Australian Government
Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education

सत्यमेव जयते
Government of India
Ministry of Human Resource Development

AUSTRALIA INDIA EDUCATION COUNCIL

Strengthening the Australia-India Knowledge Partnership: Challenges and Opportunities

A Report for the Australia India Education Council

Dr Radhika Gorur
Daniel Loton
The Victoria Institute
Victoria University

AIEC

AIEC

AIEC

Strengthening the Australia-India Knowledge Partnership: Challenges and Opportunities

A Report for the Australia India Education Council

Dr Radhika Gorur

Daniel Loton

The Victoria Institute

Victoria University

The views expressed in this report are those of the authors and do not represent the views of either the Australian Government or the Government of India.

Disclaimer

The Australian Government and the Government of India, its officers, employees or agents disclaim any responsibility for any loss howsoever caused whether due to negligence or otherwise from the use of information in this publication. No representation expressed or implied is made by the Commonwealth of Australian Government or the Government of India or any of its officers, employees or agents as to the currency, accuracy or completeness of the information contained in this report. The reader should rely on their own inquiries to independently confirm the information and comment on which they intend to act.

ISBN 978-1-921916-62-5 [PRINT]

TABLE OF CONTENTS

ACKNOWLEDGEMENTS 2
GLOSSARY 3
EXECUTIVE SUMMARY 5
KEY FINDINGS AND RECOMMENDATIONS 6
THE SCOPE OF THIS STUDY 13
- Research Design and Methodology 14
- Methods 14
- Key Concepts 14
- Overview of the Report 15
- Limitations 16

A REVIEW OF THE LITERATURE 17
- Trends in International Collaboration 17
- Potential and Expectations 18
- Challenges in Collaboration 19
- Distance 20
- Cultural Differences 21
- Multiplying Regulatory Requirements 22
- Issues with Governance and Policy 22

THE CONTEXT: RESEARCH AND INNOVATION IN AUSTRALIA AND INDIA 24
- Australia 24
- India 27
- Australia-India Research Collaboration: Mutually Advantageous 29
- AISRF 30

STORIES FROM THE FIELD 31
- The Lack of a Coordinated Approach (Finding #2) 31
- The Difficulty of Promoting Interdisciplinary Research (Finding #4) 32
- Identifying Research Partners (Finding #1, 8) 35
- Assessment of Proposals (Findings #6, 7, 8,9) 36
- Simplifying Processes (Findings #10, 11, 13, 15, 16) 38
- Fostering Long-term Engagement (Findings #1, 3, 5) 39
- Capacity Building: Opportunities for Early Career Researchers 41
- Discussion 41

CONCLUSION 43
REFERENCES 45

ACKNOWLEDGEMENTS

We would like to acknowledge our gratitude to our interviewees, who included policy makers and senior officials and researchers in Australia and India across a variety of institutions. Their patience, interest and participation are deeply appreciated. We would also like to acknowledge the help we received from the Australia India Education Council, and in particular the support of the team at the Australian High Commission in New Delhi. Particular thanks are due to Vidhi Sahae, Nerida Rixon and Peter Nolan in New Delhi, Sean Starmer in Canberra, and Sue Elliott in Melbourne for their support and advice.

The interviewees in this study were affiliated to the following institutions:

- Australian Academy of Science
- Australian Centre for International Agricultural Research
- Australian High Commission, India
- Australian National University
- Centre for Earth Sciences, Indian Institute of Science
- Centre for Genetic Engineering and Biotechnology, University of Delhi
- Centre for Nano Science and Engineering, Indian Institute of Science
- Centre for Studies in Science Policy, Jawaharlal Nehru University
- Commonwealth Science and Industrial Research Organisation, Government of Australia
- Department of Biotechnology, Government of India
- Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, Government of Australia
- Department of Microbiology and Cell Biology, Indian Institute of Science
- Department of Science and Technology, Government of India
- India Institute of Technology Delhi
- Indian Institute of Science Education and Research Mohali
- Indian National Science Academy
- International Bilateral Cooperation Division, International Division, Department of Science & Technology, Government of India
- International Centre for Genetic Engineering and Biotechnology, University of Delhi
- Ministry of Communications & Information Technology, Department of Electronics and Information Technology, Government of India
- National Council of Applied Economic Research
- Office of the Chief Scientist of Australia
- Planning Commission, Government of India
- Swinburne University of Technology
- The Energy Research Institute
- University of Melbourne

GLOSSARY

ABB	ASEA Brown Boveri
ACIAR	Australian Centre for International Agricultural Research
AIEC	Australia India Education Council
AII	Australia India Institute
AISRF	Australia-India Strategic Research Fund
ANSTO	Australian Nuclear Science and Technology Organisation
ARC	Australian Research Council
ASCRF	Australia-China Science and Research Fund
BRICS	Brazil, Russia, India, China and South Africa
CCI	Coordinating Committee on Innovation [Australia]
CCMB	Centre for Cellular and Molecular Biology
CSIR	Council of Scientific and Industrial Research [India]
CSIRO	Commonwealth Science and Industrial Research Organisation
CSTACI	Commonwealth State and Territory Advisory Council on Innovation
DAE	Department of Atomic Energy
DBT	Department of Biotechnology
DIICCSRTE	Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education
DIISR	Department of Industry, Innovation, Science and Research
DIISRTE	Department of Industry, Innovation, Science, Research and Tertiary Education
DOD	Department of Ocean Development
DoS	Department of Space
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
EU	European Union
GDP	Gross Domestic Product
ICAR	Indian Council for Agricultural Research
IICT	Indian Institute of Chemical Technology
IPRS	International Postgraduate Research Scholarships [Australia]
NGO	Non-Government Organisation
NHMRC	National Health and Medical Research Council [Australia]
NRIC	National Research Infrastructure Council [Australia]
OECD	Organization for Economic Co-operation and Development
PhD	Doctor of Philosophy
PHFI	Public Health Foundation of India
PMSEIC	Prime Minister Science, Engineering and Innovation Council [Australia]
R&D	Research and Development
S&T	Science and Technology

SFIC	Strategic Forum for International Science and Technology Cooperation [European Union]
SPR	Scientific Policy Resolution [of India]
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
STP	Science and Technology Policy [India]
TERI	The Energy Research Institute [India]
TPS	Technology Policy Statement [India]
UK	United Kingdom
US	United States

EXECUTIVE SUMMARY

This report presents the findings and recommendations arising from a study of the challenges and opportunities for successful and sustained scientific research collaboration between India and Australia. The study was initiated and funded by the Australia India Education Council and was steered by the Working Group focused on Research, headed by Prof Sue Elliott of the University of Melbourne and Prof Dinesh Singh of the University of Delhi.

Although there is a long history of collaboration between India and Australia, particularly in the medical and agricultural fields and in water management, there has been a significant increase in bilateral collaborations in science and technology in recent years. Collaborations have sprung up between universities and major national laboratories in the two nations. In 2006, during a Prime Ministerial visit to India, Australia committed $20 million over five years to set up the Australia-India Strategic Research Fund (AISRF), with India committing to meet the costs of the participation of the Indian researchers supported through AISRF. This scheme received a boost in 2009 with a steep rise in Australia's commitment, to the tune of $64 million over 10 years (up to 2015-16) with a corresponding commitment on the part of India to meeting the cost of the participation of the Indian research teams. The AISRF is Australia's biggest investment in research collaboration with any single nation, and it has catapulted Australia into becoming one of India's major research partners. With these investments, the AISRF has become a very significant, though by no means the only, sponsor of bilateral collaboration in scientific research between the two nations.

Interest in bilateral scientific collaborations between India and Australia needs to be seen within the context of increased emphasis on scientific output globally. The focus on the 'knowledge society' has placed science at the forefront of economics – scientific research has come to be seen as essential to economic growth and competitiveness. Collaborative research is an extension of this emphasis on scientific research output. There is a wide variety in scientific collaborations including partnerships between academe and industry; interdisciplinary research involving teams from different disciplines; and international collaborations.

The volume of international collaboration in science has been growing worldwide, and in particular, the BRICS nations have become more active in scientific research, and are increasingly engaging in international collaborative research.

Despite the increase in the volume, popularity and investment in collaborative research, there is little research to date on the dynamics of collaboration or the epistemic culture of collaborative science. Few descriptions exist of the day-to-day doings which make up the practices of scientific collaboration. Nor is there much understanding of the kinds of obstacles and challenges that come up in international collaborative scientific research. There are few models to evaluate the quality of collaboration. And because this is such an under-researched area, there are few suggestions with regard to how practices of collaborative science can be improved.

This report, based on empirical research, goes some way towards addressing these under-researched aspects of international collaborations in science. The thirty-three in-depth interviews with policy makers, institutional leaders and researchers in both India and Australia provided rich detail about the processes involved in collaborative research, the dynamics of collaboration, and the challenges and obstacles that arise in collaboration at the levels of policy, institutions and researchers. The report examines the conceptualisations of science and of collaborative research implicit in, and materialised through, funding policies and project guidelines as well as institutional and researcher practices, and examines their implications for the type of science that is being done and the way collaborations are being organised and conducted. Recommendations are offered to enhance the scope, nature, prospects and outcomes of scientific research collaborations between Australia and India.

KEY FINDINGS AND RECOMMENDATIONS

Finding #1

There is a long history of collaborative research between India and Australia, and the injection of funds through AISRF and high-level diplomatic visits and declarations have boosted interest in bilateral research between the two countries. However, while Australia has recognisable areas of expertise, such as water management, immunology, agriculture and climate change, USA and Europe remain the top choices for collaboration for Indian scientists. Australia has still not established itself in India as the favoured partner for collaborative research, and it is not clear that bilateral research will progress beyond ad hoc, project-based work in the long term. Most of the arrangements remain at a person-to-person level and have not become institutionalised. Some associations have become well-established and have been sustained over many years, but these have been few in number and have not been scaled up significantly.

Recommendation

Australia should identify clear areas of expertise (for example water management, agriculture, biotechnology) and promote these as part of Australia's distinctive specialisation areas, with a recognisable identity and a clear narrative, so that Australia becomes the first choice partner in specific, niche areas of research. Funding for research in these areas could be channelled through collaborative research centres to encourage sustained and on-going collaborative work on a programmatic rather than project basis.

Currently, projects move with people – when a person moves to another university, the links move with that person, rather than new links being developed. Approaches to institutionalise such collaborations, with the involvement of a group rather than individuals, and with the involvement of PhD students, should be sought and developed so that collaborations are institutional rather than person-to-person.

Finding #2

There is no clear statement of objectives or a clear strategy from the Australian side with regard to collaborative research with India, against which all the national agencies such as CSIRO and AusAID could align their priorities. Similarly, there is no clear statement from the Indian side outlining its objectives and strategies with regard to research with Australia. Although there are general declarations of knowledge partnerships between the two nations, there is no specific and clearly spelled out strategy. There are jointly agreed priorities and objectives with AISRF, but not an overall long-term national or bilateral strategic program. There are differences in priorities, in the outcomes and impacts sought, and in the expectations from collaborations between agencies within each country and between the two countries. This lack of clarity and alignment has meant that collaborations are ad hoc, people-based and project-specific rather than products of a cohesive and strategic long-term strategy.

Recommendation

Bilateral scientific collaborations should be located within the larger framework of the bilateral relationship between the two nations, and a clear, shared understanding of the goals and aims of bilateral collaboration, and a clear medium and long term strategy should be developed on the basis of complementarity and in line with national strategies and goals. These objectives and strategies should be developed with participation from related government departments, national agencies, research intensive universities, industry representatives, economists, social scientists and a range of other stakeholders. These aims and strategies should in turn be used to align and guide the priorities and strategies of national agencies.

Finding #3

There are subtle but significant variations between Indian and Australian conceptualisations of the relationships between science, technology and innovation (STI); their understandings of the interactions between STI, society, politics and nature; and their visualisations of the process and dynamics of scientific work, particularly as expressed in the STI policy of 2013. 'Science,' as conceptualised in Australian policy documents, appears to favour the 'laboratory' notion, while Indian policy documents reflect science as intimately related to innovation for social change. The Indian conceptualisation implies a complex and close relationship between science, society and social and economic issues, and sees science as being in the service of improving the quality of life more directly, whereas the implicit underpinning of science policy in Australia is that scientific progress aids the economy which in turn improves the lives of citizens.

These differences in philosophical orientations participate in the way departments are set up, in the kinds of relationships envisaged between them, and in the outcomes that are valued. In the Australian interpretation, for instance, innovation is linked more to trade and industry than education and research. Research outcomes in the form of publications and patents are valued. In India, particularly in recent policy formulations, the emphasis is more on solution-focused research where impact in terms of change in the quality of life is valued more than publications or patents.

These differences in orientations and values could potentially lead to a mismatch in the priorities and desired outcomes of collaboration. For example, publications and patents may be emphasised more in one orientation than the other. The range of disciplines and stakeholders considered to be crucial to science might differ. These differences, if left unarticulated and if not well understood, could eventually result in collaborative activities that serve the priorities of both nations in a limited way.

Recommendation

The differences in orientations to science and its relationship to society can be viewed as opportunities to expand the breadth of expertise and experience of policy makers, researchers and education institutions in the two nations. Alongside partnerships in traditional 'research and development' types of science, Australia could actively engage with India in its 'frugal innovation' and its endeavours to create innovation ecosystems that bring together a range of diverse actors to solve problems faced by the bottom-of-the-economic-pyramid. Collaborating in this type of research holds benefits for both nations. It would broaden the horizon and expand the scope of science in Australia and India. The scale and conditions of operations in India are very different to that of Australia, and collaborating with India in its 'frugal innovation' projects would provide opportunities for Australian researchers to develop new types of expertise. For India too, this is a new paradigm of research, and collaboration with Australia in this effort could lead to mutual learning and opportunities to scale up and spread the innovations to the four billion poor worldwide.

Finding #4

'Social science' is seen in the policies of both nations as a fundamentally different endeavour to 'natural science' and these differences have led to particular forms of institutional arrangements that segregate researchers by discipline and reify divisions between them. This places limitations on the kinds of projects conceptualised in collaborative research between the two nations.

Recommendation

Both India and Australia could work towards expanding the notion of 'science' as the making of knowledge, moving away from the traditional 'laboratory science' or 'natural sciences' understanding of the term. India's new paradigm of research outlined by the recently formed National Innovation Council (NInC) is solution-oriented, interdisciplinary and focused on addressing the needs of the

bottom-of-the-economic-pyramid. This could become a niche area of collaboration between the two nations, alongside the more traditional areas. Future funding schemes could incorporate a separate scheme for collaborations that involve experts from the natural and the social sciences, as well as a range of other stakeholders, such as industry and non-government organisations (NGOs).

Finding #5

The participation of industry in research is a priority for both India and Australia. Currently, a few collaborative projects involve industry participation, but by and large, this is inadequate.

Recommendation

Funding schemes similar to the ARC Linkage grants scheme could be piloted to explore if such a scheme would encourage greater participation from industry. A study could be undertaken to explore factors that inhibit industry participation, and analyse the conditions under which industry partnerships in research might flourish.

Finding #6

Funding for research will always be inevitably limited, so not all proposals can be supported. Mechanisms to select which research to fund are necessary to ensure that research funds are invested wisely. Globally, a popular approach is for peer-panels to review proposals and select the ones that will be funded, and this is the model adopted by AISRF. This has an important downside – it can take a great deal of time, effort and sometimes money to prepare full-fledged applications for peer review, particularly when the researchers involved are located in different countries. The success rate is low – typically between 15 and 20 per cent. The scale of effort and resources expended when a large majority of applications will necessarily be unsuccessful is becoming a concern globally [1].

Recommendation

Future funding schemes could consider adopting a tiered submission process. A brief Expression of Interest should be called for, and, based on this, a shortlist prepared. The shortlisted projects should then be developed and elaborated with advice from panel members so that projects may develop in ways that best suit bilateral priorities and valued outcomes. Another round of evaluation could then decide which projects will be funded. This approach would also better harness the considerable expertise embodied in peer review panels.

Finding #7

Currently, the focus of bilateral partnership in science is more on accessing expertise and on excellence. Typically, highly reputed institutions and experts are engaged in bilateral research projects. While an important benefit of collaboration is access to expertise and to excellent institutions and infrastructure, alongside this, opportunities exist for capacity-building which, at present, are not systematically being harnessed. The opportunity to build capacity in 'second tier' institutions is being overlooked.

