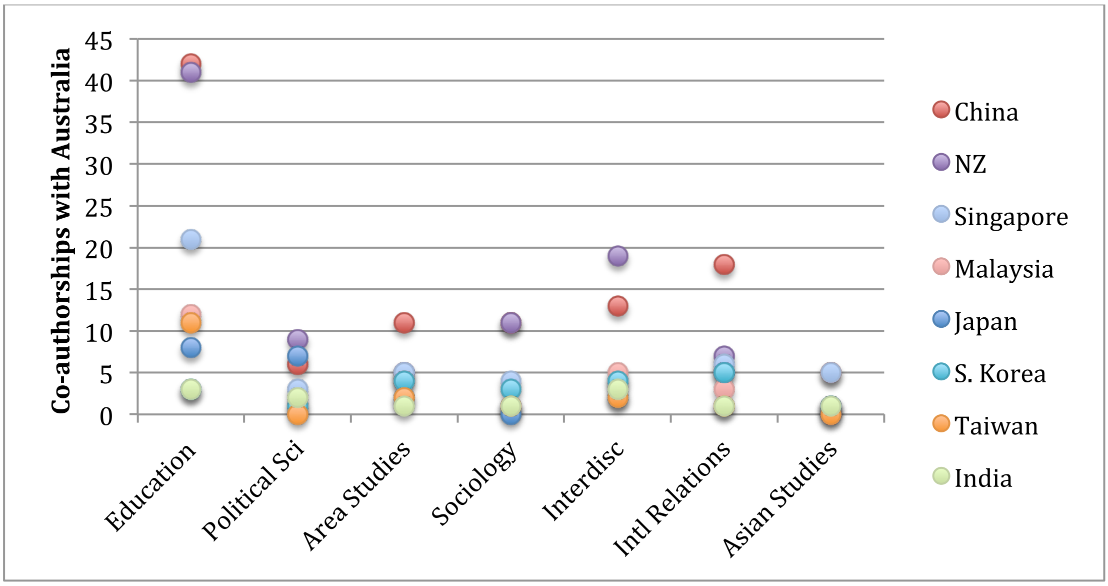
Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Multidisc=Multidisciplinary Psychology.

Figure 6.5b – Australian collaborations in business



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Mngt=Management; Operations=Operations Research & Management Science; and Tourism=Hospitality, Leisure, Sport & Tourism.

Figure 6.5c – Australian collaborations in selected social sciences



Note: Derived from TR DATA. The shows each country's co-authorships with Australia between 2010 and 2012 within journals classified by subject. Subjects are ranked (left to right) according to Australia's total number of papers published within each category. Countries are ranked in the legend by descending order of their outputs involving Australia co-authors across all subjects combined. In this instance, Education=Education & Educational Research; Interdisc=Interdisciplinary Social Sciences; and Intl Relations=International Relations.

6.6 CONCLUDING OBSERVATIONS

The analysis of Australia's regional collaboration patterns by subject or sub-field produces a number of interesting observations, some of which confirm that Australia's international networks are not strategically aligned with Australia's broader international policy objectives.

First, across nearly all subjects, other Asian research communities have low levels of collaboration with Australia relative to Australia's level of connection with China.

Indeed, China is now Australia's leading research partner in the region across all subfields analysed, with the exception of only a very few fields such as astronomy & astrophysics, cardiac & cardiovascular systems, behavioural sciences, ecology, fisheries, immunology, marine and freshwater biology, nursing, oceanography, ophthalmology, political science, sport sciences, tropical medicine.

It could be argued that this is simply a function of the scale of China's research system. However, we know this is not the critical issue since the distribution of collaborative outputs across the other nations simply does not scale with the size of their research systems.

The situation in artificial intelligence research is particularly telling in this regard. Between 2010 and 2012, nearly a half (46%) of all Australian articles published with an international co-author in artificial intelligence journals also involved a Chinese collaborator.

By comparison, only 4% of such outputs involved a Japanese collaborator, only 2% involved an Indian collaborator, and 2% involved a South Korean collaborator. This is not a function of the differences in scale of these four national research systems. It reflects something deeper.

What are likely to matter most here is not the scale of national systems, but the personal networks, linguistic abilities, and cultural interests of the researchers involved. In this respect it is perhaps worth considering whether Australia should do more to exploit migrant researchers from other parts of Asia in order to strengthen connections with countries like India, South Korea, and Taiwan.

Second, there are several areas where the scale of regional collaboration between Australia and Asia remains low, despite their relevance to international policy debates that touch on Australian interests. Some examples are listed as follows.

- In marine & freshwater biology Australia has more co-authored papers with NZ than it does with Japan and China combined, and it has fewer than half the number of co-authored papers in this field with Japan than it does in plant sciences. This is despite the intermittent tensions between Australia and Japan on the issue of whaling.

- In water resources research, Australia has strong partnerships with China, but weak relationships across the rest of the region. This is despite a popular narrative in Australia: that Australia has leading expertise in this area and that water as a resource is destined to become a growing a source of conflict around the world over the coming century.

- In parasitology and tropical medicine, which are presumably key research themes for many developing nations, Australia has very limited research connectivity with India or Malaysia. Indeed, Australia interestingly has more co-authorships with both countries in oncology or in cardiology than it does in tropical medicine.

- In energy & fuels technology, which has become a key theme for national and international policymakers, the scale of Australia's collaborations with Japanese, South Korean, and Indian researchers is amazingly low – respectively at around a quarter, a tenth, and a twentieth the scale of Australia's collaborations with China in this area.

Weak relationships in areas of potential diplomatic significance may reflect a weakness in the scale or quality of research in Australia, a weakness in the scale or quality of research in potential partners, the absence of an appropriate mechanism to facilitate joint work, or deeper cultural or political barriers to collaboration.

