Measuring the Value of International Research Collaboration

REPORT PREPARED FOR THE DEPARTMENT OF INDUSTRY AND SCIENCE

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Executive Summary

International research collaboration is a key feature of the Australian research landscape, and is integral to Australia's future. Increasing the international connectedness and depth of international engagement of research is fundamental to the long-term competitiveness of domestic research, and to ensure that research drives economic and social advancement.

At present, however, the mechanisms to understand and measure the benefits and values of international research collaboration are limited. International research collaboration is constituted by a range of activities, often interrelated, which are not always amenable to quantitative evaluation, and which are likely to be realised in complex ways across the innovation system. Bibliometrics provide a limited evidence base which cannot capture the many modes of collaboration outside co-authorships or outputs from across the research spectrum. Moreover, bibliometrics do not allow us to identify the value of international research collaboration and its system-wide effects.

The aim of this report is to inform the development of a more comprehensive approach to measuring the impact and value of international research collaboration across the publicly-funded research sector, one that is responsive to different disciplinary practices across the research system, and to the range of different activities and levels of engagement.

This will require moving beyond frameworks that focus on simple counts of incidence, to frameworks capable of tracking the complex systems and changes that are involved in international collaboration and the broad range of values that flow – in other words, a shift from focussing on questions of 'what' happened and to 'whom', to questions of 'why' and 'how'.

The report looks beyond the Australian research system to other sectors to inform its approach. The social sector, for example, has well developed approaches to measure value utilising quantitative and qualitative methods. Evaluation is here seen as an integral part of planning, and involves steps such as identifying the aims and intended outcomes of collaboration, developing agreed indicators for measuring progress towards achieving pre-set goals, and introducing a feed-back loop for learning and adjustments

into research design and programme implementation. Such approaches are distinct from the current emphasis in the research sector on *post hoc* evaluation of quality and impact.

Evaluation frameworks which take account of the diverse values that flow from international research collaboration and the deep and complex networks that are involved must also take account of a broader range of data to complement measurement and evaluation processes. There are currently significant collections of data that could be usefully repurposed into an appropriate evaluation framework, including altmetrics and data from social media use by Australian researchers and their international collaborators.

Capturing a broader range of data also allows better understanding of the networks that are involved in the creation and dissemination of knowledge. The report proposes network analysis as particularly suited to measuring and planning international research collaboration: it is able to capitalise on the range of available data; to combine these with traditional STI measures; to integrate qualitative assessment, and offers a way of bringing this range of information together to better understand the system.

The application of social network analysis ensures that the wide extent of values can be quantified at various levels, and the complex channels that value operates through can be mapped and understood. This needs to be undertaken with the Leiden Manifesto best practice guidelines for metrics-based research evaluation in view, principally, that 'quantitative evaluation should support qualitative, expert assessment'. While it may be prohibitive to measure the impacts of international research collaboration given the long time frames involved and significant issues around demonstrating causality, it is possible to explain and understand its values and to track the networks that they flow through.

Finally, the report suggests a limited trial applying network analysis to university and PFRA data to answer questions around the accessibility of data and how much work is involved in data processing and analysis. This will establish the workflow for such analysis in the future. It would also work towards the development of a set of standard guidelines for evaluating international research collaboration in policy, programme and project settings.

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1. Introduction

In an increasingly globalised higher education sector, international research collaboration has become a key feature of public research policy in Australia and abroad. International research collaboration is key to Australia's economic and social future, and harnessing the potential opportunities it presents will have benefits that extend far into the future.

Governments around the world are recognising the value of international collaboration through new policies, including around science and research diplomacy, and designing programmes that aim to foster international cooperation. The European Union's Horizon 2020 programme is an exemplar in this regard and in recent years has focused on building reciprocal arrangements and multinational collaborations.

Significant benefits accrue from international collaboration at the research system, institution, and individual researcher levels (see for example, Barlow, 2011). Benefits include access to research expertise, research scale, cooperation on societal challenges, cost sharing, risk reduction, and access to international funds. When international research teams collaborate, they bring together different cultural perspectives and methodological approaches, widening the perspective of analysis and interpretation. Such engagement enables the pooling of resources to create larger and more extensive networks of knowledge; international collaboration increases the reach and impact of a country's research and has significant career implications for researchers. Global connections between researchers and institutions have sizeable social, cultural and economic impacts, with benefits extending beyond academe.

The Australian Government's competitiveness agenda seeks to optimise Australia's comparative advantages across a range of sectors. In the international research collaboration arena, this means playing to strengths, building capacity in areas of research priority, and working on shared research challenges.

At present, however, the mechanisms to understand and measure the benefits and values that flow from international collaboration are limited. The constraints of bibliometric approaches are widely acknowledged, as is the need for more nuanced qualitative and quantitative measures to better understand the complex networks involved in international collaboration. The overarching aim of this scoping project is to inform the development of a more comprehensive approach to the impact and value of international

research collaboration across the publicly-funded research sector, one that is responsive to different disciplinary practices across the research system, and to the range of different activities and levels of engagement.

The report surveys new and emerging approaches to measuring the values that flow from international collaboration in the research sector. It considers a broader repertoire of evidence for defining, identifying and measuring the value of international collaboration, and proposes a strategic evaluative approach based on a network analysis framework. The report also suggests areas for further work around the potential of network mapping for better understanding the range of interactions, relationships, flows and values associated with international collaboration.

1.1 Scope and approach

The report was commissioned by the Department of Industry and Science to inform consideration of a more comprehensive approach to valuing international research collaboration across the publicly funded research sector. The focus of the report is therefore on evaluation frameworks and methods rather than simple metrics, although it also canvasses the ongoing discussions around developing new metrics and best practices for metrics-based evaluation of international research collaboration.

The key questions the report addresses are:

1. What value is created by publicly funded research organisations and researchers collaborating internationally?
2. How can the value of international collaboration be measured?
3. What data sources currently exist that could better inform evaluation frameworks?
4. What can be learnt from other sectors' approaches to measuring value, specifically in terms of developing methods that aim to capture values other than economic outcomes?

In answering these questions, the report surveys Australian and international approaches to measuring the value of international research collaboration, noting existing metrics, data sources and methodologies.

The 'how to measure' question in Australian research performance is customarily reduced to *post-facto* counting of outputs. Any sound

measurement system for value should start with a *pre-facto* strategic question about what the activity is intended to achieve (in this case international collaboration) and a means of knowing it is achieving these objectives along the way and on completion of the activity.

One key area of focus of the report is what can be learnt from other sectors, especially around ideas of 'social value'. In the social sector, collaborative partnerships are commonplace as a way of harnessing organisations and resources to achieve outcomes that could not be otherwise achieved. The social sector has well developed approaches to measure value utilising quantitative and qualitative methods.

The project has been guided by an Advisory Group, which consists of research leaders from the Academy and the broader academic community, including:

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- Professor Joy Damousi FAHA FASSA
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- Professor Paul Gough
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2. Defining the value of international research collaboration

International research collaboration encompasses a broad range of activities that occur at different levels of the research system, to greater and lesser intensities and across different timeframes. For example, international science and research diplomacy – where research is used to further diplomatic relations or foreign policy objectives – requires deep relationships that are developed across long time frames, and its effects are felt nationally. By contrast, a single project may be completed within a year between two researchers and may have most immediate discernible effect on their careers which translate into longer term benefits for the nation. Indeed, much of the work on international collaboration is focussed on the aggregation of individual benefits as these can translate into higher order benefits. However, as this report contends, international collaboration is constituted by a range of activities, often interrelated, which are not always amenable to quantitative evaluation, and which are likely to be realised in complex ways across the innovation system. Despite recognition of its growing importance, work on measuring and evaluating international research collaboration is currently limited, and there is a growing need to design fit for purpose approaches to inform programme design and maximise policy effectiveness.

At present, one of the primary sources of information about international research collaboration is bibliometric data, where international co-authorship and citations are used as a proxy for measuring the level and impact of international collaboration. The limitations of these data are well documented, and include problems around capturing the full range of the research spectrum, especially humanities research (see, for example, van Leewen, 2010; Archambault and V. Larivière, 2010). Humanities researchers often retain a focus on publishing books and book chapters, which are not comprehensively indexed in the commercial bibliometric databases; coverage of humanities journals also has a lower level of indexation. In addition, while bibliometrics provide some information about the number of international collaborations and with whom this occurs, bibliometrics provide a limited evidence base which cannot capture the many modes of collaboration outside co-authorships; nor do bibliometric indicators help us to identify the value of international research collaboration and its system-wide effects.

Additional quantitative approaches, such as counting numbers of international research exchanges, attendances at international conferences, or the cost of shared research infrastructure, are often good ways of tracking

the extent of internationalisation of the research sector, but do not necessarily provide a way of understanding and evaluating the deep channels of mutual exchange that occur in international collaboration and the many benefits that follow. The increasing rate of internationalisation of Australia's research system is relatively easy to track – for example, a simple count of the number of international partner investigators on Australian funded research projects over time – but this is of limited use for policy development and programme evaluation.

2.1 International principles and best practices

While globally the rate of international research collaboration is growing rapidly, approaches to identifying and measuring its value are in their early development, and the lack of suitable approaches is well known (Edlera et al., 2011; CREST, 2007). The need to 'develop additional evaluation methods that do greater justice to the variety of outputs and activities of researchers' (CWTS, n.d.) is particularly important for Australia, which participates in a dynamic regional network of research investment and output (Barlow, 2014). Groups such as the Centre for Science and Technology Studies (CWTS) at Leiden University and Rand Europe are developing frameworks and instruments that specifically take account of different research methods, communication and publication processes, and collaborative practices across disciplines (Rand Europe). In Australia, recent work produced through the Australian Council of Learned Academies (ACOLA) has emphasised transnational research value-chains as a means of tracking networks of multilateral science and research collaboration (Matthews and Cheng, 2014).

In addition, there are useful lessons to draw on from other sectors, notably the social and cultural sectors, both of which have a long history of approaches to tackling value measurement, and understanding the relative merits of quantitative and qualitative approaches. The Arts and Humanities Research Council (AHRC) in the UK has funded a two-year study that 'will advance the way in which we talk about the value of cultural engagement and the methods by which we evaluate that value' (ACHRC Cultural Value Project, n.d). In Australia a similar project underway in South Australia is examining ways to measure the value of cultural experiences over the long-term, because one of the limits of existing measurement frameworks is that 'they have such a short cycle – the annual budget, the forward estimates' (Flinders University News, 2014).

While this report initially sought to draw from this work on cultural value, both of these projects are still ongoing and not at the point where key findings have been released. Work in the social sector has therefore been the focus of our analysis. It is nevertheless recommended that the cultural value research be kept in future frame given the significant potential it offers for new ways of thinking about measuring the value which may be transferable to international research collaboration evaluation.

In the research sector, the growing demand for metrics has highlighted the need for international standards in research evaluation. In April 2015, a group of academic and professional research evaluation experts released the 'Leiden Manifesto' best practice guidelines for metrics-based research evaluation (Hicks et al., 2015):

- Quantitative evaluation should support qualitative, expert assessment
- Measure performance against the research missions of the institution, group or researcher
- Protect excellence in locally relevant research
- Keep data collection and analytical processes open, transparent and simple
- Allow those evaluated to verify data and analysis
- Account for variation by field in publication and citation practices
- Base assessment of individual researchers on a qualitative judgement of their portfolio
- Avoid misplaced concreteness and false precision
- Recognize the systemic effects of assessment and indicators
- Scrutinize indicators regularly and update them

This report takes these guiding principles as its starting point in its contribution to the ongoing discussions around developing new metrics and best practices for metrics-based evaluation of international research collaboration. The Leiden Manifesto contends that too often 'evaluation is led by the data rather than judgement' (p429). If metrics, such as citation counts, are all that is in the 'toolkit' there are ultimately implications for policy development and programme design.