Recommendation

Incentives for joint projects involving research-intensive and 'second tier' universities as co-CIs could be considered. This would be of benefit to both nations. In India, only a few elite institutions are engaged in serious research, while a large number of universities are not research active. In Australia, too, there is a desire to build the research capacities and profiles of some of its less research-intensive universities. Bilateral collaborations could become a way to encourage diverse institutions to work together, with the welcome consequence of improved skills and capacities. This would be a way for inclusion to be practiced without sacrificing excellence.

Finding #8

Interviewees repeatedly emphasised the importance of face-to-face interactions in seeding ideas for collaborative research. Scientists talked about the importance of developing professional networks and even friendships for developing ideas into collaborative projects. But while senior scientists might have opportunities to travel to conferences and meet people from different parts of the world, such opportunities are increasingly drying up in many universities and may not be available easily to early career researchers (ECRs).

There is great desire in both India and Australia to enhance the skills and networks of early career researchers (ECRs), and several schemes – institutional, national and bilateral – to encourage ECRs to travel and access laboratories and other facilities overseas so that they are able to become involved in collaborative research. However, ECRs typically operate under several constraints, which restrict their ability to take advantage of some of these opportunities, particularly if these schemes require them to be away from their home institutions for lengthy periods. They are often employed on short contracts, attached to specific projects or have teaching commitments which restrict the length of their overseas stay.

Even if funds are available, ECRs often do not know which overseas institutions to access.

Recommendation

An assessment (or reassessment) of the needs and constraints of ECRs may be useful to inform both national and bilateral policies. A study of the patterns of overseas travel among ECRs in different disciplines could be undertaken to inform the type and the level of support required.

Future funding models could consider awarding grants to *host institutions* which could then advertise the opportunity for early career researchers interested in the particular area of expertise to visit them and spend 4-12 weeks in their institution. This would resolve the issue of ECRs being unable to identify and contact specific host institutions.

In addition, more funding could be made available in future schemes for collaborative workshops which would provide opportunities for many researchers within an institution to interact with overseas counterparts. Because workshops would involve much smaller funds, early and mid-career researchers could be encouraged to apply for such funds.

In addition, more travel bursaries could be offered through universities to early and mid-career researchers.

Finding #9

Current granting schemes for open rounds of funding favour experienced researchers over ECRs. Although most projects provide funds to employ post-doctoral researchers, the valuable experience of developing the application as a joint CI is not guaranteed under current application guidelines.

Recommendation

Grant applications could incorporate a requirement that at least one ECR should be a co-investigator on applications along with senior researchers. This will help ECRs to gain experience in grant writing and also develop their track record.

Finding # 10

For some institutions, collaborations might bring prestige, new ideas and new opportunities. However, there are also new burdens, particularly administrative burdens. For this reason, institutions are not always supportive of collaborations. Moreover, the relationships in collaboration are often between researchers from the two countries and between researchers and the funding agency. The institution is largely 'absent' in the work that is done. In both countries, some scientists reported a feeling of being left to their own devices when they come up against problems whilst engaged in collaborative science. Most of the issues for scientists related to administrative issues of timely funds disbursal and issues relating to travel arrangements.

Recommendation

It is up to individual institutions to develop mechanisms to support scientists in their collaborative efforts, and it is beyond the scope of this report to make recommendations on how this might be done. However, scientists participating in collaborative projects are often quite senior members of their organisations, and are aware of the ways in which their institutions function, including where the bottlenecks might be and how responsibilities are allocated. They should be encouraged to articulate to the relevant Heads of Department or Deans or General Managers the institutional issues that arise and to seek a review of administrative practices to accommodate the increase in international collaborations.

Specific training for administrative staff to accommodate the types of issues that arise in collaborations may also be helpful.

It is common practice for funding agencies to seek progress reports to ensure that projects are on track. Whilst these are used as instruments of accountability, they could be expanded into instruments of facilitation, with opportunities for scientists to report on any challenges they might be facing, and for the funders and researchers to discuss ways in which those challenges could be addressed. Even if problems cannot be solved, such measures would provide good information to funding bodies, and scientists will feel better supported.

Finding #11

As complex and difficult as the process of writing grant application might be, the bureaucratic processes involved once the grant is awarded appeared to be a source of frustration for scientists. And since the processes in the two countries can be different, these differences could cause difficulties in coordinating such activities as recruiting PhD students or ECRs and purchasing equipment. A lack of understanding of procedures in each other's systems also led to increased anxiety and concern, and researchers needed to find a range of ways to solve unexpected problems that arose from bureaucratic complications.

Recommendation

Although some system-level constraints cannot easily be overcome, extending the Recommendation following Finding #10, funding agencies could follow up with scientists within a few weeks of the award of the grant to identify any issues scientists might be facing with a view to facilitating processes where possible.

Finding # 13

Travel was identified as critical not only to facilitate the development of projects, but also necessary for carrying out the collaborative research project. Funds for travel are usually built into the funding applications. However, some constraints and requirements with regard to travel were identified by participants as sources of frustration. Restrictions on the choice of airlines might make travel more expensive or less convenient. Given the duration of most projects, a requirement for declaring exact dates of travel at the outset is difficult.

Recommendation

As per recommendations following Findings #10 and 13, funding bodies could maintain contact with researchers periodically during the course of the collaboration. Regular contact could provide funding agencies useful feedback and the opportunity to resolve some of the challenges that researchers might be facing. It would also provide funding bodies the opportunity to review processes and tailor future schemes.

Finding # 14

Collaborative projects are especially valuable as a way to involve PhD students. Such projects provide a rich training ground and an opportunity for students to develop networks overseas. At the same time, PhD students are very useful in actually carrying out the work on such projects. However, with some collaboration schemes, funding rounds and enrolment schedules may not align in ways that allow convenient recruitment of students to work on projects and for the projects to serve their candidature.

Recommendations

Although it may be difficult to find a definitive solution to this issue, attempts can be made to introduce flexibility in funding calls and to introduce variations and options within PhD program guidelines to ensure that students get the best benefit from collaborative projects. There are already many excellent examples of students from India gaining from university collaborations, for example through the Deakin-TERI partnership and the IITB-Monash partnership [2]. These could serve as models for scaling up student participation and to also encourage staff exchanges.

Finding #15

Many current collaborations involve scientists who have had a history of previous collaborations with each other, and there is friendship, respect and trust between researchers. In many cases, researchers in the Australian team are diasporic Indians who have studied in India and are collaborating with former classmates or colleagues, and these team members act as mediators and brokers between cultures. Nevertheless, cultural differences exist and can sometimes be quite challenging. There are differences with regard to the pace of work, punctuality and timely completion of tasks. There are also differences in the ways team members participate and interact with each other. In India, a hierarchical approach and deference towards senior team members inhibits the free participation of more junior researchers in discussions and decisions.

Recommendation

Formal and informal ways can be explored to make scientists on both sides aware of cultural expectations and differences in ways of operating, with a view to accommodating and managing them. Formal ways of creating such awareness could include the preparation and distribution of brochures or information on a dedicated website, a briefing organised by the Science Officers of the host country to successful grantees of each round of applications, or opportunities for experienced colleagues to brief and mentor new teams.

Finding #16

Once the grants are awarded, researchers sometimes continue to need support to negotiate complex terrains in the other country over the course of the research. Issues may arise, such as delays in funding, visa difficulties, and difficulties with customs when equipment is taken to the partner country. Some researchers reported that they would appreciate the opportunity to seek advice, when confronted with unexpected challenges, from someone from their own country with local knowledge, who might solve, if not anticipate and deflect, potential problems. This support appeared to be particularly missed when teething problems surfaced at the start of the collaboration. As the collaboration progressed, scientists became familiar enough with the partnering team and the collaborative terrain to work through many of the issues on their own.

Recommendation

Given that both countries are interested in continued and indeed greater collaboration over time, a dedicated liaison officer at the High Commission in each country could be charged with the task of providing on-going support by being the go-to person for scientists in their dealings in the partner nation, getting periodic updates from them, and troubleshooting as needed.

Finding #17

Both Indian and Australian scientists involved in collaborative activities overwhelmingly emphasised the value of collaboration and spoke of the warm friendships that often sprang up between scientists over the course of the collaboration. Many of these collaborations have been carried out over many years and the relationships have grown stronger over time. These relationships were characterised by mutual respect, mutual learning and trust. Interpersonal relations, so often mentioned in the literature as a challenge in collaboration, appeared to be far less of an issue in the case of Australia-India collaborations. Most of the challenges and frustrations appeared to arise from bureaucratic processes, and their remedies lay in policies.

Recommendation

As Australia-India collaborations continue to rise and evolve, it is important to keep in regular contact with those involved in collaboration to understand the challenges and to address them as they arise. The commissioning of this research is a step in that direction.

THE SCOPE OF THIS STUDY

Against the background of global interest in international collaborations, and the mutual desire on the part of Australia and India in fostering robust, productive and sustained bilateral research collaborations, this research project has been commissioned by the Australia-India Education Council (AIEC) to examine the challenges and obstacles to expanding collaboration in science and research between India and Australia, and to make recommendations with regard to potential solutions to these challenges. It seeks to raise awareness among policymakers, researchers and research administrators about the impediments to strengthening Australia-India research collaboration and point towards how these might be ameliorated.

Although Australia and India have been collaborating on specific projects for many decades, the recent dramatic increase in the extent of collaboration can be viewed in the context of closer strategic engagement between these two important countries in the region, which include matters of security, trade and a 'knowledge partnership'. During Prime Minister Julia Gillard's visit to India in 2012, Australia's commitment to strengthening the knowledge partnership between the two nations was reiterated. 'Knowledge partnerships' as articulated in these commitments encompassed bilateral engagement in education, research and innovation, which were placed at the centre of the broader economic and social ties between the two nations.

Education partnerships between the two nations include a range of activities. A wide variety of twinning and articulation arrangements have been forged between Australian and Indian institutions of higher education and more are being planned. Other forms of linkages have also emerged, or are being negotiated, centred on student and staff exchange, study abroad and project-based experiences. Jointly badged programs such as the Monash-IITB partnership are flagship examples of such collaboration. Deakin's successful, on-going collaboration with The Energy Research Institute (TERI) which includes joint supervision of PhD students based in India for an award from Australia have also proven to be very successful and sustained. Collaboration in science and innovation are carried out through collaborations between universities.

But besides these engagements between education institutions, a range of other mechanisms are available for a variety of collaborative research projects, and these are the focus on this report. Collaborations exist between Australian bodies such as CSIRO, ACIAR, AusAID and Indian institutions and centres such as IARI, ICAR, CSIR in areas like land use and water management. Australian researchers have the option of collaborating with Indian scientists in through projects funded by the Australian Research Council (ARC), and similarly, Indian scientists can apply for funds to DST, DBT or other bodies for joint research projects with Australia. More recently, the AISRF has developed many schemes to promote a range of collaborations.

This project builds on previous research commissioned by AIEC to examine university partnerships between India and Australia [3]. While the earlier study provides valuable information about university partnerships, this study focuses more broadly on collaborations involving a variety of partners, and includes the perspectives of a range of policy and institutional actors in both nations. It focuses on the day-to-day processes involved in collaboration, the difficulties encountered and the ways in which these challenges are overcome. Given the huge impact of AISRF on the number of joint collaborations, several of the researchers interviewed were involved in AISRF projects. As a result, many of the findings arise from the experiences of researchers who have collaborated primarily because of AISRF support.

This report is not intended as an evaluation of bilateral collaborations or as a review of any program. Rather, privileging the lived experience of policy makers, managers and researchers, it explores the ways in which structures, concepts and people are coming together in particular ways at this juncture in collaborative exercises, and seeks ways to refine processes and enhance possibilities. It anticipates opportunities for future collaborations.

Research Design and Methodology

This research is informed by theoretical and methodological traditions in the field of Science and Technology Studies (STS), which focuses on 'the investigation of knowledge societies in all their complexity: their structures and practices, their ideas and material products, and their trajectories of change' [3]. STS is an interdisciplinary field which has roots in a range of disciplines, including history, philosophy, sociology, politics, law, economics and anthropology. In studying scientific endeavour, STS researchers focus on the day-to-day work of scientists as they engage in the production of science, after the manner of Latour and Woolgar's Laboratory Studies [4]. In STS research, no a priori distinction is made between 'scientific work' and 'non-scientific' work which might be labelled 'administrative' or 'bureaucratic' – rather, the 'doing of science' is taken to include all the activities in which scientists engage. This approach was particularly useful in this research, as a great deal of the work of international collaboration, and most of the challenges reported by researchers, appear to occur outside the 'laboratory' or the sites of what was seen as 'scientific work.'

This study was organised around two key questions:

- What are the challenges to collaboration in scientific research between India and Australia?
- What steps can be taken to encourage better and more sustained collaboration between the two countries?

These key questions were elaborated into a host of interview questions with a focus on practices. How are collaborative projects born? How do scientists across oceans and continents get together to develop collaborative projects? How are such aspects of collaboration as division of labour, authorship and sharing of resources worked out? Collaboration – particularly when it involves actors who are collaborating for the first time – is risky business – how is the risk distributed and mitigated? What are the day-to-day activities that make up the work of collaboration in science, and what challenges do scientists engaged in Australia-India research collaborations face in carrying out collaborative projects? Responses to these questions led us through a complex maze of relationships, protocols and practices.

Methods

Keeping our focus on policies, institutional norms and researcher practices in mind, the project included the study of significant policy documents and extended and in-depth face-to-face interviews with key policy players in Delhi and Canberra; with a variety of research facilitators and managers; and with researchers. Interviews were conducted in Delhi, Bengaluru, Canberra and Melbourne. Where a face-to-face interview was not feasible, interviews were done via Skype. Best practice ethical processes were followed, with ethics clearance from Victoria University. Interviewees were required to sign a declaration of informed consent or to provide consent on record in the audio taping, if the interview was conducted on Skype. Anonymity was offered if desired. Interviews were digitally audio recorded. Some interviewees preferred to speak off the record in order to be more candid and some government officials in India preferred not to be recorded. Researchers interviewed ranged in seniority from very early career researchers to very senior professors. In all, 33 interviews were conducted. Key policy documents informing science policy in Australia and India were accessed and analysed.

Key Concepts

In this study, collaboration was framed not as a single, uniform and self-evident activity, but as multiple and complex activities that vary with such factors as the scale, the actors involved, their purposes and objectives, the duration of the activity and the level of engagement. Collaborations are viewed as having differing rhythms, motivations and registers of success. Collaborations occur at a range of levels – between individual researchers, between teams of researchers, between institutions such as research centres, or between nations through bilateral agreements, particularly in sensitive areas such as defence. Each of these would involve quite different activities – collaboration would be done differently in these different arrangements, throwing up different challenges, making different

demands upon the partners involved and requiring different conditions for success. Moreover, collaboration can occur to varying extents – from a chance conversation forming the basis for some theoretical advancement, to large-scale movement of researchers or instruments; from short-term collaborations to long-term projects.

Our original brief was to examine the 'barriers' to bilateral research collaboration. Words such as 'barriers,' 'obstacles' and 'challenges' have subtly different connotations to each other. We felt that the word 'challenges' invited our interviewees more readily to discuss difficulties of various kinds and intensities, and also provided encouragement to share how they overcame these challenges. Challenges were conceptualised as arising at three levels – the policy level, at the level of institutional practices, and at the researcher level. Since policies decide priority research areas, funding rules and procedures and the types of activities that will be supported, the ways in which policies and priorities percolate into the practices of scientific collaboration were examined. Policies, in turn, arise from the conceptions of science and its relationship with society and the economy. Understandings of the nature and work of 'doing' science also configure the types of institutions that are set up, and the ways in which they are related or segregated. These tacit and explicit understandings of the nature of science as evident in policies and practices were also examined.

Challenges to collaboration were examined at various levels:

At the policy level – policies are developed to translate strategic goals into guidelines for action. Funding policies, for example, reflect national priorities and strategic directions. They dictate the nature of funding that will be made available to different types of science. Policies may prioritise certain areas of science for support in preference to others. They may promote collaborations with certain nations rather than others. Policies also dictate the ways in which collaborations will be measured, and the kinds of impacts they should seek. For these reasons, policies are significant actors that, in various ways, serve to constrain, enable and shape the possibilities of collaboration.