Understanding which factors are important in each case would be essential for policymakers with an interest in addressing the low collaboration rates in areas like these.

Third, and finally, we include a short comment about the social sciences. These fields are not easily analysed using bibliometric methods. In some areas, such as economics, publication analyses can give useful indications of collaborative activity. In other fields though, where co-authorship is more rare, collaboration may take forms that are not codified within a publication's author list.

This is clearly an issue for those fields dealt with above in figure 6.5c. But it is probably not the whole story.

Looking at outputs between 2010 and 2012, Australian researchers published 938 papers in political science journals, of which 195 (or 21%) involved an international co-author. This is a lower rate of international engagement than one observes in the sciences, but it still produced a significant number of international outputs.

Furthermore, it does seem telling that of these 195 internationally co-authored papers, only 3% involved a Chinese co-author and only 4% involved a Japanese co-author. Political scientists in Australia are connecting globally, but they do not appear to be connecting regionally.

One can do the same analysis for the fields of Area Studies and Asian Studies. In the former area, Australians published 853 articles between 2010 and 2012, of which just 72 (or 8%) involved an international co-author.

Of these 72 internationally co-authored articles, however, 15% involved a Chinese collaborator, 7 % involved a Singaporean, 7% involved a South Korean, and 6% involved a Malaysian partner. On the other hand, there was only one article in this batch involving both an Australian and an Indian co-author.

In Area Studies then it would seem that practitioners are connecting regionally, if unevenly.

In Asian Studies, by contrast, the likelihood of finding an international co-author diminishes to the point where serious analysis of this kind becomes impossible. Between 2010 and 2012, Australians published 434 papers in this field, of which only 28 (or 6%) involved an international co-author. Of these, 5 articles were co-authored with collaborators based in China, but it is difficult to draw inferences from such a small sample.

These fields are clearly important for Australia, and for Australian policymakers as they react to the dramatic changes that are underway across the region. One has to be cautious in making assertions based upon such limited data, but there is surely potential for greater Asian engagement in these fields.

Key Point 10

Finally, across nearly all subjects, Australian researchers have obvious weak links to other Asian societies compared with their level of connection to China. Australians also have weak links to Asian researchers in some specific areas of potential relevance for international policymaking. This strongly indicates that there is no strategic mechanism ensuring that the Australian research system is responsive to Australia's foreign policy objectives. In the absence of such a mechanism, there is a risk that the Australian research system will ultimately prove more likely to serve China's diplomatic interests than Australia's.

7. CONCLUSION

Asian nations have grown their research capabilities and outputs enormously over recent decades. As a consequence, there are now several large and vibrant intellectual communities working at the frontiers of knowledge in the region to Australia's north.

Australian researchers have been effective in connecting with new partners across this region, most particularly with colleagues in China. It is clear, however, that Australia has the potential to pursue a much more substantive level of research engagement in other parts of Asia – both through direct project-based collaboration and via expanded research training arrangements.

Currently, Asian researchers are most likely to connect with Australian capabilities in the physical and medical sciences. This reflects the priorities that exist in most Asian societies, as well as the emphasis on medical science that has long existed within the Australian system.

However, Australia's regional research collaborations have arguably been driven most dramatically by the raw expansion of capabilities in China. They are certainly not the product of a strategic prioritisation, which has sought to align Australian public-sector relationships with Australia's foreign policy objectives.

Australia's resulting pattern of collaboration may not serve Australia's foreign policy interests. Certainly it was not designed with such a view in mind. But nor is it clear how readily this pattern can be changed.

It is sometimes argued that Australia has a special role in brokering international research connections. This may be true for particular individuals, institutions, or fields. It may even be true in a cultural or political sense. But based upon the scale of its research portfolio, there is no reason to expect that Australia would be better suited to this role than some of the other countries across the region.

For policymakers with a goal to utilise Australia's research system to help underpin the conduct of Australian foreign affairs in the pursuit of broader Australian interests, the greater priorities at this time should be:

- helping Australian researchers, across all institutions, to form bridges with a wider cohort of countries and across a border range of fields; and

- encouraging far more intensive engagement with a more diverse set of Asian partners on the part of those particular government research agencies that operate in politically controversial fields.

REFERENCES

ABS 8104 – Australian Bureau of Statistics, *Research and Experimental Development, Businesses, Australia, 2011-12*, September 2013.

ABS 8109 – Australian Bureau of Statistics, *Research and Experimental Development, Government and Private Non-Profit Organisations, Australia, 2011-12*, June 2013.

ABS 8111 – Australian Bureau of Statistics, *Research and Experimental Development, Higher Education Organisations, Australia, 2010*, May 2012.

BR 2014 – Thomas Barlow, *ASIA 100: Benchmarking Universities in Asia and Oceania*, 2014.

DE 2014 – Department of Education, *Selected Higher Education Statistics*, accessed at www.education.gov.au in May 2014.

DIC 2013 – Department of Immigration and Citizenship, *Student Visa Program Trends*, 2006-07 to 2012-13.

NSF SEI – National Science Board of the National Science Foundation, *Science and Engineering Indicators*, 2013.

OECD MSTI – OECD, *Main Science and Technology Indicators*, 2014.

OECD RDS – OECD, *Science, Technology and R&D Statistics database*, 2014.

TR DATA – Thomson Reuters, *Customised Bibliometric Data*, supplied 2014.

UNESCO 2013 – UNESCO Institute for Statistics, *Science, Technology and Innovation Statistics*, June 2013.

WB 2014 – World Bank, *World Development Indicators*, 2014.