2.2 Measuring research quality and benefits in Australia

Australia undertakes world-class research across the full spectrum of research activity, from Science, Technology, Engineering and Mathematics (STEM), through to the Humanities, Arts and Social Sciences (HASS). This is achieved through universities and other publicly funded research organisations, such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Institute of Marine Science (AIMS). This is established through international research rankings, where, for example, Australia outperforms the US in terms of 'GDP to top university ratio' (Dudley, 2015) and has been confirmed by consecutive rounds of Excellence in Research for Australia (ERA).

Much of Australia's success in research has been built upon financial and esteem-based incentives that encourage researchers to produce academic papers. In the university sector, there has been strong evidence that this focus has led to dramatic increases in research production (Butler, 2003). This has been due to the success of Federal Government policies, such as the Higher Education Research Data Collection (HERDC), and more recently ERA, which deliver financial rewards and contributes to institutional reputation. Such incentives are reinforced by Australia's project-based funding through the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC) which are awarded in large part based on publication 'track record'.

More recently, Australian policy has focussed on delivering benefits or impacts from publicly funded research. For example, the CSIRO Impact Framework attempts to account for the social, environmental and economic impacts of its research. This has been driven in large part by a national fiscal management that demands evidence of the return on investment of public funds. As a response, much attention in the higher education sector has focussed on measuring the broad societal benefits that flow from publicly funded research – for example, the Excellence in Impact for Australia (EIA) trial (2012) which sought to evaluate research impact through case-studies. This reflects the growing international trend towards broadened research evaluation metrics combined with expert judgement (e.g. the role of case studies in the UK Research Evaluation Framework (REF) 2014).

Research excellence and impact are both important aspects of the Australian innovation system, and policies that quantify the returns on the

public investment into research are fundamental to ensure the confidence of the public in the value of investing in research. However, it is not enough for policy to simply measure research quality and research impact – it is imperative that public policy drives (and supports) the kinds of behaviours that will maximise the quality and impact of research in the long term. Such an approach must not only focus on retrospective performance measures alone, but must rather form an integral part of the forward planning of research agendas at all levels – for the research system as a whole, institutions and researchers.

A significant contribution to this can be made through an increased focus on international collaboration. This requires a shift from traditional frameworks that focus on simple measurements of incidence, to broader frameworks that are capable of tracking the complex systems and changes that are involved in international collaboration, and the benefits that flow.

2.3 Defining 'value' and 'international collaboration'

Throughout this report, research is understood as per the definition from the Higher Education Data Collection (HERDC):

> Research is defined as the creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies and understandings. This could include synthesis and analysis of previous research to the extent that it leads to new and creative outcomes.
>
> This definition of research is consistent with a broad notion of research and experimental development (R&D) as comprising of creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of humanity, culture and society, and the use of this stock of knowledge to devise new applications.
>
> This definition of research encompasses pure and strategic basic research, applied research and experimental development. Applied research is original investigation undertaken to acquire new knowledge but directed towards a specific, practical aim or objective (including a client-driven purpose) (Department of Education and Training, 2014).

Two additional definitions are used in this report in order to distinguish it from previous work on research impact, knowledge transfer and research engagement:

- **Value:** in contrast to research impact, which implies a causal link between research activities and outcomes, value can be thought of as a cumulative benefit, where results are achieved across a system or network. While impact is focussed on the question of 'what' happened and to 'whom', value is focussed on the questions of 'why' and 'how' it happened. In these key respects, where impact is fixed at points in time, value is dynamic and driven by focussing in on systems and networks. Where impact seeks to reduce and measure complexity, value seeks to understand and harness complexity towards designing effective policy, programmes and projects.
- **International collaboration:** occurs where researchers and research organisations engage with each other for mutual support and contribution to the conduct of research. This can occur as a response to top-down policy, or through bottom-up, researcher-led initiatives. Discrete collaborations vary widely in scale, intensity and duration, and their outcomes and impacts are generally measured at the level of the project or programme. The wider effects of research collaboration are likely to be achieved across a complex network or system of relations. While it may be difficult to measure the impacts of international research collaboration at this level, it is possible to explain and understand its value.

Throughout this report, international collaboration must be considered separately from references to the 'internationalisation' of the research system – this refers simply to the extent to which the Australian research system interacts with other countries' research systems. In this respect, internationalisation is one of a number of the values that follow from international research collaboration.

Finally, it is important to distinguish these definitions from research impact and research engagement which are understood as:

- **Research impact:** is the demonstrable contribution that research makes to the economy, society, culture, national security, public policy or services, health, the environment, or quality of life, beyond contributions to academia (PFRA, n.d)

- **Research engagement:** the interaction between researchers and research organisations and their larger communities/industries for the mutually beneficial exchange of knowledge, understanding and resources in a context of partnership and reciprocity. (ATSE 2015)

3. The values that flow from international collaboration

Increasing the international connectedness and depth of international engagement of research is fundamental to the long-term competitiveness of domestic research, and to ensure that research drives economic and social advancement. The UK Government, for example, has identified in its science and innovation strategy the prioritisation of spending in this area despite difficult economic conditions, because it is seen as essential to 'establish the UK as a world leading knowledge economy' (HM Treasury and Department for Business Innovation, 2014, p3). The motivations of such statements are, however, diverse; a recent survey of the research internationalisation policies of twenty leading research countries found that the drivers are as varied as broadly 'tackling global societal issues and challenges' to a focus on 'achieving research excellence in a globalised world' (European Commission, 2009, p8).

In Australia, the Minister for Education and Training has recently stated that:

> Education, training, skills, research, science and innovation are at the centre of the Australian Government's efforts to position Australia for future prosperity in an increasingly globalised world. A new architecture for Australian international education will secure Australia's place as a world leader in what has become a major industry in its own right. It will ensure that international education, coupled with a strong research and innovation system, is a key driver of Australia's future economic productivity and competitiveness (Department of Education and Training, 2015, p2).

The *Draft National Strategy for International Education*, released in April 2015 by the Department of Education and Training, outlines how international cooperation and collaboration contribute to Australia's social, cultural and economic life, affecting 'international trade, investment and goodwill' (p6). The plan will be achieved in part by investing in research, research infrastructure and high-quality international research collaborations (p13). Strategic planning of international research collaboration will allow the Government to make informed decisions about when, where and how to invest to maximise the range of values that come from international research collaboration.

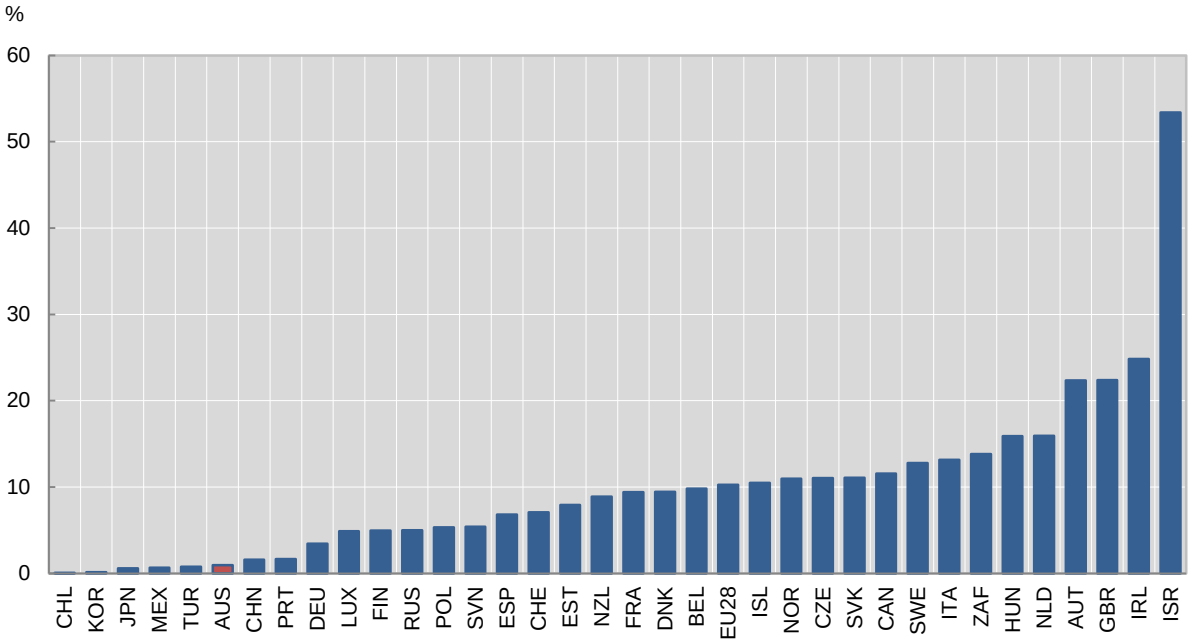
This following section provides an overview of the values that flow from international research collaboration. The values are discussed against three

broad categories: economic value; research excellence and global reputation; and delivering policy objectives.[1]

3.1 Economic value

There are many direct and indirect, economic and commercial values that flow from international research collaboration. Direct economic values come in many forms, but include investment into research and development by overseas firms and organisations, as well as funding derived through international competitive processes. Via organisations such as the Organisation for Economic Cooperation and Development (OECD), such values and their measurement have become popular drivers of international collaboration. The most basic of these values is Business Expenditure on Research and Development (BERD) from abroad (**Figure 1**).

Figure 1 BERD funded from abroad as percentage of total BERD (2011) (OECD, 2013)



There are additional and significant indirect economic values that flow from international research collaborations, including:

- Research and non-research job creation
- Development of regional communities

[1] **Appendix A** includes a full listing of the values discussed in this section

- Leveraging domestic funding to receive international funding
- Encouraging trade and investment opportunities

The full extent of the return on public investment into research and collaboration is difficult to quantify, but there is evidence from both Australia and internationally that it is high – the Cooperative Research Centres alone contribute $278M, or 0.03 per cent of Australia's GDP, annually (Allen Consulting Group). A recent report to the United States House of Representatives and the United States Senate by the National Academies also identified public investment in research as fundamental to turning around its current economic crisis (for a full account see, 'Rising Above the Gathering Storm', 2015). The findings of this report were implemented in the *America Competes Act* (2007), designed '[t]o invest in innovation through research and development, and to improve the competitiveness of the United States.

There are many well documented examples from overseas, where investments in research collaborations are usefully leveraged to create far greater economic value than investment costs. In the UK, the Integrated Ocean Drilling Programme (IODP) has been used to leverage substantially more international investment than has been invested by the UK government. The IODP research into the evolution of ocean basins is used globally as the basis for oil, gas and metal exploration and extraction, resulting in significant overseas investment from partners in the USA, Japan, China, South Korea, India, Australia, New Zealand and 17 European countries. From 2003-2013, the Natural Environment Research Council's (NERC) investment in IODP operating costs was $47m while other nations contributed $3bn (Main, 2013, p23).

The Australian APEC Study Centre (**Box 1**) is a local example of how significant value can result from sharing the costs and risks associated with large-scale infrastructure regionally. Direct international investment into large-scale research infrastructure therefore has the capacity to enter into the eco-system of the innovation economy, which has a multiplier effect, achieved through research and non-research job creation. Such indirect economic gains follow from investment in the large-scale infrastructure that supports international research and collaboration.

BOX 1: Promoting Infrastructure Private-Public Partnerships in APEC and ASEAN - Australian APEC Study Centre (RMIT)

The Australian APEC Study Centre (AASC) at RMIT delivers APEC's strategic, economic, social and educational objectives throughout the Asia-Pacific region through institutional capacity building and research.

In 2014, The AASC received a grant of $2.467m over two years from the Australian Government Partnerships for Development (GPFD) programme for the project *Promoting Infrastructure Private-Public Partnerships*, with the aim of enhancing the institutional capacity of APEC, ASEAN and EAS developing country member nations to design, finance and implement private-public partnership infrastructure projects.

This work ties into the AASC's role supporting the APEC's Asia-Pacific Infrastructure Partnership, which focuses on encouraging foreign and domestic investment in public-private partnerships. The Partnership comprises 60 international specialists from academia, asset management, commercial and investment banking, engineering, property development, information technology, law, the World Bank and the OECD.