At the institutional level – although scientists are often highly autonomous, they are intimately tied to the institutions to which they are affiliated. The reputation of the institution and the research infrastructure and environment of the institution is often a consideration for granting bodies. Institutional priorities and the demands of the institution on researchers' time play a part in the extent to which researchers may be able to engage in and carry out collaborative work. Institutions often have internal processes to vet applications for grants. Moreover, some institutional processes, procedures and requirements may hinder or frustrate engagement in international collaborations

At the researcher level – people-to-people relationships are always fraught with unpredictability. Collaboration requires particular attributes such as understanding different points of view and ways of doing things, a willingness to negotiate and to learn, and the resilience to face and overcome unexpected barriers that are outside one's power to control.

Overview of the Report

An extensive review of the literature was also undertaken to inform this study. This review is presented in two parts. The section *Trends in International Collaboration* sums up the broad patterns in the rise of international collaboration globally, and analyses some of the perceived benefits of collaboration in the literature. In the second section, Challenges in Collaboration, we survey the literature to understand what is known in the field with regard to challenges in conducting, managing and promoting international collaborations in scientific research.

Since we take the perspective that science and society are intimately intertwined, we provide contextual sketches about the development of science in Australia and India, which serve as a backdrop against which our findings can be read with greater understanding.

The results and their analysis are already summarised in the previous section – nevertheless, we have included the section Stories from the Field which elaborates the findings, often using the words of the participants themselves.

The report concludes with a brief summary of our findings and our perspective on the outlook for the future.

Limitations

University collaborations are a significant part of scientific collaborations between India and Australia. Currently, there are 387 active links between 32 Australian and approximately 250 Indian institutions. These links include joint research, student and staff exchange, joint supervision and credit transfer[1]. The nature, scope and issues around university partnerships have been comprehensively described in a separate report, *India-Australia Collaborations in Higher Education: Potential, Problems, Promises* [5]. As such, university collaborations, although a crucial aspect of the Australia-India knowledge partnership, have not been emphasised in this report. Between them, the two reports contain data based on in-depth interviews with over 90 participants in Melbourne, Canberra, New Delhi, Mumbai, Hyderabad and Bengaluru. The two reports may most usefully be read in conjunction.

The various schemes under which Indian and Australian scientists can collaborate are quite distinct in the way they are administered and managed. Given the large number of collaborative projects currently underway that are supported by AISRF, many of the researchers we interviewed were involved in AISRF projects. This has meant that some of the issues raised and the recommendations provided are more relevant to research funding programs such as the AISRF.

1 http://www.australiaindiaeducation.com/index.cfm/sd/Page/P/53/M/7

A REVIEW OF THE LITERATURE

Trends in International Collaboration

International collaboration is becoming an increasingly important aspect of scientific endeavour. Boosting international collaboration is already a major policy priority in many countries, particularly in the area of science, technology and innovation (STI). The European Union's (EU) *A Strategic European Framework for International Science and Technology Cooperation* [6], developed in 2008, outlines a number of core principles and orientations for interactions with international collaborators . Further, a special Council called the 'Strategic Forum for International S&T Cooperation' (SFIC) was set up to promote international science and technology (S&T) research collaborations. The UK, Canada, the US and many other nations have developed policy frameworks and infrastructures and special funding arrangements to foster international collaborations in research. Australia, too, considers international collaboration, particularly in science and technology, a policy priority. This is expressed in Priority #6 in Australia's strategy document *Powering Ideas: An Innovation Agenda for the 21st Century as: "Australian researchers and businesses are involved in more international collaborations on research and development"* [7].

There is more research occurring, and more of it is internationally collaborative, than ever before. Globally, according to some estimates, seven million researchers are spending around USD 1000 billion in research and development (R&D) each year, and there are over 25,000 scientific journals in which their research is being published [8]. Research collaboration has been increasing worldwide, with the average number of authors-per-article rising since the collection of publication data [9]. The growth in international STI research activity reflects the increased capacity in maturing economies around the world, including, especially, the Asia-9 nations (India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam). More and more economies are moving towards knowledge-intensive activities to generate jobs and in response to national global challenges, including that of remaining economically competitive. The private sector, too, has been investing in international collaborative research and (particularly) development. The share of internationally co-authored scientific publications and patents has increased from eight per cent to 22 per cent in recent decades [10].

Some broad trends can be observed in international collaborations. Collaboration is more common in disciplines which require substantial infrastructure and resources investment. Big science projects which involve multinational collaborative efforts, such as the Large Hadron Collider, have recently resulted in papers with over 3000 authors [11]. There is an inverse relationship between international collaboration and the development of the scientific enterprise of a nation [12, 13]. The larger the scientific enterprise, the lower the proportion of internationally co-published articles there tends to be. This is thought to reflect the reduced need for collaboration in well-resourced nations, since they are able to meet their needs internally. Likewise, there is a greater reliance of researchers in developing nations on the knowledge and infrastructure available in countries with more established scientific and academic systems. The US remains the most favoured partner in research for both India and Australia.

These patterns however are now changing dramatically. In part, this is because the increasing diplomatic and economic importance of many developing nations has encouraged countries to develop a variety of links, and scientific links become part of the 'soft diplomacy' between nations. In line with this, recent strategies in many Western nations have prioritised collaboration with the BRICS nations (Brazil, Russia, India, China, South Africa). The increase is also explained by larger investment and interest in tackling global problems – pandemics such as bird flu and global phenomena such as climate change – which have scant regard for territorial borders, and which need teams with diverse forms of expertise and experience. Increased mobility among staff and students as a result of internationalisation in universities has created international academic networks, and these have also contributed to increased collaboration in research. With university ranking schemes valuing international collaborations, there has been increased support within universities for the development of such projects.

India and China have invited particular attention in scientific collaboration. Many advanced economies have set up special strategies, institutions, infrastructures and funds to encourage collaborations with these two nations. These two Asian giants are seen as increasingly significant players in the contemporary knowledge economy. There is a perception that collaborating with them provides an edge in economic competitiveness. Moreover, just by their sheer size, these two nations are significant actors in global issues such as food and water security and health risks, including viral pandemics. The availability of a large number of PhD students in science and technology are another reason for increased collaboration between Indian universities and universities in countries like Australia and the US. In addition to the above, India scientists are fluent in English. Many countries are therefore keen to gain a foothold into India's research institutions, and to develop meaningful and sustained relationships with them.

Potential and Expectations

The most commonly cited arguments in the literature for engaging in international collaboration are summarised below:

Access to Resources

International collaboration can provide increased access to infrastructure, human capital, expertise, funding and other resources. Some contemporary problems that scientists are seeking to solve require extensive infrastructure and human capital. Such problems benefit from, and are sometimes impossible without, the pooling of resources from many nations [14]. Many topics in science are nuanced and highly specialised, and experts in the area may be few and scattered around the globe. Communication and access to specialised equipment can be essential in building projects [15]. Access to more extensive research libraries can disseminate knowledge, save unnecessary duplication of research efforts and allow researchers to engage collaboratively at the 'cutting-edge' [16]. Funding for some types of scientific research is dwindling, and more established researchers are broadening their appropriation of funding to international pools, either to increase their chances of success, or to access a fund more tailored to their specific topics of interest [17].

Pathway to Development

Research collaboration is also seen as a pathway to national and regional development. Research collaboration can contribute to building a skilled workforce and advancing social and technological innovation, as well as promoting equity, through a knowledge-to-action process [7, 18]. The exchange of knowledge and skills is particularly important for developing countries. There have been calls from within academia encouraging health and biomedical researchers in developed nations to collaborate more with their counterparts in developing nations who face significant burdens. These calls include specific policy recommendations [19-21].

Global Research for Global Challenges

There is a growing recognition that many challenges driving research are transnational or global in nature. Such challenges are either unable to be solved by a single nation, or can be solved far more effectively through multinational research. This recognition falls under the growing awareness of the interconnectedness of contemporary societies, including the globalisation of science and technology research [22]. Examples of such problems include climate change, health threats, food and water security and depleting energy resources [14].

International collaboration holds the promise of producing major breakthroughs, as teams with expertise and technology across different disciplines work together [23]. Internationally collaborative and multi-disciplinary projects offer the promise of facilitating the world's best research teams to produce the most impactful outcomes.

Output

Several studies have highlighted increasing citations for publications with international collaborators. A study of Indian cancer research outputs from 1990-2005, for example, revealed that journal articles which included at least one foreign author received, on average, nearly double the citations when compared with locally authored papers [24]. Even more dramatically, papers by teams in which more than half the authors were from overseas received on average four times the citations compared with local-only authored papers.

Evaluations on the basis of 'outputs' in the form of publications and patents reflect western and accountability-focused approaches to research evaluation. These outputs do not take into account a range of innovations in practices and processes which have the potential to improve the lives of large populations in significant ways. Such measures of outputs are therefore of limited value.

It is evident from the literature that international collaboration is on the rise globally and that it is seen as an important endeavour for national gains as well as for betterment more globally. With increasing investment in collaboration, there is now greater interest in understanding how this investment can be facilitated, nurtured and maximised. Identifying obstacles and challenges would be one way of promoting greater productivity.

Challenges in Collaboration

Given the promise and potential of research collaborations, particularly international collaborations, policy makers are understandably keen to find out what obstacles impede international collaborations, and to foster the conditions that enhance and promote them. With the rise in collaborative research activity – international and national – there has been a rise in studies of collaboration, though the number of such studies, and their scope, is small. This section sketches some of the important findings in the literature with regard to collaboration and the challenges faced in forging and sustaining collaborative work in science.

International research collaboration encompasses a broad range of activities. It can take forms as diverse as an email exchange to the creation of a multi-billion dollar piece of equipment. Collaborations may involve, among many things, the organisation of joint meetings and conferences, the development of international databases, the sharing of equipment, joint projects and experimentation and the setting of standards [25, 26]. Because of this diversity in scope, there is no consensus on any precise definition of collaboration. This report adopts the definition of "the working together of researchers to achieve the common goal of producing new scientific knowledge" [27], but this definition does not describe how closely, how often, or in what capacity such collaborative work might occur.

Many articles on international collaborations use co-authored publications or patents as indicators of collaborative activity [28-30]. Increasingly bibliometrics are being used by national and transnational agencies such as the OECD to investigate the scientific enterprise of nations in benchmarking and comparative exercises [31].

Output data in the form of publications or patents are, however, well recognised to be inadequate indicators of research quality or collaboration. How the collaboration began, the size and scope of collaboration, the extent to which different partners benefitted in terms of learning from each other, progress in and exchange of processes and methodologies, the training and mentoring of junior researchers, the novelty of the product or process – these are not necessarily captured in bibliometric figures [32]. The exact role of different collaborators in producing output may also not be captured by such metrics. Authorship conventions vary across countries and cultures and these variations put serious limitations on this kind of measurement [33].

Studies that investigate the *dynamics* of collaborative research, focusing on the everyday practices involved in collaborative research are few in number. Collaboration as an epistemic practice and culture is inadequately theorised. Most of the scientists we interviewed were very interested in the focus of

our study and said they would find research on collaboration useful in guiding their own engagements – but because studies of science are not generally seen as 'scientific,' they are seldom published in journals that scientists read. Most of the studies are small case studies – by necessity – and as such the methodologies followed are better respected in the social sciences than in the natural sciences. The studies we accessed were published in a variety of fields, including bibliometry/scientometrics [28, 34-37]; economics [23]; health sciences [16, 33, 38-43]; sociology and science and technology studies [9, 44-49]; research ethics [50, 51]; psychology [52, 53]; policy [54-59]; education [60-62]; information technology and management [63-67]; as well as a few in the so-called 'hard' sciences [14, 20, 21, 68, 69]. The topic was also investigated through conferences and forums [70, 71], and governmental or inter-governmental reports [72-74].

Research methods which may help to build knowledge on these day-to-day aspects of research collaboration include interviews and surveys with key stakeholders [71] and case-studies of particular scientific teams or enterprises, sometimes involving autobiographical accounts [34, 50]. Interviews often take the form of focus groups, arranged by a party with interest in encouraging collaboration, with many taking place at conferences [70, 71, 75]. Of these studies, a few attend to the complexities of forging and sustaining collaboration, and emphasise such issues as interpersonal qualities; varied institutional and cultural practices and priorities [23, 33]; communication difficulties and the scope for misunderstanding [71]; and the extensive resources required to work through administrative challenges [15].

Collaboration involves communication between people, and between and within disciplines, institutions, sectors and nations, with these 'levels' often posing unique dynamics [48]. It navigates both national and international regulations and legal frameworks, including those governing intellectual property, industrial relations, the ethical conduct of research and the transport of people and goods [27]. It must also traverse less explicit social structures, such as cultural and disciplinary traditions and semantic subtleties [23]. Thus collaboration is potentially fraught and poses a wide range of potential challenges and obstacles.

As internationally collaborative research covers a wide variety of activities, the challenges are also diverse. Different cross-national and cross-disciplinary partnerships will pose unique challenges, as will idiosyncrasies of the type of research. Some broadly applicable barriers are identified and discussed below.

Distance

While the era of the internet has seen the proliferation of accessible collaborative tools, international travel is still relevant for productivity in science and technology research. Face-to-face communication was a better predictor of deliverables in recent studies which included both internet-based collaboration and face-to-face meetings [76]. Case studies and interviews have also highlighted the importance of face-to-face communication [60] in science and technology research. This is in part because projects often require high level communication between parties over complex and sensitive issues, including the negotiation of agreements, which are not well facilitated by contemporary online conferencing packages.

In order to overcome this physical barrier, researchers travel overseas to meet with collaboration partners. However, international travel raises its own sets of problems. Researchers have described complex visa requirements, gruelling travel schedules and complex import/export regulations as some challenges [56, 71].

Differing time zones have also been mentioned by researchers as a possible barrier to international collaboration, with difficulties in coordinating activities outside of working hours [56], as well as maintaining continuity in working tasks across partners [21]. The importance of distance is also highlighted by the nature in which international research collaborations begin, with many being fostered from earlier face-to-face interaction, usually during a conference [38]. Likewise, the international flow of students and presence of diasporas is increasingly recognised as a bridge to international research collaboration [73, 77].

Cultural Differences

Studies of international collaboration have indicated a bias in culturally similar international collaboration, with Australia favouring the US and UK over geographically closer and larger trade partners such as China and Japan. Cultural dissimilarity is one of many psychological and socio-cultural factors which have been noted as potential challenges to international research, with many issues centred on qualities of the individual collaborators [33]. Also important are the intellectual and disciplinary practices and traditions. Studies of research collaboration often highlight that although collaborations require institutions and infrastructures to support them, the outcomes of research are ultimately the product of individual people working together.

Obviously, some degree of shared language is helpful in collaborative research and patterns of collaboration reflect this, but socio-cultural differences are not necessarily overcome by a grasp of a shared language. Socio-cultural factors can be nuanced and subtle, often revealed in miscommunications, and can have severe impacts on progress of international research and the development of long-lasting research relationships. Cultural differences may also translate into constraints on working processes or research topics, such as free use of the internet, limited access to data or political sensitivities [62]. Corruption has also been noted as an issue for some countries, including corruption in administrative processes at the University or Government levels [71].

A study of a lengthy US/China research collaboration in the area of HIV treatment revealed many interesting differences in research practice, ranging in diversity from hosting banquets and who should be invited to team meetings, to the allocation of credit and the recruitment of staff [33]. Where in China it was considered elitist and potentially even rude not to invite senior officials to meetings, regardless of their lack of direct involvement in the project, in the US, meetings included only the immediate project team. This involvement of senior officials who were described as peripheral to the project also included authorship and was explained as an expression of deference for institutional oversight, consistent with Chinese collectivist values. Differences in practice were also present at the site of research, including a restriction on hiring temporary research staff from outside of the clinical unit, which meant that permanent staff had to undertake the research in addition to daily workload. Further, the US collaborators were cautious not to overstep their level of direction so as not to be perceived as impinging on the autonomy of the collaborators. Formal banquets were a critical part of building the collaborative relationships in China, whereas the US partners found it difficult to reciprocate due to funding restrictions on food and alcohol. While conflicts arose, knowledge of the context of the collaborating partner, an openness and introspection between the collaborators on the influence of culture on their practices and willingness to compromise helped to move the project forward.

