THE UNITED STATES STUDIES CENTRE
at the University of Sydney

US-AUSTRALIAN RESEARCH COLLABORATION SURVEY

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CONTENTS

SUMMARY OF RECOMMENDATIONS

1. Australian policy makers should consider mechanisms to facilitate increased US-Australian research collaboration.

2. Attention should be given to how vibrant, bilateral collaboration can be fostered even in a period of potentially weak R&D investment.

3. Policymakers should recognise that the Australian and US innovation systems have greater similarities in their public research systems than in the R&D portfolios of their business sectors.

4. The path of least resistance for governments interested in bringing the Australian and US innovation systems closer together will be to focus on public sector research policy rather than industry policy.

5. Public-sector policies that raise the quality of Australian research, build around Australia's distinctive resources, place Australians in US research environments, and exploit Australia's history as a trusted, strategic partner to the US will all improve the systemic potential for collaboration with the US.

6. Australian policymakers should harmonise R&D policies – e.g. by increasing inter-governmental discussion about priorities, by moving Australian graduate research education closer to the US model, by aligning competitive grant processes and associated infrastructure support, by simplifying the mechanisms for establishing inter-agency agreements, and by emulating US policy approaches to the commercialisation of public-sector research.

7. Australian federal policymakers should introduce explicit incentives and mechanisms to increase the level of co-publication on papers between American researchers and researchers in Australian Government agencies.

8. Australian policymakers should explore the possibility of establishing deeper, formal relationships between Australian and US federal research agencies, the most likely themes for engagement (outside the defence area where links are already very strong) being around space sciences, geosciences, agricultural sciences, and health.

9. Policy initiatives to stimulate bilateral collaboration across the Australian public sector more broadly should emphasise systemic actions that will remove the inhibitors to collaboration and provide incentives for collaboration in ways that are agnostic as to field. Targeted initiatives at the field level should be left to individual agencies or institutions.

10. Australian policymakers should consider implementing more open processes, particularly through the competitive funding councils, for directly funding research in the US where it is part of an Australian collaboration.

11. Australian policymakers should discuss with their counterparts in the US, China, Japan, India, South Korea, Taiwan, and Singapore possible mechanisms for promoting trilateral research partnerships with a view to implementing a similar level of trilateral relationships in research as exist with European nations.

12. Australian policymakers should discuss with their counterparts in the US, Indonesia, Malaysia, Thailand, and Vietnam possible mechanisms for promoting trilateral research partnerships, the most likely areas for collaboration being in the infectious diseases / public health / tropical medicine area and secondarily in the ecology / environmental sciences / evolutionary biology area.

13. Policies to facilitate strategic engagement in 'big science' projects, access to high-end infrastructure in the US, and participation in global alliances and networks will be an important element of any collaboration strategy.

14. There is an appetite in Australia for increasing research mobility to and from the US with a focus on: PhD scholarships, pre-doctoral fellowships, postdoctoral fellowships, joint appointments (including via a Laureate-level fellowship that attracts US researchers into joint appointments with Australian institutions), and international visitor research institutes in areas like mathematics.

15. Formal inter-governmental agreements can be useful in fostering collaboration but are probably most effective in supporting collaboration in research where: (a) they reflect an underlying community of capability that is ready to engage and preferably already engaged; and (b) they are focused in such a way that it is clear who is responsible for implementation and it is clear how implementation will be resourced.

16. A truly enlightened government in the present global research environment would consider making international activity a significant component of everything it does in research. It would:

- expect an international dimension to a significant proportion of the grants in funds, including capacity for research providers to subcontract parts of a project offshore, especially to the US which already implements the same policy in many cases towards Australia;

- expect all government agencies with serious research budgets to have a formal relationship with their equivalent agency in the US (as the leading research nation) supporting joint planning, programme integration, and secondments of senior managers; and

- expect every agency to support a research investment scheme targeted explicitly at opportunistic leverage of international research funds for research projects led by Australians.

1. BACKGROUND

1.1 Objectives

The goal of this report is to explain the nature of the US-Australian research relationship, to review the scale and focus of recent collaborations, to analyse existing policy priorities, and to formulate ideas for nurturing constructive interactions in the future.

Research collaboration, and especially international collaboration, is an issue of growing importance among many research communities. There has been a clear expansion in collaborative approaches to research in recent decades (Wuchty 2007 and Matthews 2009) and Australian policy is increasingly being driven by a perception that collaboration, including international collaboration, is a key determinant of quality and visibility in research (Cutler 2008 and DIISR 2009).

In this context, the Department of Innovation, Industry, Science and Research within the Australian Government has commissioned a study into the nature of research collaborations between American and Australian researchers. This work is summarised in the pages that follow and provides:

(a) a high-level understanding of the nature and scope of collaborations currently taking place between Australian and US researchers; and

(b) suggestions about areas of policy focus and policy mechanisms that could be used to promote additional research collaboration between Australian and the US in the future.

Our work suggests that promoting Australian-American research collaboration is a constructive goal for policy-makers. Australian researchers have a special history of collaboration with the US. Over the past four decades Australians have found more research collaborators in the US than in any other country. Despite this special history though, there are likely to be considerable benefits in enhancing the Australian-American relationship. An overriding aim of this paper is to bring some evidence and some fresh ideas to light about where and how this might be achieved.

1.2 Methodology

The problem of understanding US-Australian research collaboration is not a simple one given the complexity and scale of the two research communities. For this reason, the approach that has been taken has been to marry an underpinning quantitative analysis with qualitative evaluations and considerable survey work.

Key aspects of the US and Australian research systems are presented, with a view to understanding the context in which bilateral collaboration occurs. Key datasets for this analysis have been obtained from the Organisation for Economic Co-operation and Development (OECD), the Australian Bureau of Statistics (ABS), the National Science Foundation (NSF), and the Thomson Reuters Essential Science Indicators.

Subsequently, areas of current collaboration in research are identified, with a focus on field of research, strongly collaborative institutions, and evolving trends over the past two decades. Key sources for this analysis have been the Australian Research Council, the National Institutes of Health, the National Health and Medical Research Council, the National Science Foundation, the Thomson Reuters Web of Knowledge, and the World Intellectual Property Organisation through its Patentscope database.

The subsequent analysis of policy and the accompanying policy suggestions are based upon publicly available government documents and extensive one-to-one telephone surveys of senior researchers and research administrators. The conclusions drawn however are entirely the author's and should not be interpreted either as representative of those individuals surveyed or indeed of the Department of Innovation, Industry, Science and Research, which commissioned the work.

Finally, readers must be aware of two important caveats. First, it should be noted that the focus of this report has been on research, as opposed to development. This is an important distinction and partly explains the bias in the analysis towards public-sector knowledge production rather than private-sector application. Second, informed readers would be aware that there are many ways for researchers to collaborate, many of which will not show up in the sorts of assessments that have been used here. This is a problem for all disciplines, but especially for the humanities, arts, and social sciences.

Researchers in all fields interact through visiting fellowships, by speaking to one another at conferences, by attending workshops, by reviewing one another's work, by sitting on international advisory boards, and so on. In this project, it would be impossible to quantify the vast and rich mechanisms by which Australian and American researchers work together in practice. It should be recognised at the outset therefore that while the measures we have used do indicate important areas of activity, they do not and cannot provide an exhaustive account of the collaborative interactions between these two nations.

1.3 Acknowledgements

Several individuals and organisations must be thanked for their assistance in this project.

First, it should be recognised that the Department of Innovation, Industry, Science, and Research in the Australian Government commissioned the research and took a great interest in its findings.

Second, special thanks must go to colleagues at the US Studies Centre. This research is part of the Merck Innovation Program at the Centre, which is directed by Professor Bruce McKern. Dr Sean Gallagher must be thanked also for his assistance with aspects of the bibliometric analysis.

Third, a significant number of researchers, research administrators, and policy-makers in both Australian and the US gave their time for quite extensive interviews or provided data and introductions to colleagues. Many of the ideas put forward in this report would never have been developed – or at least would never have been published in this context – without the extremely valuable input from this group.

2. IMPORTANCE OF US-AUSTRALIAN COLLABORATION

It is important to understand just how significant US collaboration has become for the Australian research community. The US is Australia's main collaborator in research, and looks likely to remain so for the foreseeable future.

However other nations too are building very strong relationships with the US research community. Contrary to expectations, linguistic and cultural affinity does not appear to have given the Australian research community any obvious, quantifiable advantage in generating joint research outcomes with US researchers.

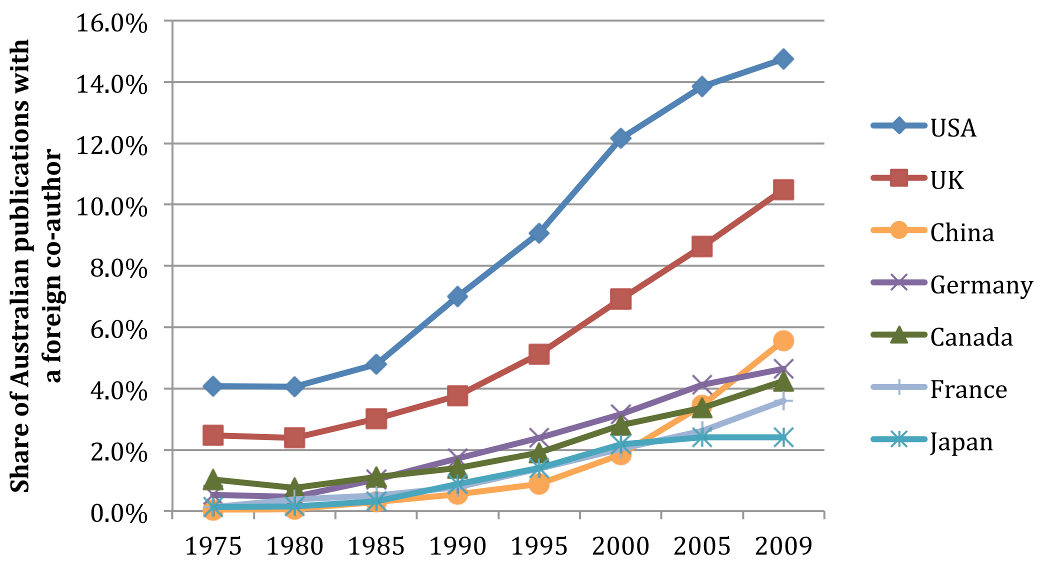
There is also growing uncertainty around global research funding, which may not be entirely beneficial for fostering future collaboration. In this context, it is very timely to be studying the US-Australian relationship in research.

2.1 The US is Australia's main collaborator in research

There is one overwhelming reason for Australian policy-makers to take an interest in driving research collaborations with the US. The US is still Australia's leading trading partner in the global economy of ideas, and can be expected to remain so for the foreseeable future.

Figure 2.1 illustrates this succinctly by showing the strong recent growth in US-Australian scientific collaboration, and the remarkably high share of Australian scientific research publications that currently have a US co-author. Only the UK comes close by scale of national collaborations.

Figure 2.1 – Australian scientific outputs with a foreign co-author



Note: Derived from Science Citation Index in the Thomson Reuters Web of Science.

From this figure it can be observed that:

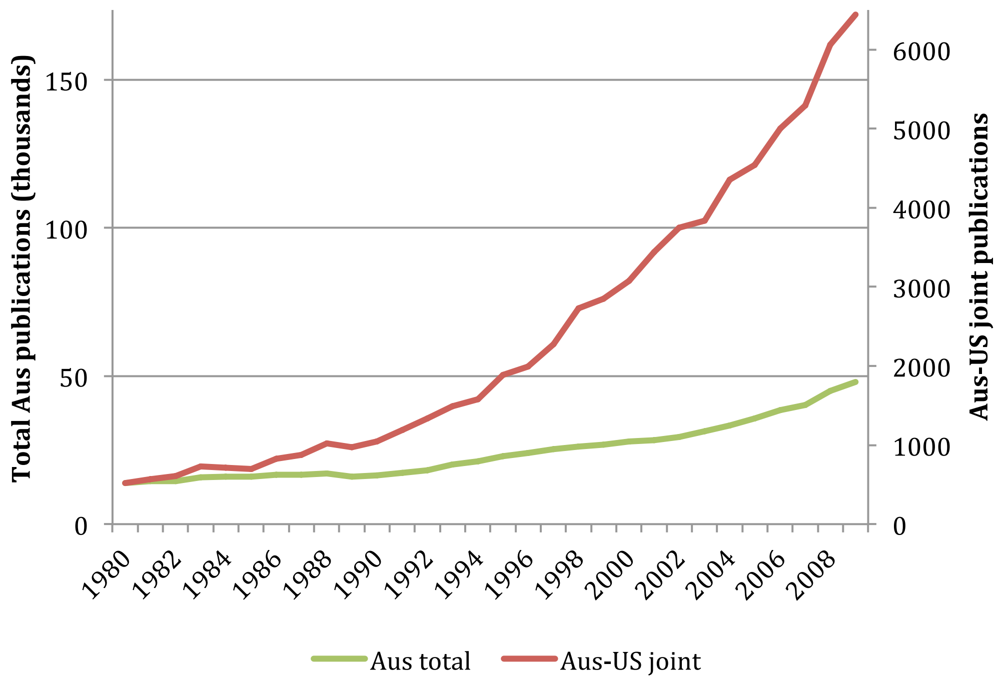
- nearly 1 in 6 Australian publications listed in the Science Citation Index had a US co-author in 2009; while, by comparison,

- 1 out of every 10 Australian publications had a co-author from the UK and just over 1 in 20 Australian publications had a Chinese co-author in 2009.

There is indirect evidence too that both Australian and US researchers are well aware – and indeed have a growing awareness – of the benefits in this bilateral relationship. Figure 2.1 showed the scale and growth of the Australian-US interaction relative to that of Australia's other international research partners.

By comparison, figure 2.2 shows the growth in US-Australian co-publications relative to the growth in total Australian outputs. It is evident from this figure that Australian researchers have not only been increasing their level of co-authorship with US researchers, but have been doing so at a far faster rate than they have been increasing their total outputs.

Figure 2.2 – Growth in Australian-US collaboration



Note: Derived from Science Citation Index, the Social Science Citation Index, and the Arts & Humanities Citation Index in the Thomson Reuters Web of Science.

It is possible that the trend here is biased to some degree by the creation of new journals and the inclusion of new titles in the citation indices, which have favoured collaborative research. Obviously too it reflects a broader tendency, which is leading to an increase in all forms of collaboration in modern research.

Nonetheless, it does suggest an interesting trajectory. It indicates: (i) an American research community that has been increasingly open to working with scientists and researchers in our part of the world; (ii) an Australian community that is increasingly receptive to working with Americans; and presumably (iii) a growth in funding and in practical mechanisms for supporting such collaboration.

Judging from these long-term trends, it is reasonable to assume that the US is not only Australia's main destination for international collaboration in research today, but looks likely to remain so for the foreseeable future.

2.2 The US is the largest research partner for most nations

There are several possible reasons for the strong association that exists between Australia and the US in research. Australia and the US have similar strategic interests, both nations share a common language, and there is strong cultural overlap between the two societies.

These factors however are probably incidental in comparison simply to the scale and global importance of US science and research. It is important to observe that US research activity has been so large and dominant over recent decades that the US has evolved into the major collaborating partner for almost every nation. The scale of this association for a number of countries is shown in table 2.3.

Table 2.3 – US share of internationally co-authored publications (2005)

Asia – Pacific – Americas			Europe – Mediterranean		
US co-authorships	as share of country's internationally co-authored articles	as share of country's total articles	US co-authorships	as share of country's internationally co-authored articles	as share of country's total articles
Taiwan	56%	12%	Israel	53%	23%
South Korea	55%	15%	Italy	33%	14%
Canada	52%	22%	UK	32%	14%
Mexico	43%	20%	Switzerland	31%	18%
China	40%	10%	Netherlands	30%	15%
Japan	40%	9%	Germany	30%	14%
Brazil	40%	14%	Denmark	28%	15%
India	36%	8%	Sweden	28%	14%
Australia	35%	14%	Russia	28%	12%
NZ	33%	16%	France	26%	13%

Note: Data derived from NSF 2008.

Especially interesting from this table is the level of collaboration between the US and non-English-speaking countries. Cultural affinity seems to have little bearing on the extent of interaction – at least as realised in joint publications. Indeed given the cultural similarities between Australia and the US, there is evidence here that the US-Australian research relationship is actually not as strong as it could be.

Among non-English-speaking nations, compared with Australia:

- Japan, China, and Israel have the US as a co-author on a higher share of their country's internationally co-authored articles; while

- Switzerland, Denmark, South Korea, and Israel have the US as a co-author on a higher share of their country's total scientific output.

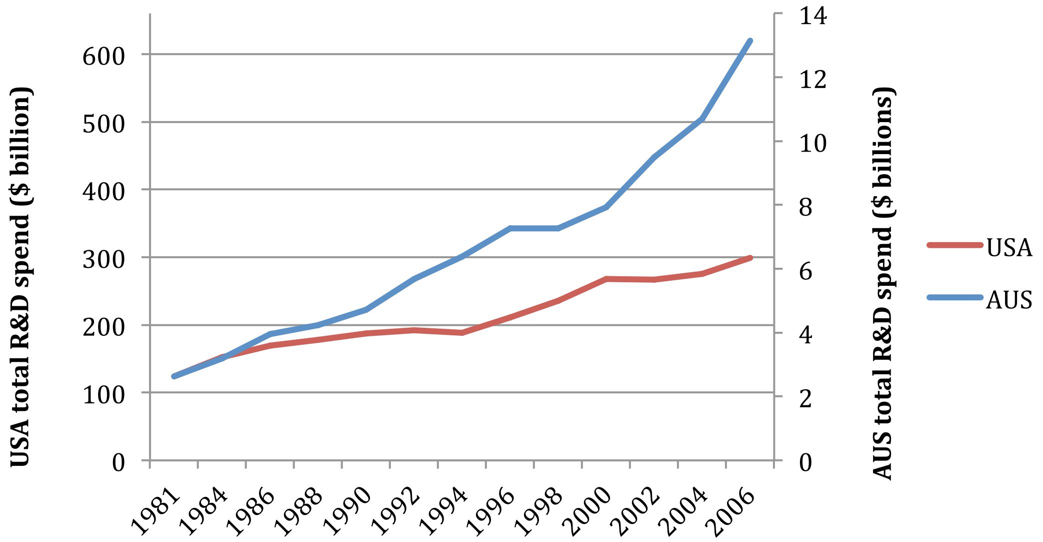
Apparently there are other drivers of collaboration apart from ease of communication or cultural or linguistic fit. Or, to put it another way, there are other societies whose research communities have either greater motivation or better mechanisms for partnering with US research than is true for Australia.

This points to serious policy questions. Should Australian governments be seeking actively to strengthen the US-Australian relationship in research? And should governments also be investing some sense of urgency into the relationship?

2.5 Emerging impediments to US-Australian collaboration

Just because Australians have a strong and expanding recent history of collaboration with US researchers, it is by no means certain that the trend will continue. It is worth remembering that the acceleration in US-Australian collaboration depicted in figure 2.3 occurred over a very long period of strong, global economic expansion. Research funds, including budgets for conferences and travel, have expanded steadily in both societies since the early 1980s.

Figure 2.4 – National R&D expenditures in constant 2000 dollars



Note: Derived from OECD 2010. Figures are in constant 2000 US dollars adjusted for purchasing power parity.

Figure 2.4 depicts this for Australia and the US, showing not just the marked real growth in R&D investment across both societies, but also the higher rate of growth in Australian R&D investment (albeit off a much lower base) relative to the US in recent years.

Association, of course, is not the same thing as causation. Because sustained growth in bilateral collaboration has occurred simultaneously with sustained real increases in R&D investment, one cannot conclude with certainty that the latter has caused the former. Nonetheless, it is prudent to question what the implications might be following a change in the investment environment.

The research communities in both Australia and the US are currently facing a range of uncertainties, and not only of a financial nature. Some of the more obvious ongoing challenges are catalogued below:

- *Economic uncertainty* – There is the global economic uncertainty and the likelihood of a period of weak economic growth in the US and Europe, with implications for R&D investment in both the public and private sectors.

- *Competitive uncertainty* – There is the emergence of China and India, and to a lesser degree Brazil, as potential collaboration partners, but also as competitors, for both American and Australian researchers.

- *Fragmentation of Knowledge* – There is the unprecedented scale in the global production of knowledge, the fragmentation of disciplines, and the associated need to build groups in research that can marry complementary expertise.

- *Cost of Research* – There is the associated rising cost of high-impact research, and what seems an inexorable rising capital cost in many areas, not just in astronomy and particle physics.

- *Demographic Change* – There are demographic challenges and projected ensuing recruitment problems for research-intensive organisations across all developed societies over the coming decade.

- *Impact of Technology* – There is the impact of technology not just in increasing research efficiency and opening up new fields of enquiry, but also in stimulating new ways of sharing and disseminating research.

- *Politicisation of Scientific Enquiry* – Finally, there is a growing political and strategic role being played by researchers globally as evidenced by the escalating interplay between research and policy.

Most of these challenges, with the exception of the first, seem likely on balance to stimulate greater international collaboration in research. All other things being equal therefore, it seems plausible that a continued surge in R&D investment would be accompanied by ongoing growth in collaboration, at least over the near term.

By contrast, the likely outcome from a global easing in research support (a highly credible scenario over the coming decade) is not so obvious. In the short term, a tightening of research budgets could actually foster collaboration as researchers in different parts of the world look for those with complementary skills to help them achieve more with less. Indeed there is much talk already along these lines in the US.

But financial constraint could also lead in time to opposing effects. Slowing growth in research budgets, for instance, could lead to less effective collaboration and ultimately to less collaboration, as researchers struggle to fund the means to get together, to build international relationships, or to work on opportunistic projects stimulated by discussions with international partners.

Scarcity of research investment could also provoke a growth in technological and scientific nationalism, in the public sector particularly, leading to a staunching of global flows of research funding, which has been an important stimulant to international collaboration over recent years.

In such an environment, it is useful to speculate how Australian policy makers can best ensure that the research relationship between the US and Australia remains strong – and indeed becomes stronger to the mutual advantage of both societies.

Recommendations

1. Australian policy makers should consider mechanisms to facilitate increased US-Australian research collaboration.

2. Attention should be given to how vibrant, bilateral collaboration can be fostered even in a period of potentially weak R&D investment.

3. RESEARCH PROFILE OF THE TWO NATIONS

The US and Australian innovation systems have been contrasted elsewhere (see, for example, Barlow 2008). It is worth pointing out several key elements of the research profile of the two nations though, as a precursor to understanding where and how research collaboration occurs.