Source: http://www.rmit.edu.au/about/our-education/academic-colleges/college-of-business/industry/australian-apec-study-centre/projects/infrastructure-ppps-and-sustainable-urban-develop/.

The same is true of sharing technologies and data collection with international research partners. Large telescopes and accelerators, for example, with budgets in the billion dollar range and timeframes for design and construction of decades, would likely be out of the question without international cooperation (Main, 2013, p9). Such examples show how collaboration enables expensive, large-scale projects to go ahead, where no individual nation or funding organisation would have sufficient 'convening power' to bring the necessary resources together (Main, 2013, p7).

These examples demonstrate that international research collaboration presents opportunities to leverage additional and substantial funding on the back of public investment. Traditionally, it has been argued that public investment in research, including 'blue-sky' research, simply corrects market failures – that industry prefers to focus on late stage commercialisation projects that have a demonstrable return to shareholders, and this is complemented by the discovery focus of many research programmes conducted by universities and other publicly funded research organisations (Main, 2013, p34). More recently, what companies such as Apple demonstrate is the extent to which publicly funded R&D actively generates markets for private sector innovation. Apple's profits, driven by sales of

devices such as the iPhone and iPad are based largely on innovations produced by publicly funded researchers and not through the company's own R&D (Mazzucato, 2013). In both cases, international collaboration acts as an important translation point, particularly in a country like Australia, where foreign exposure can be limited by geography.

Japanese companies such as Toyota and Sony are good examples of this – the success of these companies can be attributed to lessons learned by Japanese researchers who established links with US companies, participated in knowledge sharing, and licensed technologies from them. Freeman (1995) points to Japanese technology imports as a defining characteristic contributing to its success. The contributions of international technology imports and international spillovers have been empirically shown to account for income differences between countries (Acharya and Keller, 2007). Additional evidence shows that global researcher mobility directly impacts the domestic rate of knowledge and technology transfer, and that there are significant benefits for the 'home' country to researchers spending time abroad (Edlera et al., 2011). In these respects, there is strong evidence that public funding of international collaboration supports (rather than displaces) private sector R&D.

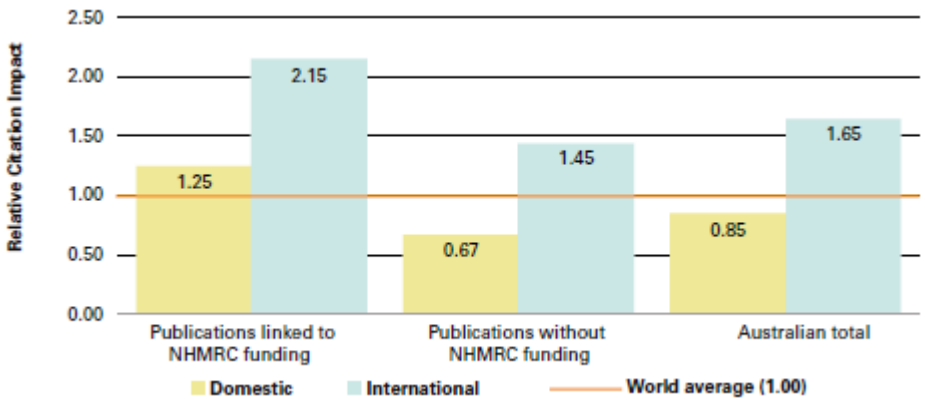
Government investment, innovation subsidies, and public capital investment in infrastructure have all shown a positive relationship between public R&D investment and private investment (Main, 2013, p4). Some of the more well-known examples of Australian research institutions collaborating with global industry are CSIRO's longstanding research relationship with Boeing, and the University of Melbourne's collaboration with IBM on the IBM Research - Australia Laboratory which is expected to employ 150 researchers by the end of 2015 (Austrade).

While direct economic investment from abroad into Australian research is desirable in its own right, this is only one of the many economic benefits that flow from international research collaboration. Research and non-research job creation, leveraging domestic funding to attract international funding, encouraging trade and investment opportunities, sharing risks associated with large infrastructure and getting projects to scale – such indirect benefits, while difficult to fully account for and calculate are significant drivers of investment into international research collaboration.

3.2 Research excellence and global reputation

It is widely accepted that international research collaboration increases the reach and academic impact of domestic research, as can be measured through proxies such as citations between academic articles, or citations in patent literature (see for example, Glänzel, 2001; Glänzel and de Lange, 2002). **Figure 2** shows evidence of this from Australia – this figure includes the normalised citation rates for NHMRC-funded publications authored with and without an international co-author. Such evidence highlights the ability of NHMRC funding to mobilise the world's best researchers on Australian projects and for this to translate into greater visibility of Australian research and peer recognition.

Figure 2 Relative citation impact of biomedical publications involving domestic and international collaborations, NHMRC and Australia, 2005–2009 (NHMRC, 2013)



The value of increasing research excellence is more broadly observed than simply increased citations, however, and operates in complex ways across the innovation eco-system, including:

- Maximising the ability to take advantage of international spillovers and knowledge transfer
- Enhancing the global reputation of Australian researchers and institutions
- Informing global research rankings
- Leveraging reputation to access international funding
- Attracting and retaining international research talent

In order to participate fully in global researcher mobility, and be well placed to make the most of international spillovers and knowledge transfer,

Australia's international research reputation is an important driver and fundamentally shapes Australia's attractiveness to investors and partners.

International collaboration enhances the reputation of participating institutions/organisations and countries, which in turn attracts increased inward R&D investment, particularly by global corporations with a large R&D budgets as they seek relevant research expertise worldwide (Research Councils UK, n.d., pp12-13). At the same time, any perceived or actual withdrawal or downgrade of support by a government for research can result in fast negative flow-throughs as international R&D investment moves to other countries, resulting in drops in GDP (Main, 2013, pp19, 55).

International reputation plays a crucial role in Australia's ability to participate in global R&D, and international research collaborations are a key driver of this. In addition to significant benefits in terms of traditional research imperatives (i.e. increasing the sum total of knowledge, increased research productivity and research that is of higher academic impact when measured by traditional bibliometric indicators) there are equally important, though less quantifiable values that research institutions experience from international engagement.

International collaborations are an opportunity to showcase research institutions' capacities on the world stage. Besides increased awareness and prestige, international reputational surveys form a significant component of leading world-university ranking systems (for instance, the QS World University Rankings and Times Higher Education World University rankings). On the back of research rankings results, Australian universities and other research institutions leverage their reputations in particular research disciplines to become a research partner of choice for overseas researchers and companies. International relationships facilitate an entrée into other audiences and outlets for Australian research and potential access to overseas capital and markets.

High profile research organisations also leverage their international standing to access funding sources. Funding opportunities include a share of the research components of the estimated $140bn in international aid funding available from multilateral banks, agencies of the United Nations, and other organisations (HM Treasury and Department for Business Innovation & Skills, p68). In Australia, the Juvenile Diabetes Research Foundation (JDRF), for example, has stated that its 'coordination of international research funding activities results in a net inflow of funds to Australia in the millions of dollars

annually' (House of Representatives Standing Committee on Industry, Science and Innovation, 2010, p7).

Global reputation and research networks further assist in attracting the best international academic staff, undergraduate and postgraduate students to Australian universities. Facilitating international research, and providing access to the best colleagues and infrastructure, encourages Australian researchers to return after overseas work experience (PMSEIC, 2006, pp2, 9).

The relatively small budgets of Australia's research institutions means that they must leverage international networks to gain access to the best research skills, technology, infrastructure and data. For the University of New South Wales (UNSW) international collaboration provides: '[a]ccess to data-bases and collections of data from overseas, samples for testing or analysis, cutting edge technology, equipment and infrastructure' (House of Representatives Standing Committee on Industry, Science and Innovation, 2010, p6). These relationships can also facilitate access to local knowledge, contacts and resources that would otherwise be unavailable to Australian researchers (OECD, 2013).

In medical research, access to global data is particularly important, as it often relies on large population study cohorts, and international clinical trials. The Clinical Oncological Society of Australia has stated that:

> [m]ulticentre clinical trials conducted through these international collaborations, have resulted in changes in standards and clinical practice guidelines, and have improved patient outcomes across a range of areas both in Australia and overseas (House of Representatives Standing Committee on Industry, Science and Innovation, 2010, p8).

While institutional reputation based on research excellence increases opportunities for inter-institutional collaboration, individual researchers are still at the centre of these important networks, and the role of individuals in establishing and maintaining research relationships cannot be overlooked. As the case study of Professor Colin Mackerras in **Box 2** outlines, individual researchers can have profound and far reaching impacts across broad spheres.

BOX 2: A bridge of mutual understanding – President Xi Jinping on Emeritus Professor Colin Mackerras (Griffith University)

When China's President, Xi Jinping, addressed the Australian parliament in November 2014, he made special mention of one person: Colin Mackerras FAHA, Emeritus Professor at Griffith University and one of the world's foremost China experts.

The President thanked Mackerras for building "a bridge of mutual understanding and amity between our people", and he praised his "tireless efforts to present a real China to Australia and the world, based on his personal experience of China's development and progress".

Since first visiting the People's Republic as a 25-year-old in 1964, Mackerras has made nearly 70 return trips to teach and undertake research. Specialising in Chinese theatre, ethnic minorities, Western perspectives on China and Australian-Chinese relations, he has written or edited nearly 50 books, including about a dozen as sole author, and produced almost 100 book chapters and articles.

But those statistics only hint at the scale of Mackerras's accomplishments, which include helping to strengthen bilateral relations through his sustained and committed efforts as a cultural ambassador. The veteran Sinologist has inspired generations of students in Australia and China to study and appreciate each other's history, language and culture. During the 1980s, he played a leading role in instituting educational exchanges.

Mackerras - who in 2014 received the Friendship Award, China's highest honour for a foreigner - has also championed the teaching of Chinese language and history in Australian schools and universities.

Mackerras describes the humanities as "an excellent vehicle for building international relationships". While trade can play a significant role, he says, "I think that studying and engaging with another people's culture over a long period fosters a deeper understanding and builds more durable bridges".

Source: Extract of 'A lifetime of cultural diplomacy helps to bind Australia and China', forthcoming in *The Power of the Humanities*, Australian Academy of the Humanities.

Many larger scale research collaborations are instigated from existing individual-to-individual researcher connections, with institution-level collaborations emerging from these relationships. Research Councils UK, the strategic partnership of the UK's seven research councils, recognises that one of the key drivers for engaging internationally is to build networks for future use – particularly for early career researchers: '[t]his experience provides them with different skills and ideas and lays the foundation for career-long collaborations' (Research Councils UK, n.d.,

p10). As an example, the Australia-Germany Joint Research Co-operation Scheme, a joint initiative of Universities Australia and the German Academic Exchange Service (DAAD), has a particular emphasis on supporting early career researchers to participate in international research collaborations because of the value of establishing international networks as early as possible in a research career (Universities Australia). By the time researchers progress into senior leadership positions, they have well-established international networks that they draw on (PMSEIC, 2006, pp44-47). International cooperation and mobility has been elsewhere referred to as 'almost a condition *sine qua non* when it comes to academic career and impact' given the significant implications for the future capacity of the domestic research workforce (European Commission, 2009, pp5-6).

Such values go well beyond individual esteem and research excellence. Developing intercultural experience and understanding exposes researchers to new perspectives and reveals new applications for their research. It also provides a nuanced understanding of global issues, and a practical knowledge of how to facilitate complex research projects and relationships (Ang et al,. 2015). Such researchers are valuable resources, providing expertise to government, connectedness for industry and informing public debates on issues of global importance. To this end the UK Government's Science and Innovation Strategy outlines the value of mobility for academic employment (HM Treasury and Department for Business Innovation & Skills, 2014, p69). The benefits of career mobility are not restricted to *our* researchers abroad, and significant benefits have been evidenced following from diasporic researchers in Australia, who play an important role in developing international research networks (Ang et al., 2015; Barlow, 2014).