A large public health study involving collaboration between universities, government departments and businesses in both India and the U.S revealed some unique challenges [78]. While the funding was provided by the National Institute for the Mentally Handicapped (NIMH), it was delivered to, and administered by, the University of Connecticut Health Centre (UCHC), and researchers reported that the perception of the Indian collaborators that flexibility in costs and cost overruns were always available in the US led to conflict during annual grant reporting. The hierarchy within Indian universities and associated impacts on research practice was also mentioned as a possible barrier. Due to the hierarchical structure, junior members of the research team hesitated to have input into discussion about the project or having their input devalued because of their position. Further, the US research team were given undue credit as the experts on conception and methodology of the project. The US team described a process of familiarisation of this hierarchy and learning to navigate multiple lines of communication. Some language miscommunications occurred, with the use of the word "shame" by a US researcher, used as a synonym for "unfortunate" or "unlucky", was interpreted as an "accusation of incompetence". The team also reported misunderstandings regarding time pressures and competing responsibilities, delays, bureaucratic procedures, and external pressures.

Multiplying Regulatory Requirements

Researchers have identified that varied institutional and reporting requirements can pose significant challenges in international collaborative research, accounting for the expenditure of significant time and resources, compared with local collaborations. Most often, regulatory requirements multiply with international collaboration as the requirements of all nations involved must be met. These tasks can include reporting and approval processes of funding bodies, national regulatory requirements including tax payments, legal agreements between collaborators and ethical approval.

The process of obtaining and managing ethical approval is one of the key difficulties in international collaborative research, including specifically in collaborative projects with India [50, 51]. Institutional review boards, the Australian equivalent of Human Research Ethics Committees (HREC), have posed notorious difficulties for international research collaborations, particularly when multiple overlapping approvals are required. In many cases locally prescribed ethical procedures are not culturally applicable in partner countries, or are difficult to implement effectively. Typically, the notion of signed consent is unfamiliar in many countries and commonly poses difficulties for recruitment of research subjects. In a large public health collaboration between Institutions in India and the US, it was highlighted that variations in language and culture at the site of recruitment, meeting national and international clinical guidelines and perceptions of autonomy were all issues, over and above those posed by the ethical review process (which occurred primarily in the US). After interviewing researchers involved, a lack of communication between collaborating partners about requirements was reported, as well as differences between the ethical review processes in India and the US. Recommendations included having researchers from the site of recruitment develop appropriate consent forms, rather than rely on the US templates.

Issues with Governance and Policy

Prominent scientists have called for greater international harmonisation and standardisation in the policies, funding priorities and quality control in science and technology research [14]. Specifically, peer-review processes differ internationally which may pose obstacles to seeking funding and the ability of young students and scientists to become involved in international collaborative research projects. Greater harmonisation has also been called for in other areas of research governance, such as intellectual property.

The rise in international research collaboration has usually been accompanied by increased research commercialisation, with the two intimately tied together in some sectors, such as biomedicine [56]. In fact, one of the key drivers for international collaboration in the biomedicine sector is the need for venture capital, in order to support the vertical translation of research outcomes into market products; with investment sometimes found more readily across borders [56, 79]. One component of the rationale of Government support for international research is advancement of their nation in a globally competitive space. A perceived imbalance in the rewards for international research can pose a barrier. As a result, the development of intellectual property policies and laws, and their application through legal agreements between collaborators, plays a part in managing this challenge. While a summary of international trends in intellectual property law are beyond the scope of this report, increasing internationalisation and harmonisation are seen as desirable and are being sought. Nonetheless, the making of agreements between international research collaborators can commonly pose difficulties and barriers in project progress, including for the researchers. Delays and conflict can arise if unanticipated consequences are present for either party in this process. Import-export controls are, similarly, legal requirements which can pose hurdles to research projects, by delaying or making impossible the shipping of research materials. In scenarios described in some studies, these controls have prevented the repair of costly equipment [71]. Setting of key terms and understanding the contexts in which the research partners operate is important.

Fortunately, with each barrier identified, factors that help to minimise them are usually readily apparent. As different actors often bring different priorities to research collaboration, it is important to clarify and understand research visions, plans and goals, as well as a leadership structure, early in the project [71].

Studies have highlighted the importance of cultivating certain personal characteristics, including an openness to others, avoidance of rapid value judgements, ability to discern and negotiate varied protocols, including information sharing, politeness, tolerance for ambiguity, flexibility and curiosity [71]. A focus on the shared vision for the research, particularly in cases where a global problem is being targeted; deep knowledge of the cultural and operational nuances of the research site, along with collective introspection on the possible influence of cultural factors on the project; and the development of trust are critical in the success of international research collaboration [33, 71].

While some of the challenges in collaborative work are generic and perhaps universal, many challenges arise as a result of idiosyncratic features that are specific to particular national, locational or disciplinary contexts. These contexts are historically shaped, and are deeply intertwined in the cultural, economic and historical fabric of society. To better understand the challenges facing the bilateral relationships in science between the two nations, we provide a contextual overview of the development of science in Australia and India, and of their bilateral relationship in scientific research.

THE CONTEXT: RESEARCH AND INNOVATION IN AUSTRALIA AND INDIA

Australia

As a young nation with a limited scholarly history, Australia drew heavily from England and Scotland in setting up its higher education institutions [80]. The first Australian PhD was conferred as recently as 1948. Prior to that, scholars were supported to undertake doctoral studies overseas, mostly in the US and UK [81]. In the post-World War II period, the priority was the development and the rebuilding of the nation. Priorities of bodies such as the Universities Commission were aimed at producing human capital with skills and training in areas that were key to national development [82, 83].

Since the conferral of the first two PhD degrees in 1948, the number of Australian PhDs has steadily increased. By 2009, Australia had awarded 94,000 PhDs [81]. Although predominantly biased in favour of men initially, with only 27 per cent of PhD graduates in 1988 being female, now many fields have more female PhD graduates than men, and there is close to parity in almost all others [81]. Australian research intensive universities are well regarded and perform well on international rankings. Australia is considered to be 'punching above its weight' in terms of its research output. Australia ranks second among OECD nations in the level of human development, with 37 per cent of its labour force employed in occupations in science and technology [31].

Australian scientists have contributed several landmark scientific discoveries and inventions to the world, and these include 'Google Maps, Biota's flu treatment (Relenza), the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) polymer bank notes and wireless networking technology, the Commonwealth Serum Laboratories' (CSL) anti-cancer vaccine (Gardasil), Cross Market Surveillance Service's stock market fraud detection system, and Cochlear's bionic ear' [84]. Several Australian scientists have received Nobel Prizes.

Australia continues to invest significantly in science, with current investment being over 2 per cent of its Gross Domestic Product (GDP) [85]. Australian science is overseen and managed by the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE), formerly known as Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE), and prior to that, as the Department of Industry, Innovation, Science and Research (DIISR). The major national science agencies, such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Nuclear Science and Technology Organisation (ANSTO), are within the portfolio of DIICCSRTE, as are AusIndustry and Intellectual Property Australia. The national agencies receive periodic funding from the government to develop their programs of research. These national agencies align with the government's priority areas and develop their own sets of priorities. Funds to universities and other research bodies are disbursed by the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC) through competitive grants schemes. Other bodies involved in this arena of science and innovation are the Commonwealth State and Territory Advisory Council on Innovation (CSTACI), the Coordinating Committee on Innovation (CCI) and the Prime Minister Science, Engineering and Innovation Council (PMSEIC). These agencies provide policy advice and work to improve governance and collaboration [31].

In addition to the Federal bodies involved in science policy and administration, each state also has its own sets of policies and activities in science. An inter-governmental committee, the CSTACI serves to coordinate and align state and commonwealth aims and priorities. In addition, there is an agreed framework of principles that guides state activities in the area.

The thrust of Australia's science policies can be discerned from some of the science and innovation strategy documents. A key document, *Powering Ideas: An Innovation Agenda for the 21st Century*, sets out a 10-year agenda, from 2009 to 2020. It is underpinned by a notion of science and innovation as vehicles for providing solutions in tough times. In the foreword, Kim Carr, then Minister for Innovation, Industry, Science and Research, explains:

> *This is a ten-year reform agenda to make Australia more productive and more competitive. Increasing our capacity to create new knowledge and find new ways of doing business is the key to building a modern economy based on advanced skills and technologies. It is the key to success in this, the global century.[7]*

There are strong links in Australia's contemporary science and innovation strategies between science and the economy. The creation of knowledge and advanced skills and technology are seen as the crucial for increasing the ability to do business and to be globally competitive. The report also outlines the role of science in solving contemporary and persistent problems and to improving the lives of its citizens:

> *Innovation is the key to making Australia more productive and more competitive. It is the key to answering the challenge of climate change, the challenge of national security, the age-old challenges of disease and want. It is the key to creating a future that is better than the past [7]*

While acknowledging the many reasons to be proud of Australia's achievements in science, *Powering Ideas* also reflects a level of anxiety with regard to the status of science and innovation in the nation:

> *Australia's recent innovation performance has been uneven, and we have failed to keep pace with the rest of the world. In the last eight years, Australia has slipped from fifth to eighteenth in the World Economic Forum's Global Competitiveness Index. Our multi-factor productivity grew 1.4 per cent a year on average between 1982–83 and 1995–96. Growth has averaged only 0.9 per cent a year since then, which is no better than we achieved in the 1960s. Since 2003–04, our productivity has actually declined.[7]*

Australia's geographical location and its small population pose particular challenges to its ability to remain influential in the region. Australia's cultural, political and economic identities are of a 'western nation,' part of the 'global north,' but geographically it is isolated from Europe and the US. And although located in the southern hemisphere, it is culturally and politically distant from its geographical neighbours. Its small population also means it has to make the most of its human resources to remain globally relevant and influential. Perhaps as a result, Australia pays close attention to its international ranking, relative to both the OECD nations and the nations in the region.

> *Meanwhile, the bar keeps rising. China's R&D spending has grown by 22 per cent a year since 1996, compared to 8 per cent a year in Australia. Australia spends 2 per cent of GDP on research and development. Austria, Denmark, Germany, Iceland, Switzerland, Taiwan, and the United States spend more than 2.5 per cent; Finland, Japan, South Korea, and Sweden spend more than 3 per cent; Israel spends more than 4 per cent. [7]*

Powering Ideas incorporated and responded to a number of other reports, including *Venturous Australia — Building Strength in Innovation: Review of the National Innovation System [86]; Collaborating to a Purpose: Review of the Cooperative Research Centres Program [87]; Building Innovative Capability: Review of the Australian Textile, Clothing and Footwear Industries [88];* the *Final Report of the Review of Australia's Automotive Industry [89];* the *Final Report of the Pharmaceuticals Industry Strategy Group [90]; the Final Report of the Review of Australian Higher Education[91]*; and the House of Representatives Standing Committee on Industry, Science and Innovation's Inquiry into *Research Training and Research Workforce Issues in Australian Universities, Building Australia's Research Capacity [92].*

Powering Ideas led to the setting up of the National Research Infrastructure Council (NRIC), which in turn produced the *Strategic Framework for Research Infrastructure Investment*. This Framework developed a number of principles to underpin decisions with regard to planning, funding and developing the national infrastructure in order to 'deliver the maximum contribution to economic development, social wellbeing, environmental sustainability and national prosperity' [93 np]. Another document – the *Strategic Roadmap for Australian Research Infrastructure [94]*, sets out a strategy to improve Australia's research infrastructure, based on the *Framework* document. The *Roadmap* considers a number of elements that make up a world class system, including collaboration.

These reports provide advice for developing a sound science and innovation strategy that maximises return on investment, takes a long term view, is sustainable, and builds capacity. As yet, Australia's efforts in the arena of science and technology have, to some extent, remained uncoordinated, scattered as they are through a range of institutions and agencies, each with its own priorities and missions and strategies. Indeed, it has been said that Australia's strategy has consisted of a 'budgets and breakthroughs' approach rather than a clear and coherent long-term plan [95]. The profusion of documents itself, it might be said, is both symptomatic and reflective of the lack of a coordinated approach to science. Added to this, there is also fragmentation in structures and agencies. In the words of the Chief Scientists of Australia:

> *'[A] total of 79 science, research and innovation programs will be funded through the 2012-13 Budget, with administration of these programs distributed across 14 portfolios, each operating under its own policy framework.' [96]*

The 2012 National Research Investment Plan [85] recognises the need for better coordination and seeks to address that need.

> *The National Research Investment Plan (the Plan) sets out, for the first time, a comprehensive national research investment planning process: a process that will enable a coordinated, wholeofgovernment approach to research investment that is structured to meet national needs and provide value for money.[85]*

A National Science and Technology Strategy has recently been released by the office of the Chief Scientist.

Science, particularly when seen as an activity of generating new knowledge, is an inherently international activity, involving international processes, collaboration and networks of peers [95]. Moreover, with early PhDs all being trained overseas, Australia has had international links in science from the outset. While these ties were generally with scientists in the US, UK and other parts of Europe, Australia's participation in the Colombo plan, which was instituted to improve regional standards of living, raise the economic output and share knowledge to encourage development, brought students from the Asia-Pacific region to Australia to study. Over the years, Australia's international links have grown steadily. Education is one of Australia's major exports and it attracts a large number of students from around the world.

Australian research is increasingly collaborative, with international co-publications tripling between 2002 and 2010. Collaboration – particularly international collaboration – is valued for a variety of reasons. This is made explicit in *Powering Ideas:*

> *Collaboration stretches our research dollars further, spreads risk, favours serendipity, propagates skills, and builds critical mass. It is increasingly the engine of innovation. Australia has everything to gain from improving connections within the national innovation system and expanding its participation in international research and innovation networks. [7]*

DIICCSRTE has an explicit focus on participating in the international science community and promotes linkages with international partners. These include the Australia-India Strategic Research Fund (AISRF), the International Postgraduate Research Scholarship Program (IPRS), as well some auxiliary support such as key staff in certain locations and support for high-level meetings across countries.

Australia's traditional partners have been the US and other OECD nations. But in recent years, there has increasingly been a focus on the Asia-Pacific for a variety of reasons. Science linkages with these nations form part of the soft diplomacy efforts in the region. Australia has had a major and long-standing investment in collaboration with China. Although the focus on China and the funds available for research in China are now reducing, the Australia-China Science and Research Fund (ACSRF) was signed in 2011 to set up Australia-China joint research centres; support group missions; and promote research knowledge exchange. This fund completes its term in 2013-2014.

In 2012 the Australian Government released the document 'Australia in the Asian Century: White Paper' [97] which charts the rising importance of Asia in defining the region and how Australia will engage with Asia more extensively. It notes that a more prominent Asia will bring:

> *The benefits of international research collaboration [with Asia] include improvements in the influence, cost effectiveness and applicability of research, access to new ideas and data, and sharing of facilities" [97].*

The 2012 *National Research Investment Plan* reflects this focus on Asia in its plans:

> *The Australia in the Asian Century White Paper recognises the importance of science and research in helping Australia seize economic opportunities in the region. Our world class research will help us compete in a region that will soon be the largest producer and consumer of goods. Scientific collaborations with our Asian neighbours will increase the flow of ideas and strengthen our knowledge base. [85]*

Australia's long engagement with India has been significantly boosted with the AISRF, which is Australia's most significant single research investment with any country.

India

The importance of science and technology for national economic security and prosperity has been acknowledged in India right from the time of its independence. However, understandings of science, technology and innovation and their role in nation-building have changed over the years. These changing understandings can be traced through the landmark policy documents over the decades. The Scientific Policy Resolution (SPR) of 1958 sought to:

> *Foster, promote and sustain the cultivation of sciences and scientific research in the country and to secure for the people all the benefits that can accrue from the acquisition and application of scientific knowledge. [98]*

In a newly independent India already riddled with multiple problems – poverty, disease, poor infrastructure, wide-spread illiteracy, communal disharmony – science was to benefit society generally, and not just the economy. The first task was to develop the infrastructure and systems that would promote research, and the government took on this responsibility, through the Ministry of Science and Technology. To oversee these developments, a number of research agencies were set up, and the Council of Scientific and Industrial Research (CSIR) was expanded. Several research institutes were established to work on the needs of the different industries, defined by the Indian Planning Commission's strategic focus on development through industrialisation. India's problems were large – almost insurmountable – and the Technology Policy Statement (TPS), released a quarter of a century later [99], reflected the complexities of reforming a nation as large, diverse and complex as India.