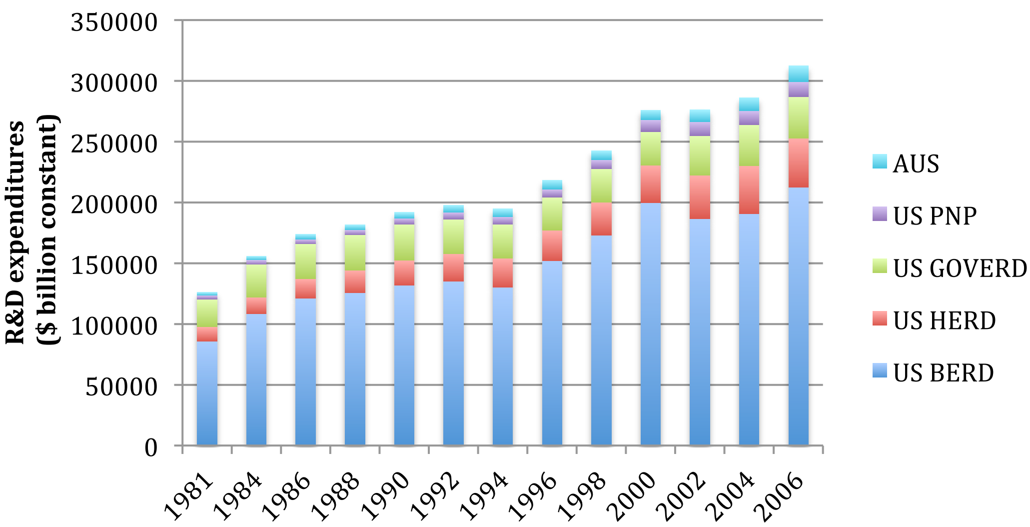
Below we contrast the research activity in Australia and the US, highlighting especially: the disparity in scale of research investment; the converging balance between public and private research investment; the different areas of focus of private-sector research investment; and the similarities and differences in the nature of public-sector research investment.

Subsequently, we summarise the benefits from collaboration and show that the advantages for Australian researchers in working with Americans are not always the same as the benefits for American researchers in working with Australians.

3.1 Disparity in scale of investment

The first point that must be made in understanding the interactions between Australian and US researchers in aggregate (though not in individual) terms is that the disparity in the scale of national investment is huge. Figure 3.1 shows the trends in US and Australian R&D activity over twenty years, by US sector and for Australia in constant 2000 US dollars.

Figure 3.1 – Scale of US and Australian R&D activity, 1981-2006

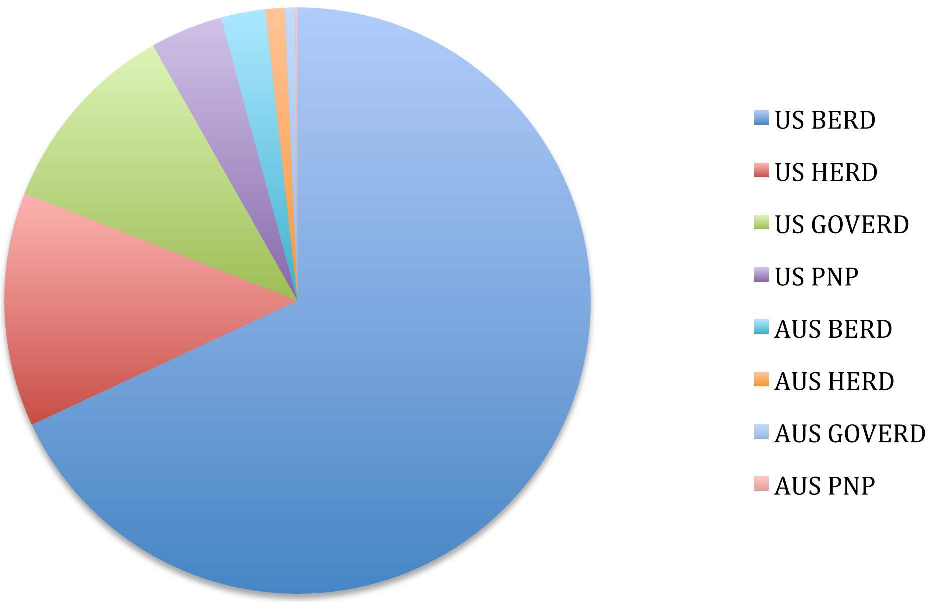


Note: Derived from OECD 2010. BERD=Business Expenditure on R&D; HERD=Higher Education Expenditure on R&D; GOVERD=Government intramural Expenditure on R&D; PNP=Private Non-Profit Expenditure on R&D.

While it is evident from this figure that the scale of Australian spending on R&D has grown relative to total US spending (implying perhaps that more Australian researchers will appear on the radar of US colleagues than ever before), it remains obvious that total Australian R&D activity is miniscule compared with the level of R&D activity in the US. Indeed, for every year in this figure except 2006, total Australian expenditure on R&D (i.e. spending by business, universities, government, and private non-profit organisations) was less than the amount of R&D expenditure in the US private non-profit sector (the smallest sector of activity in the US).

This remarkable disparity is illustrated in greater detail in figure 3.2, which breaks down R&D expenditure in 2006 by sector for both countries. This figure shows that R&D spending in Australia's leading sectors (business and universities) still remained small compared even with the smallest US sector (the private non-profit sector).

Figure 3.2 – Scale of US and Australian R&D activity, by sector, 2006



Note: Derived from OECD 2010. BERD=Business Expenditure on R&D; HERD=Higher Education Expenditure on R&D; GOVERD=Government intramural Expenditure on R&D; PNP=Private Non-Profit Expenditure on R&D.

The difference in scale of the two research communities does not necessarily mean that collaborations in research between the US and Australia will always be based around unequal relationships. One can expect broadly the following:

- *Australians will often be junior partners* – In many areas, especially in areas of big science, the US will sponsor research on a scale that confines Australian research to a niche position. In these situations, Australians will usually collaborate with US researchers as junior partners.

- *Australians will still work as equal partners in many instances* – Due to the decentralised nature of US R&D investment, whereby research is often carried out in groups of similar size and capability as those in Australia, Australians and Americans will still often work as equal partners on projects. Indeed, the majority of US-Australian university collaborations will probably be experienced in this way.

- *Australians will sometimes contrive to be leaders* – In other areas, despite the scale of total R&D activity in the US, investment in specific fields or projects may still be sufficiently low or the skills of Australian researchers may be sufficiently unique that American researchers come to collaborate effectively as junior partners on Australian initiatives.

The disparity of scale, in other words, can still enable a range of different kinds of interaction. In practice, on the other hand, there are likely to be more of the former relationships than the latter. Moreover there are two respects where the difference in scale does afford Australians a particular disadvantage in developing partnerships with American researchers.

The first issue relates specifically to the interface between research and development. As figure 3.2 shows, the most obvious scale disparity in R&D investment occurs in the private sector. It would seem credible from this figure: first, that Australian researchers will be severely constrained relative to American researchers in finding local development partners to help bring their ideas to market; second that the private sector in Australia and the US is likely to be differentiated not just by the number of firms doing R&D but also by the scale of firms doing R&D; and third that Australian researchers will typically be unlikely to have a high profile among commercial research organisations in the US.

If any of these points are true, commercial research collaborations between Australians and Americans may be harder to initiate than public-sector collaborations, and may often be negotiated by Australian partners from a position of weakness.

The second issue relates more broadly to the visibility of the Australian research community among potential American researcher partners. While collaboration between Australians and Americans may often be effective and conducted under a wide variety of terms, the disparity in the scale of the two communities probably means that it will typically be easier for Australians to identify desirable partners in the US than for Americans to identify desirable partners in Australia. This would be true in several respects:

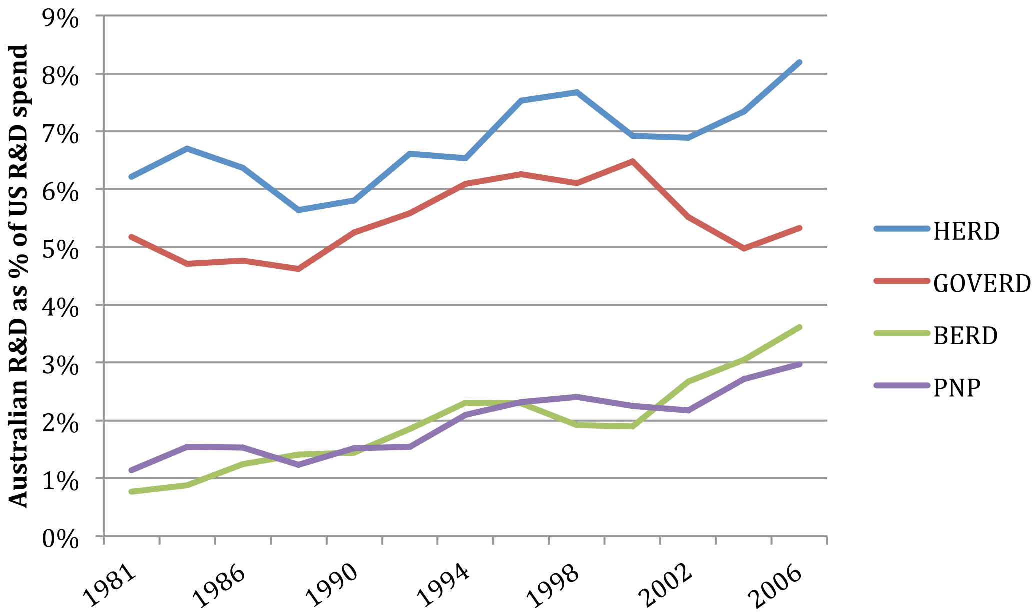
- The larger community in the US means a greater breadth of expertise. There will be far more occasions when an Australian will find a skill or facility in the US that is not available in Australia than vice versa.

- Given the scale of investment in the US, and the consequent capacity to concentrate investment around high calibre individuals or organisations, one expects the US to support a disproportionate number of individuals and organisations with the kind of reputation that attracts collaborators, independent of other factors.

- The relatively low scale of the Australian research system, combined with its geographic isolation, may mean that US researchers will not naturally come looking for collaborative opportunities in Australia, unless they have first failed to find the partners they need locally in the US (or indeed in other regions of large-scale research activity globally).

One can add slightly to this analysis linking scale with visibility. Figure 3.3 shows the scale of Australian R&D expenditure by sector of activity as a percentage of US R&D expenditure in the same sector.

Figure 3.3 – Scale of Australian R&D relative to US spend, by sector



Note: Derived from OECD 2010. BERD=Business Expenditure on R&D; HERD=Higher Education Expenditure on R&D; GOVERD=Government intramural Expenditure on R&D; PNP=Private Non-Profit Expenditure on R&D.

The evidence here would suggest that Australian private sector R&D activity (whether for profit or non-profit) has been conducted historically on a scale that is essentially negligible compared with what is happening in the US. On the other hand, the growth in Australian business R&D activity since 2000 relative to the US does imply that this may be changing and that Australian businesses in some sectors may experience both enhanced visibility and growing negotiating power with potential partners the US in the years ahead.

By contrast, government intramural R&D expenditure in Australia relative to that in the US has historically been higher than in the business sector, but the ratio has declined slightly over recent years suggesting no special positive change in visibility derived from scale. On the other hand, university R&D expenditure in Australia exceeded 8% of US university R&D expenditures in 2006, following a long period of growth in this ratio. The implication here is that Australian university researchers have probably experienced a steady elevation in reputation among potential collaborators in US universities over the past twenty years.

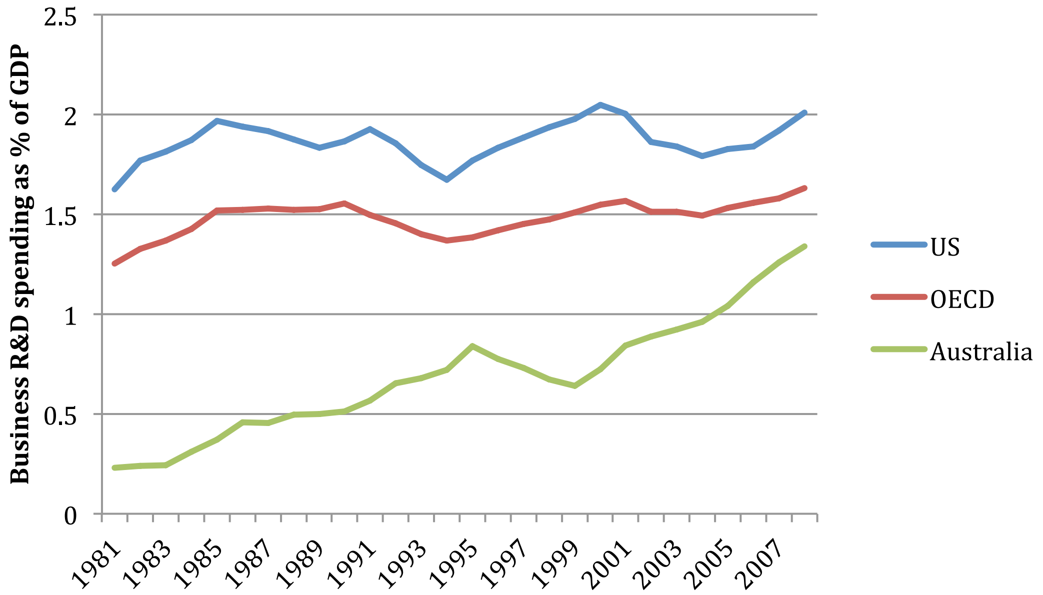
3.2 Nature of private sector investment

Having observed the difference in relative scale between the public and private sectors, it makes sense to review these two areas independently. In this section, we look in closer detail at the focus of private sector R&D investment in Australia and the US, and we identify some additional implications for bilateral collaboration.

A common tendency is to characterise Australia as a country with low business investment in R&D and to assume that this alone explains most disparities between Australia and other countries with respect to private sector R&D investment. Such an analysis however is incomplete.

Since the early 1990s, Australian businesses have grown their investments in R&D at rates significantly higher than other developed countries. Business investment on R&D as a share of GDP in Australia has steadily converged with OECD norms (see figure 3.4) and in fact this ratio is now higher than for the EU as a whole and for all English-speaking nations with the exception of the US.

Figure 3.4 – Business R&D spending as a share of GDP

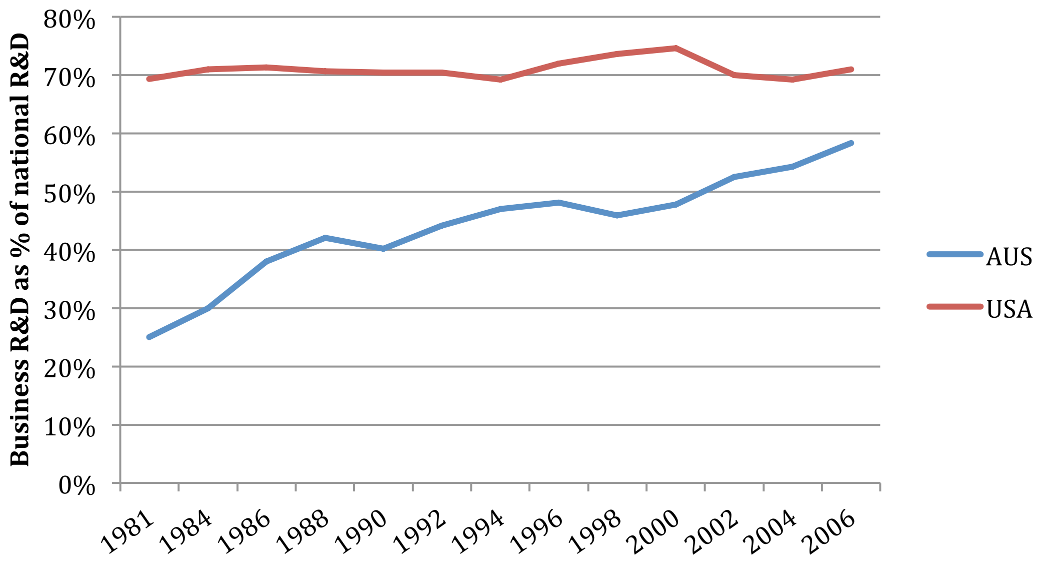


Note: Derived from OECD 2010.

Consistent with this trend, business organisations have also recently become the major performers of R&D in Australia. Figure 3.5 shows the share of national R&D attributable to business in both the US and Australia from the early 1980s to the present.

As is evident from this graph, in the US, business has consistently accounted for around 70% of total R&D expenditure over the past twenty-five years; while, in Australia, businesses' share of national R&D activity has risen steadily from less than 30% to nearly 60% of national totals over the same period.

Figure 3.5 – Business R&D spending as a share of national R&D spending



Note: Derived from OECD 2010.

There are a couple of conclusions to be drawn from these figures. On the one hand, it is likely that Australian businesses will have increased their significance and profile among US research and development partners in recent years. On the other hand, while there is still capacity for further growth in R&D investment by Australian businesses, it is implausible that this growth will be sustained at the same rate indefinitely.

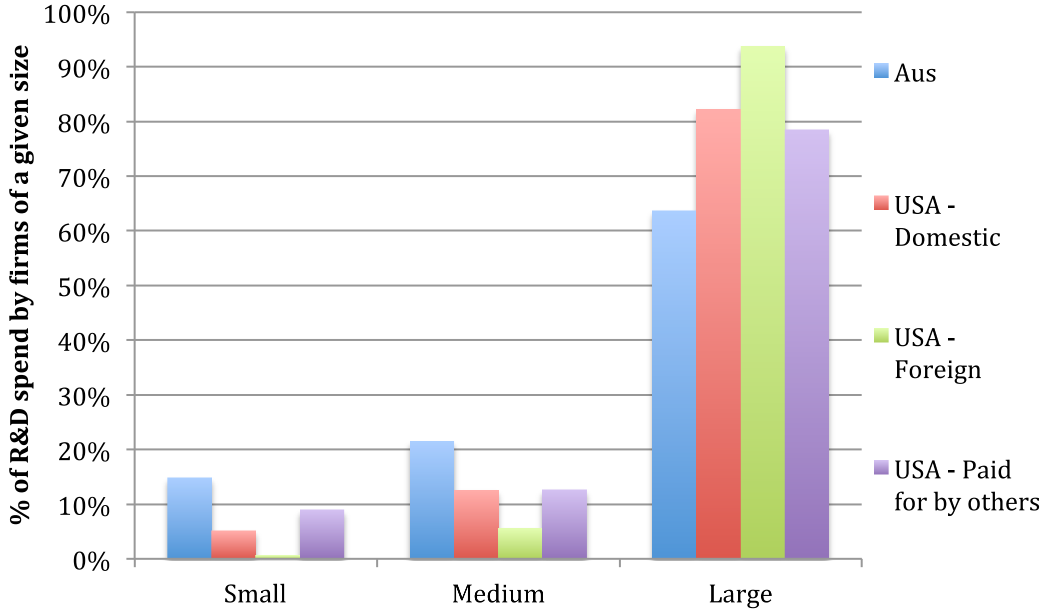
Australian R&D spending ratios (whether normalised against GDP or total national R&D investment) are unlikely to exceed those in the US any time soon. As a consequence, one can project with considerable confidence that Australian business R&D is likely to gain neither serious scale nor visibility relative to activity in the US for the foreseeable future.

This projection of ongoing disparity moreover is compounded by differences in the structure of the two economies. We will look at two issues here: first the distribution of business R&D by size of firm; and second the distribution of R&D by industrial sector.

Figure 3.6 below shows R&D expenditure by US and Australian businesses categorised by firm size. It indicates that, compared with the US domestic economy, the Australian economy has a higher proportion of business R&D performed in relatively small firms. In fact, this figure arguably under-represents this difference as there is no breakdown of data available on Australian firms with more than 200 employees, yet firms at the lower bound of this category would still be considered small companies in the US.

To expand upon this point, if one were able to disaggregate the data on co-called "large" firms in figure 3.6, it is highly probable one would find further evidence of a difference in profile by company size. One thing that is not shown in this figure is that over 30% of domestic business R&D spending in the US and over 40% of US foreign business R&D spending comes from firms with more than 25,000 employees. In Australia, the proportion of R&D activity performed in firms of this scale would almost certainly be lower.

Figure 3.6 – Business R&D expenditure by firm size



Note: (i) Derived from NSF 2008b and ABS 8104. (ii) For the purpose of this figure: "small" is defined as <25 employees; "medium" is defined as 25-249 employees; and "large" is defined as >250 employees. Australian data have been adjusted to match the survey categories used in US R&D surveys and consequently are approximate. (iii) "Aus" refers to total Australian business R&D expenditure; "USA – Domestic" refers to R&D expenditure performed by US firms in the US; "USA – Foreign" refers to R&D expenditure performed by US firms outside the US; and "USA – Paid for by others" refers to R&D expenditure performed by US firms in the US but paid for by others.

A credible implication here is that research relationships between Australian and US companies will often involve firms unevenly matched in size. Even large firms in Australia will find themselves partnering with larger firms in the US, while small Australian companies will sometimes struggle for visibility among prospective US partners that are very much larger.

This is not all, however, that figure 3.6 shows. First, as illustrated in the figure, it appears that large firms are responsible for nearly all the R&D performed by US companies outside the US. This means that where Australia attracts US companies to do their R&D in Australia, it will invariably be by attracting the interests of sizeable companies.

Second, large firms apparently perform a high share of the business R&D in the US that is paid for by organisations external to the firm. The implication here for Australian businesses is that the bigger ones will likely find it easier to attract US investment in their R&D programmes – yet, as we have seen, a disproportionate share of Australian business R&D happens in the context of smaller businesses.

All of this implies that the path for Australian companies in establishing research collaborations with US firms will often not be a straightforward one. Oftentimes they will lack the visibility to be noticed, and once noticed they will find themselves negotiating with a much larger and potentially more powerful partner.

It is difficult to see what policymakers can or should do to assist Australian firms in this context. If policymakers want to foster private sector collaboration with US firms in research, policies aimed at improving the visibility and credibility of Australian companies active in research may be useful. Such activities however can distort perceptions, including the perceptions of local investors, and may not always be desirable.

In addition, there are further complications. For one thing, what seems to be true for the whole economy may not always be true for individual sectors of industry. A perusal of the ABS data (see ABS 8104) shows considerable variation in concentration of R&D activity by firm size. For example:

- only 24% of reported R&D in the Australian agriculture sector occurs in companies involving more than 200 employees;
- only 59% of R&D in the Australian electricity, gas, water and waste services sector occurs in companies involving more than 200 employees; and
- only 27% of R&D in the Australian professional, scientific and technical services sector occurs in companies involving more than 200 employees.

Yet as much as:

- 84% of R&D in the Australian mining sector (and over 90% of R&D in the metal ore mining sector) occurs in companies involving more than 200 employees;
- 83% of R&D in the Australian food product manufacturing sector occurs in companies involving more than 200 employees;
- 81% of R&D in the Australian construction sector occurs in companies involving more than 200 employees;
- 90% of R&D in the Australian information, media and telecommunications services sector occurs in companies involving more than 200 employees; and
- 95% of R&D in the Australian finance and insurance services sector occurs in companies involving more than 200 employees.

In the latter sectors, business research collaborations with US partners may on the whole be more evenly balanced in some ways than is true in the former sectors.

A compounding factor in this respect relates to the scale of R&D activity at the sectoral level. Interestingly, one can point to a few sectors where the scale of R&D activity in Australia is not so severely dwarfed by the R&D activity in the US as one might tend to assume from the aggregated national data.

