INNOVATION METRICS
FRAMEWORK PROJECT

CONSOLIDATED REPORT

innovation.gov.au

CONTENTS

INTRODUCTION

iii

PROJECT 2: PRODUCTIVITY, INNOVATION & ECONOMIC GROWTH 135

PROJECT 3: PROGRAM-LEVEL DATA COLLECTION AND EVALUATION 191

INTRODUCTION

v

PROJECT 4: COMPLEX BUSINESS STRUCTURES AND BUSINESS FINANCIAL DATA   281

PROJECT 1
INNOVATION METRICS FOR AUSTRALIA

Anthony Arundel and Kieran O'Brien

Australian Innovation Research Centre (AIRC)
University of Tasmania
and
UNU-MERIT

EXECUTIVE SUMMARY AND RECOMMENDATIONS

For decades, innovation metrics have concentrated on 'traditional' indicators such as R&D and patents. Although useful, these indicators fail to capture the diversity and complexity of innovation processes, particularly in the majority of sectors where innovation rarely requires R&D. Innovation surveys, such as the innovation section of the Australian Business Characteristics Survey, provide the opportunity to construct innovation metrics that can substantially *deepen* our understanding of R&D and related activities and *broaden* our understanding of other types of innovative activities.

The purpose of this report is to fill some of the gaps in the available innovation metrics for Australia. Two major 'gaps' are indicators for firm level capabilities, or *how* firms innovate, and indicators for knowledge flows. A second set of gaps consist of indicators for entrepreneurship, demand for innovative goods and services, environmental innovation, the use firms make of innovation support programs, and innovation in the public sector. For each of these seven topics, this report reviews the issues, summarizes what we know about innovation measurement, and describes how relevant indicators could be constructed for Australia. The main findings are presented in summary tables of proposed indicators for Australia that include both simple indicators (based on responses to a single survey question) and composite indicators (based on responses to two or more survey questions). The tables, summarized below, identify indicators that can be constructed from existing data and indicators that would require new survey questions or data collection exercises.

TABLE A: SUMMARY OF INDICATOR TABLES		
Table	**Description**	**Page numbers**
9	How firms innovate (innovation modes)	69
11	Knowledge flows	80 – 82
12	Entrepreneurship	89
13	Innovation demand	95
14	Environmental innovation	103
15	Use of innovation support programs	109 – 110
16	Public sector innovation	114

The selected indicators in each of these tables build on research in Australia and abroad to test new innovation indicators. For innovation demand, environmental innovation and particularly for public sector innovation, there is only limited experience in developing innovation indicators. This lack of experience results in both minor and major omissions in the proposed innovation metrics.

The Australian context for innovation indicators

What types of new innovation indicators are required for Australia? The answer to this question depends on the structure of the Australian economy and innovation system.

The largest contributors to Australian GDP and exports are the resource intensive industries (agriculture and mining), low and medium-low technology manufacturing, and services. R&D investment in many of these sectors is low, but as a percentage of value-added, is near or above the average for a group of OECD comparator countries. Conversely, Australia has a very small R&D intensive high-technology sector. These structural characteristics explain why 69% of the total innovation expenditures by Australian firms do not involve R&D.

The main challenge for the Australian innovation system is to maintain and increase the innovative capabilities of Australian businesses. This requires 'absorptive capacity', or the ability of firms to assess the relevance of new technology and knowledge produced elsewhere and to efficiently use this technology and knowledge to increase productivity and the quality of goods and services. The absorptive capacity of the Australian innovation system requires R&D capabilities, a range of other methods of innovating such as investing in new technology, and an effective system for acquiring and sharing knowledge produced both within Australia and overseas. The public research sector plays a key role in building absorptive capacity, both through training engineers and researchers that work in the business sector and through linking Australia to technological developments elsewhere in the world.

Innovation metrics are therefore required that can 1) track the innovative and absorptive capabilities of the business sector, the public sector, and the public research sector, or *how* these firms and institutions innovate; and 2) track how useful knowledge *flows* among the various actors in the Australian innovation system. Furthermore, firms compete in product markets characterized by different patterns of innovation. Consequently, metrics also need to be available at a disaggregated sector level. At a minimum, innovation indicators for the business sector should be provided for six sector groups that reflect the structure of the Australian economy: natural resources, medium-high and high technology manufacturing, medium-low and low technology manufacturing, infrastructure, general services, and knowledge intensive business services. The Australian economy is also dominated by small and medium sized businesses that face a different set of problems than large firms. Innovation metrics need to be available for small firms so that their innovative capacities can be fully understood.