Things changed dramatically after India liberalised its economy. The Science and Technology Policy (STP) of 2003 reflected a confident India that saw itself as a global player in science [100]. Launching the 2003 policy, the then President of India, Dr APJ Abdul Kalaam, declared:

> *Today India has become one of the strongest in the world in terms of scientific manpower in capability and maturity. Hence, we are in a position not only to understand the technologies that we may have to borrow, but also to create our own technologies with extensive scientific inputs of indigenous origin. Basically we have come a long way since our independence, from mere buyers of technology to those of who have made science and technology as an important contributor for national development and societal transformation. [100]*

In the 1990s, India allowed nearly 100 multinational companies to set up R&D facilities in India. In the past couple of decades, India has witnessed an explosion in innovations, with some highly visible inventions such as the low-cost car 'Nano'. These innovations have not been restricted to the area

of science and technology, but embrace such areas as banking, marketing and service delivery. They are not merely focused on products, but on systems and practices. Dr Vijay Raghavan, Director of the National Centre for Biological Sciences (Bengaluru), confidently asserts:

> *In 20 years global science will be driven by Indian scientists. There are new interfaces in science, with new rules, where new countries can contribute on an equal footing' [101]*

The shifts in science policy have resulted in significant changes in the extent and pattern of Federal, State and private investments in science, technology and innovation. STI is overall the concern of the Ministry of Science & Technology. The Ministry has several departments: the Department of Science and Technology (DST), Department of Scientific & Industrial Research (DSIR), Department of Atomic Energy (DAE), Department of Space (DoS), Department of Biotechnology (DBT) and Department of Ocean Development (DOD). DST is in charge of developing and implementing policy and facilitating and promoting research. Some of the Departments have a number of institutions, laboratories or councils under them. For example, the Council for Scientific and Industrial Research (CSIR), which sits under DSIR, has some 40 institutes and 100 field stations throughout the nation, dedicated to different branches of science [102]. India has also established a number of 'Technological Parks' and 'Innovation Centres' which include over 400 research laboratories designed to work largely on local problems[103].

Although there is also a huge amount of private investment in innovation as well through individual entrepreneurs, giant business houses, non-government organisations (NGOs), and by banks and hospitals, almost 80 per cent of India's science investment is through public funds [101]. Currently, most Indian companies do little R&D. Infosys, for instance, spends on 2.1 per cent of its revenue on research and development [104]. Only the pharmaceutical companies currently appear prepared to invest substantially, with a rise of over 300 per cet in R&D spending reported in the last five years. While the current investment in STI is to the tune of 0.8 per cent of the GDP, the 2013 STI Policy aims to more than double investment to 2 per cent of the GDP in the next five years[105]. However, it is visualised that this is only possible if roughly half of this investment comes from the private sector.

India's population of 1.18 billion is growing at 1.5 per cent a year, causing scarcities – many acute – in the area of water, food, fuel, education and healthcare [73, 106]). Adding to these scarcities are the huge inequities in India, so that a sizeable section of the population is challenged even more acutely. These factors have led to innovations that are focused on extracting greater value from any activity. Several terms are now used to describe India's innovations focused on improving the lives of the very poor, such as 'frugal innovation,' 'inclusive innovation,' and 'affordable innovation' [73, 107, 108].

The '*Decade of Innovation: 2010-2020 Roadmap'* [109] calls for a paradigm shift in how innovation is conceptualised, and advocates a new 'Indian model of development' with a 'frugal, distributed, affordable, diverse, and malleable innovation' [109] focused on the 'bottom of the pyramid' – the population that earns less than $2 a day. 'Frugality' here refers to both the affordability of products and services that are developed, and a concern for developing innovations that are of low cost to the environment. Most of all, the *Roadmap* notes that such innovations would be useful not only to India's poor, but to the 4 billion poor people around the world[109].

Such solution focused research breaks away from seeking the traditional prizes of research – publications and patents – and instead seeks to develop innovations that alleviate the problems of the very poor. Recognising that this means innovations in processes, structures and relations, as well as technologies and scientific innovations, it seeks to create innovation ecosystems in which a range of stakeholders can participate. Alongside these new forms of innovation, India continues to seek to develop its conventional science capabilities as well, and to increase its publication and patent outputs, and increase the amount of research in its universities in particular.

These historical and contemporary factors play a large role in the types of international collaborative research in which it will take interest, and in what it has to offer to its partners in collaboration. India has now become very keen to foster research collaborations with international partners to increase its research output and to tackle its many problems. Another interest is in competing with China in terms

of research output; while China has seen a dramatic increase in publications, India's growth in this regard has been much less impressive. This is despite India's language advantage – most scientists in India are fluent in English. Traditionally partnering with the US and with European nations in research, India is now forging much greater links with Australia than ever before.

Australia-India Research Collaboration: Mutually Advantageous

Australia and India show great promise as partners for collaborative research. Both countries share the common ideals of democracy and world security. Each is a key player in the region. Both countries also share a raft of common challenges: sustaining agricultural production in a changing climate, managing the increasing burden of chronic disease and providing their populations with reliable, affordable and sustainable sources of energy, to name but a few. These shared values and interests were described in a joint statement issued by the two governments in 2009:

> *India and Australia are two countries with shared interests and shared values. We are both pluralist democracies. We are both global in our outlook, but also closely integrated into the Asian region. Our economic relationship is expanding rapidly. We have a shared desire to enhance and maintain peace, stability and prosperity in Asia. We both value multilateral institutions and recognise the need to reform and renovate them. [110]*

With both countries recognising the benefits of research collaborations with each other, efforts have been on at the highest levels to establish and nurture collaborations. Research collaborations between India and Australia are framed within the bilateral focus on knowledge exchange, which is itself part of the strategic partnership between the two countries. Both countries believe that international collaboration in research can bring benefits to each nation, and that there is great complementarity and mutual benefit in research partnerships; and both are active in promoting greater linkages between Australian and Indian researchers.

Some Australia-India collaborations have existed for years, and there are several excellent examples of on-going and mature partnerships. The Australian Centre for International Agricultural Research (ACIAR), for instance, collaborates with India's Indian Council for Agricultural Research (ICAR) on a range of problems of mutual interest, such as food security in other South Asian states, the management of natural resources and the challenges of research. Begun in 1983, the collaboration has had time to mature and expand. The new medium term strategy for 2011-2016 that was jointly developed by the two bodies has seen increased co-investment from ICAR and other Indian partners. Specific areas of mutual research interest have been identified, among which are agricultural water management, developing fast breeding and improved varieties of certain cops and developing policy advice in the face of climate change.

Australian universities have set up a range of active research partnerships with a variety of organisations in India. The IITB-Monash academy, which was supported by AISRF as part of its targeted allocation, has emerged from a partnership between the Indian Institute of Technology, Bombay, a leading technology school, and Monash University, and it is centred around research on topics of mutual interest. CSIRO is also a partner in this collaboration. It has attracted highly talented PhD students into the program which awards a jointly badged degree. Students often work on interdisciplinary research programs and are jointly supervised by academics at Monash University and IITB.

Deakin University also has a range of research partnerships with public and private agencies in India. It collaborates with such organisations as The Energy Research Institute (TERI), a deemed university, and the Public Health Foundation of India (PHFI), a public-private partnership. In these programs, joint research projects funded by external sources are set up, and PhD students recruited. These students are typically jointly supervised by Indian and Australian partners, while the degree is awarded by the Australian institution. Similar arrangements are also present between Deakin University and Vimta Laboratories, Hyderabad, which is a leading contract research and testing organisation. RMIT has research collaborations with research laboratories such as the Centre for Cellular and Molecular Biology (CCMB) and institutions such as the Indian Institute of Chemical Technology (IICT).

RMIT's collaboration with ASEA Brown Boveri's India Research Centre was recently announced. The joint venture aims to set up the Australia-India Research Centre for Automation Software Engineering in Bengaluru. This type of arrangement between a business and a university is of particular interest to Australia, since research partnerships with business organisations is one of Australia's research priorities. Deakin's arrangement with such companies as Reliance India and Biocon are also examples of university-business research partnerships. Deakin has in fact set up an India office to assist the development of partnerships and to facilitate existing partnerships.

In recent times, large diplomatic and trade missions have been organised to raise the profile of Australia in India and to promote bilateral engagement in research, among other links. Whilst such missions often generate announcements of funding schemes or the intention to collaborate, it takes detailed planning and effort to translate them into actual joint research projects – and sometimes such processes can take many years.

AISRF

The commitment to bilateral research collaborations between the two nations was significantly scaled up with the institution of the Australia-India Strategic Research Fund (AISRF). With a focus on the development of strategic alliances between researchers in the two countries, AISRF is Australia's largest fund for collaboration in science with any single country. It is also one of India's largest sources of support for international science. Australia's commitment of $64 million over the life of the program supports Australian researchers' participation in joint research and other collaborative activities with their Indian counterparts. The Government of India meets its researchers' costs.

The fund supports collaborative projects and workshops in priority areas agreed to by the two governments. It has recently supported a fellowship program for scientist exchange. AISRF funds both public and private sector researchers to participate in leading edge joint projects and workshops. By making collaboration with an eligible partner from the other nation a requirement of the application, the fund ensures meaningful and real collaboration.

Funding is provided under various components, such as the Indo-Australian S&T Fund; the Indo-Australian Biotechnology Fund; the Grand Challenge Fund; the targeted allocation program (now completed) and the recently started Australia-India Fellowship Fund, which is run by the respective science academies in each country (Australian Academy of Science and Indian National Science Academy).

Despite these developments, the current levels of research collaboration between the two countries are modest in scope and range. Although the actual quantum of collaboration is relatively low, current levels of collaboration represent a seven-fold increase between 1995 and 2010 [96]. Whereas Australia had a very small presence as a potential research partner some years ago, it has recently surged into prominence, in large part as a result of the AISRF. Australia-India collaborations have addressed significant areas of mutual interest, such as improving water quality, innovations in cardiac therapy, cancer detection, crop genetics and remote sensing of marine ecosystems [111].

The future of bilateral collaborations in science depends not only on successes in current engagements, but in the development of deep, long-term ties and on-going programs of research that extend beyond specific and potentially finite programs such as AISRF. Australia's current focus on becoming a more significant participant in Asia augurs well for sustained interest in bilateral science collaboration between the two nations.

STORIES FROM THE FIELD

Although the literature review revealed some of the issues and challenges that confronted scientists engaged in international collaborative research, it is our 33 interviewees who brought alive to us the dynamics and nature of collaboration, with their often impassioned accounts. They were able to highlight the issues particular to the Australia-India relationship. Many of our interviewees were senior scientists who had engaged in a variety of research collaborations with various nations, and were able to describe the issues from a rich wealth of background knowledge. Similarly, our readings of the policy documents were immensely enriched by our conversations with high level policy makers in both India and Australia.

While the Key Findings and the accompanying recommendations that follow the Executive Summary are largely distillations from our interview data, in this section, these data are presented in their more 'raw' and authentic form. Interviewee voices are privileged here – and often presented verbatim.

Where possible, the findings that correspond to the results are indicated in parentheses.

The Lack of a Coordinated Approach (Finding #2)

Collaboration is intensely people-focused, and collaborations are often initiated by individual researchers or teams of researchers. But the possibilities for collaboration, including the availability of funding, the prioritisation of areas of research, the identification of specific research partners as being of strategic importance, the sustainability of collaborations, and the prospects for long-term engagement are all affected by high-level government policies and approaches.

In the case of India and Australia, some interviewees felt that there is no identifiable and coordinated approach, and no clear or detailed bilateral statement that sets out the goals and scope of the relationship in science between the two nations. Nor is there a national statement in either nation that outlines the nation's objectives and strategies relating to this bilateral relationship. A clear statement outlining the purposes and strategies would serve to coordinate and align the priorities and policies of the many budget lines and institutions through which investments in science are disbursed.

Australia's science investment, which, in 2012-2013 is in the region of $ 9 billion, will be disbursed and managed by a slew of departments and agencies, and across 14 portfolios [96]. While each has its own set of policies and priorities, there is no coordinated policy framework A senior research administrator elaborated this point in our interview:

> *What I would find really helpful is a higher level, sort of whole-of-Australian government position around the area – it could be around research – if we had a bilateral relationship, what are all the different agencies' perspectives, and can we have a strategy document about what are the objectives, what are we trying to do here. At the moment we have a Department of Innovation view, we have an AusAID view, we have a SEWPAC [Department of Sustainability, Environment, Water, Population and Communities] view – the Environment Department under Minister Burke –they hold an MoU with India on water management, AusAID is trying to do things in the region, the Department of Innovation is investing in some science things, they've all got a completely different view, and I don't think they ever talk to each other. And we try to navigate between all this, and it's a bit like herding cats. And when we start to do something that requires a Prime-Ministerial announcement, PMO [the Prime Minister's Office] gets interested and PM and C [Department of Prime Minister and Cabinet] gets interested and every one of those has a view as well. And DFAT's [Department of Foreign Affairs and Trade] got a view of course, as well, and so to have a more coordinated view: so what does our bilateral relationship with India look like, what are we trying to do here, where do our aid objectives sit below that, relative to trade objectives, and how can our research or science actually underpin this. Where does it make a difference and where is it irrelevant. For some [projects] this may be irrelevant. But [when you] have that stronger view and to have that as something that is*

part of the higher level political dialogue between countries, then you might get the same view from India to say: here's what we're looking for from our relationship with Australia, here's how we would like to access expertise and capability and knowledge, but all of this stuff about knowledge and research, I don't think, ever even sees the light of day at a political, proper bilateral level. (Senior Research Administrator, interview transcript)

Australia may now be close to developing such a coordinated approach. In his interview, the Chief Scientist, Prof Chubb, indicated the imminent release of a national policy statement with regard to science in Australia. This statement elaborates five national priority focus areas (grand challenges), with three research priorities under each challenge area. This statement could guide the areas shortlisted for collaborative work with specific research partners internationally.

[T]he Australian Government has signed off on five grand challenges, which Australia's research community should be helping us to meet. Under each of those 5 there are 3 research priorities, so the government will be announcing on the 23rd June fifteen elaborated…strategic research priorities. I think that the government should say "Our international collaborations have to be focussed on aspects of those 15." (Chief Scientist, interview transcript)

Such coherence and focus may also facilitate the promoting collaboration in particular niche areas of common interest.

Similarly, in India, there are several departments and agencies involved in governing 'science'. The organisation of the governance structures influences the kinds of projects that can be envisaged, the collaborations that are imagined and realised, and the extent to which efforts and resource management can be coordinated and synergies maximised.

The Difficulty of Promoting Interdisciplinary Research (Finding #4)

Many participants noted that interaction and collaboration between researchers in the natural sciences and those in the humanities and social sciences was important in solving global and social problems. The Chief Scientist, Prof Chubb, noted:

Scientists just dumping a new discovery or a new thought or a new suggestion into a community that is unprepared and unsuspecting is going to find resistance, increasingly. And it takes one person to put out, on the internet, some highly critical and inflammatory commentary and suddenly it spreads, you know it's all over the place, and whether it's right or wrong for a lot of people is not material, all they want to do is fight it. So it's a very much more complex world, and I don't think we can understand the world without quality research in the humanities and social sciences. (Chief Scientist, Interview transcript)

However, it is not easy to initiate or put together multidisciplinary projects that involve researchers from across various 'camps,' particularly in international collaboration. Differences in areas of research, methodologies, registers of proof and other aspects of epistemology are reinforced through divisions in university and government structures, specialised journals and conferences and a discipline-focused, rather than problem-focused, approaches to research. Researchers from across disciplines have few opportunities to meet each other and plan joint investigations, even within the same university. Such disciplinary isolation is a global feature and not peculiar to the Australia-India partnership.

Funding rules also play a part in keeping the sciences apart. The AISRF, for example, focuses on the natural sciences, and although there is a great deal of scope for interdisciplinary work, this is largely among natural scientists. While the Grand Challenge Scheme of AISRF acknowledges the value of social and natural scientists working together, the projects are conceptualised as predominantly natural science projects. On the Indian side, the social sciences are supported by a separate body, the Indian Council for Social Science Research, which is not involved in any formal partnership with the Australian Government.