The OECD collates business R&D data for the manufacturing, utilities, construction, and services sectors (but not for mining or agriculture) via its ANBERD database (ANBERD 2009). Using this dataset one can identify sectors where Australian business appears to have a reasonable scale of activity relative to business in the US.

Unsurprisingly, most of the industrial sectors that stand out in this respect are in services. Three sectors where the scale disparity between US and Australian business investment in R&D is not quite so severe are:

- financial intermediation;
- wholesale and retail trade; and
- telecommunications services.

The only areas of manufacturing where Australian businesses invest on a scale that might make them visible in the US by scale of activity are:

- basic metals manufacturing; and
- food products, beverages and tobacco manufacturing.

An argument could be made that these may be areas where commercial collaboration will not necessarily be overwhelmingly one-sided.

In high-tech areas, by comparison, the disparity in scale of R&D investment appears to widen drastically. According to the data in the OECD ANBERD database, in four key industrial high-technology sectors in 2006, there was well over 100 times as much business R&D expenditure in the US as there was in Australia. These sectors were:

- pharmaceuticals manufacturing;
- aircraft and spacecraft manufacturing;
- office, accounting and computing machinery manufacturing; and
- electronic valves and tubes and other electronic components manufacturing (i.e. mainly the semiconductor industry).

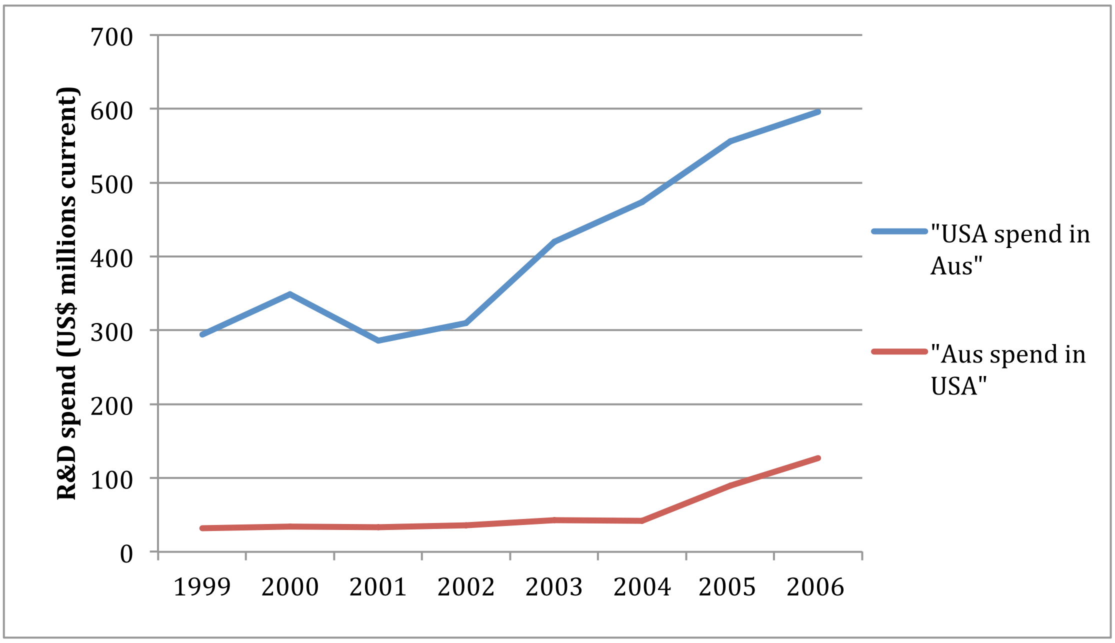
These are areas where research partnerships are not impossible (indeed they are all but essential for Australian researchers trying to get products developed in these industries), but they are also areas where partnerships will often be uneven, and where collaborations will often involve large corporations in the US and Australian public sector researchers or companies trying to commercialise public sector research developed in Australia.

The challenge here for policymakers interested in promoting business research collaborations is not at all simple. Should the focus be to bring larger firms together, or to help small Australian firms in particular to connect with US firms? And should programmes be agnostic as to sector, or should they focus on sectors where Australia has some existing strength relative to US business, or otherwise on sectors where the scope for connections seems constrained and Australian business seems disadvantaged?

Usually the justification for policy intervention in the private sector relates to a problem of market failure, but the complexity of the situation in this instance makes it difficult to sustain this sort of argument. Below we present some indicative evidence suggesting that (consistent with the observations made above) the extent to which American and Australian businesses engage on research is actually quite weak.

Figure 3.7 shows investments in R&D by US-based affiliates of Australian multinationals, and by Australia-based affiliates of US multinationals. In 2006, the final year in this series, the ratio of US spending in Australia to Australian spending in the US was around 5 times. This is significantly lower than the ratio of total US business R&D spending to total Australian business R&D spending, and suggests perhaps that Australian firms are currently more willing (relative to their total R&D outlays) to invest in the US than American firms are to invest in Australia.

Figure 3.7 – R&D performed abroad by foreign affiliates of multinational corporations



Note: Derived from BEA 2009.

Bilateral corporate investment in R&D of course is not made solely via this mechanism, for which reason it is interesting to compare this data with another complementary piece of analysis. Table 3.8 provides information about the trade in contract research between the US and several other nations, including Australia.

It shows US trade in contract research services with countries ranked by scale of total bilateral trade (i.e. the summation of US imports and exports). In our view this is a more important metric than trade balance, and interestingly it reveals that Australians are not especially active in contract research activities with the US: not compared with other English-speaking nations, like the UK, Ireland, Canada, Israel, and India; nor compared with several other countries with small populations such as Ireland, the Netherlands, Switzerland, Israel, Belgium, and Singapore.

Table 3.8 – US trade in research, development, and testing services, 2007

	US exports ($ millions)	US imports ($ millions)	Total bilateral trade ($ millions)
UK	1,023	2,616	3,639
Japan	1,798	636	2,434
Ireland	1,936	361	2,297
Netherlands	1,276	981	2,257
Germany	930	973	1,903
Switzerland	1,506	323	1,829
Canada	515	1,007	1,522
France	394	644	1,038
Israel	68	713	781
India	51	607	658
Belgium-Luxembourg	233	306	539
Singapore	268	62	330
Australia	70	226	296
Italy	126	149	275
Mexico	51	195	246
China	34	191	225

Note: Derived from BEA 2009.

The evidence, in other words, is that the two business communities probably do not collaborate as much in research as might have been expected given the cultural, linguistic, and strategic ties that bind these two nations. Yet this now should no longer surprise us. The evidence here is also entirely consistent with the structural differences we have highlighted above: (i) the lack of scale in Australian business R&D at both the national level and at the firm level; and (ii) the especially low scale of business R&D activity in Australia in those key high-tech sectors (e.g. pharmaceuticals, aircraft, and semiconductors) where US industry has evolved a very strong focus.

Many Australian researchers in business undoubtedly would benefit if they could find ways to increase their exposure to research partners and development opportunities in the US. The implication above, though, is that there are systemic problems impeding research collaboration between American and Australian firms, and it is not easy to envisage policies that will readily overcome these problems without potentially proving counterproductive in other respects.

The complexity of the situation means that policymakers are probably best off continuing to leave decisions about private sector collaboration to the commercial judgement of people performing R&D within Australian and US businesses.

3.3 Nature of investment outside the business sector

We turn now to the nature of public sector investment in R&D in the two societies, where there is arguably much broader alignment of interest. As we saw above in figure 3.2, there is a significant difference in the scale of R&D investment in US universities versus Australian universities and in US government agencies versus Australian government agencies. Yet, as shown in figure 3.3, the difference is not so vast as is true in the private sector.

Moreover, while the scale of investment in the US does naturally generate capacity to support significantly larger projects than are possible in Australia, this has probably not been the main impact of the higher levels of research investment in the US. It is interesting to note that the average first year allocation for approved Australian Research Council Discovery Projects in 2011 will be AUD$108,467. This compared with a mean annual size for National Science Foundation grants in 2010 of USD$113,529.

One should be cautious about drawing too strong a conclusion from this single example. Differences in success rates and the capacity for holding multiple grants afforded by the greater plurality of funding bodies that exist in the US mean that American researchers do currently have the potential to attract investment on a greater scale than is typically possible in Australia.

For the vast majority of researchers in practice though, the comparison between National Science Foundation funding and Australian Research Council Funding does highlight an important point: at the level of individual researchers, the differences in the playing field will not be so vast as might be imagined from the aggregated data.

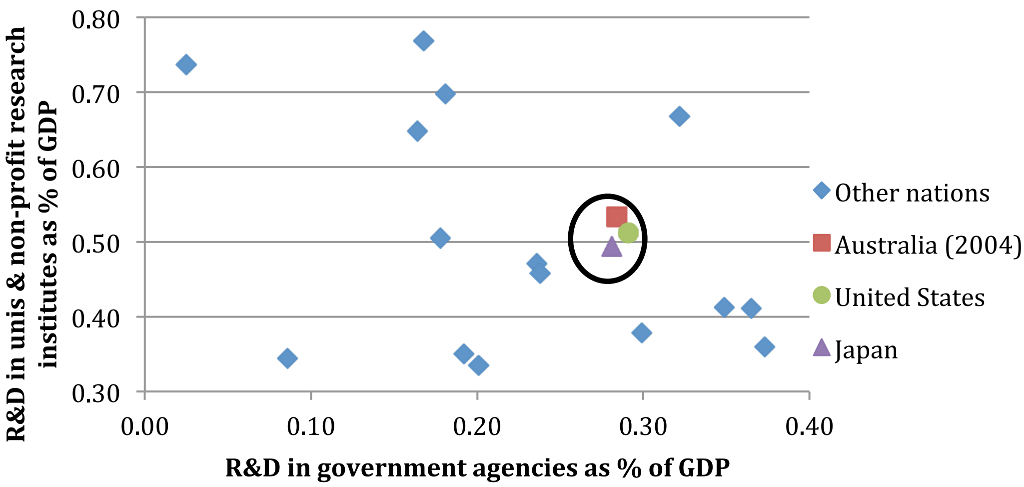
And what is true for individuals also appears true for organisations. The scale disparities that exist within individual institutions (as revealed, for example, by contrasting R&D expenditures at the universities of Sydney or Melbourne with those at Harvard or Johns Hopkins University) while significant are not overwhelming.

All of this suggests that the prospects for Australian researchers to participate on equal terms with US collaborators are far more pronounced than one might conclude just by looking at the overall R&D expenditure data – and are certainly more pronounced than is the case in the private sector.

There is also a greater alignment of public sector activity by field of research and by organisation than is true for the private sector. Whereas we observed some misalignment by industrial sector of activity (especially in contrasting R&D activity in high-technology sectors like pharmaceuticals, aircraft manufacturing, computing machinery, and semiconductors), there is considerable similarity in the structure and focus of public-sector research across the two nations.

This is evidenced, on the one hand, by the similar balance of spending that has existed in recent years across government agencies, universities and private non-profit research institutions. Figure 3.9 shows that, compared with other developed countries, Australia and the US invest a very similar proportion of GDP into government agency R&D, and a similar proportion of GDP into R&D across universities and private non-profit research institutes.

Figure 3.9 – Non-business R&D expenditures in OECD nations, 2006



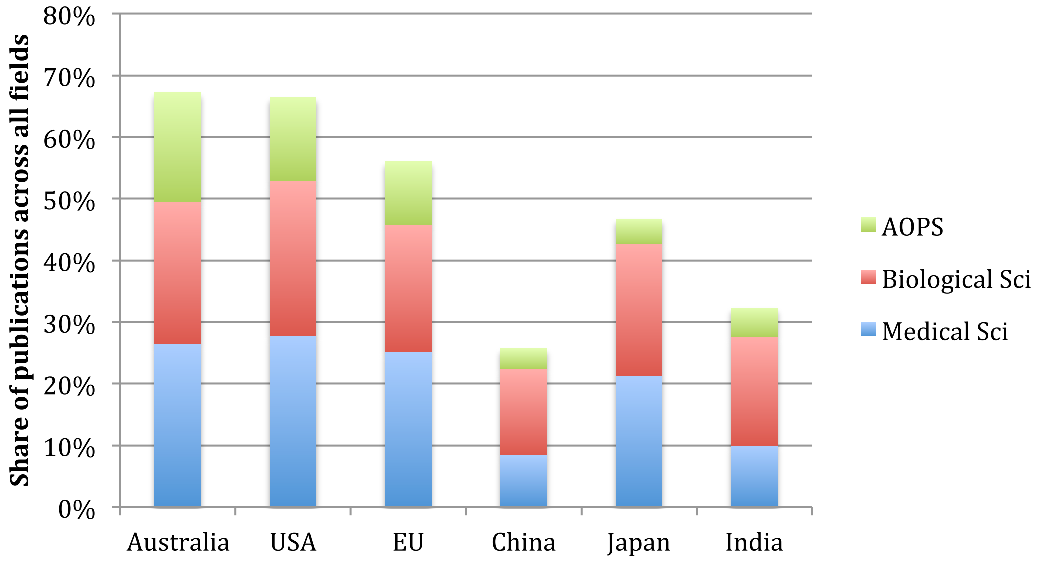
Note: Figure reproduced from Barlow 2009, based upon OECD data. R&D expenditures by universities and private non-profit research institutes have been combined. US universities' data has also been corrected to account for the lack of reporting of capital expenditures. The figure assumes that US universities make capital R&D expenditures at roughly the same rate compared with current expenditures as Australian universities do.

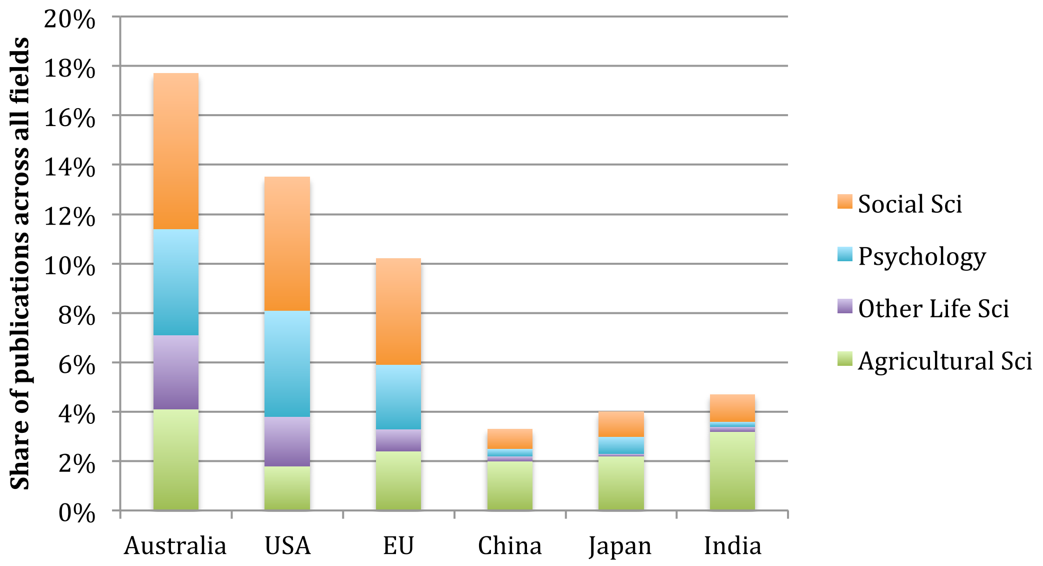
The mixture of investment across government agencies, universities, and private research institutes arguably provides Australia with a broader mixture of options for connecting with US research than is true for other developed countries. Whether Australia has been able to exploit this congruence, though, is another matter – and is doubtful to some degree given the data about co-authored scientific articles presented above in table 2.3, suggesting that policies on international collaboration have failed in certain respects over recent years.

This noted, the data on national activity by research field show that the US and Australian researchers systems do provide a very promising platform for bilateral collaborative research activity. Publications data are closely aligned with public sector research activity, and figures 3.10 and 3.11 show the proportion of scientific outputs across thirteen field clusters for Australia, the US, and a range of other regions.

It is obvious from these figures that Australia and the US are both overweight in life sciences and social sciences, and underweight in physical sciences and engineering compared with Asian nations in particular. The US and Australia are especially unusual for having more than 50% of their scientific outputs in the life sciences, and for having less than 20% of their outputs in the core disciplines of physics and chemistry.

Figure 3.10 – Share of national outputs in the life and social sciences



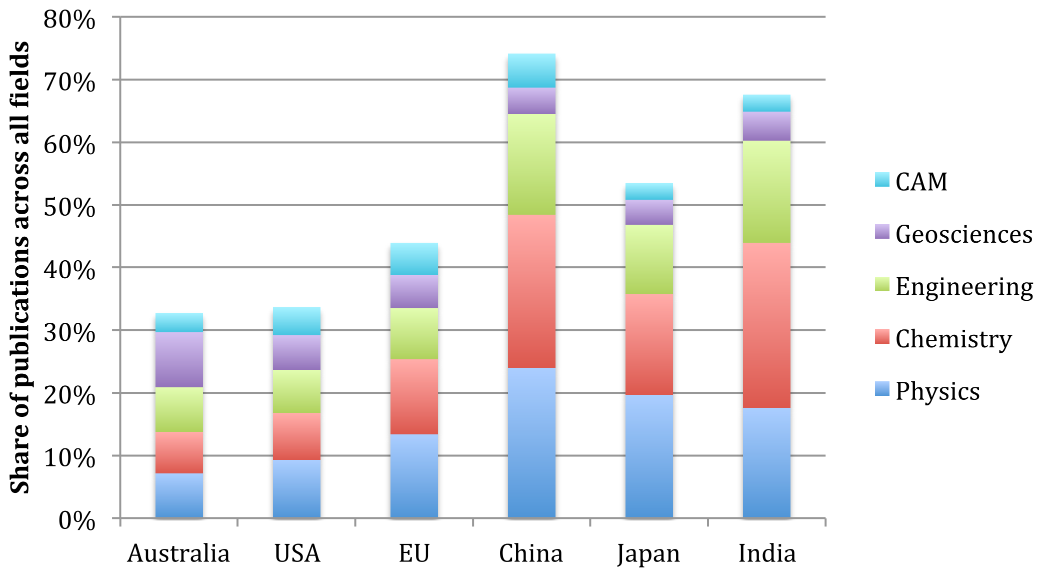


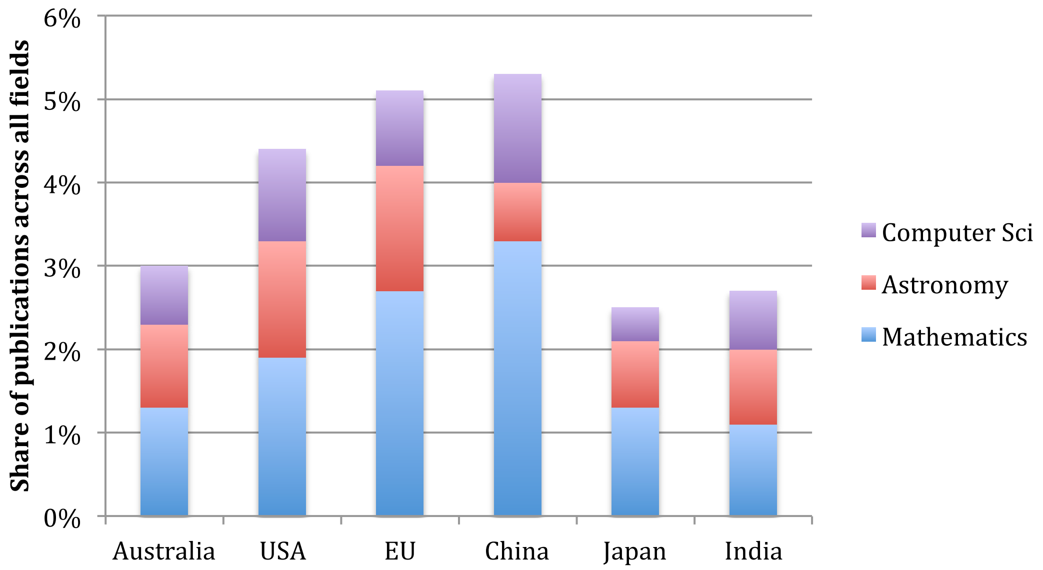
Note: Derived from NSF 2010. The first graph shows life and social sciences as a share of total national outputs, while the second breaks down the outputs designated as "AOPS", which encompasses agricultural sciences, other life sciences, psychology, and social sciences.

While similar in these respects, there are still points of variation that are worth picking out. From the figures, it is clear that Australia has a high share of outputs in agricultural sciences and geosciences compared with the other nations shown, including the US. Likewise, it would seem that Australia's national weightings in physics, chemistry, mathematics, and computer science are low compared not only with other Asian nations but also with the US.

By contrast, the scale of Australian research endeavours in agriculture and geosciences is likely to render Australian research especially visible to prospective US partners in these fields. This notion is strengthened by the citation data shown separately in table 3.12. These are areas where citations per Australian authored papers have been close to US norms over the past decade.

Figure 3.11 – Share of national outputs in the physical, engineering, and information sciences





Note: Derived from NSF 2010. The first graph shows the physical, information, and engineering sciences as a share of total national outputs, while the second breaks down the outputs designated as "CAM", which encompasses computer sciences, astronomy and mathematics.

US researchers are also likely to have good awareness of Australian research in the biological and medical sciences, not least in our own region because of the low degree of focus in these fields among leading Asian countries. The quality of Australian papers in these fields however (as measured by citations per paper, and summarised in table 3.12) is not quite so strong relative to US performance.

One cannot predict precisely from national publication metrics or citation metrics which fields will have the greatest levels of bilateral collaboration. Some disciplines are inherently more collaborative than others. In addition, apparent alignment at the field level may belie disconnections at the subfield level. Australian plant scientists, for example, have historically studied wheat, while US plant scientists have taken greater interest in corn. The interests of these two communities have not necessarily been closely aligned.

Nonetheless, the point can be made that the Australian portfolio by broad field of activity closely mirrors that of the US. Relative to the US, Australian researchers generate a solid number of outputs across all the twenty-two fields listed in table 3.12. The quality of outputs, as measured by citations per paper, is more variable (an issue to which we will return), but the opportunities for collaboration clearly encompass the full range of disciplines.

Table 3.12 – Australian papers and citations per paper by research field relative to the US

Field	Australian papers in the field as a % of US papers in the field	Citations per Australian paper in the field as a % of citations per US paper in the field
Plant & animal science	17%	91%
Environment / ecology	15%	94%
Geosciences	15%	90%
Space science	9%	93%
Mathematics	8%	94%
Agricultural sciences	18%	80%
Engineering	9%	86%
Clinical medicine	9%	83%
Immunology	9%	83%
Microbiology	9%	83%
Pharmacology & toxicology	7%	81%
Social sciences, general	10%	76%
Psychiatry / psychology	9%	78%
Biology & biochemistry	8%	77%
Physics	7%	73%
Molecular biology & genetics	6%	76%
Materials science	11%	63%
Economics & business	10%	49%
Computer science	10%	65%
Chemistry	8%	66%
Multidisciplinary	7%	54%
Neuroscience & behaviour	6%	66%

Note: (i) Derived from ESI 2010. Includes publication and citation data for the period 2000 to 2010. Note that there is evidence that some disciplines (such as physics) have significantly improved citation performance in Australia over the latter half of this decade. (ii) Data are ordered first into bands by the ratio of citations per paper (final column) and then re-ranked within each band by ratio of papers (middle column).