Overall, international research collaboration creates significant reputational value for Australian researchers and institutions. This is translated into important opportunities for additional value creation across a broad range of areas, including international spillovers and knowledge transfer, improved performance in global research rankings, accessing international capital and attracting world-class researchers to Australia. These values are derived from individual interactions, and can be scaled up through inter-institutional and inter-governmental relationships.

3.3 Delivering policy objectives

Since 1945, Australia has made important contributions to multilateral treaties on a range of issues such as international trade, Antarctica, World Heritage,

marine pollution, the law of the sea, international fisheries, ozone depletion, biodiversity conservation and climate change. These problems cross national borders. Issues such as the need for global standards in ICT for activities around information exchange, data access, network operating and security protocols also require collaborative, global responses (PMSEIC, 2006, p10). In each case, Australia's contribution to these major international issues has drawn heavily on its research base. Significant values can be identified as following from these activities, including:

- Having a seat at the table on issues of global importance
- Exercising 'soft power'
- Creating and bolstering bilateral and multilateral diplomatic relationships
- Meeting international obligations such as delivering development aid

By investing and taking a key role in multilateral research initiatives, a country can ensure that its national priorities and strengths are taken into account in negotiations to set the international agenda (Main, 2013, p53). Without this participation, Australia is limited in its ability to influence agendas for international issues of global significance, such as health, food production, environmental issues and economic issues. In a recent report to the UK Treasury, it was noted that science is an increasingly important element of 21st century diplomacy and 'a source of considerable "soft power" around the world' (HM Treasury and Department for Business Innovation & Skills, 2014, p68). A recent report from the Australian Council of Learned Academies (ACOLA) also recognises the potential role for science and research diplomacy in advancing Australia's interests (Ang et al., 2015).

To this end, nations are increasingly creating links between research policy, innovation policy and foreign policy, in recognition of the value that research brings in delivering strategic policy objectives.

The Royal Society has summarised the roles of research in diplomacy as follows:

- informing foreign policy objectives with scientific advice (science in diplomacy)
- facilitating international science cooperation (diplomacy for science)

- using science cooperation to improve international relations between countries (science for diplomacy) (The Royal Society, 2010, pvi).

Barlow has outlined the contribution of research and science in meeting a number of policy objectives, including:

- To improve general relations between nations
- To resolve issues of international disagreement
- To coordinate a response in a moment of crisis
- To gather information on other societies
- To forge strategic advantage
- To provide humanitarian and development aid (Barlow, 2014, p9)

Bilateral research collaborations can bolster existing bilateral government agreements, and facilitate future arrangements. By identifying shared priorities, for instance, Australia can consider allocating resources to areas of particular need. There are also anticipated future economic benefits from access to developing markets and partnerships with emerging innovation leaders (PMSEIC, 2006, p47).

Using research collaboration to deliver strategic development priorities and capacity building aims between developed and developing nations is gathering increasing support internationally. The OECD has reported extensively on the effects of international research cooperation between developed and developing countries. It has found that links between science policy and aid policy are increasing in some countries, and are moving beyond 'traditional technology transfer' to 'support scientific collaboration for development goals and to strengthen research capacity'. Increasing research capacity is expected to lead to the creation and use of new knowledge that will improve economic growth in developing nations, and building sustainable research capacity may lead to less aid dependence in the future (OECD, 2013, pp3-7).

BOX 3: Translating cutting-edge research into real change for the disadvantaged – the Life Course Centre (University of Queensland)

The ARC Centre of Excellence for Children and Families over the Life Course (the Life Course Centre) was established in September 2014 to research and address issues relating to family background, persistent disadvantage and growing income inequality, which the World Economic Forum claims is the greatest economic risk facing Australia and other nations in the coming decade.

The Life Course Centre is based at the University of Queensland and has 10 international partner universities, with additional nodes at the University of Western Sydney, the University of Melbourne and the University of Sydney.

It is tackling the global problem of income disparity via collaboration between four Australian universities, five Australian government agencies, two non-government organisations, and draws on existing international research networks of partner researchers and institutions.

The Life Course Centre brings together international expertise with Australian researchers "to address the problem of deep and persistent disadvantage. The Centre's structure provides a strong collective capacity and powerful partnership networks to translate cutting-edge research findings into real change for disadvantaged children and families."

Source: Life Course Centre

Research collaboration can play an important role in achieving a range of policy outcomes as discussed here (exercising 'soft power', creating and bolstering bilateral and multilateral diplomatic relationships, meeting international obligations such as development aid) – in each case, research relations, embedded in policy planning, act as a means for successful policy outcomes.

4. Evaluating international research collaboration

The analysis provided above demonstrates that it is possible to identify and document the values that flow from international research collaboration. To date, the evaluative processes and frameworks employed to measure international collaboration have been driven by *post-hoc* approaches with data collected after the event. These frameworks cannot capture the complex systems and changes that are involved in international collaboration and the broad range of values that flow from it.

Specific work on measuring and evaluating these complex systems is currently limited, and in its early development. There is a growing need to design fit for purpose approaches and indicators to undertake this. Much of this work in recent years has been carried out by the European Commission especially around the Framework Programmes for Research and Technological Development for the European Research Area. From the existing literature, the following three observations provide an overarching framework to think about the value of international collaboration:

1) International research collaborations are used to realise both 'broad' and 'narrow' outcomes
2) Collaborations are entered into because of top-down policies and bottom-up relationships
3) Research collaborations are entered into for the mutual benefit of multiple participants

4.1 Extending existing frameworks

At present, there are a range of science and technology indicators (STI) used by the OECD to measure research internationalisation. These can be thought of as measuring the 'narrow STI cooperation paradigm', where the aim is to 'improve the quality, scope and critical mass in science and research by linking national (financial and human) resources and knowledge with resources and knowledge in other countries' (European Commission, 2009, pi). Increasing the number of scientific publications which include an international co-author or attracting more international investment into domestic R&D both belong under this category.

Increasingly, international research collaboration is being embedded in other policy settings to deliver 'broad STI' policy objectives. Activities such as

research diplomacy or delivering development aid through building research capacity are part of a 'broad STI cooperation paradigm' (European Commission, 2009, pii). This observation effectively distinguishes between policies where science and research are ends in themselves and those where research and science are used as a means to another policy end.

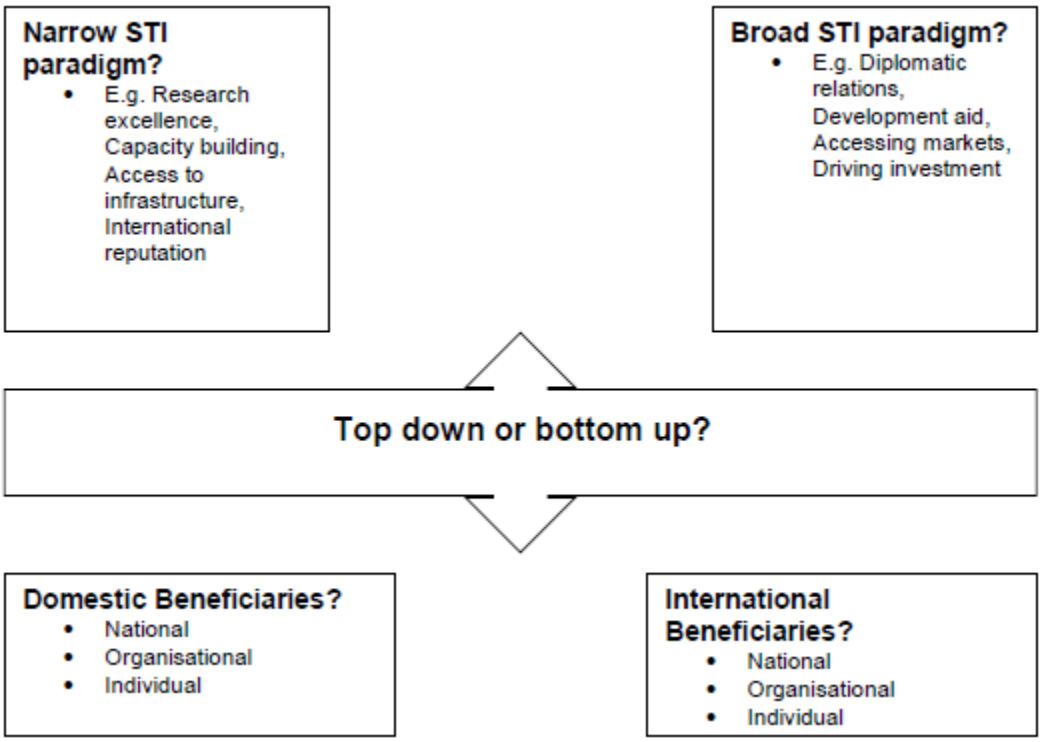
It is important to also distinguish between international research collaboration from the perspective of top-down policy initiatives and bottom-up research activities (see Adams et al., 2007), and to use this as a way of identifying and evaluating value. A top-down policy might be, for example, where Government fosters international research collaborations in order to gain access to new and emerging markets (CREST, 2007, piii); bottom up activities might take the form, for example, of two academics partnering on an international research grant based upon a common research interest. In this respect, a top-down vs bottom-up framework identifies different modes by which the 'narrow' or 'broad' STI paradigms are initiated.

Finally, it is clear that there are multiple beneficiaries from international research collaborations, and that different activities will affect nations, research institutions and researchers differently. For example, an international research grant may have a major value for the researcher in the short term through career advancement, while having longer term value to the institution and the nation through institutional capacity building, access to global markets, knowledge exchange and spillovers. Large-scale shared infrastructure, on the other hand, may have significant short term value for the nation in terms of research reputation, job creation, foreign investment, while the institution and researcher may derive significant value through access to world leading facilities, risk sharing and attracting global research talent.

When thinking about the beneficiaries of international research collaborations, it is also important to consider that collaboration creates mutual benefits that flow for each participant. When looking at the value to Australia, it is therefore important not to overlook the fact that all participants in the collaboration stand to gain from the interaction. As an example, research has sometimes been used to deliver international development aid: in this case, the one country stands to meet its international obligations, contribute to stable diplomatic relations, or access emerging markets, while the recipient country stands to increase its own research capacities with the long term aim of decreasing its dependency on development aid, to improve the living standards of its population. In this regard, increasing bilateral access to national funding schemes is an anticipated outcome of opening up of

European research programmes (Primeri et al., 2014). **Figure 3** summarises these considerations and serves as a framework throughout this report for thinking about identifying and evaluating international research collaboration.

Figure 3 Framework for thinking about the value of international research collaboration



In terms of identifying the value of international collaboration, as well as measuring and evaluating it, it is clear that different combinations of the elements in **Figure 3** will inevitably shape the evaluation – for example, identifying the values of a researcher-instigated relationship with an international university because it hosts unique research infrastructure, will be very different from identifying the values of a government policy building research capacity in regional partner countries as part of its aid delivery.