International comparability of survey-innovation indicators

Internationally comparable innovation metrics provide opportunities for benchmarking Australia's performance against other OECD countries. Six factors determine the international comparability of Australian innovation indicators obtained from innovation surveys: the reference period, differences in the distribution of firms by size, differences in industry structure, service sector coverage, the design of response categories, and question wording. Indicators can be constructed to adjust for four of these six factors, but there is no solution to two of them: differences in the reference period and in question wording. The most serious issue for comparability is the use of a one year reference period in the Australian Business Characteristics Survey compared to two or three years in other OECD countries. This substantially reduces international comparability for indicators of relatively infrequent activities, such as collaboration.

Capabilities or how firms innovate

Businesses innovate through a variety of methods, ranging from adopting new technologies 'off the shelf' to expensive in-house R&D projects. There are also many intermediate methods of innovating such as modifying technology or combining existing knowledge in new ways. Each method requires a different set of skills and in-house capabilities, with technology adoption requiring the lowest level of innovative capabilities and R&D the highest level. The distribution of capabilities is partly influenced by sector-specific factors, such as the ability to purchase productivity-enhancing technology on the market and technological opportunities to develop innovations in-house.

New composite indicators for *how* firms innovate can be constructed from the Australian Business Characteristics survey, using two or more survey questions. The indicators assign each firm to one of several discrete categories (or innovation modes) that describes the firm's highest level of innovative capabilities. These include input modes for in-house capabilities and output modes for the characteristics of the firm's innovations. Figure A provides an example of an output mode with five categories, using data from the Tasmanian Innovation Census. The percentage of each axis gives the share of all Tasmanian firms that are assigned to the category. For example, 12% of manufacturing firms are active on international markets and develop new to market innovations, compared to only 5% of service sector firms.

Figure A: Distribution of output modes for Tasmanian firms
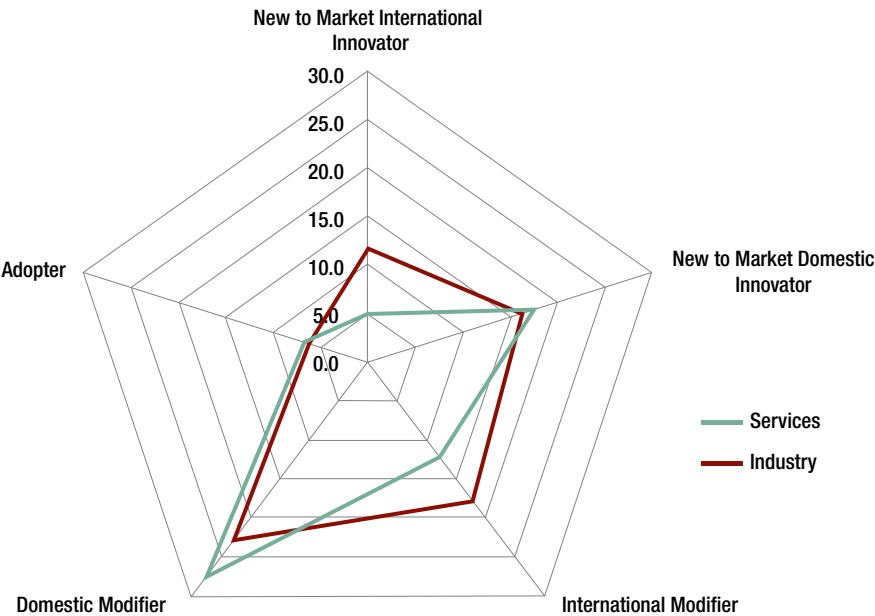
Definitions

New to market international innovator: Introduced a product innovation that is new to international markets.

New to market domestic innovator: Introduced a product innovation that is new to domestic markets.

International modifiers: Develops innovations in-house, but its innovative products or processes are already available on international markets.

Domestic modifiers: Only operates on domestic markets, products or processes only new to the firm.

Adopters: Firm has no in-house development – it acquires technology from others.

Composite indicators for innovation modes are a valuable addition to currently available indicators for R&D performance or the share of firms that innovate because they provide a deeper understanding of the pattern of innovation capabilities across sectors or firm size classes. Table 9 describes six innovation mode indicators that can be constructed from the Business Characteristics survey data, plus an additional indicator that could be constructed for user innovation.

Knowledge flows

A well-functioning system for sharing knowledge forms the 'wheels' of an innovation system. Key areas for indicator development include collaboration, knowledge flows from the public research sector to firms, and knowledge flows that connect Australian businesses and universities to knowledge produced outside of Australia. Table 11 describes 32 potential indicators for knowledge flows.