Elsewhere in this report we will look in greater detail at the implications of the apparent congruence in emphasis across both nations' public research portfolios. In one other respect however it must be remembered that the two innovation systems have cultivated quite different expectations from their public-sector researchers.

For each of the four main sectors performing R&D in Australia and the US, figure 3.13 shows the division of activity, as measured by expenditure, between basic research, applied research, and development. Relative to the US:

- Australian universities report performing a significantly lower proportion of basic research;

- Australian government agencies report performing a significantly lower proportion of development work; while

- Australian private non-profit research institutes report a fairly similar distribution of R&D by type of activity.

Table 3.13 – The split of activity between basic research, applied research, and development by sector, 2007-08

	Business Sector		
	Basic research	Applied research	Development
USA	5%	21%	74%
Australia	6%	34%	61%
	Higher Education Sector		
	Basic research	Applied research	Development
USA	71%	21%	8%
Australia	50%	41%	9%
	Government Sector		
	Basic research	Applied research	Development
USA	18%	28%	54%
Australia	30%	56%	14%
	Private Non-profit Sector		
	Basic research	Applied research	Development
USA	50%	33%	17%
Australia	43%	35%	22%

Note: Derived from NSF 2010 and ABS 8112.

This may not be significant. These data are derived from surveys, and American and Australian researchers may have very different views of what these terms mean. But the observations do prompt questions.

Are university researchers with a basic research focus more likely to want to work with other basic researchers? Is the applied focus of research at Australian universities restricting Australian researchers' potential to work with partners in US universities? Are Australian government agencies more likely to find interested partners within US universities than within US government agencies? Does the US government sector provide an alternative avenue from the private sector for the development of Australian technologies?

The answers to these questions may not matter much to individuals or firms in Australia trying to engage with organisations in the US, but at a systemic level they are worth thinking about. For Australian policymakers interested in fostering enhanced collaboration with the US research base, generic actions such as moving the Australian higher education research portfolio further down the basic end of the spectrum may prove just as effective in increasing the number and quality of US collaborations as more specific and targeted collaboration schemes would be.

Recommendations

3. Policymakers should recognise that the Australian and US innovation systems have greater similarities in their public research systems than in the R&D portfolios of their business sectors.

4. The path of least resistance for governments interested in bringing the Australian and US innovation systems closer together will be to focus on public sector research policy rather than industry policy.

4. DRIVERS OF COLLABORATION

Given the dominance of the US within the global economy of ideas, it may seem obvious that relationships with American researchers are useful to Australians. Likewise, given the scale and growth in collaboration, presumably these same relationships are also of utility to individuals and organisations in the US. What, in a more specific sense though, motivates researchers in these two countries to work together?

In the previous section, we identified ways in which the structure of the research communities in the US and Australia are aligned, providing a platform for collaboration across the two societies. But alignment of interest by discipline or sector does not motivate collaboration; it merely creates the conditions for collaboration.

In this section, we summarise the specific drivers of US-Australian collaboration. We argue that the underlying motivations for collaboration are quite often asymmetrical: the incentives for collaboration in the US are often quite different from those operating in Australia. We suggest, however, that the policy frameworks supporting research in both nations provide good opportunities for increasing the incentives for bilateral collaboration.

4.1 Drivers of collaboration

As a general rule, researchers collaborate because it allows them to ask questions and to find answers that they could not get if they worked on their own. By way of illustration:

- in some areas, the questions being asked may be sufficiently complex that they can only be answered via a collaboration of researchers with complementary expertise;

- in some areas, the size of questions and the scale of activity (as measured by the infrastructure required, or the size of the teams, or the access to different environments) required to answer them may necessitate joint work; while

- in some areas, the specific drivers may be more social in nature – for instance the policies of journals, institutions, learned societies, and governments may themselves mean that funding or publication requires collaboration.

In nearly all instances, however, the same basic principle applies: researchers are collaborating to do things that simply they couldn't do on their own.

Now this general principle arguably applies equally to both American and Australian researchers. It is a universal principle and, in some respects, it fosters a disregard for national boundaries. The best researchers, for instance, often say that they simply try, within the constraints of the funding and the networks open to them, to form the optimal teams for the problems they are working on, regardless of issues like nationality or geography. According to this thesis, the most important determinants of international collaboration are really the same everywhere: expertise, track record, and personal relationships.

In practice though things are not so simple. The implications of this general rule about collaboration are not really straightforward in practice and are rarely equivalent among all parties. For our study, several researchers and research administrators were asked what they saw as the most important drivers of (and benefits from) US-Australian collaboration. Many of these ideas are listed below in box 4.1 and box 4.2.

The first observation to be made about these lists is that they are not symmetrical. In practice, the factors that drive Australians to collaborate with Americans are sometimes quite different from the factors that drive Americans to collaborate with Australians. One implication here is that presumptions by both parties about the other will not always be accurate.

The second observation is that outside a few key areas it looks as though Australians may have greater incentive to build relationships with American researchers than vice versa. If this is true, it is a consequence largely of the disparity in the scale of the two nations' research capabilities discussed earlier, but may also imply (a) that Australians do not always end up working with the best Americans and (b) that Australians may sometimes feel hard pressed in negotiations around joint research with US organisations.

This said there are clear areas where Australia can offer particularly strong and distinctive attributes for attracting American collaborators. The idea of the unique Australian resource is an extremely powerful one in areas of research, like astronomy, where geography is important. Similarly, the fact that Australia and the US share strategic interests has been critically important in fostering deep relationships in defence science between the two nations.

Other ideas listed in box 4.2 provide potential advantages, but would not be considered primary drivers of collaboration. The attractiveness of the Australian landscape and lifestyle (and the cultural familiarity of Australian society) is an important inducement but is unlikely to be the main motivation for Americans to collaborate with Australian researchers. Likewise, while Americans may derive efficiencies by teaming up with Australians in key areas, the benefits would be considered of secondary importance behind other factors.

This leaves the critical issue of research quality. Table 3.12 in the previous section showed the low citation impact of Australian publications relative to American ones across a range of fields. The data here suggest that in many areas the quality of Australian research is currently more likely to serve as a deterrent than an inducement to collaboration with Americans.

Box 4.1 – Benefits to Australian researchers from US collaboration

There are many reasons for Australian policy-makers to take an interest in driving research collaborations with the US.

- *Acquiring "effective" scale for Australian research* – The scale of R&D investment in the US is more than 20 times greater than the scale of R&D investment in Australia. (See OECD 2010.) As a consequence, US partnerships afford Australian researchers with important opportunities to (a) access a breadth of expertise that simply doesn't exist in Australia, (b) participate in bigger team research projects than would be possible to implement in Australia, and (c) access more expensive and powerful infrastructure than exists in Australia.

- *Access to the frontiers of knowledge* – The US remains a dominant force globally in research, a commanding producer of new knowledge globally, and the lead nation in global research as measured by citation impact. (See Barlow 2008 and Adams 2010.) If Australians wish to remain connected to the latest trends in knowledge production, they will benefit by nurturing ongoing close links with the US.

- *Raising Australian standards* – The US arguably supports the world's most competitive national research environment, hosting a disproportionate share of high-performing individuals and institutions. (See for example ARWU 2009 and ISI 2010.) By connecting with the US, Australian researchers and research organisations have a powerful mechanism for enhancing their own performance in research.

- *Raising perceptions about Australian standards* – Australian research is cited on average at significantly elevated levels when Australians co-publish with Americans. Australian articles published with US co-authors receive more than 50% more citations than Australian articles published without any international co-authors (Matthews 2009). By connecting with the US, Australian researchers may have a mechanism for enhancing not just the quality but also the international visibility of their research.

- *Gaining access to a large and sophisticated market* – The US economy provides a natural market for many Australian ideas, and represents a potential source both of development funding and of expertise in finding a path to market for the outcomes of Australian research. This is especially significant in high-technology areas like biotechnology, defence technology, aerospace, and manufacturing.

- *Furthering common strategic interests* – The US and Australia face similar strategic challenges relating to issues like national security, demography, rising healthcare costs, the control of infectious disease, natural resource management, and so on. By working with the US, Australian researchers can often advance national strategic interests more rapidly than would be possible working alone.

Box 4.2 – Benefits to US researchers from Australian collaboration

There are many reasons for US policy-makers to take an interest in driving research collaborations with Australia.

- *Access to outstanding researchers* – The best researchers typically want to work with others of similar calibre. Not all Australian researchers would be considered outstanding in the US context, but some are. Not all Australian research organisations have a strong international reputation, but some do. Where Australia supports outstanding researchers, US researchers are more likely to be drawn to work with them.

- *Access to unique environments and facilities* – Australia provides stable, developed-world access to several unique environments (e.g. the southern sky, the southern ocean, the barrier reef, the tropical environment of the north, the Australian terrestrial ecosystem, and several geological environments). These are unique resources for research, providing a focus for collaboration across specific fields like astronomy, earth systems science, infectious diseases, and biodiversity.

- *Access to "similar but different" datasets* – Australia can also provide an effective social laboratory for studying many problems analogous to those experienced in the US – although placed in a different context. Australia offers opportunities in this respect especially in epidemiology, population studies, studies of minority populations, and across the social sciences generally.

- *Efficiency dividend* – In selected areas American researchers can derive logistical or cost benefits by working with Australians. For example, US researchers seeking access to the Antarctica have long sought logistical collaborations with Australian scientists; while field researchers working on seasonally dependent organisms have been able to double their productivity by working part-time in the southern hemisphere.

- *Experience of the Australian lifestyle* – Australia is a beautiful country, populated by friendly, English-speaking people, and these two facts seem generally to be appreciated among educated Americans. Many Americans apparently love Australia, and the desire among American researchers to travel for lifestyle purposes should not be underestimated as incentive for bringing US researchers to Australia.

- *Furthering common strategic interests* – The US and Australia face similar strategic challenges relating to issues like national security, demography, rising healthcare costs, the control of infectious disease, natural resource management, and so on. By working with Australian researchers, in niche areas of local expertise, Americans can often advance their own national strategic interests more rapidly than would be possible working alone.

Having noted these points, there are four obvious areas that can be regarded as important for Australian policymakers interested in increasing the scale and quality of collaboration with US researchers, especially in the public sector:

- *Research quality* – An ongoing policy emphasis on improving the quality of Australian research outputs will help to make Australians more visible and more attractive to potential research partners in the US.

- *Unique resources* – Building capacity and infrastructure around Australia's unique resources is an important mechanism for fostering globally distinctive capabilities in Australia that others, including US researchers, will want to link to.

- *Personal relationships* – Placing Australians in US research environments will be pivotal in building the experiences and the personal relationships necessary to understand what drives collaboration from the American point of view.

- *Strategic interest* – In areas (like national security) where US researchers have strong incentives to work with trusted international partners, Australians have a decisive comparative advantage in developing US partnerships.

4.2 Policy alignment

In addition to the generic points raised above, government policy can also create other incentives to foster international collaboration in research. However, there are currently few specific policy instruments for building links specifically between Australia and the US, the main exception being the formal, deep and enduring policy relationship that exists in defence.

This said, there is alignment of research policy across the two research systems, creating good conditions for bilateral collaboration, even if there are not yet explicit programmes directed to these ends. Below we look at this alignment from two perspectives: by comparing the policy framework for research; and by contrasting the present government priorities for research in both countries.

The policy framework for research is extremely diverse in the US, involving a wide variety of funding mechanisms and performing agencies. This diversity, coupled with a tendency for supporting investigator-lead (i.e. bottom-up as opposed to top-down) research projects, means that the potential for government direction is not always clear-cut. It means that international collaborations are in general more likely to be initiated by grassroots interest than via federal policy directives.

There are similarities though in the policy mechanisms used to support research in the two countries. Three key points of this similarity are summarised as follows:

- *Similar approach to industry policy* – Both nations have essentially free market industry policies complemented by tax concessions (or credits) for R&D investment and some direct grants for industrial R&D projects.

- *Similar use of national competitive grant processes* – Both nations provide funding to university researchers via peer reviewed competitive grant processes in the fundamental sciences, engineering and technology, social sciences, medical and health sciences, and humanities.

- *Similar emphasis on mission-oriented research in government agencies* – Both countries support a balance between curiosity-driven research, performed largely in universities, and a more mission-oriented style of research performed in government agencies.

The similarities suggest that a simple way of positioning the Australian research system in order to drive collaboration with the US would be to harmonise the broader research policy arrangements across the two countries before worrying about the development specific programmes targeting collaboration.

For example, coordinating funding cycles and adopting related processes across grant awarding bodies should increase the ease with which programmes targeting collaboration could be implemented in the future – including the ease with which funding is able to flow across jurisdictions.

Currently NIH awards are made to Australian institutions without the accompanying overhead that is made to US institutions and without the overhead allocation that accompanies NHMRC grants. Yet the direct flow of NIH funding to Australian institutions is now around $14 million annually, and the indirect flow of grants (i.e. where Australian institutions receive funding via subcontract to a US NIH grant recipient) is likely to be much higher than that.

If bilateral funding activity of this kind continues to grow, then matching processes will eventually need to be implemented to ensure that the work supported in this way is properly resourced and is also not diluting Australian Government investment in institutions that is intended for other uses.

Issues of comparative process, like this, will become increasingly important in an increasingly globalised context and may ultimately prove more important (and certainly more systemic) in enabling collaboration than targeted schemes that invest in a relatively small number of joint projects.

Another example, where harmonisation of policy arrangements could make a significant difference in bringing the two research systems closer together, can be found in the mechanisms that are used to establish formal bilateral relationships between US and Australian government agencies.

Establishing formal agreements with government agencies is probably not a straightforward exercise anywhere in the world. Australian researchers however have reported particular obstacles in arranging formal agreements with US

Government research agencies. Indeed there have been instances where research organisations funded by the Australian Commonwealth have been compelled to established companies expressly to expedite relationships with US Government Laboratories because the process for signing an agreement directly at the agency-to-agency level is too complex and difficult.

Of course most of the collaboration between US and Australian agencies goes on at the level of individual researchers. Collaborative activity can usually occur without formal agreements. Nonetheless a simplification of process, and an improved understanding on both sides of the steps necessary to create formal partnerships between government research agencies, could presumably help agencies with mission-oriented research projects to align their objectives and work on problems in complementary ways.

Moving to a higher level, perhaps the most obvious area where harmonisation could have a big impact is in the selection of national research priorities.

Top down policies to foster collaboration are unlikely on the whole to achieve much in the US context, since the research system there is so decentralised. There may be a place for such approaches specifically in stimulating inter-agency activity, but even is this case policies are likely to be implemented at the agency level rather than the national level.

National research priorities are neither comprehensive nor excessively prescriptive in the US or in Australia, but in both countries they do provide a mechanism for bridging research within topical and important themes across the whole of government.

The current areas of federal government priority for research in Australia and the US are summarised in box 4.3 and box 4.4. It can be seen from these boxes that the Australian priorities (which have lasted almost a decade) are broader than the more White House priorities (which are designated only for a year). Nonetheless there are clear areas of overlap in the areas of:

- frontier technologies for industry;
- improving health outcomes;
- energy technologies;
- climate change;
- the management of natural resources; and
- national security.

While this bodes very well in principle for policymakers with a desire to bring the US and Australia closer together, and suggests immediate possibilities for areas where Australians and Americans could join forces around research themes of common national interest, one should be cautious about jumping to hasty conclusions about the congruence of whole-of-government approaches to research in the US and Australia.

Box 4.3 - Priorities of Australian federal research policy

Since 2002, the Australian Government has had four broad research priorities. (These complement newer innovation priorities, which are more structural in nature but do not identify specific areas of research.) These research priorities have been refined slightly since 2002, but have acted as long-term priorities for government-sponsored research in Australia.

(i) **An environmentally sustainable Australia** – involving support for (a) improving water productivity and protecting rivers and groundwater; (b) transforming resource-based industries to deliver wealth while protecting the environment; (c) overcoming soil loss, salinity and acidity; (d) reducing and capturing emissions in transport and energy generation; (e) managing, protecting, and finding economic value in Australia's biodiversity; (f) advancing the exploration and development of deep-earth resources and improving extraction processes while minimising ecological and social impacts; and (g) increasing our understanding and responding to the impacts of climate change and variability.

(ii) **Promoting and maintaining good health** – involving support for (a) counteracting the impact of genetic, social and environmental factors which impact negatively on the health of infants and children; (b) developing better strategies to improve the health of ageing people; (c) ethical, evidence-based preventative healthcare; and (d) understanding the relationship between health outcomes and Australia's social and economic fabric.

(iii) **Frontier technologies for building and transforming Australian industries** – involving support for (a) breakthrough science that can facilitate technological innovations; (b) emerging technologies such as nanotechnology, biotechnology, and ICT that will underpin the industries of the future; (c) advanced materials for diverse applications; (d) smart information use for business and creative applications; and (e) promoting an innovation culture and economy by understanding the factors conducive to innovation and its acceptance.

(iv) **Safeguarding Australia** – involving support for (a) protecting Australia's critical infrastructure (including financial, energy, communications, and transport systems); (b) enhancing Australia's capacity to interpret and engage with other societies in its region and around the globe; (c) protecting Australia from the impact of invasive species and pests; (d) developing rapid identification techniques to protect Australia from terrorism and crime; and (e) developing transformational defence technologies and modes of operation.

Box 4.4 – Priorities of US federal research policy

The 2012 White House Budget required agencies to redirect their research resources "as appropriate, and consistent with their mission" to address six challenges. These challenges (see EOP 2010) are summarised as follows:

(i) **Promoting sustainable economic growth and job creation** – involving support for (a) manufacturing, especially in robotics, cyber-physical systems, and flexible manufacturing, (b) biotechnology, especially to address critical national needs in agriculture, energy, health, and environment, and (c) two specific areas currently receiving interagency investment, nanotechnology and data-intensive research.

(ii) **Defeating the most dangerous diseases and achieving better health outcomes for all while reducing health care costs** – involving support for (a) technologies like imaging, bioinformatics, and high-throughput biology to accelerate discovery in the life sciences, and (b) technologies to reduce the time needed to develop vaccines for future pandemics.

(iii) **Moving toward a clean energy future to reduce dependence on energy imports while curbing greenhouse gas emissions** – involving support for (a) clean energy technologies like solar energy, biofuels, and green building technologies, and (b) R&D on advanced vehicle technologies.

(iv) **Understanding, adapting to, and mitigating the impacts of global climate change** – involving support for (a) climate change science, and (b) research for measuring, reporting, and verifying greenhouse gas emissions.

(v) **Managing the competing demands on land, fresh water, and the oceans for the production of food, fiber, biofuels, and ecosystem services based on sustainability and biodiversity** – involving support for (a) integrated ecosystem management research, and (b) ocean observing capabilities, including under conditions of climate change and in the context of stressors such as oil spills.

(vi) **Developing the technologies to protect our troops, citizens, and national interests** – involving support for (a) cybersecurity R&D, (b) research that will assist in establishing nuclear non-proliferation, and (c) research into chemical and biological agent defences.

Looking in detail at the priorities listed in box 4.3 and box 4.4, the alignment is not perfect. While the goals are often the same, the focus is often slightly different. In many areas there are subtle points of difference in the way these priorities are articulated by the two governments, and these differences are worth elaborating upon:

- *Frontier technologies* – Both nations have a focus on biotechnology and nanotechnology, but the US Government also has a more overt emphasis on biotechnology (explicitly mentioning agricultural, environmental and energy biotechnology as well as health biotechnology) and an additional focus on robotics, flexible manufacturing, and data-intensive research, whereas the Australian Government also has a focus on materials, innovation, and the use of information specifically within businesses and creative industries.

- *Improving health outcomes* – Both nations have an interest in improving the health of their populations through research, but the US Government has a focus on new technologies, on accelerated discovery, and on reducing healthcare costs, whereas the Australian Government has a focus on prevention, health, and the relationship between health and social and economic factors.

- *Energy technologies* – Both nations are interested in research to reduce or control carbon dioxide emissions in transport and energy generation, but the US Government is also interested in reducing its dependence on energy imports.

- *Climate change* – Both nations are interested in understanding, adapting to, and mitigating the purported impacts of climate change, though the US Government has particular interests at the present time in improving its capacity to measure, report and verify greenhouse gas emissions, and in improving its ocean observing capabilities.

- *Management of natural resources* – Both nations are interested in the management and conservation of ecosystem services and in biodiversity, though the Australian Government has also identified other explicit interests in water, in land degradation and salinity, in mining, and in protecting Australia from invasive species.

- *National security* – Both nations have a broad focus on research to protect their troops, citizens, and national interests, but the US Government is especially focused on cyber-security, nuclear non-proliferation, and chemical and biological agent defences, while the Australian Government has more generic aspirations, including the surprising aspiration of better understanding others.

These differences should be appreciated in those instances where governments or government agencies seek to define areas of common focus for their research agencies, based upon common perceptions of national priority. They may indicate that Australia in particular would benefit from a formal, regular dialogue between say the Australian Chief Scientist and the US Director of the Office of Science and Technology Policy, if such a thing does not already occur.

In any event, they illustrate a theme that is consistent across many areas of research policy: a story of Australian and US governments operating with very similar, but not perfectly harmonised objectives and processes.

4.3 Policy misalignment

This theme of improving policy alignment can be extended to other areas where there is currently much less similarity of practice. In particular, there are two elements of policy where there is currently very little harmonisation and where greater alignment might reap substantial benefits for collaboration:

- research training; and
- commercialisation of government-sponsored R&D.

In the case of research training there appears to be the capacity for some big changes. Although there are similarities in the style of programmes managed through the ARC or the NHMRC and the NSF or the NIH, the same cannot be said of the way PhD training is conducted in the two countries. US PhDs tend to take longer and tend to involve a considerable coursework component than is the case in Australia.

Part of the reason for the difference here no doubt relates to the undergraduate experience in the two countries. Whatever its cause though, there is evidence that students do not travel as much between Australia and the US to do PhDs as might have been expected given the linguistic and cultural match.

The survey of earned doctorates, which analyses the countries of origin for international students earning doctorates at US colleges and universities, consistently shows that Australians account for less than 1% of US international PhD students graduating from US universities. Indeed, in 2008 and 2009 Australia was outside the top 40 nations by number of citizens earning doctorates at US colleges and universities (SED 2010).

According to this survey, only 66 Australians completed a PhD in the US in 2007 – a figure equivalent to less than half a percent of US international PhD students completing that year and equivalent to only around 1.5% of total PhD completions from Australian universities (not counting international students).

Some Australian research students would of course have opportunities to travel to the US on a temporary basis for conferences, or to access equipment, or as part of a collaborative venture during the course of their Australian PhD projects. By and large though Australian students are evidently not travelling to the US for an extended period in order to do PhDs at US institutions.