4.2 Planning to measure international collaboration

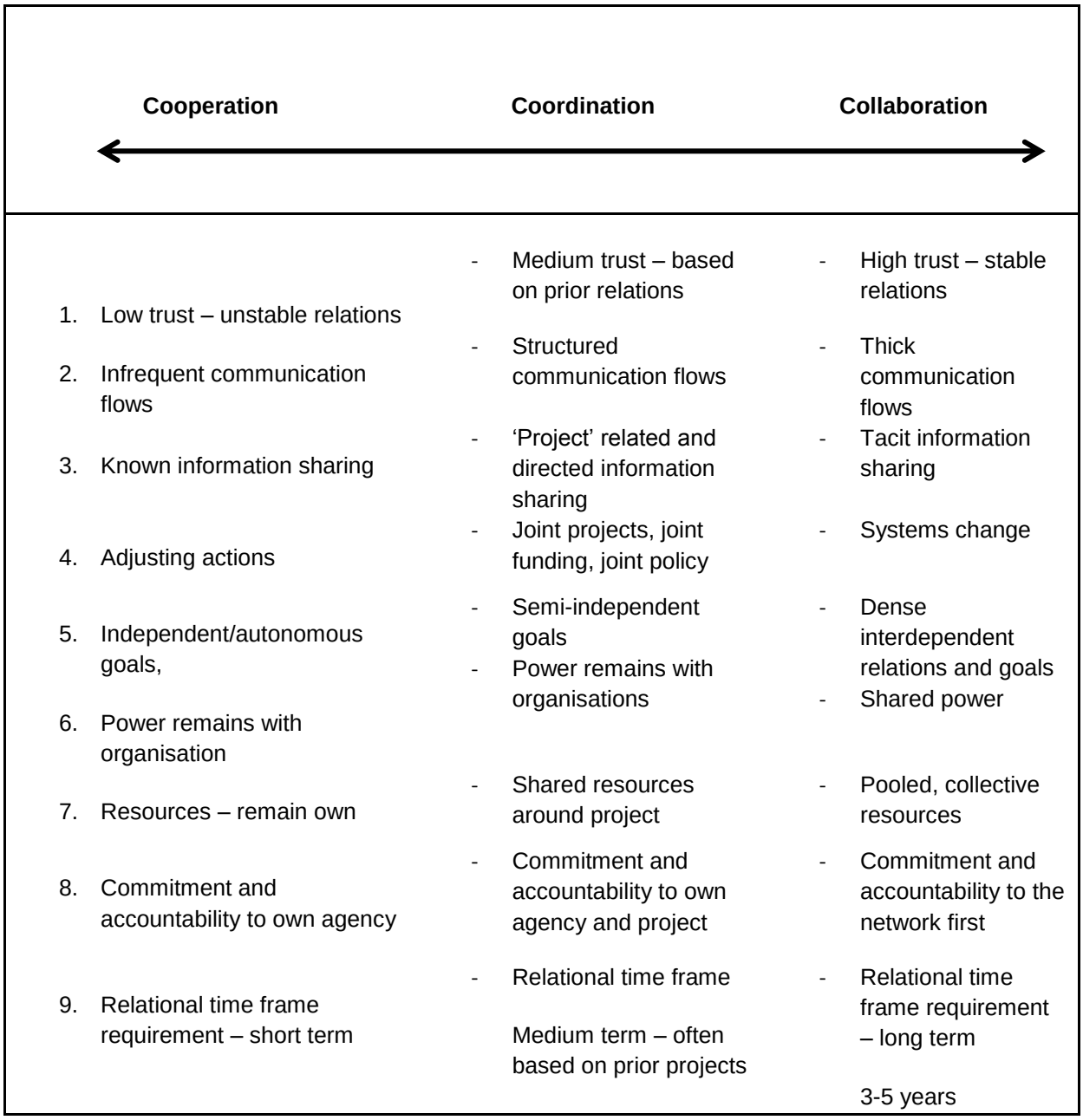
In key ways, valuing international collaboration is very different to measuring research quality and research impact. The concept of 'value' must be delinked from associated concepts such as 'research impact' in its various forms. The following example illustrates the differences: there are well-known values and benefits of a university undertaking international research collaborations – it increases the international visibility of a university which can

result in financial and reputational value; this in turn may lead to academic impacts (higher citation rates) or economic impacts (an increase in the university's standing in international research rankings leads to increases in international student numbers). In this example, the 'value' is clearly distinct from the academic and economic 'impacts', and can be found in the networks, channels and systems of collaboration, rather than in the outcomes.

Such distinctions are commonplace outside of the research sector. The value of collaborative partnerships in the social sector is well recognised. Given the risks entailed and the effort required in effective partnering, collaboration is rarely valued as an end in itself. It is rather valued for harnessing organisations and resources to achieve outcomes that could not be otherwise achieved, most notably getting to scale through 'collective impact', 'catalytic philanthropy', 'transformative scale,' and other collaborative methodologies (Roob and Bradach, 2009; Bradach and Grindle, 2014; Kaina and Kramer, 2014; Kramer, 2009). Collaboration is also valued for achieving efficiencies, improving advocacy, and winning greater brand recognition.

Given the varying aims, missions, and mechanisms driving collaboration in the social sector, advances in assessing its value generally begin by classifying the nature of collaboration involved, situating the proposed collaborative relationship on a spectrum from less to more integrated partnerships, and setting out what it is that each partner brings to the collaboration and hopes to get out of it. **Figure 4** provides a 'relationship continuum' which equates the depth of an engagement with the value that flows.

Figure 4 Relationship continuum (Keast and Mandell, 2011)



From this perspective, evaluation is an integral part of planning collaborative ventures, and involves steps such as identifying the aims and intended outcomes of collaboration, developing agreed indicators for measuring progress towards achieving pre-set goals, and introducing a feed-back loop for learning and adjustments into research design and programme implementation. Evaluation is not something that should be developed *post hoc* as is currently the case with international collaboration (and measuring

research 'excellence' and 'impact'), but is tailored to the aims and outcomes of each project as it is being designed.

Despite substantial differences governing the place of research in different sectors, applying a social sector approach to international research collaboration has benefits over existing, static and *post hoc* measurements. While measurements such as those employed by the OECD to measure BERD financed from abroad, may be well suited to describe the internationalisation of research activities (i.e. whether there are more or less of these activities over time), simply counting these is not adequate to capture the intricate network of relations, and system-wide changes that constitute international research collaboration.

Applying the lessons of social sector collaboration to international research collaboration would require activities such as:

- asking partners to set out what the international research collaboration is intended to achieve at institutional, programme, and project levels;
- classifying collaborations on a spectrum from more to less intense, and substantively from purely research (pure and applied) to commercial, educational, or other policy objectives;
- encouraging research partners to consider the nature and intensity of the partnership required to achieve their agreed objectives – on the principle of 'fit for purpose';
- setting milestones; and
- offering learning opportunities (points of review and feedback loops) to improve research design and cooperation.

4.3 Programme and policy evaluation

The social sector approach aligns closely with recent changes in Australia to the Public Governance, Performance and Accountability Act 2013 (PGPA Act). Under section 39 of the PGPA Act, Commonwealth entities will be required to implement annual performance statements from July 1 2015 to improve outcomes to:

> […] improve the quality of non-financial performance reporting by introducing a particular emphasis on planning for results. Simply put, these documents should explain what an entity wanted to achieve and

what it did achieve in a given year, and when taken together for a number of years, what was achieved over time.

At the highest level, the intention of this is to 'allow parliamentary and other users to see the links between government policy goals, expenditure, activities and their outcomes more clearly' (Department of Finance, 2010, pp4-5). It is therefore important to articulate the value of international research collaboration where it is also delivering policy objectives and programmes that are related to, but broader than, science and research policy. The Australian National Audit Office (ANAO) guidelines for performance measurement of programmes include measuring the effectiveness of policy and programmes:

- through the goods and services produced and delivered under the programme (deliverables); and
- the effectiveness of the programmes in achieving objectives in support of respective outcomes (KPIs)(ANAO, 2013, p49).

As noted in a recent Finance discussion paper, there are a range of difficulties with developing programme-level KPIs, including:

- there is often no direct link between the objectives, deliverables and KPIs of an entity
- many KPIs include vague or ambiguous terms, or wording that is open to interpretation
- entities use the term 'objectives' differently – some to describe the aim of a programme, some to outline what a programme will do, and some to explain the functions of an entity
- many KPIs link to an objective but not to a deliverable
- many KPIs appear to be an extension of a deliverable (some KPIs are more like deliverables), or the distinction between a KPI and a deliverable is not applied consistently across an entity, or while deliverables have been well structured, KPIs have not been
- many KPIs do not list timeframes for achievement
- many KPIs are not readily measurable, many do not provide quantifiable targets, and many include targets with questionable relevance

- it is generally difficult to understand or assess the past performance of KPIs (trend data) due to changes to programmes and/or changes to KPIs, coupled with the reporting period being relatively narrow (Department of Finance, 2010, p11).

In order to address these shortcomings, ANAO has advised the following guidelines for Government entities to follow)[2]:

- improve the specification of outcomes and programme objectives, noting their importance to measuring an entity's outcome
- clearly articulate the purpose, objectives, strategies and associated priorities, and performance indicators of an entity through clearer linkages between strategic plans, programme documentation and Portfolio Budget Statements
- ensure that performance information relates to the objectives of the programme and enables an assessment of the extent to which the objectives are being achieved
- develop and implement more representative sets of KPIs to measure qualitative and quantitative aspects of a programme. These improved KPIs should measure the relative effectiveness of the strategies used and the extent to which objectives are being met.

As with the social sector approach, evaluation needs to be seen as an integral part of planning, and must be done with the specific goals of the collaboration in mind. In the case of international research collaboration, this should be done with consideration of the 'broad' or 'narrow' objectives, whether the collaboration results from specific policies or researcher-led initiatives, the intensiveness of the collaboration and who the various beneficiaries are.

Given the growing trend for international research collaboration to be embedded in other settings and to deliver 'broad STI' policy objectives, in contexts where research is being mobilised for broader policy outcomes, it will be important to strike a balance between the traditional research imperatives (i.e. advancing scientific knowledge measured via traditional research indicators) with policy and programme goals which may not be realised until well into the future.

[2] **Appendix B** summarises the ANAO criteria for evaluating KPIs.

For example, in the case of research collaboration in support of development aid, it is likely that any impact on capacity-building will not be realised in the short term, and therefore is unlikely to be measurable (OECD, 2013, p8). However, this can be mitigated by linking the long term capacity building outcomes to short term programme outcomes (e.g. developing a new crop or medication) (OECD, 2013, p14). This work should include tangible short term reporting outcomes.

Planning KPIs should meet short term policy objectives, with the understanding that long term policy objectives may require long time frames to be realised, be difficult to identify when they *are* finally realised, and difficult to measure. This approach is similar to the CSIRO Impact Framework, in which 'the process of creating impact begins with deploying inputs, to conduct research activities and produce outputs, which themselves are translated through short to medium term outcomes into long term impact' CSIRO). Such approaches are distinct from the current emphasis in the research sector on *post hoc* evaluation of quality and impact.

5. Data for International Collaboration

The growing need to develop fit for purpose frameworks and measures of international research collaboration is largely driven by the diverse values and the system-wide effects that collaboration can have. Evaluation frameworks also need to take account of a broader range of data to complement the planning approach proposed in chapter 4. There are currently significant collections of data that could be usefully repurposed into an appropriate evaluation framework. This section provides an outline of these existing data. Not all of these are currently formally collected, however, they are all currently accessible (some to researchers, others to institutions and government).

5.1 STI indicators

Science and technology indicators (STI) have become a standard form of gauging a country's rate of research internationalisation. Such measures have become particularly important to economies whose base is in high-end manufacturing, and the so-called knowledge-economy. A set of common metrics are used to compare the relative rates of collaboration amongst countries. These can be split into three broad groups:

- financial indicators, which show the level of co-investment across countries into R&D;
- bibliometric indicators, which identify co-authorship across borders; and
- intellectual property indicators, which focus on activities such as co-patenting.

These can be measured at the national level, but can also be broken down into sub-sectors within the national innovation system; e.g. universities, publicly funded research organisations, government, the industrial sector etc.

Financial indicators are commonly used to measure the amount of investment into a national innovation system from international sources. There is a range of ways this can be captured across different parts of the national innovation system. In the private sector, BERD funded from abroad is a common measure of finance into domestic R&D in the private sector. Characteristically, international funding of BERD is provided by private sector sources. However, economic relationships can also be measured as outward foreign direct

investment (OFDI) – that is, how much has been invested into other countries' R&D.

For the higher education sector, additional data on international research funding is available through the HERDC and data from the national competitive grants programmes (such as from ARC and NHMRC). **Table 1** shows the international data for ARC-funded research since 2011.