Optimally, indicators for knowledge flows should be available between specific types of actors, such as knowledge flows between the public research sector and businesses located within and outside Australia, or between public research institutions within Australia and their counterparts elsewhere in the world. In practice, this level of detail is rarely available. The most complete set of indicators can be constructed for collaboration, using the Business Characteristics survey.

Surveys of TTOs can provide indicators on knowledge flows from the public research sector to firms via patents, research contracts and consultancies, licensing, and the establishment of spin-offs. These indicators of formal methods of knowledge transfer need to be supplemented by survey measures of informal knowledge transfer from the public research sector to firms, such as when firms obtain knowledge produced by the public research sector from reading publications, attending conferences, or informal personal contacts.

Labour mobility is an important mechanism for knowledge flows. This is difficult to capture without specialized surveys, with the possible exception of data for graduate students.

Entrepreneurship

Entrepreneurial activity involves the founding and early-stage growth of new firms. New firms can be created by individuals or spun off from larger firms or from

the public research sector. Entrepreneurship involves individual attitudes to risk, opportunities that reduce risk, receptiveness to new ideas, and access to capital. Innovation research is primarily interested in the creation of firms that develop new technology, use technology in new ways (for example new business models to exploit the capabilities of the internet) or which are based on new organizational structures. There are no indicators for entrepreneurial attitudes of the population that can be limited to innovation.

Table 12 describes 10 indicators for entrepreneurship. They cover 1) churn (the sum of the number of firm births and deaths), 2) start-up formation by universities and businesses, 3) fast growing 'gazelles' (firms that are less than 5 years old and with sales growth of 20% per year), 4) the supply of capital to start-ups and young firms, and 5) management training.

Innovation demand

The two main drivers of innovation are supply side factors such as scientific research and technological opportunities and demand side factors that provide an economic incentive for investment. Both innovation research and policy instruments focus on supply side factors, partly because of a lack of good indicators for innovation demand. Demand for innovative products can be divided into domestic consumer demand, foreign demand, and government demand. In all cases it has both quality (buyer sophistication or lead markets) and quantity aspects (expenditures on innovative goods and services).

Table 13 includes 11 indicators for innovation demand, grouped into four categories: lead markets, government procurement, business sector demand and barriers to innovation due to a lack of demand.

Environmental innovation

Environmental innovation (or eco-innovation) can be defined as new or significantly improved products, processes, and business methods that avoid or reduce harmful environmental impacts or which create environmental benefits compared to alternatives. How to measure environmental innovation has attracted increasing attention, due to concerns over environmental threats from climate change and resource constraints.

Environmental innovation indicators need to manage three characteristics of eco-innovation. First, environmentally beneficial innovations can be intentionally developed to meet environmental goals or regulations, or the environmental benefits can be a side-effect of other goals such as cost reduction or product quality improvement. Indicators need to cover both intentional and unintentional environmental innovations. Second, many environmental innovations are based on adopting new process technologies and organizational or business methods. Therefore, indicators need to cover both the development of environmental innovations in-house and their acquisition from other sources. Third, environmental risks and benefits can occur at any stage in the life cycle of a good or service. Therefore, indicators need to cover the entire life cycle of a product, from the sourcing of inputs, through manufacture and distribution, to after sales use.

There is only limited experience with measuring environmental innovation. Table 14 provides examples of 12 types of environmental innovation indicators, covering several types of investment in environmental innovation, organizational eco-innovation, drivers of environmental innovation, how firms eco-innovate, different types of environmental innovation, and barriers to environmental innovation.

Use of innovation support programs by firms

A key policy interest is the effectiveness of programs to support innovation by firms. Current surveys focus on tax credits and other incentives for R&D, but innovation surveys can be used to ask managers if their firm uses other types of innovation support programs, such as innovation advice services or support for skills development, hiring researchers, or collaboration. Surveys can also include a question on impacts: if government support was 'crucial' to any of the firm's innovation projects.

Nine different types of innovation support programs were identified for Australia. Firms can be asked if they applied for or used each type of innovation support program. Table 15 provides examples of nine indicators for each of these innovation programs, an impact indicator, and three composite indicators for the use of innovation support programs.