Nor do they have many opportunities for participating in formal collaborative degree programmes. In 2008, the US Council of Graduate Schools surveyed its members about their participation in international collaborative degree programmes. They found that of those institutions offering international collaborative degree programmes at the masters or PhD level, only 3% had a collaborative masters degree programme with an Australian institution and none had an equivalent programme at the PhD level.

By contrast a significant number of institutions had collaborative degree programmes at the PhD level with universities in Europe, China, and South Korea (CGS 2010).

The implication of all this is more profound than might be assumed just from a consideration of the relationship between American and Australian researchers. Because of the large number of outstanding young researchers from all over the world who come to the US to do their graduate work, the US PhD provides not just an education but also an opportunity for researchers to build a truly global network early in their careers.

Australians who do their graduate work in Australia will not always have this same opportunity.

Research training then may be one area where policymakers can make a rapid difference to the level of engagement between American and Australian researchers over the long term – although the initiative on this issue would likely need to be taken on the Australian side as there is no central agency in the US responsible for graduate research training.

The other area that seems ripe for much greater alignment and for bilateral reform relates to the commercialisation of intellectual property developed through joint projects.

Australian researchers in the public sector often comment on the challenge of dealing with the "unreasonable" policies regarding intellectual policy implemented by US agencies. One Australian researcher observed in a background survey for this report, "It is US policy that if you enter a contract with the Department of Energy, they will steal your IP."

On the other hand, US researchers often comment on the risk-averse, lengthy, and bureaucratic agreements that are typically used by Australian institutions when formalising the intellectual property arrangements arising from joint research projects.

These issues may be difficult to resolve. For example, the development of a high-level inter-government agreement establishing a framework for dealing with intellectual property in joint ventures between American and Australian government entities may be helpful; but it might also create as many problems as it solves.

Alternatively, the publication of open guidelines for government-funded research entities could make IP negotiations less surprising for all parties (and presumably therefore also less painful); but such an approach would do little to change whatever underlying impediments exist in practice.

If dealing with negotiations at the front-end of a collaboration is challenging, there may be other, simpler policies that can be implemented in Australia to improve what happens at the back-end, when a public-sector research collaboration transitions to commercialisation.

The US arguably has better mechanisms (both private and public) for commercialising public research than Australian does. The scale and structure of its economy means that in many areas there is far more development expertise and development investment than is available in Australia. There are, consequently, strong incentives for Australian researchers in many areas to push the results of their research ultimately into development in the US.

Yet Australians can be disadvantaged in this process by geography, by their lack of US networks, by their capacity to raise funds for development locally, and by their general lack of visibility in the US.

Box 4.3 – The SBIR and STTR programmes

Small Business Innovation Research (SBIR) programme

The SBIR programme requires all US federal agencies with an extramural R&D budget over $100 million to set aside 2.5% of this budget for small businesses to engage in R&D for commercialisation. Grants are typically modest in size, competitively allocated, milestone-driven. The aim of the programme is to increase private sector commercialisation of federal R&D.

Eleven federal agencies participate, including the National Science Foundation, the National Institutes of Health, the National Aeronautics and Space Administration, the Environmental Protection Agency, the Department of Defense, the Department of Homeland Security, the Department of Agriculture, and the Department of Energy.

Small Business Technology Transfer (STTR) programme

The STTR programme requires US federal agencies with an extramural R&D budget over $1 billion to set aside 0.3% of this budget for small businesses to collaborate formally with a research institution in R&D. Grants again are typically modest in size, competitively allocated, milestone-driven. The aim of the programme is to increase private sector participation in federal R&D.

Five agencies participate in this programme: the National Science Foundation, the National Institutes of Health, the National Aeronautics and Space Administration, the Department of Defense, and the Department of Energy.

Box 4.5 summarises two US policy initiatives, one of which has been operating for more than 20 years, to support the commercialisation of research in small US firms. There are no analogous programmes in Australia, and Australian firms are not eligible to apply for these schemes in the US.

This is an area where policy harmonisation might bring considerable benefits to Australian researchers. If similar schemes existed in Australia, the potential would arise for bilateral projects linking Australian public sector research with both Australian and US development firms, potentially enabling a closer integration of US and Australian innovation and a more effective commercialisation process, to the mutual benefit of all parties.

Recommendations

5. Public-sector policies that raise the quality of Australian research, build around Australia's distinctive resources, place Australians in US research environments, and exploit Australia's history as a trusted, strategic partner to the US will all improve the systemic potential for collaboration with the US.

6. Australian policymakers should harmonise R&D policies – e.g. by increasing inter-governmental discussion about priorities, by moving Australian graduate research education closer to the US model, by aligning competitive grant processes and associated infrastructure support, by simplifying the mechanisms for establishing inter-agency agreements, and by emulating US policy approaches to the commercialisation of public-sector research.

5. AREAS OF EXISTING COLLABORATION

Given the decentralised nature of the US research system, and the importance of bottom-up processes, the most successful way to expand the level of US-Australian collaboration in research is probably to build upon those areas where there is already existing activity.

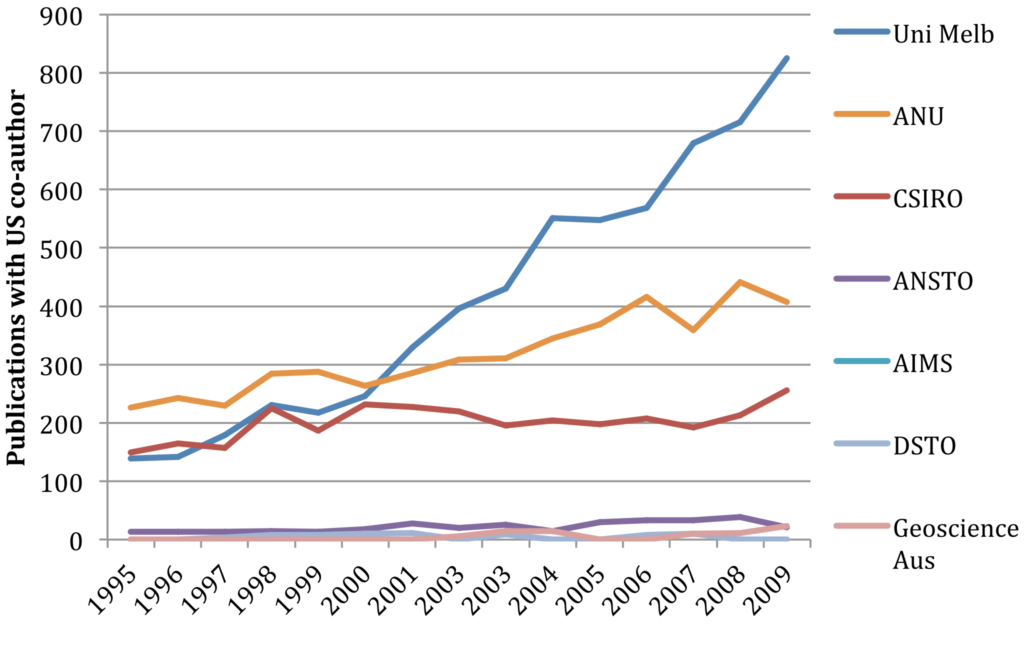
In this section, we look in greater detail at the specific institutions, fields, and sectors where American and Australian researchers are most obviously working together.

5.1 Critical institutions involved in Australian-US collaboration

The big story of the past decade has been the growing importance of universities in Australian-US research collaboration. Historically in Australia the two main organisations involved in research collaborations with US organisations were the ANU and the CSIRO. Both of these organisations were operated as large research institutes with a focus on high-quality research.

Since 2000 however both the ANU's and the CSIRO's level of US engagement has been overtaken by many of the larger Australian universities, which have expanded their research activity and improved their research quality substantially.

Figure 5.1 – Trends in co-authorship with US collaborators among key federal agencies compared with the University of Melbourne



Note: Derived from WOK 2010.

Figure 5.1 illustrates this point very clearly. It presents the number of publications with a US co-author being produced by researchers at the University of Melbourne as compared with the number of such publications produced by researchers at Australian federal research agencies, including the ANU – and it reveals a striking disparity in activity.

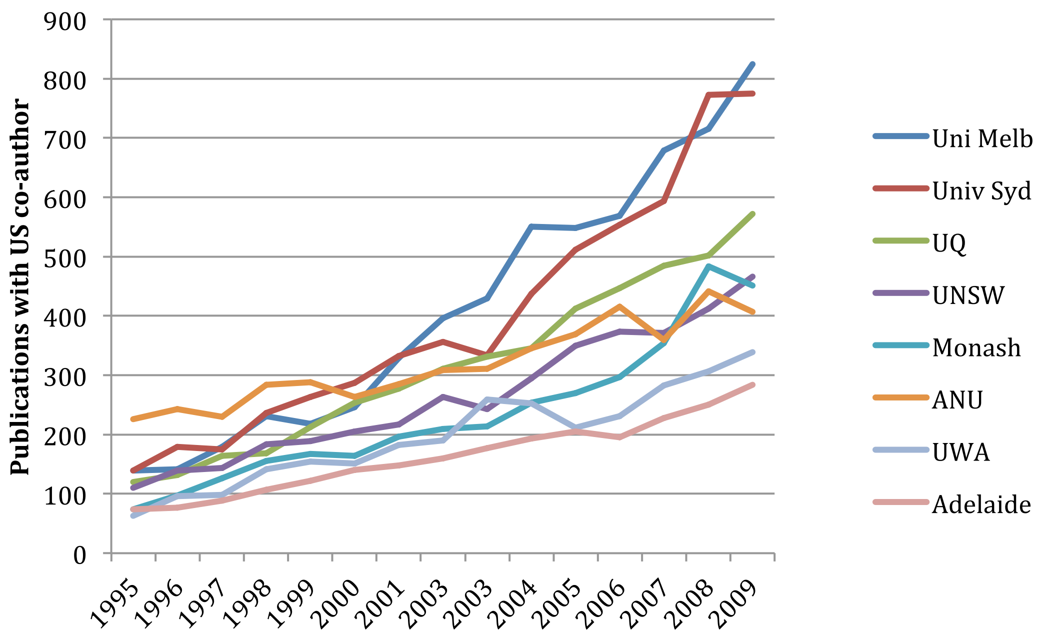
While collaborations have at least grown at the ANU, the figure shows that across the CSIRO, the Australian Institute of Marine Science (AIMS), the Australian Nuclear Science and Technology Organisation (ANSTO), and the Defence Science and Technology Organisation (DSTO) the number of co-authorships with US researchers have remained surprisingly stable.

In the case of DSTO this doesn't bear concern, as publications are not an important output for that organisation. For the other government agencies though it is natural to question why their levels of US engagement have remained so flat, during a period where collaborative university activity has strengthened so markedly.

Figures 5.2 and 5.3 add some depth to this story. They show that the growth in US collaboration at the University of Melbourne is consistent with trends across the Australian higher education sector. Figure 5.2 shows the expansion in university co-authorship with US collaborators for the eight universities with the largest research portfolios, while figure 5.3 shows the trend for a number of other universities with slightly smaller research portfolios.

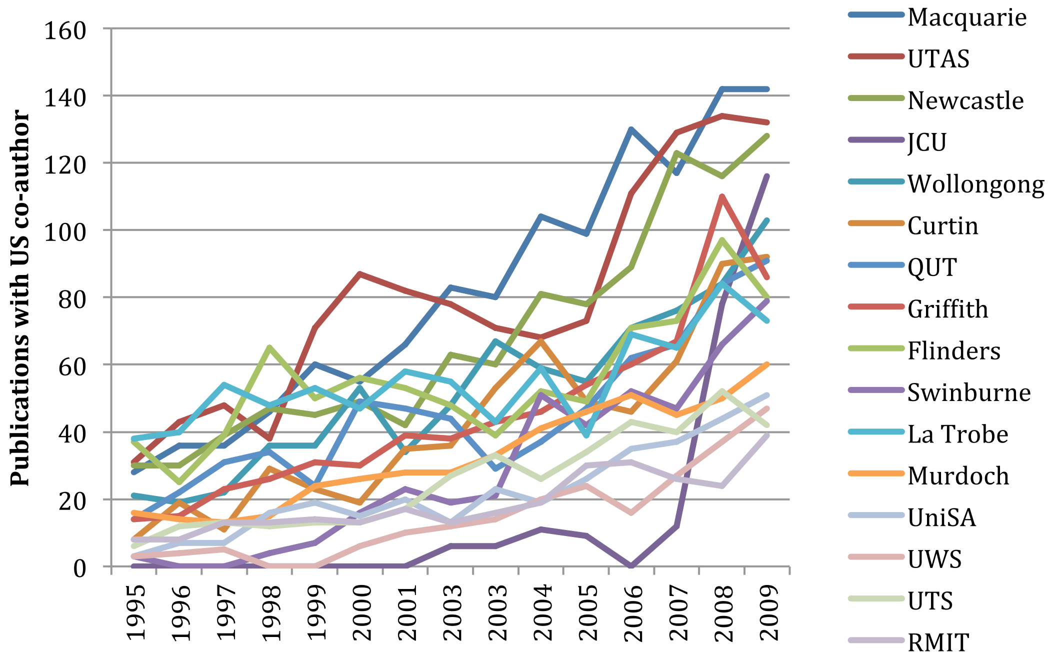
In all cases the story is one of growing US engagement, and even at some of the small institutions (e.g. James Cook University) the up-kick has been dramatic.

Figure 5.2 – Trends in university co-authorship with US collaborators (larger universities)



Note: Derived from WOK 2010.

Figure 5.3 – Trends in university co-authorship with US collaborators (mid-sized universities)



Note: Derived from WOK 2010.

The lesson in all this for policymakers interested in developing the US-Australian research relationship is not straightforward. Using publications data inherently biases the analysis to favour universities – CSIRO for example reports very high levels of engagement with US industry. Nonetheless, government research organisations do publish scientific articles and the data here are consistent with a number of different hypotheses. For instance:

- *Collaboration follows investment* – Australian universities received substantial increases in R&D investment between 2000 and 2009, at a time when project investment in Australian government agencies held fairly steady. According to this argument Australian Government agencies have simply lacked access to the resources to expand their level of engagement with the US.

- *Americans prefer linking to universities* – Given the decentralised nature of the US research system and the emphasis on investigator-initiated projects, it may be that the flexible and decentralised research environment at universities is most conducive to initiating and maintaining collaborations with US researchers.

- *Government agencies are impeded by process constraints* – In the previous section, it was suggested that it is not easy for Australian and US government agencies to enter into formal collaboration arrangements. Yet given the directed nature of research in these agencies, such arrangements may be important in facilitating meaningful collaborations.

Whatever the explanation, it would seem from the data that a concerted focus on expanding the levels of collaboration between Australian government agencies and US researchers would be a useful element of policy at the present time. It would also seem wise to prepare for a slowing in the growth of US collaboration in Australian universities should R&D funding in this sector slow into the future.

Turning next to the other side of the equation, it is worth making some observations about the US partners in these interactions. Interestingly, the vast majority of Americans co-publishing with Australian researchers were based at universities – mirroring the situation in Australia. There was also a surprisingly lack of correlation between time zone and level of interaction.

Table 5.4 counts the organisations with a large number of Australian co-authored outputs by time zone and state. It suggests that collaboration tends to flow with scale of activity rather than with ease of interaction, although there is some evidence of an impact of geography. No other state comes close to California for the number of organisations with really high (>100 co-publications) levels of Australian collaboration. The tendency for east coast institutions to have 50-100 rather than >100 joint publications with Australian researchers likewise suggests that ease of access is not entirely irrelevant in assessing the potential for collaboration.

Table 5.4 – US collaborating organisations by time zone and state, 2009

Time zone	**Pacific**	**Mountain**	**Central**	**Eastern (north)**	**Eastern (south)**
n > 100	8	0	3	8	3
n > 50	12	3	13	28	7
State	**CA**	**MA**	**NY**	**PA**	**TX**
n > 100	7	1	1	3	0
n > 50	10	8	6	0	4

Note: Derived from WOK 2010. The data show the number of organisations with n publications co-authored with Australian researchers. Eastern time zone states are divided into states north of and including Virginia and states south of and including North Carolina. Note that some US government agencies have been left out of the above analysis as they operate across a range of different regions.

While universities predominate in these figures, it is worth mentioning also the main government agencies involved in Australian research collaborations, as evidence by the co-publications data. Over the past decade, at least as determined from this data, the key US federal government agencies listed in order of the scale of their interaction with Australia were:

- NASA;
- the National Cancer Institute;
- the Agricultural Research Service of the US Department of Agriculture;
- the US Geological Survey;
- the Argonne National Laboratory;
- the Centres for Disease Control and Prevention;
- the Los Alamos National Laboratory;

- the National Oceanographic and Atmospheric Administration;
- the National Institute for Allergy and Infectious Disease;
- the Oak Ridge National Laboratory; and
- the Lawrence Livermore National Laboratory.

The top five organisations in this list each published between 50 and 100 papers with Australia co-authors in 2009, although the joint outputs should probably be seen as an underestimation of their importance for Australian research.

The facilities for example at the Argonne National Laboratory (and to a lesser degree at Oak Ridge National Laboratory) have long been used by Australian researchers for structural analysis, though not all of this work would lead to co-authorship on a paper.

ANSTO in Australia has some very enduring relationships with the US National Laboratories at Argonne, Los Alamos, Oak Ridge, and Lawrence Livermore, including interactions in education and nuclear forensics, which do not necessarily lead to research publications.

The Centres for Disease Control and Prevention have a history of international collaboration around disease surveillance and response that is complementary to their research activity.

NASA and NOAA are both a source of data for Australian researchers and many of the activities sponsored by these organisations do not have publications as their primary output anyway.

These points noted, one can suggest (a) that there is a solid level of interaction between Australian researchers and these organisations, and (b) that an Australian policy focus to improve collaboration with US government agencies could sensibly take any of these organisations for its starting point.

In this respect it is worth highlighting the disciplinary focus of the first four organisations in this list:

- space;
- health;
- geosciences; and
- agriculture.

It is probably no coincidence that Australians have found close alignment with US government laboratories in these fields. These are areas where Australians have a perceived historical strength, and it may be that efforts to establish deeper and more formal relationships between the two governments will seem most plausible and valuable from the American point of view in these four fields.

Certainly it would seem likely that Australia will find a larger number of champions for closer Australian ties within those top agencies than in some of the others. The next section looks at the fields of bilateral engagement in greater detail.

5.2 Main fields of engagement

Some indication about fields of collaboration can be obtained by analysing outputs from the Thomson Reuters Web of Knowledge. In this instance, we have counted outputs by subject category, deriving three key measures:

(i) scale of collaboration – average annual publications with both Australian and US authors over the decade 2000-2009;

(ii) intensity of collaboration – joint publications in each subject category as a share of Australia's total output into that subject category; and

(iii) growth of collaboration – the growth in US-Australian joint authored papers by publication count across the two decades, 1990-1999 to 2000-2009.

Now, there are some important notes that must be made about this data and its interpretation.

First, as far as possible it is useful to evaluate both scale and intensity metrics simultaneously. For this reason, in the tables that follow we have often ranked subject categories into bands of performance by one of these two metrics and then re-ranked within each band by the other. This is done to avoid emphasising one metric at the expense of the other.

Second, one should be cautious about aggregating the data shown in these tables, or about counting the number of subject categories clustered around a particular theme. Where a journal is associated with more than one subject category, the number of co-authored publications will be attributed to both categories. This does not prevent one from comparing the scale of activity between two subject categories, but it will lead to errors in some instances (especially in related fields) if one is tempted to add the data together.

Third, it will be seen from the data that the social sciences, arts, and humanities subject categories do not register strongly either by scale of collaboration or by intensity of collaboration. However, it is not possible to conclude from this that researchers in these fields are unengaged with US scholars. On the contrary, the data here is more likely to reflect differences in the nature of collaboration and of the practice of research in these fields compared with the sciences, an issue that will be discussed at greater length below.

These points having been noted the key elements of our field analysis are summarised below in tables 5.5 to 5.8.

Table 5.5 shows the subject categories with very high intensity of co-authorship with US researchers. Some of these subject categories are also areas of very low scale of collaboration (e.g. mathematical psychology and cell & tissue engineering), but many are not.

Table 5.5 – Subject categories where >18% of Australian research papers have a US co-author, 2000-2009

Subject Category	Average annual pubs with US and AUS co-authors	Proportion of total AUS pubs with US co-authors (%)	Growth in US-AUS co-authored papers from 1990-99 to 2000-09
Astronomy & astrophysics	266	48%	2.2 x
Multidisciplinary sciences	107	32%	2.3 x
Physics, particles & fields	44	36%	3.0 x
Genetics & heredity	185	25%	2.0 x
Hematology	138	26%	3.1 x
Meteorology & atmospheric sci.	69	28%	2.1 x
Physics, nuclear	25	25%	1.4 x
Oncology	168	22%	4.6 x
Cardiac & cardiovasc. systems	104	20%	4.4 x
Geochemistry & geophysics	98	21%	2.6 x
Evolutionary biology	74	22%	3.9 x
Biology	65	22%	2.7 x
Physics, multidisciplinary	65	22%	2.8 x
Virology	48	24%	2.6 x
Rheumatology	35	22%	4.8 x
Tropical medicine	18	24%	4.9 x
Neuroimaging	9	23%	8.5 x
Psychology mathematical	4	21%	1.8 x
Biochemistry & molecular biol.	271	19%	2.1 x
Immunology	166	19%	2.1 x
Infectious diseases	71	20%	4.2 x
Developmental biology	37	18%	2.7 x
Biodiversity conservation	32	19%	8.5 x
Business	27	19%	4.0 x
Nuclear science & technology	19	19%	1.7 x
Social sciences, math methods	10	20%	1.5 x
Cell & tissue engineering	5	18%	10.2 x
All fields	**4580**	**13%**	**2.5 x**

Note: Derived from WoK 2010. (i) Subject categories are grouped first by intensity of collaboration (i.e. proportion of Australian publications with US co-authors) and then by absolute scale of collaboration (i.e. average number of annual joint publications). (ii) Shading indicates an especially high growth in co-authorships since 1990-1999.

By contrast, table 5.6 shows the subject categories with high scale of co-authorship. Some of these categories have very low intensity of collaboration (e.g. psychiatry and general and internal medicine) and several have an intensity of collaboration that is below the incidence of US co-authorship across all Australian papers. This latter fact is quite striking given that the figures for "all fields" in these tables include those in the social sciences and humanities where co-authorship rates are naturally low.