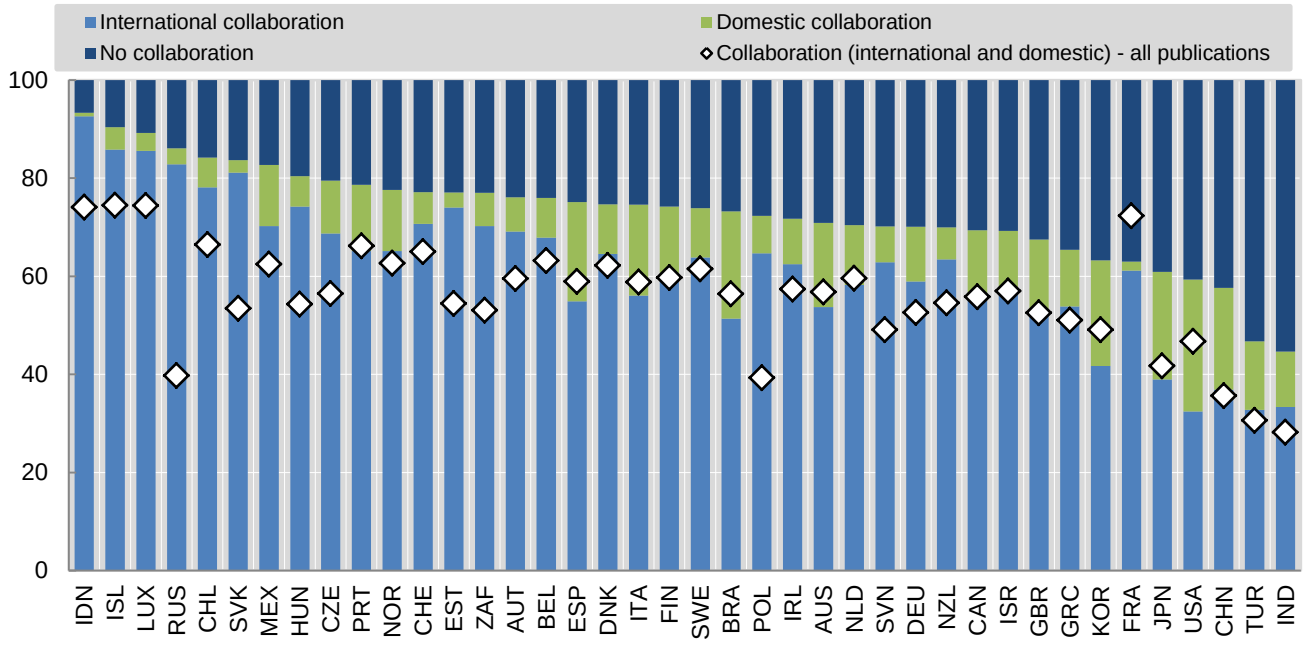
The other most common STI uses bibliometric data: the inclusion of international co-authors on scientific papers has been observed to increase citation rates. Such observations are common across the globe, where the proportion of the world's most highly cited science for most countries is comprised mainly of internationally co-authored papers. With the exception of Korea, Japan, United States, China, Turkey and India, more than 50 per cent of the top cited publications in each comparator country (**Figure 5**) represent international collaborations.

Table 1 Instances of international collaboration in ARC-funded research since 2011, by funding allocation year (ARC, 2015)

Country of intended collaboration[3]	2011	2012	2013	2014
United States of America	1752	1807	1829	1738
United Kingdom	1061	1081	1116	1075
Germany	572	596	584	554
China	376	385	398	394
France	418	423	416	366
Canada	391	390	391	360
Japan	291	280	280	254
New Zealand	220	226	239	211
Netherlands	188	200	214	202
Italy	178	172	183	168
Switzerland	164	166	172	182
Sweden	140	146	146	142
Singapore	115	117	125	129
Spain	99	117	120	125
Denmark	100	109	106	108
India	95	81	87	85
Belgium	82	70	83	82
Indonesia	67	68	70	69
Norway	64	62	71	71
Korea, Republic of (South)	67	63	61	61
Other	943	932	969	942
Total	**7383**	**7491**	**7660**	**7318**

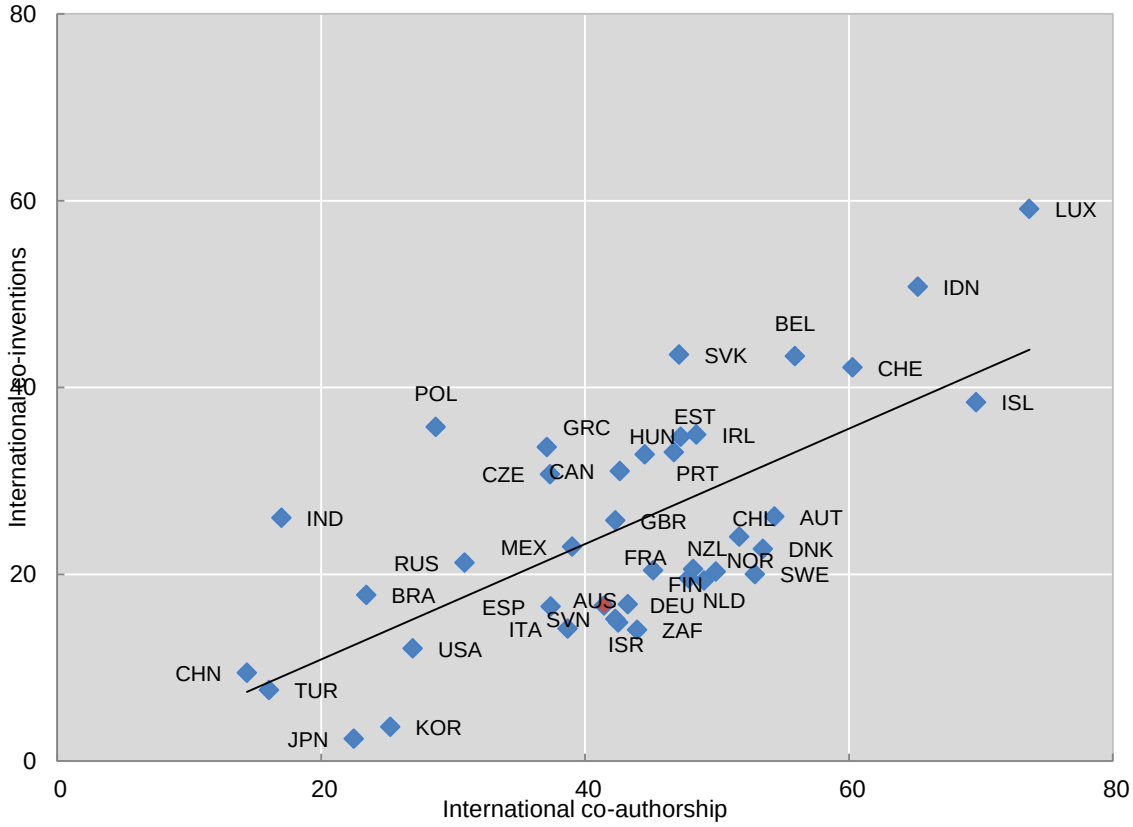
[3] The data in this table refers to instances of collaboration and represents all new and ongoing projects that have a funding allocation in a given year. Some projects involve collaboration with more than one country and therefore are represented more than once in these figures. The table does not include projects that may have been funded under the Special Research Initiatives scheme and the Linkage Learned Academies Special Projects scheme. The information shown is limited to that which was current at the time research proposals were approved for funding and accordingly excludes any post-award variations that may subsequently have been approved (ARC, 2015).

Figure 5 Top-cited publications, by type of collaboration (2003-11) as a percentage of top-cited and all documents (OECD, 2013)



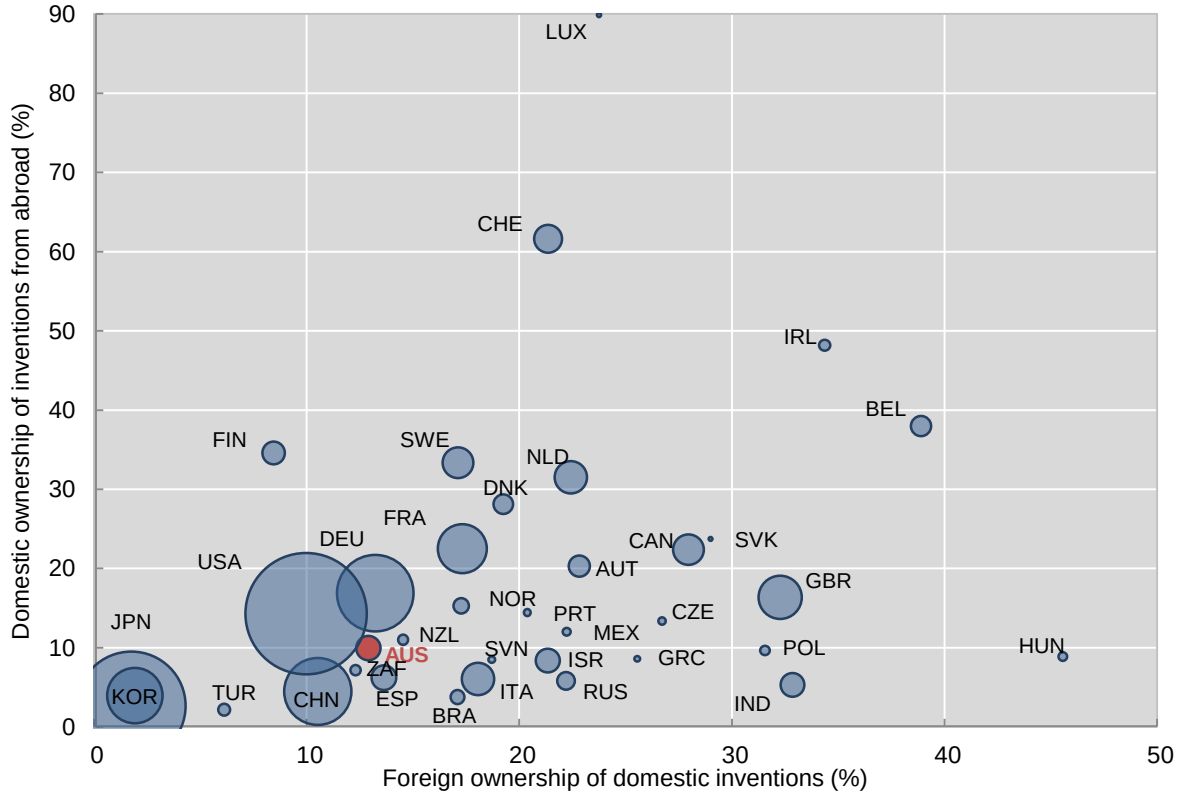
Aside from generating greater impact there are additional benefits that derive from international collaboration on science. It is common for higher rates of international co-authorship to be accompanied by higher rates of international co-invention. This positive correlation is shown in **Figure 6** where rates of international co-authorship are shown alongside international co-invention in patents. These data are commonly used as proxies to measure the internationalisation of domestic research.

Figure 6 International collaboration in science and innovation, 2007-11; co-authorship and co-invention as a percentage of scientific publications and PCT patent applications (OECD, 2013)



As with economic indicators, these can be tracked as both inward and outward flows and relationships (**Figure 7**).