Public sector innovation

The public sector accounts for 22% of Australian GDP and for up to 50% of GDP in other OECD countries. The economic significance of the public sector, combined with good opportunities for performance enhancing innovation, has attracted academic and policy interest in measuring innovation in this sector. Experimental surveys have been conducted in several OECD countries, but to date there is no consensus on a framework for measuring public sector innovation or if measurement guidelines for the business sector can be directly applied to the public sector.

The main challenges for developing indicators for public sector innovation include designing questions that are applicable to public organizations that vary substantially in size, the services they provide (such as government administration, health or education) and the level of government (local, state, or national); identifying who should respond, and how to produce results that are comparable across different levels of government and types of services.

Table 16 provides a list of main topics that have been explored in experimental surveys of public sector institutions: enablers of innovation, types of innovation, implementation methods, inputs, sources of ideas and knowledge, impacts and barriers. The table does not provide further details because of a lack of consensus and experience with measuring public sector innovation.

Conclusions and recommendations

The following Figure provides a graphic overview of the types of innovation metrics that are proposed in this report. The Figure adopts an actor-centric perspective of the main players in the Australian innovation system: the public research sector, government sector, business sector and their equivalents outside of Australia. The Figure highlights the importance of demand 'pull' on innovation investments, firm level innovative capabilities (how firms innovate), and knowledge flows between the different actors.

The analyses in this report lead to ten recommendations for an innovation metrics system for Australia:

1. Policy development and evaluation requires a full complement of innovation metrics that can tell the full story for how innovation occurs in the business and public sectors. Metrics should not be evaluated in isolation – a wide range of metrics need to be considered.

2. The highest priority is to develop new metrics for knowledge flows and for *how* firms innovate. These metrics are required to supplement existing metrics for collaboration and R&D.

3. Metrics are required for both domestic and international knowledge flows. They need to capture how Australian firms and public research institutes share knowledge within Australia and acquire and share knowledge with sources outside of Australia.

4. New composite indicators for how firms innovate and for knowledge flows should be constructed from the data collected by the Business Characteristics survey.

5. Minor changes or additions to the Business Characteristics survey questions could improve the supply of relevant metrics.

6. Notwithstanding points 4 and 5 above, all composite metrics and new survey questions that are proposed in this report need to be thoroughly tested to ensure that they provide reliable and useful information.

7. Wherever possible, new indicators should be provided at a high level of sector disaggregation, since the drivers, barriers, and opportunities for innovation are sector specific. Confidentiality concerns will limit the possible level of sector disaggregation.

8. Indicators should also be provided for different firm size classes, since smaller firms face different opportunities and constraints than larger firms. Employment weighted indicators should also be provided, where relevant or helpful for policy.

9. International benchmarking and comparisons of Australian innovation metrics with metrics from other countries need to be made carefully. Several Australian innovation metrics constructed from the Business Characteristics Survey, for example, are not comparable with equivalent metrics for Europe or Canada, due to fundamental differences in survey reference periods and question wording. Direct comparisons that fail to consider these differences can be highly misleading.

10. Productivity growth in advanced economies is increasingly driven by innovation in the business and government service sectors, but there are currently very few innovation indicators for the latter. The development of indicators for environmental innovation also lags behind its economic and social importance. Both are key areas for the future development of new innovation indicators for an Australian innovation metrics system.