Table 5.6 – Subject categories averaging >80 joint US-Australian publications per annum, 2000-2009

Subject Category	Average annual pubs with US and AUS co-authors	Proportion of total AUS pubs with US co-authors (%)	Growth in US-AUS co-authored papers from 1990-99 to 2000-09
Astronomy & astrophysics	266	48%	2.2 x
Multidisciplinary sciences*	107	32%	2.3 x
Hematology	138	26%	3.1 x
Genetics & heredity	185	25%	2.0 x
Oncology	168	22%	4.6 x
Geochemistry & geophysics	98	21%	4.6 x
Cardiac & cardiovasc. Systems	104	20%	4.4 x
Immunology	166	19%	2.1 x
Biochemistry & molecular biol.	271	19%	2.1 x
Peripheral vascular disease	90	17%	4.3 x
Cell biology	136	17%	1.8 x
Ecology	152	16%	4.4 x
Gastroenterology & hepatology	80	16%	3.1 x
Geosciences, multidisciplinary*	103	16%	2.7 x
Endocrinology & metabolism	115	16%	3.0 x
Zoology	81	14%	2.5 x
Neurosciences	170	14%	3.2 x
Environmental sciences	98	13%	3.7 x
Clinical neurology	115	13%	4.9 x
Marine & freshwater biology	80	13%	3.5 x
Pharmacology & pharmacy	95	12%	3.0 x
Public, environ. & occupat. Health	100	12%	3.5 x
Plant sciences	92	12%	1.9 x
Psychiatry	91	9%	4.5 x
Medicine, general & internal	93	7%	2.5 x
All fields	**4580**	**13%**	**2.5 x**

Note: Derived from WoK 2010. (i) Subject categories are ranked by intensity of collaboration (i.e. proportion of Australian publications with US co-authors). (ii) Shading indicates an especially high growth in co-authorships since 1990-1999.

Looking at these two tables, the areas that stand out most clearly for either their scale or their intensity of interaction are as follows:

- *Astronomy and astrophysics* – Nearly half of Australia's astronomy and astrophysics papers over the past decade had a US co-author. This subject category is also the second-largest field by scale of activity, reflecting both the "big science" nature of research in this area and also the advantage provided by Australia's access to the Southern sky.

- *Molecular and cell biology* – A high proportion of Australian publications in journals relating to genetics, hematology, biochemistry, cell biology, and immunology have a US co-author. This reflects not just a global US dominance in these fields, but also the significance of large-scale science and multi-author papers in many of these areas.

- *Cancer, cardiovascular disease, diabetes, obesity, and neurosciences* – There has been strong growth in US-Australian co-authorship in journals relating to oncology, cardiac and cardiovascular systems, peripheral vascular disease, endocrinology & metabolism, neurosciences, and clinical neurology. This has resulted in high scale of collaboration in these areas and strong intensity of collaboration in oncology and cardiovascular research, although the intensity is low in neurology and neurosciences.

- *Earth systems sciences* – Perhaps unsurprisingly, given Australia's strong history of research in these areas, geochemistry and geophysics and multidisciplinary geosciences are also areas with strong evidence of US-Australian collaboration, measured by both scale and intensity. There is also very high intensity of collaboration in meteorology and atmospheric sciences, though the scale and growth of collaboration seem low for these areas given their prominence over the past decade.

- *Biological environmental sciences* – In three key environmental sciences (ecology, evolutionary biology, and biodiversity conservation) there is evidence of either strong scale of interaction or strong intensity of interaction. However, the impact here is apparently focused on bio-environmental systems. Curiously, there is lower intensity of collaboration in journals associated with zoology, marine and freshwater biology, plant sciences, and in journals associated with environmental sciences more broadly defined.

- *Tropical medicine and infectious diseases* – These have been high-growth areas for collaboration over the last decade and Australians publishing in these areas now work with a fairly high intensity of US co-authorship. The absolute scale of collaboration in both these subjects however remains somewhat limited, especially in tropical medicine.

- *Particle physics / nuclear physics / nuclear science and technology* – These are three subject categories where Australia doesn't publish in large volume, but where intensity of co-authorship with the US is high. These are areas where Australians have an important dependence on US partnership due to the scale of infrastructure required to make serious advances in these fields.

- *Multidisciplinary sciences* – This is one of only two subject categories where American and Australian researchers co-published more than 100 papers a year and where more than 30% of Australian publications had a US co-author. This is significant as many of the most prestigious journals (e.g. Nature and Science) are classified in this subject category. The high level of co-authorship here is consistent with anecdotal argument that having US co-authors helps Australian researchers to publish work in high impact journals.

These have been the most obvious and noteworthy areas of interaction over the past decade. But table 5.6 also highlights a few areas of weakness – notably fields where despite a considerable volume of US-Australian co-authorship, the interaction is based upon only a very modest proportion of Australian research.

The subjects that must be mentioned in this context are: pharmacology and pharmacy; public, environmental and occupational health; plant sciences; psychiatry; and general and internal medicine. Not shown in the table too are some other fields with slightly lower but still reasonable scale of collaboration but again with very low intensity. These include: sport sciences; obstetrics and gynaecology; paediatrics; physical chemistry; and surgery.

The significance of this list is largely that one should not conclude from the levels of collaboration in areas like genetics or oncology that all areas of medical or biomedical science support high interactions between American and Australian researchers. In many areas of medical research the linkages are relatively weak.

Table 5.7 – Subject categories with > five fold inter-decadal growth in Australian research papers with a US co-author: 1990-1999 to 2000-2009

Subject Category	Average annual pubs with US and AUS co-authors	Proportion of total AUS pubs with US co-authors (%)	Growth in US-AUS co-authored papers from 1990-99 to 2000-09
Obstetrics & gynaecology	45	10%	5.0 x
Biodiversity conservation	32	19%	8.5 x
Health care sciences & services	26	9%	7.5 x
Critical care medicine	22	9%	6.8 x
Geriatrics & gerontology	20	11%	6.4 x
Dermatology	20	12%	6.2 x
Nanoscience & nanotechnology	18	10%	9.6 x
Gerontology	15	10%	6.9 x
Neuroimaging	9	23%	8.5 x
Philosophy	8	6%	5.1 x
Emergency medicine	7	7%	17.0 x
Family studies	6	10%	5.0 x
Cell & tissue engineering	5	18%	10.2 x
Medicine, legal	3	7%	5.7 x
Psychology, psychoanalysis	1	9%	6.0 x
Literature	1	<1%	6.0 x
Religion	1	<1%	6.0 x
All fields	**4580**	**13%**	**2.5 x**

Note: Derived from WoK 2010. (i) Subject categories are ranked by absolute scale of collaboration (i.e. average number of annual joint publications). (ii) Shading indicates >13% of Australian publications in this subject category had US co-authors.

In this context, it is also important to consider the trends and whether some subject categories are experiencing very significant expansion in US co-authorship. Table 5.7 presents some information along these lines by picking out those subject categories with a very high inter-decadal growth in co-authorships.

One should note here that the vast majority of these subjects have both low intensity and low scale of collaboration. It is interesting, however, to observe that several of these areas have been regarded as exciting growth areas for research over the past decade, regardless of their potential for international collaboration. For example:

- biodiversity conservation;
- health care sciences & services;
- geriatrics and gerontology;
- nanoscience and nanotechnology;
- neuroimaging; and
- cell and tissue engineering.

The momentum that exists in these subjects has probably been compounded by the creation of new journals with a specific focus on these fields over recent years. In addition, the level of outputs in the fields relating to these subject categories is probably under-represented due to a tendency by researchers in many of these areas to publish in more generalist journals.

Nonetheless, data here may indicate that researchers in both the US and Australia would benefit from a push by policy-makers in these areas. Such a move would be consistent with a strategic philosophy that seeks to identify and then accelerate the nascent trends that are already underway in our national research systems.

This raises an interesting dilemma for policy-makers however:

- whether to focus on strengthening activity in those areas where there is demonstrable evidence that the research community already values collaboration; or

- whether to try to build intensity and scale of engagement in areas of broader government priority where collaboration levels may be modest at the outset.

This problem is illustrated (albeit only in an indicative sense) in table 5.8, which looks explicitly at subject categories relating in various different ways to current perceived environmental challenges.

The evidence here suggests that fashion in research, and indeed in government priority specifically, does not necessarily translate rapidly into Australian-US collaboration.

Table 5.8 – Publications in subject categories relating to perceived environmental challenges, 2000-2009

Subject Category	Average annual pubs with US and AUS co-authors	Proportion of total AUS pubs with US co-authors (%)	Growth in US-AUS co-authored papers from 1990-99 to 2000-09
Meteorology & atmospheric sci.	69	28%	2.1 x
Tropical medicine	18	24%	4.9 x
Infectious diseases	71	20%	4.2 x
Nuclear science & technology	19	19%	1.7 x
Biodiversity conservation	32	19%	8.5 x
Oceanography	54	17%	2.8 x
Ecology	152	16%	4.4 x
Applied & microbial biotechnol.	63	14%	3.7 x
Environmental sciences	98	13%	3.7 x
Marine & freshwater biology	80	13%	3.5 x
Plant sciences	92	12%	1.9 x
Forestry	15	11%	3.4 x
Water resources	34	10%	2.5 x
Transportation science & tech	4	10%	1.9 x
Fisheries	27	9%	4.0 x
Energy & fuels	17	9%	1.5 x
Transportation	5	8%	1.9 x
Environmental engineering	12	6%	2.6 x
All fields	**4580**	**13%**	**2.5 x**

Note: Derived from WoK 2010. (i) Subject categories are ranked by absolute scale of collaboration (i.e. average number of annual joint publications). (ii) Shading indicates an especially low growth in Australian publications in this subject category with US co-authors.

From table 5.8 one can make the following observations:

- *Understanding global environmental systems* – There is reasonably high scale of collaboration and/or strong intensity of collaboration in several areas of research where understanding often requires a level of global analysis – e.g. meteorology, oceanography, ecology, tropical medicine, and biodiversity conservation.

- *New environmental technologies* – On the other hand, with the exception of nuclear science and technology, there is limited evidence of collaboration by scale, intensity or growth metrics in subject categories specifically relating to energy, transportation, and environmental technologies. This may be because researchers working in these areas are publishing in more generalist journals, but it may also indicate a very modest level of engagement across these areas.

- *Water and bushfires* – Although water resource management and bushfire research are sometimes mentioned in the Australian community as areas of special national expertise, the evidence that US researchers see value in working at significant scale with Australians in these areas is not strong. There is considerable scale of joint activity in the relevant subject categories of plant sciences and environmental sciences, but only modest intensity; while in the forestry and water resources subject categories scale and intensity metrics are both low.

This analysis belies considerable underlying complexity. The data on transportation research for example does not account for private sector activity and especially for the extreme levels of federal government support in Australia for development projects in transportation technology (specifically in the automobile industry), some of which are conducted within US firms.

Likewise the analysis does explain why co-authorship rates in journals relating to water resources are as low as they are. There may be a low level of US research interest in this area, a disconnection of interest at the subfield level, a blurring between science and social science outputs, a tendency to produce outputs that are not listed in the Web of Knowledge, or a tendency for joint US-Australian publications on water research to be published in the high impact multidisciplinary journals.

On the other hand, the data may simply reflect a genuine lack of bilateral activity in this area. At face value it would seem that US and Australian researchers in both these latter two areas have not historically felt the same imperatives to engage as has been true, say, in the global environmental systems area.

Given that all of these themes are politically topical, these data do illustrate a fundamental challenge in designing mechanisms to foster increased US-Australian collaboration: namely that those areas where governments may want the research community to engage may not always coincide with those areas where the research community has itself shown an interest in engaging.

Table 5.9 highlights a related issue. Engineering research is an area where engagement with the US might be seen to be especially beneficial for Australia, given the market orientation of much research in this area, and the scale of development opportunities in the US. Yet Australian outputs in journals associated with engineering subject categories show both low numbers of publications with US co-authors and low intensity of collaboration, as measured by the share of Australia's output with US co-authors.

The low intensity of collaboration in areas like mechanical engineering, chemical engineering, industrial engineering, and manufacturing engineering is especially striking; and those areas of engineering that do show reasonably strong intensity of collaboration (e.g. aerospace engineering, petroleum engineering, electrical engineering, and ocean engineering) are the exception rather than the rule.

Is this a deficiency? An argument could be made that it is more important for future policy to stimulate collaborative research in areas with low connectivity to the US than to focus effort in expanding collaboration in other areas where the relationship is already thriving.

Table 5.9 – Publications in engineering subject categories, 2000-2009

Subject Category	Average annual pubs with US and AUS co-authors	Proportion of total AUS pubs with US co-authors (%)	Growth in US-AUS co-authored papers from 1990-99 to 2000-09
Aerospace engineering	8	17%	3.9 x
Petroleum engineering	4	14%	1.8 x
Electrical & electronic engineering	79	13%	2.0 x
Ocean engineering	5	13%	2.4 x
Biomedical engineering	14	9%	2.1 x
Civil engineering	22	9%	1.9 x
Geological engineering	6	8%	1.7 x
Multidisciplinary engineering	10	7%	1.7 x
Mechanical engineering	14	7%	2.4 x
Environmental engineering	12	6%	2.6 x
Chemical engineering	24	6%	1.8 x
Industrial engineering	5	6%	3.3 x
Manufacturing engineering	3	3%	1.6 x
All fields	**4580**	**13%**	**2.5 x**

Note: Derived from WoK 2010. (i) Subject categories are ranked by intensity of collaboration (i.e. proportion of Australian publications with US co-authors). (ii) Shading indicates an average of > 20 co-authored publications in this subject category per year.

This argument may have relevance for the social sciences and humanities too, although the data here is difficult to interpret. For several reasons, one expects to see lower levels of co-authorship in the social sciences and humanities than in the sciences. For one thing, there are substantially fewer authors per paper in general in these fields than is true in science and technology.

But this is not the only compounding factor. In a way that is not analogous with the sciences, low co-authorships do not always reflect actual patterns of collaboration in the social sciences and humanities. By way of illustration:

- *Non-traditional outputs* – Where Americans and Australians collaborate on policy reports or creative work or research that is published in non-traditional ways, this will not be picked up using the bibliometric analysis employed here.

- *Co-authorship of books* – American and Australian researchers may co-author books by dividing up the chapters amongst themselves. An analysis of articles or even of book chapters would not recognise this form of collaboration.

- *Workshops* – Workshops can be extremely important in driving collaborative outcomes in the humanities and social sciences, yet the formal outputs from such undertakings are often published independently, or as a book where once again individual researchers each take charge of a chapter.

- *Shared datasets* – Individuals may work together to create shared datasets, but then publish independently in their interpretation of such datasets. Once again this won't show up in co-authorship counts, though it does show up in acknowledgements sections of research reports.

Table 5.10 – Humanities and social science subject categories with > five joint US-Australian papers per annum 2000-2009

Subject Category	Average annual pubs with US and AUS co-authors	Proportion of total AUS pubs with US co-authors (%)	Growth in US-AUS co-authored papers from 1990-99 to 2000-09
Business	27	19%	4.0 x
Management	32	12%	3.1 x
Economics	57	11%	1.8 x
Social sciences, math methods	10	20%	1.5 x
Psychology, social	18	15%	3.8 x
Business, finance	12	14%	2.4 x
Health policy & services	15	10%	4.6 x
Anthropology	15	8%	2.5 x
Education & educational research	16	5%	1.7 x
Psychology, educational	6	11%	2.0 x
Family studies	6	10%	5.0 x
Hospitality, leisure, sport	7	9%	1.5 x
Education, special	8	9%	4.0 x
Archaeology	6	8%	4.1 x
Law	6	8%	2.9 x
Linguistics	7	7%	3.2 x
Communication	6	6%	2.5 x
Philosophy	8	6%	5.1 x
Planning & development	5	6%	1.3 x
Social sciences, interdisciplinary	6	5%	2.1 x
Social sciences, biomedical	8	5%	2.7 x
Geography	6	5%	1.9 x
Sociology	8	5%	1.1 x
Political science	6	2%	1.6 x
All fields (incl. science & tech)	**4580**	**13%**	**2.5 x**

Note: Derived from WoK 2010. (i) Subject categories are grouped first by absolute scale of collaboration (i.e. average number of annual joint publications) and then by intensity of collaboration (i.e. proportion of Australian publications with US co-authors). (ii) Shading indicates an especially high growth in co-authorships since 1990-1999. (iii) Some areas of psychology have been excluded from this analysis on the grounds that they are sciences rather than social sciences.

These points noted, as figure 5.10 shows, it is possible to identify a number of areas in the social sciences especially where there is clear evidence of joint US-Australian activity.

The subject categories that stand out most prominently from this table can be categorised as follows:

- *Business* – Areas like business, management, economics, and finance lead this listing both in terms of scale and intensity of collaboration. Business and management also stand out for having experienced high growth in collaborative outputs.

- *Human studies* – There is a small cluster of subjects including social psychology, anthropology, educational psychology, special education, family studies, archaeology, geography, and sociology with fairly strong indications of engagement relative to most other social sciences.

- *Selected humanities* – The humanities fields with the most overt connections to US research appear to be law, linguistics, and philosophy. However, due to the caveats noted above it is especially difficult to judge the actual scale of collaborative activity across the humanities.

The difficulty of measuring collaboration in the social sciences and humanities attests again to the challenge in pointing to particular fields that obviously require strategic government investment in order to foster greater US-Australian research engagement.

In its broadest terms, conundrum for policymakers is whether policy efforts to expand US-Australian collaboration should focus on:

(a) *areas of high existing interaction* – i.e. those areas like astronomy or genetics or particle physics or meteorology where the relationship clearly matters;

(b) *areas of growing interaction* – i.e. those areas like nanotechnology or cell & tissue engineering or biodiversity conservation which are hot emerging areas of science;

(c) *areas of high collaborative intensity but low scale* – i.e. areas like business or neuroimaging or tropical medicine where Australia's well connected but small research community may have good prospects of scaling up rapidly while maintaining globally significant levels of performance;

(d) *areas of high scale but low collaborative intensity* – i.e. areas like plant sciences or neurosciences or pharmacology or general medicine, where greater intensity of engagement with the US might provide Australia with a rapid escalation in the quality and visibility of its research;

(e) *areas of apparent weak engagement* – i.e. areas like chemical engineering and mechanical engineering that have weak levels of co-authorship with US researchers and where enhancing US engagement might prove invaluable in ensuring that Australian research is relevant to global markets; or

(f) *areas of government priority regardless of what the data shows about existing levels interaction* – i.e. areas like energy or land and water management where Australia may have particular expertise that is underappreciated in the US and vice versa, and where a deliberate initiative to force researchers together is warranted.

Clearly, selecting the optimal themes for targeted collaboration programmes will never be a straightforward exercise. The ideal scenario is probably to focus on all fronts, but there is no optimal way to achieve this.

Programmes that are agnostic about discipline will naturally tend to drive activity in areas with strong existing collaboration, but they will also tend to encourage researchers in other areas to try to initiate collaborations. Programmes that are targeted at specific areas on the other hand may skew interaction around particular themes, regardless of capacity to develop really meaningful and beneficial interactions.

Given the chaotic, distributed approach to research policy in the US however it would seem astute for an Australian Government as a whole to emphasise systemic actions that will remove the inhibitors to collaboration and provide incentives for collaboration regardless of field. More targeted initiatives at the field level are probably best worked out by individual agencies or institutions – but are of course most likely to be effective in those fields where there is already serious bilateral engagement.

5.3 Research in the medical and health sciences

An interesting observation that can be made from the above data relates to the level of US-Australian activity taking place in the medical and health sciences. Given the high strategic weighting by world standards (and by Asian standards especially) that is given to this area of research in both Australia and the US it is not surprising that the two countries should find common ground in this field.

Especially striking in this area though is not just the level of co-publication, but also the level of co-investment. Table 5.11 provides an estimate of the level of internationally leveraged funding from recent NHMRC grants. It reveals that there has been substantial international co-investment around NHMRC grants in recent years and that the vast majority of this activity originates in the US.

There is an English-language bias at play here. Table 5.12 shows that a solid majority of international partners listed on NHMRC grant proposals are based in English-speaking countries. But the level of US investment is more important than this, with Americans accounting for ~70% of international leveraged funding compared with ~30% of international research partners on Australian grants.

Table 5.11 – International leveraged funding from NHMRC grants ending between 2004 and 2008

Leveraged from	Amount	%
USA	$114 million	73%
Unknown	$18 million	12%
Not USA	$23 million	15%
Total	$156 million	100%

Note: Data obtained from Roland Wise at the NHMRC Statistics Unit.

Table 5.12 – NHMRC Project grant applications with international partners

Country	Number of proposals in which researchers from these countries are involved as partners	% of all proposals involving an international partner
USA	111	32%
UK	50	14%
NZ	32	9%
Canada	20	6%
Germany	12	3%

Note: Data obtained from Roland Wise at the NHMRC Statistics Unit.

There would be many explanations for the level of US investment in Australian medical and health sciences. Foundations would play a role, as would the private sector. Looking through the co-publication data, only a handful of US corporations showed up as co-authoring papers with Australian researchers in 2009, and all were from the pharmaceutical or biotechnology sector. The firms involved were:

- Amgen;
- Novartis Pharma;
- Eli Lilly;
- Glaxosmithkline; and
- Bristol Myers Squibb.

Extremely significant too though – both in its own right and because of the precedent it sets – is the investment that is currently made in Australian research by the National Institutes of Health (NIH).

The NIH has an enlightened policy of supporting research wherever it may occur, so long as it meets the objectives of the organisation, is of the highest calibre, and passes their peer review process. US peer reviewers are obviously cautious about seeing US taxpayer funds spent overseas, but where a proposal is strong and if there is a belief that the investigators will deliver outstanding results, there is no regulatory impediment to supporting research in Australia.

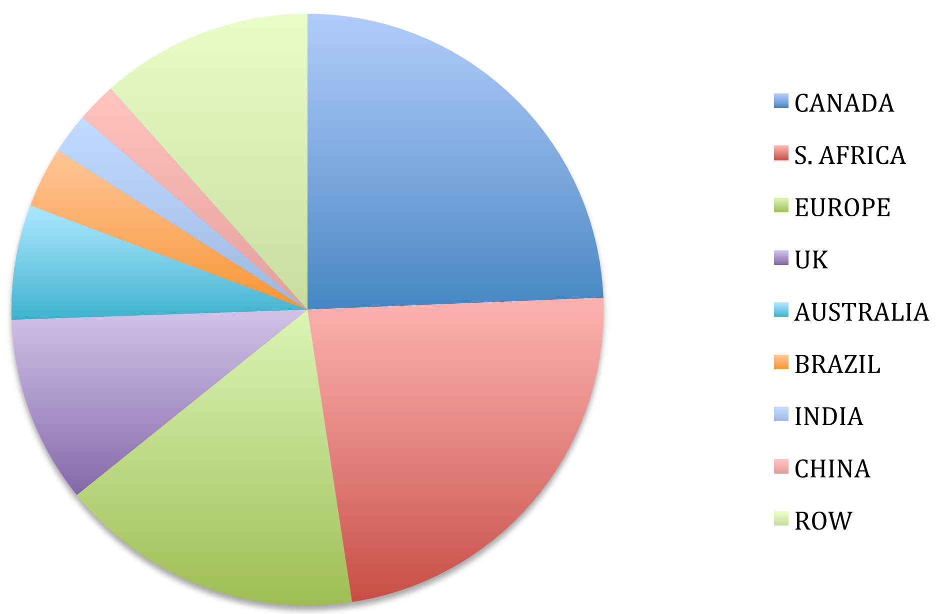
The consequence of this policy has been very exciting for Australian researchers. In 2009, the NIH spent approximately $14 million on research funded directly at Australian institutions, but the true level of investment would have been much greater.