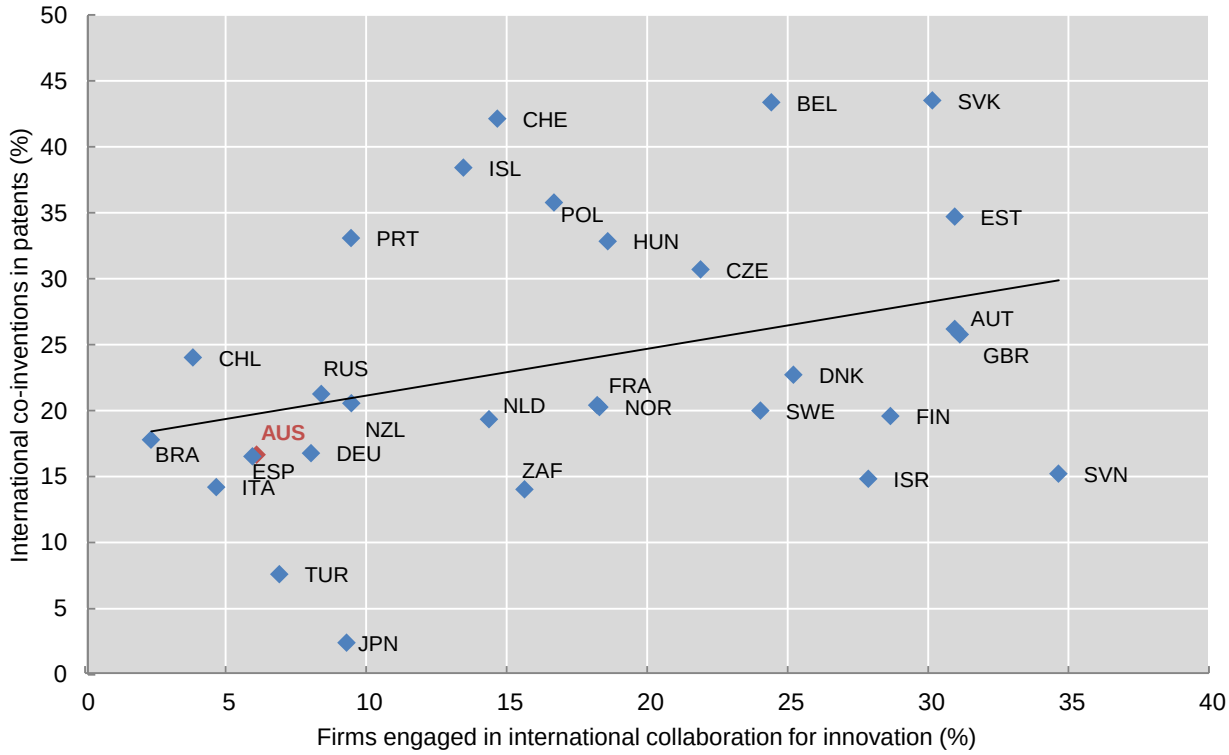
Figure 7 Cross-border ownership of patents, 2009-11, as a percentage of total patents by countries (OECD, 2013)



These figures relate to the ability of a country to appropriate the returns of knowledge produced abroad by acquiring the legal rights to intellectual property. Often this is related to the presence of multinational firms in a country (OECD, 2013, p65).

The utility of these data is the ability to then be able to combine them into more detailed levels of analysis, such as in **Figure 8**, which illustrates the relationship between firm-level international collaboration and international co-invention.

Figure 8 International collaboration on patents, 2007-11 and innovation, 2008-10; as a percentage of PCT patent applications and of product and/or process innovative firms (OECD, 2013).



5.2 Additional indicators of internationalisation and collaboration

The OECD metrics cited above are useful broad generic indicators but are limited in the scope of activity that they capture. In order to adequately measure the value of international research collaboration, additional data and additional approaches are required. A list of potential additional data is presented below. In some cases, these are already collected as part of other national data collections, for example, the National Survey of Research Commercialisation:

- Industry partners from abroad
- Industry contracts from abroad
- Community and government contracts from abroad
- International MoU/MoAs
- Researcher mobility (both into and out of the country)
- Staff participating in international projects

- International higher degree research (HDR) student enrolments
- International HDR completions
- Altmetrics from international sources
- International prizes (peer reviewed and non-peer reviewed)
- Researchers participating in major international events (e.g. exhibitions)
- Researchers presenting in international conferences

In 2014, the Higher Education Funding Council England (HEFCE) conducted its regular research assessment, the Research Excellence Framework (REF). For the first time, this exercise included a component of the assessment based on case studies of research impact. In March 2015, HEFCE, in association with Digital Science and the Policy Institute at Kings College (London), have created a publicly accessible database of the case studies submitted to REF 2014.

The case studies are an invaluable source of qualitative and quantitative data. They present a rich literature including a large number of examples of international research projects, their claimed impact as well as a series of metrics demonstrating these impacts. Seventy-five per cent of all references to geographical locations in the cases studies were to countries outside the UK (Digital Science and King's College, p41). A random sample of 200 case studies that related to BRIC countries (Brazil, Russia, India and China) identified that impacts ranged from creating spin-offs and agreements of licencing, through to informing government policy in those countries, creating online resources for public use and technology development (p66). This database represents an important resource to further investigate more nuanced 'counting' based approaches to the evaluation of international research collaboration.

5.3 Social media and 'Altmetrics'

In recent years, research evaluation methodologies have moved away from relying solely on the traditional channels of scholarly communication, and have begun to focus on 'grey' literature (scholarly work communicated through media, social media and policy reporting) and forms of social impact. So-called 'Altmetrics' have recently developed to capture the diverse 'impacts' that academic publishing through alternate channels of scholarly communication is having (Priem et al., 2010).

Academics in Australia are leading the world in terms of adoption of social media into research workflows (Nicholas and Rowlands, 2011). A recent study of the patterns of academics' use of social media found that it is being incorporated into every aspect of the research lifecycle, including:

- Identifying research opportunities
- Research collaboration
- Securing support
- Reviewing the literature
- Collecting research data
- Analysing research data
- Disseminating research findings
- Managing the research process.

Similar patterns of usage were observed across all disciplines (Nicholas and Rowlands, 2011).

The same survey identified that the single biggest benefit of using social media was to communicate internationally. As a means of scholarly communication amongst academics that use social media, it was cited as important a dissemination channel as scholarly monographs (Nicholas and Rowlands, 2011, p81). These results are impressive, given the relatively recent history of social media in the academic context.

In Australia, universities are also taking to social media as a means of communication. The University of Melbourne, for example, maintains a social media presence across Facebook, Twitter, Google+, YouTube, Pinterest, LinkedIn and Instagram. Monash University has expanded its social media presence into China, where it hosts Australia's largest account on the Chinese social media platform Sina Weibo (McMalcolm, 2014). Recent data on institutional Facebook usage showed that between March 2011 to March 2012, 24 Australian universities increased their Facebook fans by more than 100 per cent (Twig Marketing, 2012).

An important new data source in the online media landscape is *The Conversation*, an independent news outlet where content is sourced from the academic and research community. Its readership is currently over 2.5M (*The Conversation*, 2014b) readers per month, with an estimated 35 per cent from outside of Australia (*The Conversation*, 2014a). *The Conversation* has a rich set

of readership metrics that cover the range of social media usage, as well as re-posting by traditional media outlets. In addition, *The Conversation's* metrics can distinguish between readers from industry, government, universities and other sectors. This represents an extensive data source for the global reach of Australian researcher's contributions.

6. Measuring international collaboration: network analysis

As already discussed, across the OECD an expansive set of metrics are used to monitor the internationalisation of R&D. The draw of these indicators is that they can be relatively easily collected and compared in order to track the internationalisation of research, or the 'narrow STI paradigm'.

To adequately understand and evaluate the 'broader STI paradigm', however, requires a more complex approach to identify and measure the value of international research collaboration.

6.2 Knowledge networks

Increasing attention has been paid in bibliometric research to the networks that are involved in the creation and dissemination of knowledge (for specific examples in national contexts see Kwon et al., 2012; Glänzel and Schlemmer, 2007). Traditionally, the unit of measurement in scientific network analysis, which focusses on using bibliometric databases of scientific research articles, is a relationship of co-authorship across national borders. Co-authorship networks offer 'a perspective on the ranks and positions of countries which provides an alternative to ranking shares of publications and citations' (Glänzel and Schlemmer, 2007). Scientific network analysis has also been used to identify the emergence of scientific topics over time (see Kim et al., 2012), and the influence of individual scholars in a particular network of authorship (Takeda et al., 2010).

While this approach provides a useful alternate perspective to citation analysis, co-authorship only measures a limited range of the collaborations that occur in science and research discovery. The formal rules around attributing co-authors on a scientific paper mean that many important contributions are overlooked in this analysis (Laudel, 2002). The approach is further limited by lower levels of humanities, arts and social science research indexed, and its narrow focus on publishing relationships.

Social network analysis, which emerged from the social sciences, has potential as the key analytical method for understanding international research collaboration. In social network analysis, there are two units of measurement: nodes (which could refer, for example, to individual researchers or to institutions) and edges (which is any relationship that ties nodes together, such as, co-authorship of an academic article, or having studied at a particular university). Social network analysis attempts to quantify

the relationships between nodes in various ways, and has developed a range of measures to demonstrate the importance of a particular node to an overall network. **Figure 9** presents an example of a social network analysis applied to international scientific research collaborations.

Figure 9 Network analysis for selected organisations in Arctic and Antarctic research (Science-Metrix, 2014)

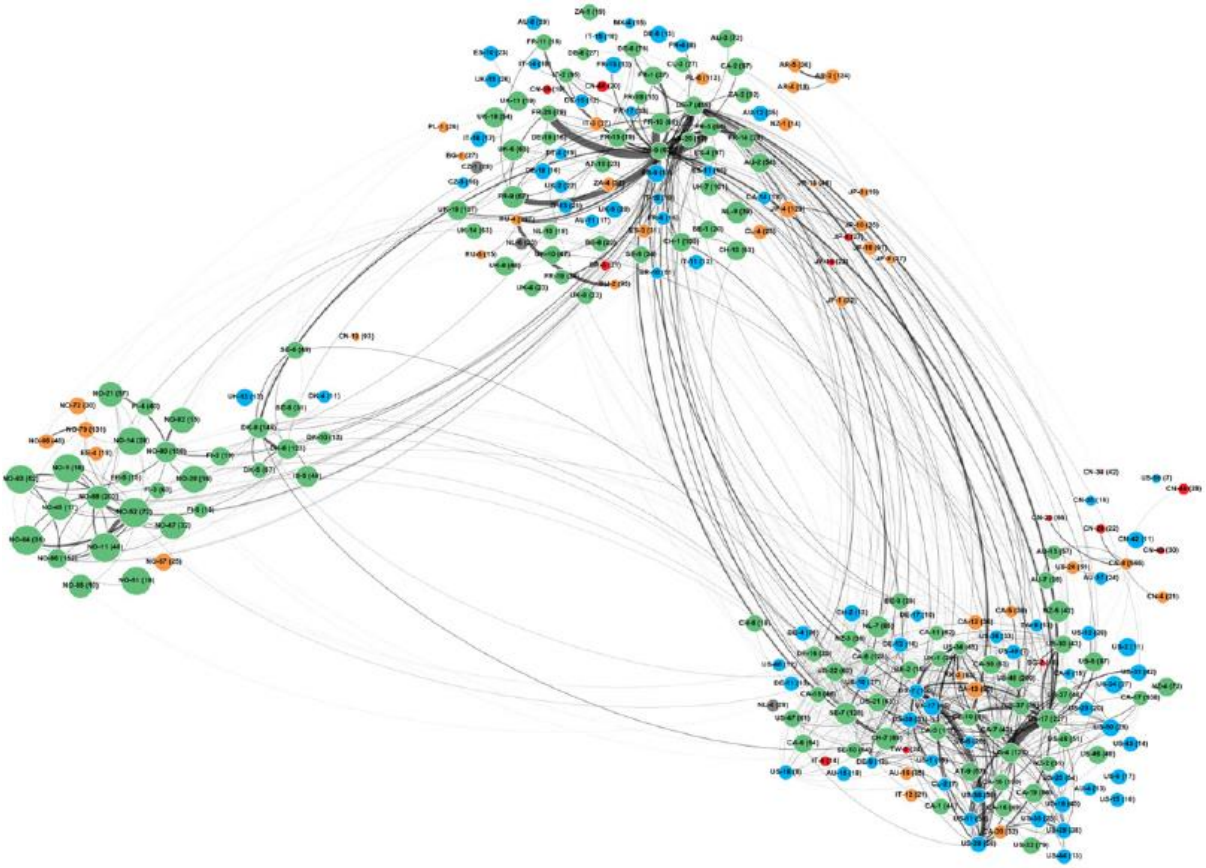


Figure 9 shows a network analysis produced for the Norwegian Research Council, showing selected organisations in Arctic and Antarctic research. The colour of the nodes represent the degree of specialisation of the organisation in the research field, the size of the nodes represent a composite measure of research impact and specialisation, and the number of publications between organisations is represented by the width of the edge between them (the thicker the edge, the greater the relationship). Based on this analysis, the authors were able to draw a number of conclusions, including: Norwegian universities should seek greater research collaborations with Canada, the US and New Zealand on Antarctic and Arctic research; Norway should seek to capitalise on its research relationship with The University of Copenhagen, given its strategic relationships with European and US research organisations in this field (Science-Metrix, 2014).