These structural divisions, as they currently exist, make it difficult to access funding for interdisciplinary projects that go across the natural and social sciences. Despite the emphasis on multi-disciplinary and multi-stakeholder, solution oriented and frugal innovation in the new DST policies, there is no bilateral fund currently that supports such projects, despite some interest among scientists:

> *We did get a couple of enquiries from people in the social sciences that may have had a bit of science, and I went back to the Department in India, and the answer was always no. Because the Indian side does not allow for it, it has to be pure science. (Senior Manager, interview transcript)*

In both India and Australia, institutions such as the Learned Academies are divided according to discipline, although there are some opportunities for transdisciplinary projects for the Academies through the Australian Councils of Learned Academies (ACOLA) in Australia.

> *We realise, as an academy, that we need to be more inclusive and we are working more, trying harder, to include people in the social sciences and the humanities. The academy has 22 national discipline committees, and there is one called earth systems science, it's about global climate change, but it draws from many of the social sciences….There is a little bit of education happening there … we are all realising that we can't solve these problems with the physical or biological sciences, we have to bring others in. (Senior Manager, interview transcript)*

The lack of a coordinated approach noted above also discourages interdisciplinary work, particularly the involvement of the social sciences and the humanities, even with 'grand challenge' research programs aimed at solving complex societal problems. Responsibilities for governance and promotion of science are distributed across a variety of departments and institutions, reifying divisions:

> *I know in Australian research institutions, there is more multidisciplinary work and there seems to be that paradigm shift in research to work together across disciplines, but in India I see, from my basic experience, that doesn't happen. There is an institute for everything and each institute is physically separate from each other so you're not getting researchers from different disciplines even working in the same building….And so even if you look at who does science in government, you've got the ministry of Science and Tech, the ministry of Earth Science, the ministry of Space, so, you know… it's across four or five ministries, so it's quite fragmented. (Policy Official, interview transcript)*

These divisions are deeply structural and are replicated in institutions:

> *Many of the institutes of excellence in India are focused towards science and technology – IISc, IITs and so on. On the other had you have institutes that are mainly focused on social aspects, IIMs to some extent, but schools like … By accident we seem to have naturally polarised into these two spheres and it is difficult to build [collaborations] on this. (Senior Scientist, interview transcript)*

However, it is in India that some of the most innovative, multidisciplinary projects are emerging. With India's focus on science as a means for solving social problems, there is a much more intimate relationship between science and society. As one interviewee noted, there is a page devoted to science in many daily broadsheet newspapers. In many projects, NGOs and activists participate to spread new ideas or practices among the population. Organisations such as the Indian Agricultural Research Institute now employ social scientists, who participate in their research programs. As a senior scientist at IARI explained, earlier, the goal of research at IARI was to develop new products and practices – their actual percolation through society was not their focus. But over the years, they began to value the impact of their research on society, and this realisation forced them to think in more interdisciplinary ways (interview notes).

We have not really paid enough attention to this very important component [involvement of social sciences], and perhaps that's one of the reasons why many of the research outcomes could not really be translated into their adaptations or into the system. But in the last ten years or so, we have consciously [used the approach] that social and economic analysis has to be done wherever it is directly related. If it is … a problem-solving project, or product development, then it has to be allowed... I'm sure in the coming years there will be a substantial component of this. (Senior Scientist, interview transcript)

Some long-standing Australia-India collaborations also offer excellent examples of collaborations with the social sciences. A senior manager at the Australian Centre for International Agricultural Research (ACIAR), describes the social sciences as providing a greater understanding of the contexts in which STI projects operate, as well as informing ways to maximise impact:

Our projects have a considerable amount of social economics built into it. We talk about multiple partners, we have social economists, we have livelihood specialists, we have communications specialists. So the newer projects have a pretty big component because if we do not know what the social-economic, cultural context within which our technology will be applied it's not going to be successful, ever. Now it's a major part of the project, before starting the project we can benchmark the communities, the practices, the social-economics; all our project teams have social economists in them now. (Senior Manager, interview transcript)

However, bringing people together from very different disciplines is challenging, as our participants noted. They highlighted the differences between social scientists and the harder science researchers, including working styles, communication styles, priorities and methods across scientific disciplines:

I think pure scientists work in teams as opposed to social scientists, for example, so I think that's one difference there. (Senior Manager, interview notes)

So deep are the differences, it feels as if the different scientists speak different languages:

Initially, interdisciplinary work was pretty hard… because they were all speaking different languages! (Senior Manager, interview transcript)

Having a driver or champion in setting priorities across disciplines, by developing shared goals, and persisting with the program helps:

Four years have gone down, [and now] people are comfortable with each other. The researchers, the NGOs, the social scientists, they all sit at the same table, and speak more or less the same language, because their goals are similar. It's very heartening to see that. And it can happen, it requires a good champion or driver, it doesn't happen on its own. (Senior Manager, interview transcript)

But the rewards are worth the effort, and it is work that needs to be done:

Somehow we've got to get a focus on the various disciplines across those broad areas across working better together, understanding each other, sharing thoughts if not a vocabulary, and working out how we can affect the community at large…. Because ultimately that's the end-game I think. Not to say 'I'm a social scientists so I'm not talking to you', or 'I'm a physicist so I'm not talking to you', but to say 'what's the purpose of all this?'" (Chief Scientist, interview transcript)

In their own ways, the current policy climate in India and Australia favour such interdisciplinarity. India's focus on frugal innovation for improving lives of the bottom-of-the-economic-pyramid, and the interest in both nations on solving 'grand challenge' problems and of having a prominent presence in the region provide synergies for developing exciting new forms of research. University systems are notoriously slow to reform, but bilateral funding schemes might be more nimble, and could become catalysts that stimulate changes in the university sector in both nations.

Identifying Research Partners (Finding #1, 8)

Many projects come about in a very organic fashion. In many cases, there are long associations between researchers. They might have met at a conference, and come to know of each other's work over the course of time. In some cases, a visit to an institution to do a talk can lead to exploring possibilities of working together, as in these examples:

> *[In 2004] there was a very eminent professor from Melbourne University. He had met me at a conference in Kathmandu, so he came to India and he knows me as a trade economist. Well he came to India with one of the senior program research managers with NCAER. They were looking for a partner in the issues in agriculture markets, competition and regulation issues. [H]e had [visited] various institutes of management, some universities and research institutes. Somehow both of them were not convinced with whatever discussion they might have had there. He called me through someone I had met in Kathmandu, and said 'can I come and have a cup of tea with you?' So we went out for lunch. By the end of the lunch, he told me that he had found his partner… (Senior Scientist, interview transcript)*

The importance of face-to-face meetings in the development of projects was emphasised repeatedly.

> *We … encourage people to make use of mobility funds and various other funding programs to travel over and meet people to start discussions about potential collaborations. We get delegations coming through here from time to time, and trade missions going over there from time to time which can help as well, but in the general communication and connection between researchers, with any part of the world, is one of the big things which has to be overcome…. Regular face-to-face connections and communication and visits make a huge difference because a lot of … barriers can be broken down. (Senior Manager, interview transcript)*

Yet the funding available to attend conferences, develop serendipitous opportunities, and form a network of peers is shrinking in most Australian universities. Collaborations between India and Australia, whether through national agencies or the AISRF, incorporate some amount of travel funding. Although some of the bureaucratic processes attached to travel create complications, this aspect of the research is highly valued by researchers.

The role of the Indian diaspora is not to be underestimated. Many of the Australian research teams have members of Indian origin, who have connections in India in the form of old classmates or former colleagues:

> *One of [the challenges] is finding the right people to work with. Generally the communication and connection with partners overseas … it's remarkable the proportion of our Indian partnerships that involve someone [in Australia] with an Indian background. So they have their own connections, know the system, they know the people, they may have studied there, they may have a supervisor or some colleague there, so that makes that initial connection much easier for them. For people who don't have their own connection into India already, sometimes they use a colleague who does, and make a connection that way. (Senior Manager, interview transcript)*

Sometimes, though, projects may require components of expertise where no one on the team has any connections. In this event, it becomes difficult to know whom to contact and sometimes researchers appeal for help to locate possible partners:

> *From the Indian side… I have had a number of queries from the Indian side asking which institutions in Australia – and then I always point them to the Excellence in Research Australia report that ranks Australian institutes by their discipline strengths. (Policy Officer, interview transcript)*

The problem of finding the right partner is particularly pronounced for early career researchers, and this is discussed further under a separate heading.

Having a programmatic rather than project approach will alleviate the ad hoc need for finding partners. This could be in the form of partnerships in particular sectors, such as minerals and metals or biotechnology, as ongoing or long-term research programs, rather than dependent on particular funding rounds generating discrete research projects. Such approaches already exist in the areas of agriculture and health, and may serve as models. For example, ACIAR's support for collaborations with India in the field of agriculture, which began in 1983, has matured over the years into a systematic rather than ad hoc program. Its medium-term strategy, developed in conjunction with ICAR, supports clusters of projects that build upon and support each other. Harnessing synergies in this way can have a more significant impact than several unrelated projects on their own.

Institutional collaborations also offer possibilities for sustained partnerships and the development of networks through staff and student exchanges. However, at least in Australia, while internationalisation continues to be high on the agenda of priorities, the funds available to forge and sustain such links are always uncertain and often shrinking.

Assessment of Proposals (Findings #6, 7, 8,9)

Different agencies have different protocols for assessing funding applications. In all cases, projects would need to be assessed on the basis of the soundness of the proposal, the importance and potential benefits of the research and the calibre of the researchers. While the data reported in this section refers to the AISRF, the processes adopted by AISRF are by no means unique – they are very similar to process followed globally in the assessment of research proposals.

The AISRF adopts the approach of a competitive grants scheme where proposals are assessed by a peer-review panel on published criteria. Apart from the merit of the project itself, and its alignment with national priorities, its viability and its ability to make a significant contribution are evaluated. The panel also considers the track record of the investigators and the research infrastructure of the participating institutions. In this way, AISRF can be sure it is funding excellent projects which have a very high likelihood of successful completion and of generating useful science. Whilst this makes very good sense in terms of ensuring that money is well spent, and the project is successfully completed, it also biases success towards large national laboratories and experienced researchers, and does not serve to build new capacity, as some of our interviewees pointed out:

> *[I]f you cast your eyes through the list of successful applications and the Indian hosts for them, it is actually dominated, I think the last two or three years it's been exclusively national institutes and IITs. (Scientist, interview transcript)*

It must be emphasised here that the AISRF is focused on excellence and not capacity building, and its present assessment structure serves this need well. However, there is an opportunity here, in future funding schemes to do both: focus on excellence *and* support capacity building. Encouraging large, well-equipped national laboratories and agencies to collaborate with second-tier universities within their country in developing international teams and consortia would help to build capacity and spread excellence. This can be done through making collaboration with second tier universities a requirement of the award, or a feature that would be privileged in assessing the proposal. Such an arrangement would serve the knowledge partnership very well.

Similarly, a requirement that early career researchers should be included as joint CIs in developing project proposals would ensure that the next generation of researchers are being trained and are getting opportunities to develop their networks nationally and internationally.

As with many national and international funding programs, a majority of the submissions to the AISRF are unsuccessful, with the success rate being around 17 per cent. Getting an international grant proposal together can be a resource-intensive process, in many cases involving overseas travel and many hours of work. The review panels also spend time going through proposals, a majority of which will be unsuccessful. We emphasize again that this process is not unique to AISRF – it is a well-established tradition in research globally and it is the system followed by the NHMRC and ARC in

Australia. A recent paper published in *Nature* calculated that the amount of time spent on unsuccessful grant applications to NHMRC in 2012 alone was to the tune of four *centuries* of researcher time [1]. This gives a sense of the scale of effort and time that goes into developing applications. As moves are made more globally to reform grant assessment processes, future funding schemes in the bilateral knowledge partnership could also consider how the assessment processes could be revised to make the effort more focused with more efficient processes.

Future funding schemes could consider alternative approaches. A tiered process, which opens with a call for brief expressions of interest in a fairly narrow set of priority fields, followed by a call for more developed proposals for short-listed expressions of interest would reduce this expenditure of researcher time and energy. The resubmitted proposals could then be improved with input from the panel and then a final selection made of projects that show the most promise. This suggestion was seen as a much more sensible approach to funding.

> *I would say that we MUST do that (a staged process). You know internally also, for Indian projects also, I have been advocating the same thing. Please don't have gatekeepers. You know, maybe, some people who are new to the whole business – some colleges, who are completely new – they don't even know how to write proposals – so unless somebody holds their hand and takes them through this process once, how are they going to learn. So rather than – if you send me the proposal [for me to assess], you know, it is very easy, I can say, what nonsense, these guys don't even know how to write it, forget it – end of the chapter. Rather than that .. as you are suggesting, help them. Of course, the idea should be sound. If the idea is not sound, you can stop at that level and say hey, you know this idea doesn't look like it has much going for you, and therefore think of something else. (Senior Scientist, interview transcript)*

Another possibility is requiring that potential collaborators initially engage in a joint workshop or avail of a travel fund to meet and develop project ideas, and such preparation becomes a pre-requisite for applying for more substantial project funding. This, again, would facilitate the participation of early and mid-career researchers. Currently, there is provision to get funds for conducting workshops, but these are not necessarily seen as pre-cursors to bigger projects. Conversely, open rounds for bigger projects do not require that a prior workshop has been successfully completed:

> *There is no provision for continuity of what you may develop in that workshop. Most of these workshops are geared to identifying research gaps, or some kind of gaps, or strategy, to move forward with research or implementation. But there is no structure to do that. Actually that should be a precursor to fund the actual research projects. Because then the research project would be much better grounded, on the actual problems and the relevance to the problems you're addressing. There is no connection between the two schemes, and that to me is probably a weakness. (Scientist, interview transcript)*

Future funding schemes could also consider sponsoring gatherings to initiate conversations which may seed collaborative projects.

> *[I]it could just be like a one-day workshop, you don't even have to call it a networking workshop, you could just call it about 'discussing the comparative urban water situation in Sydney and Bangalore', for example. Something vague, which everybody has some sort of interest in, so you have something to talk about. (Early career researcher, interview transcript)*

Many researchers commented that they found the bilateral science funding assessment process opaque. The processes of appraisal of proposals are different in India and Australia. The two panels have similar criteria, but their rankings sometimes do not coincide because their requirements are different. The Indian teams are sometimes invited to make a presentation to the panel. Many of our interviewees suggested that the panels perform joint appraisals. They also felt that greater transparency and coherence was desirable. Some researchers suggested that more feedback on their proposal – whether successful or not – would be useful. These findings are supported by the findings in the review of the AISRF conducted in 2013 [112].

Simplifying Processes (Findings #10, 11, 13, 15, 16)

Bureaucratic processes were a source of great frustration, and this was expressed quite forcefully by both Indian and Australian researchers. Most of the issues with regard to bureaucracy concerned the disbursal in funds and the delays that occurred as the project moved through various departments and offices. In schemes such as the AISRF, which is more time-bound, perhaps, than longer-term engagements such as those of ACIAR, this can be particularly problematic. Because project work is often conducted simultaneously at two sites or more, these activities need to be coordinated and work in tandem. When one party has the funds and has started work, and the other experiences a delay, this coordination is disrupted.

Some of the delays experienced by our interviewees were several months long, setting back the process from the outset, delaying the purchase of equipment and the appointment of personnel.

> *It happened in our project too. Our Australian counterparts got the money. When the project was sanctioned, they told us it was sanctioned and within the next three weeks or something their money arrived. Here we were still waiting to hear…. whether the project is sanctioned or not. Three months later, we get a mail saying "your project is not sanctioned". So I write to the guy and say do you think we have a mistake here because our Australian counterparts – their project is sanctioned. Then he writes back and says – I made a mistake. From there onwards I'm waiting, waiting, waiting – three months! – no money comes. Then I ask him and he says "oh, now it is with accounts and accounts should be clearing it, it has gone from my office" – and he gives me the accountant's name and number, that I should check with that guy.…I said come on, this is not right – why should I be the one to talk to the accountant – you should talk to him. Another month passes by. It took something like eight months after our Australian counterparts had the money that the money arrived here. Absolute mess! (Senior Scientist, interview transcript)*

This kind of delay has a domino effect on the research counterparts – and could seriously set back PhD students' research or post-doctoral researchers' employment.