This is because, in addition to the direct grants, there are other grants where Australian researchers are subcontracted on an award initially made to a US institution. These grants are called "domestic with a foreign component". In 2009, Australians received direct funds from the NIH via around 40 direct grants, but Australians received indirect funds from the NIH through over 200 US domestic grants with a foreign component.

This implies that total NIH investment in Australia is considerably higher than $14 million.

The investment obviously brings with it opportunities to perform research that would otherwise not be supported. Equally important though it also brings international recognition, a stamp of approval via an extremely rigorous peer review process, the potential for reputational benefits of the sort that can lead to other funding opportunities, and above all enhanced prospects for collaboration with American scientists.

Figure 5.12 – Value of foreign awards made by NIH in 2009



Note: Derived from the NIH Research Portfolio Online Reporting Tools (RePORT). Australia accounted for 6% of foreign awards by value in 2009.

Currently most of the medical research collaboration that happens between the US and Australia would be independently supported on both sides: Australian bodies fund work in Australia and US bodies fund work in the US and the researchers involved find the means within the national budgets available to them to do things together.

Opening up the operation of funding councils so that they can operate internationally has the potential to transform this arrangement and to bring much greater integration of research across the two communities.

Figure 5.12 shows that Australians are already receiving a disproportionately large share of the foreign award funding made by the NIH – 6% of direct investment outside the US in 2009 and an even higher proportion of the total NIH funding flowing to developed countries outside the US.

At the same time, table 5.13 reveals that this direct funding is being allocated to a diverse range of organisations in Australia, encompassing:

- 10 universities;
- 5 medical research institutes;
- 2 government agencies; and
- 2 biotechnology companies.

Table 5.13 – Australian institutions receiving direct NIH funding in 2009

Organisation	Awards	Value (USD '000)
University of Melbourne	5	2,422,771
Queensland Institute of Medical Research	6	2,107,993
Biota Scientific Management	1	1,615,004
University of Sydney	5	1,094,531
Monash University	3	992,811
CSIRO	4	835,797
Walter and Eliza Hall Institute	4	788,929
Starpharma Ltd	1	757,912
Flinders University of South Australia	2	652,752
University of Queensland	2	589,940
University of Western Australia	2	356,449
Australian Hearing Services	1	269,486
University of Adelaide	1	264,871
Baker Heart Research Institute	1	259,063
James Cook University	1	256,009
Ludwig Institute for Cancer Research	1	199,743
La Trobe University	1	186,033
St Vincent's Institute of Medical Research	1	154,548
University of New South Wales	1	53,302
Total	43	13,857,944

Note: Derived from the NIH Research Portfolio Online Reporting Tools (RePORT).

All of this can only mean that the best Australian researchers are well known and well trusted among their US colleagues. The policy arrangements that enable this to happen should not be taken for granted however.

At some point US policymakers may question the merit in funding research in other countries, while funding bodies in other parts of the world do not see fit to return the favour.

If one had to pick one field of research where a focus on driving US collaboration might make special sense, the medical and health sciences would surely warrant a special mention given the unusual (and extremely positive) policy arrangements that are currently in place for sponsoring US research in Australia.

5.4 Trilateral partners

Under the Obama administration, the US State Department appears to be making a concerted effort to place science and technology at the forefront of its foreign policy agenda. This development is based upon the view:

- that science and technology can be used to build bridges between countries; and
- that science and technology can be used to solve problems for all countries.

This raises a question as to whether there may be special opportunities for Australia in fostering trilateral research relationships, where Australia and the US can support the development of a third partner through research.

The analysis of co-authorships on papers is once again useful in this respect. Table 5.14 shows the share of joint US-Australian papers that also have an author from a third country over a thirty-year time frame. The data here suggest the following:

- *Developed-world partnerships are already strong* – The trilateral relationships are strongest among English-speaking countries (especially England and Canada) and then among European countries.

- *Developing-world links are weak outside our region* – There is limited trilateral collaboration between Australia, the US, and nations in the Americas, Africa, or the Middle East.

- *Links to Asia are relatively modest* – There has been excellent growth in trilateral collaboration among Asian nations, but compared with the scale of outputs now being produced among Asian nations, the level of trilateral interaction is weak.

The second point should not be taken without qualification. There is a modest level of trilateral interaction involving Brazil, Chile, Mexico, and Argentina in the Americas and there is a modest level of trilateral interaction involving South Africa, Israel, Turkey, Kenya, and Iran in the Middle East and Africa.

There may be good reasons and good opportunities for developing three-way schemes to support research in these countries. Without additional information though, the most sensible focus for policies promoting trilateral collaboration would seem to lie in Asia.

Table 5.14 – Share of joint US-Australian co-authored papers that also have an author from a third country

	Country	2000-2009	1990-1999	1980-1989
Europe	England	12.6%	8.7%	5.8%
	Germany	8.9%	5.6%	0.1%
	France	6.5%	4.1%	1.8%
	Italy	5.0%	2.6%	0.8%
	Netherlands	4.2%	2.8%	1.3%
	Switzerland	4.1%	2.3%	1.0%
	Spain	3.3%	1.2%	0.4%
	Sweden	2.9%	2.0%	0.9%
	Scotland	2.5%	1.4%	1.1%
	Belgium	2.5%	1.0%	0.5%
	Denmark	1.9%	1.2%	0.7%
	Poland	1.9%	0.5%	0.2%
	Austria	1.9%	0.6%	0.3%
	Russia	1.8%	0.9%	0.2%
	Finland	1.3%	0.8%	0.4%
	Norway	1.1%	0.7%	0.7%
Americas	Canada	8.7%	5.8%	3.9%
	Brazil	1.6%	0.6%	0.2%
	Chile	0.9%	0.5%	0.3%
	Mexico	0.8%	0.5%	0.1%
	Argentina	0.8%	0.3%	0.1%
Asia / Pacific	Japan	5.0%	3.4%	1.5%
	China	3.7%	1.0%	0.3%
	New Zealand	2.8%	1.9%	1.3%
	India	1.7%	0.7%	0.4%
	South Korea	1.6%	0.3%	0.1%
	Taiwan	1.5%	0.3%	0.1%
	Singapore	1.3%	0.3%	0.1%
	Thailand	0.7%	0.3%	0.2%
	Indonesia	0.4%	0.2%	0.1%
	Malaysia	0.3%	0.1%	0.1%
	Philippines	0.3%	0.2%	0.2%
	Vietnam	0.3%	-	-
Africa / Middle East	South Africa	1.5%	0.9%	0.7%
	Israel	1.4%	1.1%	0.7%
	Turkey	0.4%	0.1%	-
	Kenya	0.2%	0.1%	0.1%
	Iran	0.2%	-	-

Note: Derived from WOK 2010. Shading indicates high growth in trilateral partnerships between the 1990s and the 2000s.

After the US, the two nations that publish the most scientific articles now are China and Japan. Yet there remain several European countries with much higher rates of joint authorship with American and Australian researchers. Similarly for India, South Korea, and Taiwan. The rate of trilateral partnership with these countries is much lower than with European nations whose scientific outputs are at similar or lower levels.

This may reflect a quality disconnect, a mismatch of investment by research field, a cultural gap, or simply the rapid growth in Asia's scientific base – a new reality that research communities in Australia and the US may not completely have caught up with yet. Whatever its cause though, there is clearly an opportunity for greater trilateral engagement if the experience with Europe is anything to go by.

One should not inflate Australia's potential role in developing such an arrangement however. The US is already very well connected into the research systems of these nations. As we saw in table 2.3, these nations have a US co-author on around 10% of their publications and on around 40% of their publications with an international co-author.

The situation with South-East Asian nations is not so clear cut. The obvious nations where Australia has close links (not least from its international student activity) and a strong regional interest are Indonesia, Malaysia, Thailand, and Vietnam.

These are all countries where the science base is small by world standards, and where the level of trilateral activity is rather negligible. An argument could be made though that Australian researchers do have the potential to serve as a bridge to these societies in critical areas.

Interestingly the journals in which Australian and American researchers are jointly publishing with researchers from this region are mainly in the following subject categories:

- infectious diseases;
- public health;
- biochemistry & molecular biology;
- ophthalmology;
- general medicine;
- gastroenterology and hepatology;
- ecology;
- microbiology;
- oncology;
- environmental sciences;
- applied microbiology;
- tropical medicine;
- evolutionary biology;

and, in the social sciences subject categories:

- education in scientific disciplines; and
- family studies.

This is a pattern that is quite different from that which one observes when Australian and American researchers publish jointly with researchers from other regions. In other regions, astronomy and physics feature a lot, as well as geosciences, atmospheric sciences, and a broader sweep of molecular biology subfields.

It suggests that the best opportunities for trilateral partnership with South-East Asian countries are probably in the infectious diseases / public health / tropical medicine area and secondarily in the ecology / environmental sciences / evolutionary biology area.

5.5 Links between business organisations

Publications do not provide a good measure of business collaboration because outside of the biotechnology and pharmaceuticals sectors businesses don't tend to be interested much in publishing papers.

In our context, this doesn't matter a great deal. As we observed early on in this report, policymakers interested in driving research collaboration between the US and Australia will find the greatest potential within the public sector.

It is interesting though to compare the publications data with what can be gleaned about business activity from international patenting activity.

There are many hazards in the analysis of patents. Some organisations (and indeed nations) seem to patent in very different ways, meaning that quantitative comparisons can be problematic. There are strong national biases in patenting activity according to patent office, meaning that one has to be careful about the choice of database one uses.

In Australia too the dominant industry sectors in the economy are typically not sectors that invest a great deal in patents, meaning that patents are an incomplete indicator of research activity for Australia in particular.

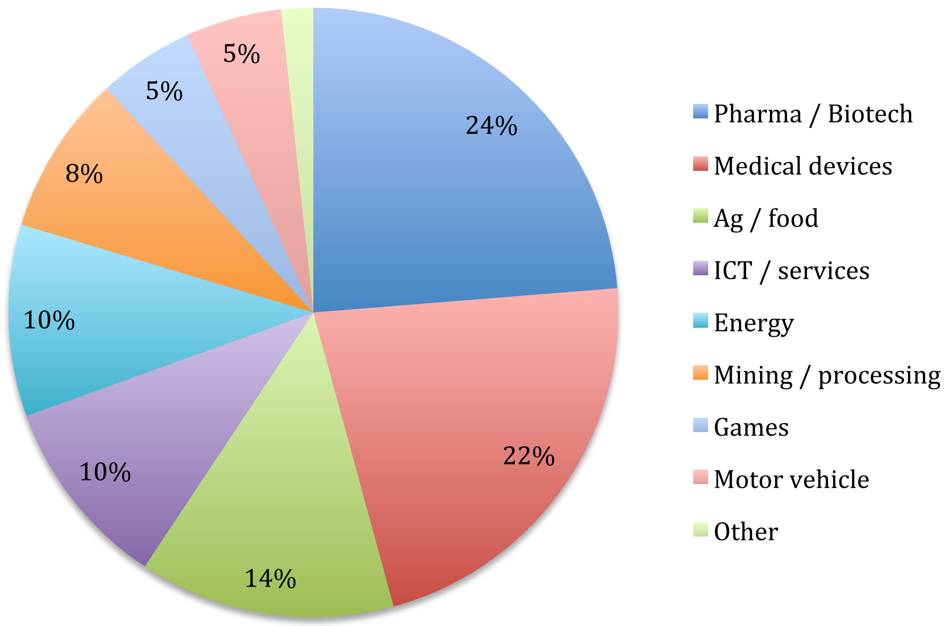
Other countries generate a large number of patent applications per $ million of R&D expenditure: South Korea (3.3), Japan (2.4), China (2.0), New Zealand (1.0), Germany (0.7), and US (0.7). In Australia, by comparison, we get just 0.2 PCT patents per $ million R&D expenditure (WIPO 2010). This means that any analysis of collaboration in the patent literature will present only a tiny subsection of the interactions between Australian and US researchers in business.

These caveats noted, figure 5.15 looks at international (PCT) patents published in 2010 with both an American and an Australia inventor. There were just 59 patents in this group, a sufficiently small number that they were able to be assessed individually. This meant it was possible to move beyond the international classifications and regroup by most likely industry of application.

The results are not surprising. They show a dominance of joint inventions in the areas of pharmaceuticals and medical devices. They show activity in agriculture, food production, ICT services, mining, energy, and processing of mineral and energy products.

These are all areas that one associates with the Australian economy. For the most part too they are areas that are consistent with the other findings about research focus in this report.

Figure 5.15 – PCT patents with American and Australia co-inventors, 2010



Note: Derived from the WIPO Patentscope database 2010. Patents were categorised according to most likely sector of application. The mining / processing category includes patents registered by Bluescope Steel for the casting of metals.

Now this is only a partial representation of the real extent of bilateral collaboration that occurs around international patents. The volume of PCT patents assigned to Australians but with an inventor resident in the US (or likewise assigned to Americans but with an inventor in Australia) is considerably larger than this.

Nonetheless it provides an indication of where the joint commercial research projects are happening, and suggests above all that the balance of activity reflects a mixture of effects presumably due largely to: (a) the structure of the Australian economy; (b) the structure of Australia's knowledge base; and (c) the patenting-intensity of different industrial sectors.

Fashion is perhaps a less important factor here than might have been expected, but it is not entirely unimportant. Of the patents classified in figure 5.15 under energy: one relates to photovoltaic manufacturing, one relates to using steam engines as a energy storage device, one relates to the design of louvers for new building construction, and three relate to the petroleum industry. In other words, there appears to be neither an absence of activity nor an emphasis of activity in the fashionable area of clean energy technology.

This snapshot offers a valuable perspective. It suggests that Australian and US researchers are working together on commercial ventures in the sectors where they would be expected to. There are certainly no surprises – either of strong bilateral activity or weak bilateral activity – in this data.

It implies very strongly that the big problem for policymakers in bridging research in the private sector is not that of skewing the system towards one technology or another but rather that of finding ways to increase the total scale of mutually beneficial activity.

Recommendations

7. Australian federal policymakers should introduce explicit incentives and mechanisms to increase the level of co-publication on papers between American researchers and researchers in Australian Government agencies.

8. Australian policymakers should explore the possibility of establishing deeper, formal relationships between Australian and US federal research agencies, the most likely themes for engagement (outside the defence area where links are already very strong) being around space sciences, geosciences, agricultural sciences, and health.

9. Policy initiatives to stimulate bilateral collaboration across the Australian public sector more broadly should emphasise systemic actions that will remove the inhibitors to collaboration and provide incentives for collaboration in ways that are agnostic as to field. Targeted initiatives at the field level should be left to individual agencies or institutions.

10. Australian policymakers should consider implementing more open processes, particularly through the competitive funding councils, for directly funding research in the US where it is part of an Australian collaboration.

11. Australian policymakers should discuss with their counterparts in the US, China, Japan, India, South Korea, Taiwan, and Singapore possible mechanisms for promoting trilateral research partnerships with a view to implementing a similar level of trilateral relationships in research as exist with European nations.

12. Australian policymakers should discuss with their counterparts in the US, Indonesia, Malaysia, Thailand, and Vietnam possible mechanisms for promoting trilateral research partnerships, the most likely areas for collaboration being in the infectious diseases / public health / tropical medicine area and secondarily in the ecology / environmental sciences / evolutionary biology area.

6. POLICIES FOR IMPROVING COLLABORATION

The dominant focus of this report has been to map the landscape in which US-Australian research collaborations are occurring, and to deduce from this a number of principles and high-level recommendations that would be useful to policymakers in thinking about how to strengthen this relationship.

In assessing both the nature of existing collaboration and the scope for improving collaboration, a number of senior researchers and research administrators were interviewed in both Australia and the US. Considerable effort was taken in these conversations to identify the similarities and differences of perception across the Pacific, and to collect specific ideas about useful policy directions for any government seeking to facilitate US-Australian collaboration into the future.

These ideas are catalogued below under five headings:

- major initiatives;
- researcher mobility;
- formal agreements;
- commercialisation; and
- generic actions

One constant theme that emerged from the discussions was that it is not easy to prioritise among these ideas. Much depends upon the specific nature of an opportunity when it presents itself, and a balanced research system would support a mixture of these activities.

6.1 Major initiatives

It is easy to appreciate that a large-scale partner like the US affords collaborative opportunities for researchers in Australia to participate in large science projects and to access infrastructure that would simply not be possible in any other way.

We see three particular ways in which Australians are currently seeking to connect with US researchers on major initiatives: through big science projects; by accessing US research infrastructure (and by providing US researchers with access to Australian infrastructure); and by involvement in data sharing projects and formal research networks.

(i) Big science

For half a century the US has led the world in investment in very large-scale science projects, and Australia has good incentives for supporting its research community to participate in these initiatives. In areas of physics, astronomy, oceanography, and genetics, for example, it can be difficult to do serious research without being a part of a big science project.

There will also be instances where Australia provides a special advantage due to a unique resource and consequently has the opportunity to partner in a big science project on very favourable terms.

The Square Kilometre Array is an obvious example here, as, on a smaller scale, is the Laser Interferometer Gravitational Wave Observatory (LIGO). The latter provides a very apposite and timely illustration as US researchers recently offered to site a $140 million detector in Western Australia as part of this project if Australia would invest an equivalent sum to build a local facility around it.

The timeframe for making this decision however is short in Australian political terms, which highlights a perennial problem for Australian policymakers. With only a few exceptions, Australia tends to be an opportunistic partner in big science projects. This means that rather than driving opportunities themselves, Australian policymakers are typically forced to react to a perceived opportunity created by the investment choices being made by other, larger countries.

Purchasing a role in a major project is very smart if it is the right project, but these are rare, focused, and they require a government to pick a specific area of research for a good reason. Australian research policy is not very sophisticated in this respect and the consequence is that Australians tend to miss out on participating in any serious way in these sorts of ventures.

Australian policymakers also need to think about how they can influence the attitudes of their counterparts in the US to projects of this kind. This is a particular issue at the moment in relation to the Square Kilometre Array.

In any event, an overhaul of the mechanisms by which the Australian Government makes decisions in relation to big science projects would be beneficial and would assist in improving the Australian Government's capacity to act strategically in fostering international collaborations in research.

(ii) Infrastructure access

There is a long history in Australia of travelling for research, and the practice of travelling to use a major facility in the US is a relatively common one. Australian organisations cannot afford to build scientific infrastructure on the scale that is possible in the US so in some areas Australian research is inherently dependent upon the US relationship.

On some US facilities, furthermore, the arrangement is made under very favourable terms to individual researchers: time on a facility may be awarded based on a peer review process and the main costs to individual Australian researchers may simply be the costs of travelling to get there. Local organisations like ANSTO have been critical in facilitating this process.

The benefit to Australians in accessing US infrastructure too does not reside solely in the infrastructure itself. Equally important is the opportunity that facilities provide for meeting other researchers who have an interest (and an expertise) in the same piece of infrastructure. Given this, it is widely recognised in Australia that access to major US facilities is valuable both in its own right and as a mechanism for initiating international relationships and collaborations. There are two areas however where there may be capacity for fresh policy thinking.

First, there may be a need for greater consideration of the opportunity costs that come when investing in local facilities. There is evidence (unsurprisingly) that the opening of the Australian Synchrotron has diminished the use by Australian researchers of the synchrotron at the Argonne National Laboratory in the US. The reduction in this activity presumably does not outweigh the gains in terms of access to a local synchrotron, but one has to question whether the Australian synchrotron has had unintended consequences for US collaboration.

Second, and this point clearly relates to the first, there is a perception among some Australian researchers that we undersell our own major facilities. The OPAL neutron source, for example, has 20-30% of its users coming from other countries. If Australia is serious about building bridges to the US community, a key goal for investment in landmark Australian facilities might be that they offer sufficiently differentiated capabilities globally that they can act as a magnet to bring US researchers to Australia.

(iii) Data sharing and networks

In addition to the big science initiatives and the opportunities for collaboration afforded by major facilities, there is another mode of large-scale interaction that seems to be growing in importance across the global research community. This is the idea of networked research, or of the regional or global alliance, and represents an under-appreciated mechanism for strengthening the connections between Australian and US researchers.

There are many, many projects being set up across a range of fields and usually empowered by Internet technologies, but a few examples of networked research might be:

- the International Epidemiologic Databases to Evaluate AIDS (IeDEA);
- the Census of Marine Life;
- the Global Foot and Mouth Disease Research Alliance (GFRA); and
- the Epigenomics of Plants International Consortium (EPIC).

These sorts of initiatives will be undertaken all around the world regardless of what policies may exist to support them in Australia. The virtual global network is a logical organisational structure for researchers dealing with global problems and for researchers trying to collaborate on problems that involve sharing lots of information.

Researchers obviously participate in such activities depending upon their capacity to convince funding bodies to invest in them, and it is unusual for such initiatives to be led out of Australia. Yet these sorts of initiatives do provide a mechanism for Australian researchers to gain a greater degree of visibility in global terms than might not easily be managed via other means. This is arguably an area where Australian policymakers have the potential to stimulate closer ties with US researchers and influence over what may sometimes become major global research projects with relatively modest outlays.

6.2 Researcher mobility

Collaboration in research is a social activity. It involves personal relationships. It is dependent not just upon effective communication but usually also upon the ability of researchers to travel in order to meet and interact with one another. Unsurprisingly therefore there is a widespread view that those policies that foster researcher mobility will also tend to foster collaboration.

Here we present some reflections about the benefits of policies designed to encourage: postgraduate student mobility; postdoctoral fellowships; visiting fellowships; joint appointments and recruitment; and short-term travel.

It should be noted at the outset that mobility is regarded as beneficial in both directions between Australia and the US. There is also a general view (though this is tempered a little depending upon the field) that the longer a researcher is able to spend in another place the more likely they are to form a deep collaboration there.

(i) Postgraduate student mobility

We have already addressed the modest level of formal PhD student mobility between Australia and the US, and the lack of formal collaborative degree programmes. This does not mean however that there are currently no interactions taking place.

Collaboration during PhD training currently tends to happen where a faculty member from one country happens to collaborate with researchers in the other country, and sets a PhD student to work on an aspect of this project. In many such instances the student may have opportunities to travel during their PhD, although this isn't part of any formal arrangement. It is driven essentially by individual relationships, supported on an opportunistic basis by research grants.

There would probably be benefits in establishing more formal mechanisms for fostering PhD mobility. The French Cotutelle programme affords a working model. However, it is not clear how such a scheme would be implemented in the US as a whole (which has a much less centralised education system than in France) and where the nature of the PhD experience remains different in some respects from that in Australia.

One solution could be to target a particular region in the US and to negotiate, say, at the state level rather than the federal level. There is no reason for example why Australian policymakers and universities should not aspire to implement a Cotutelle-type arrangement, including necessary fee waivers in both directions, between Australian universities and the University of California system. Given the strength of Californian-Australian collaborations identified in the previous section this could be a very promising model.

A more straightforward approach of course would be for governments to foster postgraduate student mobility simply by expanding the number of scholarships that bring a student from one nation to do their entire PhD in the other. The Australian-American Fulbright Commission and the American Australian Association offer well-managed programmes along these lines, and many of those spoken to the course of this survey suggested Australian Government support for a drastic expansion of the Fulbright programme.