6.3 An expanded social network analysis approach

An expanded social network analysis approach has even greater potential to measure the value of international research collaboration. Such an evaluation methodology has the benefit of being capable of meeting the following criteria:

- identify and evaluate mutual exchange;
- accommodate a range of values and data pointing to those values;
- be relevant to both 'broad' and 'narrow' objectives;
- facilitate planning for KPIs from the start of a collaboration; and
- identify value at the system, institutional and researcher levels.

This needs to be undertaken with the Leiden Manifesto best practice guidelines for metrics-based research evaluation (outlined earlier) in view. Chief among these is that 'quantitative evaluation should support qualitative, expert assessment' (Hicks et al., p430).

There are a range of reasons why a social network approach is particularly suited to measuring and planning international research collaboration: first and foremost, it is able to capitalise on the range of available data, including the high social media usage by Australian academics, and universities, and to combine these with traditional STI measures and additional metrics such as MOAs etc. Network analysis would give us a way of bringing this range of data together to better understand the system. It would provide significant possibilities for measuring the extent of international collaboration, identifying the most important participants in a bilateral or multilateral network, which could assist with policy development.

In terms of programme evaluation, identifying relevant KPIs from the available data, including this in a social network analysis and using it as the basis for monitoring and evaluation, allows for sophisticated feedback loops in addition to measurement. As outlined in the CSIRO Impact Framework, feedback loops are an important feature of such evaluation systems to ensure the research is relevant, realistic and that risks are identified and mitigated throughout its lifecycle (CSIRO, 2014).

Another advantage of social network analysis is that it includes a range of measures that allow comparisons to be made between the different 'nodes' in a network. The two most common measures are 'Betweenness Centrality' and 'Eignevector Centrality'. Both measures allow the more important nodes in a network to be identified. 'Betweenness Centrality' establishes the importance (centrality) of a node (a researcher, an institution etc.) within the network of collaboration by quantifying 'the number of times a node occurs on the shortest path between any two other nodes. It was introduced as a measure of the control of a human on the communication between other humans in a social network'.

'Eigenvector Centrality' also measure the importance of a node within a network of collaborations, but 'assigns relative scores to all nodes in the network based on the concept that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes. In essence, it weights collaborative connections according to how well-connected the partner node is; Google's PageRank algorithm, which weights search results according to the frequency of their inbound and outbound links, works on the same principle' (CSIRO, 2013, pp201-202).

An example of these is presented in **Table 2**, produced by CSIRO. This example shows the top ten most important nodes (in this case research organisations) in the Australian publishing network.

Table 2 Australian collaboration network metrics (CSIRO, 2013)

INSTITUTION	EIGENVECTOR CENTRALITY	BETWEENNESS CENTRALITY
UNIVERSITY OF SYDNEY	1.00	7,364,192
UNIVERSITY OF MELBOURNE	0.98	6,595,552
UNIVERSITY OF QUEENSLAND	0.91	6,259,104
MONASH UNIVERSITY	0.86	5,081,769
UNSW	0.85	4,749,859
UNIVERSITY OF WESTERN AUSTRALIA	0.79	4,489,725
CSIRO	0.62	4,169,045
UNIVERSITY OF ADELAIDE	0.71	3,357,084
ANU	0.54	1,712,072
UNIVERSITY OF TASMANIA	0.50	1,678,112

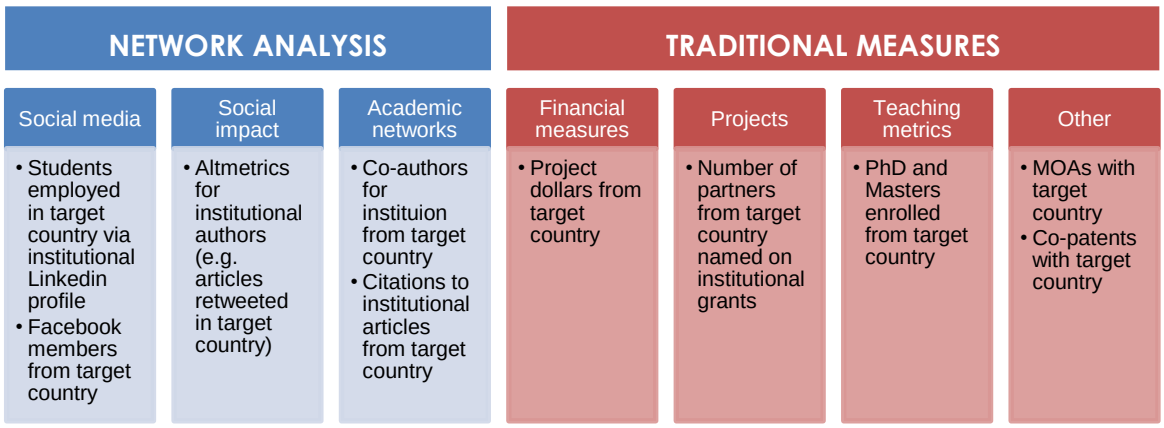
Data Source: WoS Access Database (May 2013); Articles, Reviews & Proceedings Papers, 2011-2012

This provides a guide to the relative importance of the different institutions to the collaborative research publications from Australia between 2011-2012. In this case, The University of Sydney is the most important node on both measures of centrality (Eigenvector=1.00 and Betweenness=7,364,192).

While these measures are limited to the national collaboration network in this example, and the data are limited to co-publications, this analysis can be scaled up to international collaborations, and expanded out to accommodate the full range of data identified in this report, across the 'broad' and 'narrow' paradigms.

There is no comprehensive model for this analysis developed as yet, but **Figure 10** shows a potential use case where data from different scholarly and social media sources might be usefully combined with traditional measures of research collaboration into evidence for policy development.[4]

Figure 10 Hypothetical combination of network analysis with traditional measures to identify most relevant institution to research collaboration with 'target country'



As a methodology, the ability to accommodate a vast range of data means social network analysis can be applied on a case-by-case basis. It is thus well suited to the social sector approach and the ANAO requirements where evaluation is a key component of planning for international collaboration. The data that feed into the analysis are useful KPIs in their own right, but the application of social network analysis allows that the wide extent of values can be quantified at various levels, and the complex channels that value

[4] Data from most social media services are available through Application Programming Interface (API) services and are accessible to institutions and analysts.

operates through can be mapped and understood. This creates significant opportunities for feedback loops, improved planning and reporting, which is integral to the social sector approach.

This approach also means that data are collected on an as-needs basis, and can be performed with limited resources – there is no need for a national data collection (though, obviously, many of the data discussed in this report are included in existing national data collections) as data are collected throughout the life of a project/programme, or otherwise collected to assist with developing specific policies. Additionally, there is no large scale infrastructure required to conduct this type of analysis – the main costs associated with this are the labour costs associated with a skilled analyst.

Given the complexities of how value flows through various channels and at different levels in international collaboration, the diverse forms of value that are realised, and the range of data that are required to adequately understand this, a simple metrics-driven approach is not suited to planning and evaluating policy and programmes of international research collaboration. Social network analysis provides a methodology that can map value flows across complex systems and can be customised to the needs of individual use-cases.

7. Conclusion and next steps

International research collaboration is a feature of the Australian research landscape, and key to Australia's social and economic future. At present, there is no agreed approach to measuring the values that flow from international collaboration in the research sector. Where data exist, they are currently used to measure the extent to which a national innovation system is internationalised; this is a limited approach, and takes no account of the diverse values that flow from international collaboration or the deep and complex networks that are involved.

Where the focus is on internationalisation as an end in itself, such approaches provide limited use for policy and programme development and evaluation. To adequately do this requires moving away from frameworks that focus on simple measurements of incidence, to frameworks capable of tracking the complex systems and changes that are involved in international collaboration and the broad range of values that flow – in other words, a shift from focussing on questions of 'what' happened and to 'whom', to questions of 'why' and 'how'. This requires a dynamic approach that assists in understanding the systems and networks through which international research collaboration occurs. This information can then be used to design effective policy, programmes and projects, and maximise the benefits of research investment.

As outlined in this report, international research collaboration is complex – in terms of the 'broad' and 'narrow' objectives involved, the motivating factors, the range of available data, the direct and indirect values that follow, the different levels at which value operates and the mutual benefits that are represented. The scale and scope of international research collaboration are greatly varied. While it may be prohibitive to measure the impacts of international research collaboration given the long time frames involved and significant issues around demonstrating causality, it is possible to explain and understand its values and to track the networks that they flow through. Given the variables involved, it is important that such considerations are incorporated into the planning of projects, programmes or policies. The method of an expanded network analysis proposed in this report is capable of fulfilling these requirements.

In order to fully develop the framework and methodology proposed, the following additional work is required:

1) Undertake a limited trial applying network analysis to university and PFRA data to answer questions around the accessibility of data and how much work is involved in data processing and analysis. This will establish the workflow for such analysis in the future.
2) Develop a set of standard guidelines for evaluating international research collaboration in policy, programme and project settings. This will expand on the work undertaken here, in line with ANAO guidelines for developing KPIs.

These additional pieces of work will result in fully realised examples that demonstrate the appropriateness of this approach. In addition, it will result in an accompanying set of guidelines for the effective implementation of expanded network analysis in planning for policy, programmes and projects involving international research collaboration.

In addition, the scope of this project did not allow a detailed analysis of industry research connections; and teaching and research engagement in the international collaboration sphere. Network analysis could potentially inform our understanding of this broader consideration of the research system.

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Appendix A – Summary of Values

Direct funding from abroad

Research and non-research job creation

Development of regional communities

Leveraging domestic funding to receive international funding

Encouraging trade and investment opportunities

Maximising the ability to take advantage of international spillovers and knowledge transfer

Enhancing the global reputation of Australian researchers and institutions

Inform global research rankings

Leverage reputation to access international funding

Attract and retain international research talent

Having a seat at the table on issues of global importance

Exercising 'soft power'

Creating and bolstering bilateral and multilateral diplomatic relationships

Meeting international obligations such as delivering development aid

Appendix B – Criteria for the evaluation of the appropriateness of KPIs[5]

Criteria Characteristics Explanation		
Relevant *Relevant KPIs contribute to conclusions that assist users' decision making.*	**Focused** *The KPI should address a significant aspect/s of the program objective.*	The KPI should assist significantly in informing whether the program objective is being achieved.
	Understandable *The KPI should provide sufficient information in a clear and concise manner.*	The KPI should be stated in plain English and signal the impacts of program activities to inform users.
Reliable *Reliable KPIs allow for reasonably consistent assessment of a program.*	**Measurable** *The KPI should be quantified (allowing for results to show trends when measured over time).*	The KPI should be capable of being measured to demonstrate the performance of the program.
	Free from bias *The KPI should be free from bias, and where possible, benchmarked against similar activities.*	The KPI should allow for clear interpretation of results.
Complete(3) *A set of KPIs that allow for the overall assessment of a program to inform users' decision making.*	**Balanced** *The set of KPIs should provide a balanced examination of the overall performance story, both* (4) *quantitatively and qualitatively.*	The set of KPIs should provide an overall picture of the impact of a program on the target group/s.
	Collective *The set of KPIs should be representative of the program objective.*	The set of KPIs should demonstrate the extent of achievement against the program objective.

[5] ANAO, p63.