Institutional differences mean that some scientists have less control over the way the funds are spent and much less autonomy in spending, frequently requiring many layers of hierarchy to approve research-related equipment. It appeared that the scientists and administrative staff had little awareness of the constraints under which each operated:

> *The bureaucratic knots and hassles that we have tied ourselves in, it is an incredible mess – it is all put as 'checks and balances' – but there is nobody in those positions that are signing these papers or moving these papers [who are] looking at themselves as facilitators. Not a single guy is looking [at himself] as a facilitator. He's looking as a guy who's checking. "You must be doing something wrong, and it's my job to [catch you out]". Not: "Okay – you don't understand how to do this, let me help you and get this through". This is a major shift which is required. Our suffering is because of this. Even if I'm looking at your paper and there is something wrong, I'm very happy- there is something wrong so I can set it aside – it can't go beyond me – and I have no obligation to tell you that there is something wrong [you have to go and chase it when nothing happens]. These kinds of things which are more mindset related are the biggest hindrance. We could do phenomenal work if that support was there. Right now India's number one problem is that we can't deliver anything on time. NOTHING. We can do nothing on time. (Senior scientist, interview transcript)*

Sometimes rules with regard to visas also change without notice, causing disruption to travel plans. The Indian government, in keeping with its rules, requires that researchers travel on the national carrier, and this poses problems when there are no direct flights on the carrier to the destination. A great deal of researcher time is spent negotiating with New Delhi to obtain permission to travel by more convenient alternative airlines which are often also cheaper. Most of the interviewees had resorted to

using funds from other sources to make their trips to Australia as per the grant agreement, since it was too tedious to negotiate exceptions to this rule. Many researchers felt that these negotiations took too much of their time away from doing 'science'.

> *We figured out some way of using only part of the money and figured a way to travel [using other funds] (Senior Scientist, interview notes)*

This is an area where institutional support could perhaps serve to alleviate frustrations. An efficient administrative support system could work out how to manage these issues so that researchers' time is better utilised and they are able to focus on project work.

Joint meetings and workshops where the two groups – scientists and administrative staff in universities, laboratories and other institutions – could meet and understand from each other how the project works, what processes are involved and how the actions of one group would affect the other could help alleviate some of the challenges. Meetings between administrative personnel involved in administering bilateral projects could also facilitate the exchange ideas about efficiency in processes.

Australian researchers engaging in collaboration with India for the first time were particularly unprepared for the kinds of challenges posed by the bureaucracy. A workshop or an information package that briefs scientists about what to expect in the partner nation could be useful.

The AISRF grant application process can also be further streamlined by making the Indian and Australian requirements more similar:

> *Problems I see for the average person is the requirement on the Indian side and requirements on the Australian sides. We need to streamline those so that there is minimal difference of requirements, in terms of the application process itself. [When] you have to address one thing here and one thing there … it becomes a bit of a hodgepodge and [that] doesn't really help us. (Senior Scientist, Interview transcript)*

Some of our interviewees commended us for taking an interest in their trials and tribulations as they engaged in bilateral collaborations. They appeared to feel that once the grant was awarded, they were left to their own devices, with little support from their own institution or from the granting body. They also felt they had not been asked to provide any feedback. Although scientists are required to provide reports on their projects for the sake of accountability, their feedback and suggestions with regard to process are seldom solicited. Building an element of such feedback into the interim and final reports of grants could be useful in addressing sources of distress.

Fostering Long-term Engagement (Findings #1, 3, 5)

Traditionally, Australia and India were not strong research partners, but there is a desire on the part of both governments to grow the partnership. The institution of the AISRF has given the partnership a huge boost. A number of new relationships are developing as a result, and the network is growing. At this stage, collaboration between India and Australia is at a project level, and is based on a people-to-people connection rather than a programmatic and long-term engagement. Over the coming years, ways to make this partnership durable and sustainable will need to be developed. Some programs are already long-running and some of the relationships have become consolidated, but these have not expanded to involve multiple stakeholders:

> *We've been working with India for decades on plant research, but we haven't had particularly strong enterprise level connections. So it's been more collaborations on a project basis or peer-to-peer collaborations. So we haven't had that structured, top-down, strategic engagement with India. (Senior Research Administrator, Interview transcript)*

AISRF is also a potentially limited-duration program, and it is also presently project-based. This project-based approach may serve to generate some networks across borders, but it is certain to lead to

sustained collaborative research as might be the case with the setting up of research centres. India's relationship with some of the other nations is much older and more sustained through institutional and strategic links:

> *India has a very long term collaboration with France, where there is an Indo-French scientific research institute for the advancement of science [for which] 50% funding [comes] from India and 50% funding from France, and the Institute is located in Delhi itself. With the U.S. we have 3 or 4 institutional collaborations … it's a very long term [relationship], whether it is in agriculture, or whether it is in nuclear [science], or in terms of energy … doing that through the United States Educational Foundation, there is a continuing exchange of scholars. Now there are two or three institutions… which have put a lot of money into bilateral sciences, medical science, health issues, sanitation. (Senior Academic, interview transcript)*

Finding niche areas of interest and complementarity in expertise and resources augurs well for longevity in research relationships:

> *Germany and India also established the Indo-German Institution for the advancement of science. The German foundation here mainly focusses on renewable energy technologies, and India has a lot to do with Germany, because Germany has already said that in the coming 10-15 years they're going to do away with nuclear technology and go to renewable technologies, and India has expertise in that area. (Senior Academic, interview transcript)*

While Australia's interest in India is heightened because of India's rising importance in the world, India has a choice of research partners. There is a sizeable and influential diaspora in the US and a much bigger engagement on all levels – diplomatic, trade and education – with the US. The US is also the biggest producer of research and has made itself much more relevant as a research partner in the long run. If Australia is to increase and sustain its collaboration in India, it will need to find ways to capitalise on the gains provided by AISRF:

> *Obviously [the US and European countries have] got a lot longer history with India in science collaboration and they've expanded – for example the UK have agreements with the department of energy and the Indian Council of Medical Research – so their collaboration has expanded across the ministries – when you look at India there is quite a range – who does research and who does science – there is not the one department, so it is spread out across quite a few. So the bilateral engagement – and the AISRF has played a really important role in bringing the two communities together where that link wasn't before this program and …the Indian government is keen and enthusiastic – they invest a lot of money as well to get their scientists to work with other scientists in the international community. (Senior policy officer, interview transcript)*

If the investment in the AISRF and the long-term links forged through collaborations through the efforts of CSIRO and ACIAR and AusAID and other agencies is to be converted to a sustained, on-going partnership, a more structured approach is needed. Closer university ties and joint PhD programs, such as the IITB-Monash partnership (in which CSIRO is also a partner) would likely have immense benefit. Low-cost but symbolically significant and productive schemes such as annual lecture series that bring Indian and Australian researchers to each other's institutions can also have a significant impact. An example is the KR Naryanan Lecture series organised by the ANU, and the corresponding series at NCAER:

> *In 1994 there was a conference at ANU…I had a paper there and went there. That was the year when a lecture series in the honour of our former president … was established in ANU. So every year or every two years ANU invites an Indian scholar. [list names of a few]. During our visit in November, 1994, delivered the first lecture. Then we came back and after two or three lectures were held there, we developed an idea that we should reciprocate, and we started a lecture series called Sir John Crawford Lecture Series. Since then we have had seven lectures in the series, one every year or two. These lecture series keep going on each year…. So this is our 20 year old r/ship between ANU and NCAER. (Senior Scientist, interview transcript)*

On the whole, current approaches and arrangements favour an ad-hoc, researcher-to-researcher, project-based approach, but do not encourage a long-term, focused, sustained, programmatic approach with a clear focus and clearly prioritised areas of engagement. Having clarity around the scope and purpose of the bilateral engagement in science would be helpful. Successful long-term collaborations should be studied to understand how they can be replicated in other fields.

Capacity Building: Opportunities for Early Career Researchers

Both India and Australia place a high premium on opportunities for developing the new generation of scientists. However, currently the schemes in place at best offer limited training and employment opportunities. Collaborative projects often incorporate the funds to hire postdoctoral researchers and also recruit PhD students to work on the projects. While these are very welcome opportunities, they are perhaps not as useful as opportunities to for travelling and visiting other institutions and building international networks.

Even if funds are available to ECRs to travel to the host country, it is not easy for ECRs to identify partners overseas and prepare joint projects, particularly as their opportunities to travel and attend conferences are also be limited. Even if they manage to find partners and develop a project and get awarded a grant, most early career researchers are either attached as post-doctoral researchers on time-bound projects, or they are lecturing and bound by university teaching schedules. It is difficult for them to get permission or encouragement to stay overseas for over three months, as required in the AISRF ECR Fellowship scheme:

> *[In] this program, they have to go for a minimum of 3 months, maximum of 12. But many ECRs have said to us that their home institutions will not let them go for more than 3 months because if they do it it's seen as a junket. And so very few, I think only 2 or 3 people, are actually going for the 12 months, most are going for the 3 months, and some are even are actually saying to us 'can I split it in two', because it's seen that I'm going back to see my grandparents or whatever as a junket, or the duties, the administrative duties or teaching duties are so onerous, that I can't go. (Senior Administrator, interview transcript)*

With regard to PhD students, timing becomes an issue in collaborative projects. Some institutions have specific times in the year when they admit PhD students, and these may not coincide with the schedule of funding rounds. The duration of the grant is usually much less than the duration of the PhD.

> *If the PhD student isn't starting out right when the grant kicks in, he's not going to be introduced for the first year, two years, because students have course work that keeps them busy, so they can't work so much on the research. So in that sense, for the timing to work out, it becomes tricky. You need to have a pool of students who are just on the verge, they haven't decided the topic, or this is very similar to what they were going to do in their thesis, and they are just completely geared up, and right then the grant comes in, and that's fantastic. (Senior Scientist, IIT Delhi, interview transcript)*

The Monash-IITB institute, however, is an example of collaboration dedicated to PhD students. With the first batch of students earning their PhDs in 2013, it could serve as a model for collaboration in a PhD program. Other examples include Deakin's association with The Energy Research Institute (TERI), where collaborative projects provide funding for jointly supervised PhD students.

Discussion

Our interviews were semi-structured and had open-ended questions. They were conducted in conversational style, and data amounted to nearly 50 hours of recordings. We found that the conversations with the three groups – policy makers, managers and scientists had certain recurrent, common themes. All three groups were unequivocally supportive of international collaborations in research and of Australia-India collaborations. As the conversation proceeded, they became engaged

in finding ways to build the Australia-India knowledge partnership. All three groups were in agreement that the social sciences should somehow be included in 'scientific' projects.

Our participants spoke with passion and with humour. While they expressed deep frustration with some of the issues – especially the bureaucratic hassles that kept them from performing the science which they wanted to do, they were, without exception, supportive of ways to build the Australia-India knowledge partnership. Many of the research partners had become friends, and there was affection and respect and an enduring connection.

Problem-solvers by nature, our researchers' stories revealed the ways they harnessed a variety of resources to keep their collaborative projects going despite the challenges that presented themselves. And being problem solvers our interviewees also offered solutions to the issues that confronted them. Their solutions are incorporated into the recommendations we make in this section as well as, more explicitly, at the start of this report.

CONCLUSION

The knowledge partnership between India and Australia has come a long way. Declarations of interest in forming a knowledge partnership have been well supported by funding, particularly through the AISRF, scaling up the number of collaborative projects, and making the profile of the partner nation more prominent in each country.

The prospects for India-Australia collaborations in science appear very bright. The long experience of collaboration, the commitment of considerable funds, and the rising strategic importance of Australia-Asia cooperation more widely in the region mean that both governments are keen to nurture this partnership, not only through scientific collaboration, but also through collaborations in education and training. Universities and other educational institutions too are keen to promote collaboration. Just as importantly, all the researchers and policy makers we interviewed were convinced of the importance and value of collaborative work, and expressed great mutual respect for each other's calibre and quality of expertise. There were many warm stories of friendship, camaraderie and connection. Without exception, scientists thought of science as a universal and unifying language and practice. Having English as a common language of communication also seen as being of great help.

The keenness and focus on Australia-India collaboration in science at the political and diplomatic level might provide the right opportunity to raise the level of engagement so that it can go beyond a project-based and ad hoc approach. The university sector engagement has been under-utilised till date, and greater opportunities for higher research degree student and staff mobility will be helpful in ensuring that the collaborations are sustained over time and that they continue to grow.

There are some exciting opportunities ahead for the Australia-India knowledge partnership which could be explored, to the mutual benefit of both nations. The vibrant innovation scene, particularly in India, offers novel possibilities for breaking down discipline-based boundaries and to engage in solving problems in an interdisciplinary way. Both Australia and India have particular areas of expertise which are of mutual benefit and interest, which augurs well for productive engagement in the pursuit of solutions to large and seemingly intractable problems. There are also opportunities to invite greater industry partnership to maximise the impact of research. The major opportunities are outlined below:

- With India poised to engage with 'frugal innovation' on a grand scale, the very nature of 'science' and 'scientific work' is undergoing a paradigm shift. Interdisciplinary, multi-stakeholder, solution-focused research which aims to produce not only scientific knowledge and innovations, but also involves innovations in marketing, banking, etc. to address the needs of the very poor have been declared a priority in India. Partnering in such projects could be of mutual benefit to the two nations. However, current mechanisms for partnership would need to change or new ones introduced to accommodate these kinds of partnerships and projects.
- While 'excellence' has been a focus and a guiding concept in the development of the Australia-India knowledge partnership, the partnership could expand to also accommodate 'inclusion' to the benefit of both nations, without compromising 'excellence'. Both nations have institutions which could benefit from raising their research capacity. By encouraging excellent institutions and second-tier institutions to work together, the partnership could benefit both nations and raise the capacity of a larger group of institutions.
- Both nations already acknowledge the importance of early career researchers to the future of the research enterprise, and both nations invest in developing the capacities and networks of ECRs. A study of the constraints and needs of ECRs and their trajectories of career growth may be helpful in tailoring ways to build their capacity and encourage their growth.
- While 'scientific research' evokes notions of white coats and laboratories, a great deal of the work of 'collaboration' happens in policy offices and in accounting departments and in administrative offices. Training and awareness sessions involving administrative personnel involved in managing and administering collaboration may be useful.

Australia and India differ in a number of ways – the challenges they face are different; the structures and institutional arrangements are different; their approach to science, innovation and technology are different; and the relationship between science and society are different. Each country has expertise in different areas of science. These differences need not be considered barriers or obstacles, but sources of excitement and opportunities for the researchers working together to learn collaboratively. They provide the complementarity that forms the basis for good collaboration.

REFERENCES

1. Herbert, D.L., A.G. Barnett, and N. Graves, *Funding: Australia's grant system wastes time.* Nature, 2013. **495**(7441): p. 314-314.
2. Rizvi, F., R. Gorur, and C. Reyes, *India-Austraila Institutional Collaborations in Higher Education: Potential, Problems, Promises*, 2013, Australia India Educational Council: Melbourne. p. 39.
3. Jasanoff, S., *The Idiom of Co-production*, in *States of Knowledge*, S. Jasanoff, Editor 2004, Routledge: London and New York. p. 1-12.
4. Latour, B. and S. Woolgar, *Laboratory Life - The Construction of Scientific Facts*1979, Princeton, NJ: Princeton University Press.
5. Rizvi, F. and R. Gorur, *India-Australia Institutional Collaborations in Higher Education: Potential, Problems, Promises* 2013, Australia-India Education Council: Canberra. p. 40.
6. European Commission, *A strategic European framework for international science and technology cooperation.* European Commission, Brussels, 2008.
7. Commonwealth of Australia, *Powering Ideas: An Innovation Agenda for the 21st Century*, I. Department of Industry, Science and Research, Editor 2009, Commonwealth of Australia,: Canberra. p. 68.
8. The Royal Society, *Knowledge, networks and nations - Global scientific collaboration in the 21st Century*, 2011: London. p. 114.
9. Luukkonen, T., O. Persson, and G. Sivertsen, *Understanding patterns of international scientific collaboration.* Science, Technology & Human Values, 1992. **17**(1): p. 101-126.
10. National Science Board, *Globalization of Science and Engineering Research - a companion to science and engineering indicators*, 2010.
11. Aad, G., et al., *Measurement of the differential cross-sections of inclusive, prompt and non-prompt J/ψ production in proton–proton collisions at.* Nuclear Physics B, 2011. **850**(3): p. 387-444.
12. Aksnes, D.W., J.W. Schneider, and M. Gunnarsson, *Ranking national research systems by citation indicators. A comparative analysis using whole and fractionalised counting methods.* Journal of Informetrics, 2012. **6**(1): p. 36-43.
13. Frame, J.D. and M.P. Carpenter, *International research collaboration.* Social Studies of Science, 1979. **9**(4): p. 481-497.
14. Suresh, S., *Research funding: Global challenges need global solutions.* Nature, 2012. **490**(7420): p. 337-338.
15. Abdalla, F. and F. Irani, *International Research Collaborations: The Process and Its Benefits.* Perspectives on Global Issues in Communication Sciences and Related Disorders, 2012. **2**(1): p. 32-37.
16. Freshwater, D., G. Sherwood, and V. Drury, *International research collaboration Issues, benefits and challenges of the global network.* Journal of Research in Nursing, 2006. **11**(4): p. 295-303.
17. Leydesdorff, L. and C. Wagner, *Macro-level indicators of the relations between research funding and research output.* Journal of Informetrics, 2009. **3**(4): p. 353-362.
18. Maxwell, S. and D.L. Stone, *Global knowledge networks and international development*. Vol. 7. 2013: Routledge.
19. Costello, A. and A. Zumla, *Moving to research partnerships in developing countries.* BMJ: British Medical Journal, 2000. **321**(7264): p. 827.
20. Coloma, J. and E. Harris, *From construction workers to architects: developing scientific research capacity in low-income countries.* PLoS Biology, 2009. **7**(7): p. e1000156.