Of course the idea of sending Australians in significant number to do their PhD in the US could be a politically challenging one, especially if policymakers lack faith in their own capacity to create a sufficiently engaging research environment in Australia as to encourage these people eventually to return. Increasing the number of Australians doing PhDs in the US would however tend to create deep, life-long networks and if done on a large scale would likely stimulate a great deal of Australian-US collaboration over the long term.

Another alternative to the Cotutelle model is the idea of the pre-doctoral fellowship. A scheme that supports Australian students in the third year of their PhD to spend six months in a US research group or that enables an Australian student to spend a year of their PhD in the US without being penalised for a late completion would improve student mobility and would also be likely to drive subsequent uptake of postdoctoral positions in the US.

A reciprocal scheme that supports American students part-way through their PhD to spend six months in a top Australian group would also deepen the relationship between US and Australian researchers and would likely strengthen perceptions in the US about the quality of Australian research.

(ii) Postdoctoral fellowships

The advantages in encouraging postgraduate students to travel can be applied equally in the case of postdoctoral fellows. Indeed there may be some advantages in a focus at the postdoctoral level: differences in the two education systems are no longer important, and student fees are no longer part of the equation. On the other hand, postdoctoral fellows may also be more likely than postgraduate students to have the sort of financial commitments that provide a disincentive to long-term stays in another country.

If Australians want their country to have a research workforce that is comfortable working with Americans and that has the experience and connections to attract not just collaborations but also research funding from the US, then postdoctoral experience in the US is invaluable.

An interesting observation can be made here in respect to the NIH. Australians who win direct NIH funding tend to have had extensive postdoctoral experience in the US, tend to know the NIH well, and tend to have worked with US partners. Providing talented Australians with time in the US gives them the contacts and understanding to access NIH funds even after they return.

Yet Australians are not well represented among NIH fellows. The National Institutes of Health have around 6000 scientists in their intramural laboratories and foreign researchers currently take up around 2700 of these positions. Australians are a tiny minority in this cohort however. The numbers of scientists by foreign nationality are currently as follows:

- China – 530;
- India – 349;
- Japan – 239;
- South Korea – 230;
- Germany – 109;
- Canada – 97;
- UK – 80; and
- Australia – 22.

The implication here is that in 20 years time it won't be Australian researchers winning a disproportionate share of foreign NIH funding, but rather Indians, Japanese, and South Koreans.

By participating in such small numbers Australians are also missing opportunities to build trilateral relationships. When Australians do postdoctoral work in the US, especially in the major laboratories, they do not just engage with Americans, they also build a network of the very best young researchers from other parts of the world. In other words, one effective way to build long-term collaborations with East Asian researchers is arguably to send more Australians to work at the NIH.

There are a few ways in which policymakers could facilitate an increase in postdoctoral mobility. Targeted fellowship schemes are an obvious mechanism, and are widely employed by other countries. The Japan Society for the Promotion of Science for example funds fellowships for Japanese scientists to work at the NIH. There is no reason why the Australian Government should not contemplate something similar.

Policymakers might also consider introducing a mobility year into early career research fellowships, designed to foster links and collaborations with US groups. There may be advantages in such an idea both in infrastructure-intensive research and in areas like mathematics, the theoretical sciences, the social sciences, and the humanities where mobility is not constrained by infrastructure and the opportunity to spend even a short time in a leading US group (or perhaps in several groups) could make a profound difference to an Australia's long-term career.

Finally, there is another related policy that could have an impact with limited direct outlays by the Australian Government. Several Australian universities would consider investing their own funds in postdoctoral fellowships based in the US if they could count the recipient's outputs in Australian Government audits of research performance (e.g. through the Higher Education Research Data Collection and the Excellence of Research in Australia initiative), on the basis that they are paying for the research. This is an unorthodox suggestion but it could drive some very interesting behaviour.

(iii) Visiting fellowships

At a more senior level there is a complementary role to be played by visiting fellowships. There is some activity of this kind already between Australia and the US, funded in some cases for a year or six months, often for staff on sabbatical, and in other cases for shorter periods.

A nice example is that of the Fulbright Distinguished Chair in American Political Science. It supports a leading US professor to conduct collaborative research at Flinders University over a 4-5 month period. It is the first Fulbright Distinguished chair funded in the East Asia Pacific Region.

There are powerful benefits in getting active and successful researchers to spend several months working in another institution, especially where they can be embedded in the workings of another research group. In this context, the visiting fellowship is a great mechanism for effecting knowledge-transfer, for deepening relationships, and for generating the sort of momentum that can make collaborations last a long time.

There are many different conceptions about what visiting fellowships should entail and what they can be expected to achieve, but in our survey two interesting ideas of a targeted nature were raised.

First, it was suggested that there would be benefit in directly funding Australian academics to go to the US and get together with US colleagues specifically in order to work on a joint proposal to US funding agencies, where the Australian involved will be a Chief Investigator or a Partner Investigator. This, it was felt, would afford a mechanism to make Australians more visible to potential funders in the US.

A different thesis though holds that there are usually greater benefits in visiting fellowships that bring Americans to Australia. As one researcher put it: "When an Australian goes to the US, they meet just one of us; but when an American comes here they meet many of us and they see for themselves the research environment in Australia."

An idea put forward along these lines is to provide a mechanism to pay the salaries of early career researchers in the US for three months in the year, on the basis that they come out to Australian institutions and work on Australian research projects over the American summer. Such a model, which has been trialled at one Australian university as an internally funded initiative, has been found to have the long-term benefit that Americans targeted in this way often continue working on Australian research problems even after they return to the US. This model can also be seen as a steppingstone for recruiting young US staff to Australia.

(iv) Joint appointments and recruitment initiatives

This brings us to the related idea of joint appointments. There are several benefits in making joint appointments between US and Australian organisations.

People on joint appointments tend to carry – and to transfer – lots of embodied knowledge. Joint appointments can deepen institutional relationships and increase the likelihood of other kinds of inter-institutional interaction. In the case of Australia and the US they provide a mechanism for Australian institutions to improve their citation performance dramatically. Joint appointments can also serve as a bridge to recruitment and they can play an important role in bringing researchers with US funding into the Australian research system.

Furthermore, in the case of very high profile people (e.g. Nobel Laureates and Fields Medal winners) joint appointments may provide the only effective mechanism to get these people to spend sustained periods of time in Australia. A good example of how this can work is suggested by the case of the Nobel Laureate, Peter Doherty, who spends nine months of the year in Melbourne and three months in Memphis.

Despite the benefits, Australian institutions do not always find it easy to be flexible about these sorts of arrangements. Certainly, some institutions in Australia have found joint appointments easier to implement than others. A key issue seems to be the extent to which organisations have the flexibility to respond quickly when good opportunities present themselves.

This is arguably an issue for institutions to deal with according to their own strategic priorities. For policymakers though, a fellowship programme at the Federation/Laureate level but which explicitly seeks to bring researchers to Australia on a part-time basis via joint appointments could assist tremendously in: raising the calibre of candidates applying from the US in such schemes; increasing the level of US research funding that is brought into Australia; and raising the visibility of the Australian research system and in lifting the performance of Australian universities in global rankings.

(v) Short-term travel

There is a diversity of views in the Australian community about the benefits of explicit federal funding schemes to support short-term travel. A common view is that such activities ought to be supported implicitly through competitive grants or via institutional resources – in other words that individual research groups ought to be able to manage this sort of thing using the general funds they are able to raise for their research.

There is also some ambivalence about the extent to which short-term activities, such as speaking at conferences, are likely to drive collaboration. Participation at international conferences is clearly critical for individuals who wish to build visibility, stay in touch with the latest development in a field, and meet potential collaborators, but a common view is that people usually need to stay in a place for longer periods if they are to build continuing relationships.

In some fields, however, initiatives focused on short-term travel can be useful in driving collaboration and would be difficult without targeted initiatives. This is obvious in those cases where collaboration involves an Australian researcher and a major US facility, and programmes to support Australians who get competitive time on international facilities are regarded as extremely valuable.

There is another category of activity too that seems to be growing in importance in areas like mathematics, and in many areas of the social sciences and humanities. In these fields, international workshops have assumed a growing importance as a mode of interaction.

Under this model, researchers get together not for a series of seminars reporting the outcomes of their research but to work actively and explicitly on generating specific outcomes such as the publication of a book or the development of a new theory. In mathematics this has become an extremely common and productive mode of interaction internationally, yet there are not obvious mechanisms to support this in Australia.

By contrast with the situation overseas, the Mathematisches Forschungsintitut Oberwolfach in Germany, the Isaac Newton Institute for Mathematical Sciences in Cambridge, and the Banff International Research Station in Canada are all run effectively as international visitor research institutes, to which researchers converge for periods from a week to several months in order to solve specific problems.

Australia would be a very attractive place to site a similar initiative, but it should be recognised that other, large-scale institutes in mathematics also support extensive visiting scientist programmes. The Mathematical Sciences Research Institute at Berkeley and the Pacific Institute for the Mathematical Sciences in Canada are two obvious examples here. An effort to provide mechanisms for travel to and from Australian centres in mathematics (and other fields with similar modes of interaction) would seem enormously beneficial.

6.3 Formal agreements

Historically most of the interactions that have occurred between American and Australian researchers have been initiated by individuals and pursued by individuals without the active involvement of governments. It is likely too that this will remain the dominant mode of engagement for the foreseeable future, and policies intended to promote collaboration will usually be most effective when focused at this level.

There is nothing wrong with this approach. It is dynamic and is likely to be responsive to trends in research as they evolve across both national research systems. Often, though, bottom-up arrangements will lead to interactions that lack depth and are ephemeral, while in some situations the lack of capacity in Australia for complementary top-down initiatives has meant that Australian organisations have missed out on potentially transformative opportunities.

In a world where the balance of power in research is changing too, and where many other countries are developing formal bilateral relationships, it is arguable that the US relationship can no longer be expected to take care of itself solely via grassroots interactions.

Here we summarise some of the ideas raised in our survey about initiatives intended to develop stronger formal relationships between the two countries, relating to: inter-governmental agreements; inter-agency agreements; institutional agreements; and the integration of specific government programmes.

(i) Inter-governmental agreements

High-level inter-government agreements such as treaties and memoranda of understanding should rarely be seen as a cause of bilateral collaboration but they can facilitate collaboration or expand the scale of collaboration in ways that are useful to both nations.

An example of a high-level agreement that has had significant consequences for collaboration is the Antarctic Treaty. By requiring parties to make data from their research freely available, this treaty has arguably stimulated collaborative rather than competitive approaches to research in Antarctica.

Then there is the enduring collaborative relationship that exists in defence research. This has grown out of an architecture established through the Technical Cooperation Program, a decades-old, formal agreement involving the US, the UK, Canada, Australia, and New Zealand. While, the more recent signing of the Australia-US Treaty on Defence Trade Cooperation is perceived within the defence sector to present Australian research-intensive firms with improved prospects for operating (and collaborating) in the US defence market.

Yet another example is afforded by inter-governmental agreements about migration. Most Australian researchers find it easy to travel to the US to collaborate, but those unable to travel on a standard E3 visa, and who must instead apply for a J1 visa, find the process expensive and complicated and a clear deterrent to collaboration. Government agreements on migration can be critical for collaboration.

High-level agreements, needless to say, are widely perceived as useful for creating a positive framework for collaboration, even though the consequences in practice will depend upon the way in which the interaction is ultimately played out in individual agencies, institutions or companies.

This latter point does suggest though that formal inter-governmental agreements are probably most effective in supporting collaboration in research where: (a) they reflect an underlying community of capability that is ready to engage and preferably already engaged; and (b) they are focused in such a way that it is clear who is responsible for implementation; and (c) it is clear how implementation will be resourced.

Thus, in 2008, the Premier of Victoria signed a memorandum of understanding with the California Institute for Regenerative Medicine (CIRM), which subsequently led to the creation of the Victoria-California Stem Cell Alliance, which has supported collaborative research and joint funding of projects involving CIRM and Victorian institutions. It was the existence of researchers and investment in both countries in this area, the targeted nature of the agreement, and the resources that eventually accompanied it that ultimately rendered this successful.

In a similar vein, the relationship that is now being nurtured between the National Renewable Energy Laboratory (NREL) of the US Department of Energy and the Australian Solar Institute, and associated research groups at Australian universities and at CSIRO will presumably only flourish if the agreement can combine the underlying research capabilities of the two nations in this area with new resources and a clear understanding of who is responsible for nurturing the collaboration.

Likewise, in trying to develop stronger trilateral relationships in research between Australia, the US, and other nations in the Asia-Pacific, formal inter-government agreements will only work if such agreements have clear objectives, an existing baseline of research activity, and if they are followed up with clear mechanisms for implementation.

All of this resonates with a common observation in Australia: namely that targeted schemes are more effective than broad agreements in driving collaboration. But focus itself is not the ultimate cause of success – focused schemes tend to work, largely because they force policymakers to allocate responsibilities and resources to agencies for implementation.

This is especially apposite with respect to the US-Australia relationship. One area where formal agreements between the US and Australian governments are probably not needed is in creating symbolic announcements and good will. As one senior US administrator remarked, such agreements are unnecessary in the case of Australia because “we already understand each other so well.”

(ii) Inter-agency agreements

On a different level, inter-government agreements can also be fashioned (at least in principle) between government agencies, and arguably there are very strong opportunities here – and the appetite for such activities seems to be growing globally at the moment.

The Global Alliance for Chronic Disease, for example, brings together six of the world's health research funding agencies, including the NIH and NHMRC, with a common objective. There is no reason why more of these sorts of initiatives should not be implemented directly between American and Australian agencies. Yet where are the mechanisms for initiating such ideas on a bilateral basis?

With the exception of the defence relationship through the Defence Science and Technology Organisation in Australia, there is not strong evidence of deep, formal, strategic relationships between Australian and US government laboratories and funding agencies. In this report, we have focused predominantly on the interactions of researchers, but inter-agency agreements could play an important role in promoting bilateral relationships among decision-makers.

It is interesting to note that most relationships between Australian and US agencies are currently based around specific researchers and around specific themes of research, but do not seem to be embedded in an organisational sense via a strong network of interactions among senior managers and administrators.

With this in mind, one idea that emerged from our survey of researchers in the US and Australia was for the implementation of a formal programme to facilitate much greater exchange of officials on secondment between the ARC, NHRMC, CSIRO, ANSTO, and AIMS and their corresponding US organisations. Such a proposal would require a small investment but could have a profound impact in bringing the two research systems closer together.

It would increase the levels of trust at an important level. It could lead to a greater occurrence of joint strategic planning among senior staff in government agencies. It would presumably make it easier in the long run to negotiate formal agreements focused on particular research projects. It would greatly improve the understanding of US funding processes across the Australian research community.

In addition, it could increase the capacity for Australian agencies to operate as brokers of US partnerships. This is a role that has been played very successfully by DSTO. Since the relationships between DSTO and the US military run very deep, and since DSTO is highly trusted in the US, it has been able to afford Australian university researchers with the credibility to establish research links with the US defence community. By strengthening and deepening the organisational and personal relationships in other agencies one could imagine brokering activity of this sort occurring across a much wider section of the Australian research community.

(iii) Institutional agreements

Another mode of collaboration is via formal institutional agreement, particularly among universities or other non-profit research institutes. This has not been widespread between American and Australia organisations, although the practice is growing.

For example, there is a formal agreement between Curtin University and the Colorado School of Mines involving student and staff exchanges. Likewise, the University of Melbourne has a formal relationship in eHealth and computation with Vanderbilt University.

Typically institutions are quite selective in choosing partners for these sorts of relationships. This reflects a tendency to see such partnerships as long-term ventures. There is also a growing recognition that these relationships take a lot of time and money to work.

In most instances, there is no reason for government to become involved in these relationships, but there is an interesting problem that sometimes emerges in this context. Some years ago the Media Lab at MIT offered to invest in an offshore "branch" institute based in Australia. The proposal came with a substantial amount of philanthropic funding attached, but there was a catch: the initiative would only be supported if the Australian Government was willing to match the offshore investment.

Occasionally these sorts of ideas will be thrown up and there will be a dimension to the proposal that is beyond the reach of an Australian institution. The Australian Government will be approached and asked whether there is room for providing strategic assistance. A similar concept, for example, has recently been floated for bringing an offshoot of the Scripps Research Institute in San Diego to Australia.

Presumably, given the right environment and in particular formal avenues for leveraging Australian funding, more proposals of this nature would rapidly emerge. Yet there are currently no straightforward processes for effecting government investment into these sorts of initiatives, and as a consequence they tend not to happen.

(iv) Programme integration

There is a perception that US agencies fund more generously, are a lot less demanding and bureaucratic in their procedures, are much faster in providing decisions, and are more interested in supporting basic research than is true in Australia. Benchmarking Australian agencies against US agencies and finding ways to integrate procedures may be useful in continuously improving Australian research funding processes. But, this sort of activity may ultimately also assist Australian researchers to develop US relationships.

Earlier in this report we raised a specific issue along these lines: the way in which NIH income is categorised in the Higher Education Research Data Collection. This is a specific problem that either the Australian or the US government could address, but there is also an important principle behind this issue.

The experience of research administrators in Australia is that it is not always easy to implement joint funding schemes across national boundaries. Issues relating to the timing of funding processes, to the alignment of priorities, and the desire to protect sovereignty over funding decisions have proved an impediment in the past to the orchestration of joint schemes between the ARC and the NSF. A persistent effort to align Australian and US processes would presumably smooth efforts to implement joint programmes in the future across a wide variety of agencies.

In the absence of such activity, bilateral grant schemes can be implemented but their potential effectiveness may be reduced. In the absence of strong integration, as an alternative model, providing a blanket bias for supporting proposals involving international collaboration would also stimulate collaboration but more along grassroots lines.

6.4 Commercialisation

In most areas, Australian businesses will need to continue to build bridges to the US to develop and market the products of their research. We don't believe there are strong arguments for government intervention in this area. There are two ways, however, in which Australian policymakers may be able to make a contribution that could simplify the process of getting Australian research into products in American markets.

The first relates to initiatives that improve the visibility and credibility of Australian research. In engaging with US organisations, there is a visibility issue for Australians in both the public and the private sectors. Generic policies that improve the quality of Australian public sector research and that bring high profile American researchers to Australia would help in this respect; so too would government endorsement of Australian technologies in areas like defence where the Australian Government is a potential customer for these technologies.

The other idea, which was raised earlier in the report, was that all Australian federal agencies with an extramural R&D budget over a certain threshold should mimic the American Small Business Innovation Research (SBIR) Programme by setting aside 2.5% of their extramural research budget for small businesses to engage in R&D for commercialisation of public intellectual property. Such an initiative could be implemented as a steppingstone to the creation of a bilateral scheme that supports research and commercialisation projects bridging the two countries.

This may be useful too for agencies where research is mostly conducted in house. CSIRO for example has deep (and lucrative) contractual arrangements with large

US firms like Dupont, GE, Boeing, Procter and Gamble, Exxon and Pepsi. An SBIR programme might enable the CSIRO to leverage some of these relationships in order to create a stronger R&D service industry in Australia.

Finally, there may a role for government too in ensuring that intellectual property policies relating to the research it funds do not constrain collaboration. What this means in practice, however, must be thought through very carefully. It could mean, for example, that organisations funded by the Australian Government to do R&D should be audited on a regular basis to establish efficiency of process in managing and negotiating contracts relating to their intellectual property. On the other hand, Australian organisations should in many cases be expected to protect their intellectual property, even if it means reduced collaboration.

6.5 Generic action

American and Australian researchers already work together in large numbers and across a wide range of sectors and fields. But there is tremendous scope for deepening the relationship.

There are specific areas that seem ripe at the present time for governments to build more formal relationships. The joint activity in solar energy research already underway is a targeted initiative that will stimulate collaboration if well implemented. There is an impressive alignment of research in government agencies in areas like space, health, agriculture and geosciences, which should serve as a basis for more formal organisational arrangements.

Indeed, this is a particularly topical idea in the agriculture domain where a formal research agreement between US and Australian departments of agriculture has been envisaged as an alternative to the rolling funds currently provided in Australia for the most part via the CRC programme and the rural R&D corporations.

It is obviously also critical in the space sciences, not least given Australia's strong interest in ensuring that the Square Kilometre Array is ultimately sited in Australia and is back with substantial investment from the US as well as other nations.

Looking at the research base of the two nations, one could develop good rationalisations for a myriad of other targeted schemes supporting bilateral collaboration in areas as diverse as (by way of example) archaeology, business and economics, cell and tissue engineering, ecology and biodiversity, global comparative studies, health care services, mathematics, medical imaging, meteorology, nuclear science, oncology, tropical medicine, and so on.

Indeed, one should probably mention too those other areas of current expansion in the US research system, which we have not touched on in this report, where Australia has been slower to create research capability, but could potentially piggyback through US partnerships. These are fields like digital research in the humanities, cloud and mobile computing, fusion research, and synthetic biology.

The ultimate problem for policymakers in supporting the US-Australian relationship in research is that they are confronted by an extraordinary richness of opportunity. For this reason, policies that support the overall environment for collaboration, and which make Australian researchers attractive partners, will in the long run likely prove more significant than schemes targeting particular fields.

With this in mind, we have made several observations throughout this report about policies that would have systemic impacts, with clear benefits in fostering more US-Australian collaboration. There is one bigger idea, though, that would have a really profound consequence.

A truly enlightened government in the present global research environment would consider making international activity a significant component of everything it does in research. It would:

- expect an international dimension to a significant proportion of the grants in funds, including capacity for research providers to subcontract parts of a project offshore, especially to the US which already implements the same policy in many cases towards Australia;

- expect all government agencies with serious research budgets to have a formal relationship with their equivalent agency in the US (as the leading research nation) supporting joint planning, programme integration, and secondments of senior managers; and

- expect every agency to support a research investment scheme targeted explicitly at opportunistic leverage of international research funds for research projects led by Australians.

A policy of this nature, which is focused on increasing international collaboration wherever it may occur, will tend to raise the level of US collaboration implicitly. It would save policymakers from having to make controversial choices about sectors and fields, where the information available to them will always be imperfect, and where they may become captive to particular interest groups. It would also revolutionise the quality, dynamism, and openness of Australian research.

Recommendations

13. Policies to facilitate strategic engagement in 'big science' projects, access to high-end infrastructure in the US, and participation in global alliances and networks will be an important element of any collaboration strategy.

14. There is an appetite in Australia for increasing research mobility to and from the US with a focus on: PhD scholarships, pre-doctoral fellowships, postdoctoral fellowships, joint appointments (including via a Laureate-level fellowship that attracts US researchers into joint appointments with Australian institutions), and international visitor research institutes in areas like mathematics.

15. Formal inter-governmental agreements can be useful in fostering collaboration but are probably most effective in supporting collaboration in research where: (a) they reflect an underlying community of capability that is ready to engage and preferably already engaged; and (b) they are focused in such a way that it is clear who is responsible for implementation and it is clear how implementation will be resourced.

16. A truly enlightened government in the present global research environment would consider making international activity a significant component of everything it does in research. It would:

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