21. Glew, R.H., *Promoting collaborations between biomedical scholars in the US and sub-Saharan Africa.* Experimental Biology and Medicine, 2008. **233**(3): p. 277-285.
22. Jayasuriya, K., *Building Australian Research Capacity on Asia: A New Problem-Oriented Strategy.* Indo Pacific Governance Research Centre Policy Brief, 2012(1).
23. Lowe, P. and J. Phillipson, *Barriers to research collaboration across disciplines: scientific paradigms and institutional practices.* Environment and planning. A, 2009. **41**(5): p. 1171.
24. Lewison, G. and P. Roe, *The evaluation of Indian cancer research, 1990–2010.* Scientometrics, 2012. **93**(1): p. 167-181.
25. Wagner, C.S., et al., *Science and Technology Collaboration: Building Capacity in Developing Countries?* , 2001, RAND Science and Technology: Pittsburgh, PA.
26. Clarke, L. and A. Plume, *Knowledge, networks and nations: Global scientific collaboration in the 21st century. London: The Royal Society*, 2011.
27. Katz, J.S. and B.R. Martin, *What is research collaboration?* Research policy, 1997. **26**(1): p. 1-18.
28. Schmoch, U. and T. Schubert, *Are international co-publications an indicator for quality of scientific research?* Scientometrics, 2008. **74**(3): p. 361-377.
29. Gantman, E.R., *Economic, linguistic, and political factors in the scientific productivity of countries.* Scientometrics, 2012. **93**(3): p. 967-985.
30. Leydesdorff, L., et al., *International collaboration in science: the global map and the network.* El profesional de la información, 2013. **22**(1): p. 87-95.
31. OECD, *Science, Technology and Industry Outlook 2012*, in *Science, Technology and Industry Outlook* 2012, OECD. p. 466.
32. Cole, J. and S. Cole, *Measuring the Quality of Sociological Research: Problems in the Use of the" Science Citation Index".* The American Sociologist, 1971. **6**(1): p. 23-29.
33. Chen, W.-T., et al., *Challenges of cross-cultural research: Lessons from a US-Asia HIV collaboration.* Nursing outlook, 2013.
34. Wagner, C.S., *Six case studies of international collaboration in science.* Scientometrics, 2005. **62**(1): p. 3-26.
35. Anuradha, K. and S.R. Urs, *Bibliometric indicators of Indian research collaboration patterns: A correspondence analysis.* Scientometrics, 2007. **71**(2): p. 179-189.
36. Subramanyam, K., *Bibliometric studies of research collaboration: A review.* Journal of information Science, 1983. **6**(1): p. 33-38.
37. Hennemann, S., D. Rybski, and I. Liefner, *The myth of global science collaboration—Collaboration patterns in epistemic communities.* Journal of Informetrics, 2012. **6**(2): p. 217-225.
38. Clark Callister, L., et al., *Collaborative international research.* The Journal of Continuing Education in Nursing, 2006. **37**(1): p. 39.
39. Katsouyanni, K., *Collaborative research: Accomplishments & potential.* Environ Health, 2008. **7**(3).
40. Musil, C.M., et al., *Considerations for preparing collaborative international research: a Ugandan experience.* Applied nursing research: ANR, 2004. **17**(3): p. 195.
41. Carroll, J.K., et al., *Enhancing international collaboration among early career researchers.* Patient education and counseling, 2010. **80**(3): p. 417-420.
42. Ndlovu, R., *A model for international research collaboration.* Int. Nurs. Rev, 1999. **46**(4): p. 117.
43. Muula, A.S., *Goodbye Collaboration, Welcome Partnerships in International Research?* Croatian Medical Journal, 2010. **51**(4): p. 359.
44. Duque, R.B., et al., *Collaboration Paradox Scientific Productivity, the Internet, and Problems of Research in Developing Areas.* Social Studies of Science, 2005. **35**(5): p. 755-785.

45. Nedeva, M., *When David met Goliath: research collaboration in the context of changing political realities.* Innovation: The European Journal of Social Science Research, 1999. **12**(3): p. 287-303.

46. Bozeman, B., D. Fay, and C.P. Slade, *Research collaboration in universities and academic entrepreneurship: the-state-of-the-art.* The Journal of Technology Transfer, 2013. **38**(1): p. 1-67.

47. Powell, W.W., et al., *Network dynamics and field evolution: The growth of interorganizational collaboration in the life sciences1.* American journal of sociology, 2005. **110**(4): p. 1132-1205.

48. Kraut, R.E., J. Galegher, and C. Egido, *Relationships and tasks in scientific research collaboration.* Human–Computer Interaction, 1987. **3**(1): p. 31-58.

49. Ponds, R., F. Van Oort, and K. Frenken, *The geographical and institutional proximity of research collaboration*.* Papers in Regional Science, 2007. **86**(3): p. 423-443.

50. McIntosh, S., et al., *Ethical review issues in collaborative research between US and low–middle income country partners: A case example.* Bioethics, 2008. **22**(8): p. 414-422.

51. Somsekhar, H., et al., *Review of multinational human subjects research: experience from the PHFI-Emory Center of Excellence partnership.* Indian journal of medical ethics, 2012. **9**(4): p. 255.

52. Maton, K.I., et al., *Community-based interdisciplinary research: Introduction to the special issue.* American journal of community psychology, 2006. **38**(1-2): p. 1-7.

53. Haines, V.A., J. Godley, and P. Hawe, *Understanding interdisciplinary collaborations as social networks.* American journal of community psychology, 2011. **47**(1-2): p. 1-11.

54. Georghiou, L., *Global cooperation in research.* Research policy, 1998. **27**(6): p. 611-626.

55. Bruneel, J., P. D'Este, and A. Salter, *Investigating the factors that diminish the barriers to university–industry collaboration.* Research policy, 2010. **39**(7): p. 858-868.

56. Gilding, M., *'The tyranny of distance': Biotechnology networks and clusters in the antipodes.* Research policy, 2008. **37**(6): p. 1132-1144.

57. Barnard, H., R. Cowan, and M. Müller, *Global excellence at the expense of local diffusion, or a bridge between two worlds? Research in science and technology in the developing world.* Research policy, 2012. **41**(4): p. 756-769.

58. Bammer, G., *Enhancing research collaborations: three key management challenges.* Research policy, 2008. **37**(5): p. 875-887.

59. Arunachalam, S., R. Srinivasan, and V. Raman, *International collaboration in science: Participation by the Asian giants.* Scientometrics, 1994. **30**(1): p. 7-22.

60. Goddard, T., N. Cranston, and J. Billot, *Making it work: Identifying the challenges of collaborative international research.* International Electronic Journal for Leadership in Learning, 2006. **10**(1): p. 1-5.

61. Chevan, J., *Culture, Language, and Resources: Overcoming Barriers to Research Collaboration With Physical Therapist Education Program Faculty in a Developing Country.* Journal of Physical Therapy Education Vol, 2012. **26**(1).

62. Fell, D.W. and K. Kim, *Developing International Collaborations in Physical Therapy Academia: A Case Example Emphasizing Education and Scholarship.* Journal of Physical Therapy Education Vol, 2012. **26**(1).

63. Chinchilla-Rodríguez, Z., et al., *New approach to the visualization of international scientific collaboration.* Information Visualization, 2010. **9**(4): p. 277-287.

64. Poltrock, S. and M. Handel, *Models of collaboration as the foundation for collaboration technologies.* Journal of Management Information Systems, 2010. **27**(1): p. 97-122.

65. Fjeldstad, Ø.D., et al., *The architecture of collaboration.* Strategic Management Journal, 2012. **33**(6): p. 734-750.

66. Stead, G.B. and T.F. Harrington, *A process perspective of international research collaboration.* The Career Development Quarterly, 2000. **48**(4): p. 323-331.

67. Bagshaw, D., M. Lepp, and C.R. Zorn, *International research collaboration: Building teams and managing conflicts.* Conflict Resolution Quarterly, 2007. **24**(4): p. 433-446.

68. Jacobs, N. and M. Amos, *Removing barriers to interdisciplinary research.* 2010.

69. Adams, J., *Collaborations: The rise of research networks.* Nature, 2012. **490**(7420): p. 335-336.

70. Ghosh, S., *A Report on US-India Program for Exploratory Experiences for Researchers and Students (PEERS).* 2009.

71. Sloan, S.S. and T. Arrison, *Examining Core Elements of International Research Collaboration: Summary of a Workshop*2011: National Academies Press.

72. Boekholt, P., et al., *Drivers of International collaboration in research.* Final Report, 2009.

73. Bound, K. and I.W. Thornton, *Our Frugal Future: Lessons from India's Innovation System* 2012: Nesta.

74. Annex, A. and B. Annex. *Meeting Global Challenges through Better Governance*. in *Meeting Global Challenges through Better Governance International Co-operation in Science, Technology and Innovation: International Co-operation in Science, Technology and Innovation*. 2012. OECD Publishing.

75. Paul, P.S., C. Wood, and J. Yohe, *Lessons Learned from International Research Partnerships.* Global Research Collaborations, 2008: p. 25.

76. Vasileiadou, E. and R. Vliegenthart, *Research productivity in the era of the internet revisited.* Research policy, 2009. **38**(8): p. 1260-1268.

77. Australian Government, *Australian Government Response to the House of Representatives Standing Committee on Industry, Science and Innovation inquiry report: Australia's International Research Collaboration*, 2011, Australian Government: Canberra. p. 22.

78. Schensul, S.L., et al., *Multilevel perspectives on community intervention: an example from an Indo-US HIV prevention project in Mumbai, India.* American journal of community psychology, 2009. **43**(3-4): p. 277-291.

79. McKelvey, M., H. Alm, and M. Riccaboni, *Does co-location matter for formal knowledge collaboration in the Swedish biotechnology–pharmaceutical sector?* Research policy, 2003. **32**(3): p. 483-501.

80. Gascoigne, J., *The cultural origins of Australian universities.* Journal of Australian Studies, 1996. **20**(50-51): p. 18-27.

81. Dobson, I.R., *PhDs in Australia, from the beginning.* Australian Universities' Review, The, 2012. **54**(1): p. 94.

82. Gallagher, A.P., *Coordinating Australian University Development: A Study of the Australian Universities Commission, 1959-1970. University of Queensland Press Scholars' Library*1982: ERIC.

83. Australia Universities Commission, *Universities Commission: What it is and what it Does*1944: Universities Commission.

84. Australia, C.o., *Powering Ideas: An Innovation Agenda for the 21st Century*, 2009: Canberra. p. 76.

85. Department of Industry Innovation Science Research and Tertiary Education, *2012 National Research Investment Plan*, 2012, Commonwealth of Australia. p. 132.

86. Cutler, T., *Venturous Australia: building strength in innovation [Cutler review].* 2008.

87. Mary Josephine, O.K., *Collaborating to a purpose: review of the cooperative research centres program*2008: Department of Innovation, Industry, Science and Research.

88. Green, R., *Building innovative capability: review of the Australian textile, clothing and footwear industries.* 2008.

89. Bracks, S., *Review of Australia's automotive industry: final report.* 2008.

90. Commonwealth of Australia, *Pharmaceuticals Industry Strategy Group: Final Report 2008*, 2009, Commonwealth of Australia: Canberra.

91. Bradley Denise, *Review of Australian higher education: Final report*2008: Department of Education, Employment and Workplace Relations.

92. Evans, T., P. Macauley, and M. Margot, *Submission to the House of Representatives Standing Committee on Industry, Science and Innovation: Inquiry into Research Training and Research Workforce Issues in Australian Universities.*

93. Department of Innovation, I., Science and Research,, *Strategic Framework for Research Infrastructure Investment*, I. Department of Innovation, Science and Research, Editor, Department of Innovation, Industry, Science and Research. p. 4.

94. Department of Innovation, I., Science and Research,, *2011 Strategic Roadmap for Australian Research Infrastructure*, 2011. p. 108.

95. Meyer, P.H.a.R., *Science Policy: Beyond Budgets and Breakthroughs. Discussion Paper on Enhancing Australian Government Science Policy*, 2011, Australian National University: HC Coombs Policy Forum: Canberra. p. 31.

96. Chubb, I., *Australia India Task Force Report Launch: 10 Minute Speech*, A.s.C. Scientist, Editor 2013: University of Melbourne. p. 10.

97. Australian Government, *Australia in the Asian Century White Paper*, 2012, Commonwealth of Australia: Canberra.

98. Government of India, *Scientific Policy Resolution 1958*, G.o.I. Department of Science and Technology, Editor 1958, Ministry of Science and Technology: New Delhi.

99. Government of India, *Technology Policy Statement, 1983*, D.o.S.a. Technology, Editor 1983, Ministry of Science and Technology: New Delhi.

100. Government of India, *Science and Technology Policy, 2003*, D.o.S.a. Technology, Editor 2003, Ministry of Science and Technology: New Delhi.

101. Leadbeater, C. and J. Wilsdon, *The Atlas of Ideas.* London: Demos, 2007.

102. Government of India, *About the System*, D.o.S.a. Technology, Editor 2013, Minister of Science and Technology.

103. Department of Science and Technology, G.o.I. *Technology Innovation Management & Entrepreneurship Information Service*. 2013 [cited 2013 13/06/2013]; Available from: http://www.techno-preneur.net/.

104. Infosys, *Annual Report 2011-12*, 2012. p. 110.

105. Government of India, *Science, Technology and Innovation Policy 2013*, M.o.S.a. Technology, Editor 2013, Ministry of Science and Technology: New Delhi. p. 22.

106. Government of India, *SRS Statistical Report 2011*, M.o.H. Affairs, Editor 2011, Office of the Registrar General & Census Commissioner, India: New Delhi. p. 132.

107. Rajan, Y.S., *Shaping the National Innovation System: The Indian Perspective.* 2012.

108. Singh, R., V. Gupta, and A. Mondal, *Jugaad—From 'Making Do'and 'Quick Fix'to an Innovative, Sustainable and Low-Cost Survival Strategy at the Bottom of the Pyramid.* International Journal of Rural Management, 2012. **8**(1-2): p. 87-105.

109. Innovations, A.t.t.P.M.o.P.I.I.a., *Presentation on Decade of Innovations 2010-2020 Roadmap*, A.t.t.P.M.o.P.I.I.a. Innovations, Editor 2011: New Delhi. p. 45.

110. Australian High Commission India, *Meeting between the Prime Minister of India, Dr Manmohan Singh, and the Prime Minister of Australia, Mr. Kevin Rudd - Joint Statement*, A. Government, Editor 2009: New Delhi.

111. Australian Academy of Technological Sciences and Engineering and The Australia India Institute, *Science Technology Innovation: Australia and India*, 2013, Australian Academy of Technological Sciences and Engineering and Australia-India Institute Melbourne. p. 76.

112. Department of Industry Innovation Science Research and Tertiary Education, *Evaluation of the Australia-India Strategic Research Fund*, 2013, DIISRTE: Canberra. p. 94.

AUSTRALIA INDIA EDUCATION COUNCIL

AIEC