KNOWLEDGE FLOW
INDICATORS

INTERNATIONAL
ENVIRONMENT

DEMAND INDICATORS

PUBLIC R&D
SYSTEM

KNOWLEDGE FLOW
INDICATORS

GOVERNMENT
SECTOR

DEMAND INDICATORS

DOMESTIC
BUSINESSES
AND
CONSUMERS

KNOWLEDGE FLOW
INDICATORS

DEMAND INDICATORS

BUSINESS INNOVATION–FIRM AND SECTOR
LEVEL INNOVATION CAPABILITIES

INDUSTRY SECTOR
A

INDUSTRY SECTOR
B

INDUSTRY SECTOR
C
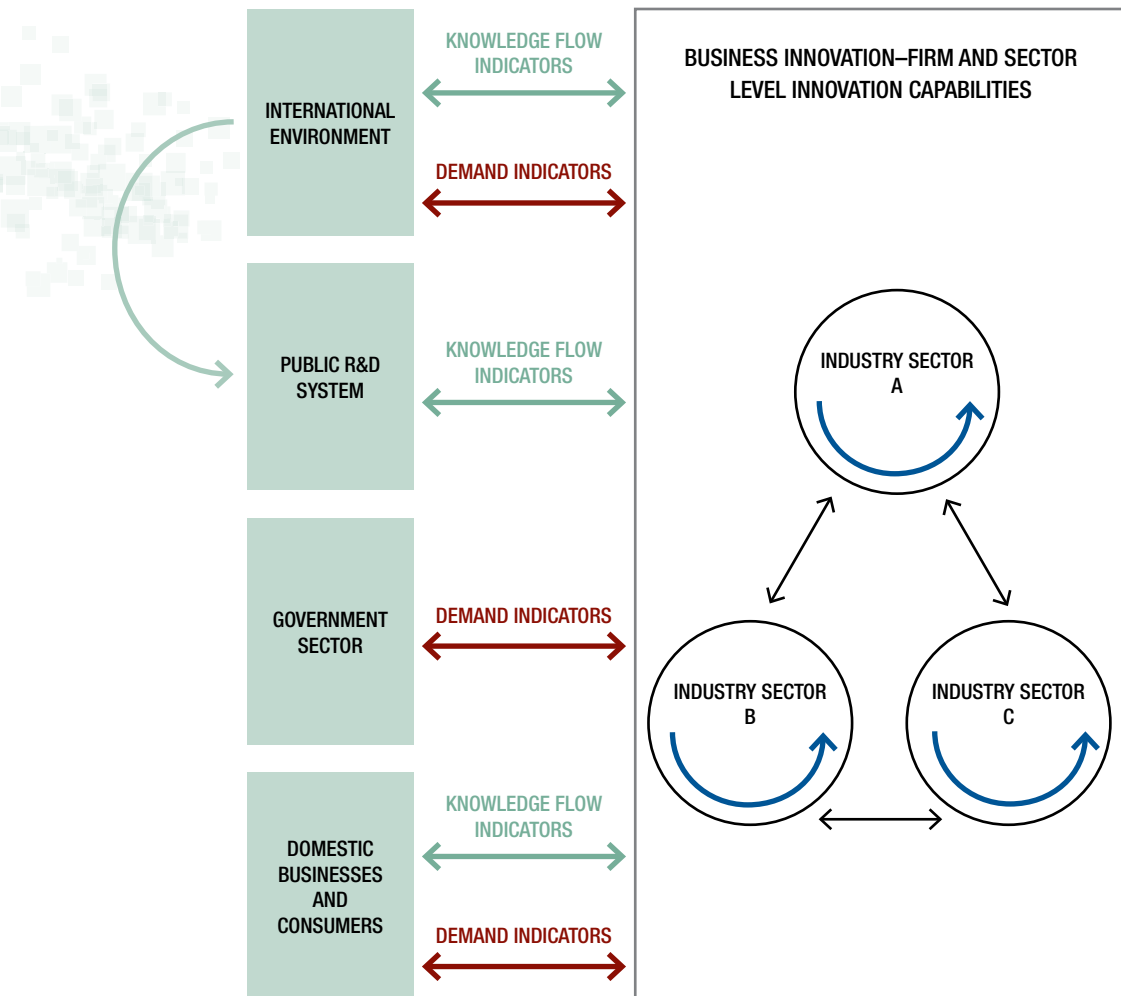
Knowledge flow indicators

International business to business, business to public research institute, international collaboration, international knowledge flows, international knowledge sourcing, absorptive capacity, domestic collaboration, KT from public research

Demand indicators

Lead markets, government procurement

Indicators - how firms innovate

Creative-inventive/modification/adoption, innovation modes, environmental indicators, entrepreneurial indicators, Absorptive capacity, domestic collaboration, domestic business to business knowledge flow indicators, business to business sector demand

1. INTRODUCTION

Innovation never occurs in isolation. All innovations depend on a body of knowledge and expertise that develops over decades and is shared, transmitted, and developed by loose networks of individuals, educational institutions, government agencies, firms, and non-profit organizations. Many of the boundaries of these institutions and networks are shaped by culture and language, the market reach of firms, and supported by taxes. This creates a national dimension to many innovation systems, although innovation systems can develop at the local, regional or international level and a national system will interact with all of these different levels. The concept of a national system of innovation has developed as a practical method for studying and improving innovation dynamics at a national level. Indicators that describe different parts of an innovation system and how they interact with one another are an essential prerequisite for an analysis of an innovation system.

The most widely used innovation indicators have been available for decades. Examples include R&D expenditure and bibliometric data, dating back to the early 1960s, patent data available for over a hundred years in many countries, and innovation survey data, available in some countries since the early 1990s. Nevertheless, the OECD's Blue Sky Forum report (OECD, 2007), the OECD's Innovation Strategy Scoping Paper (OECD, 2009), and the recent Cutler report (Cutler, 2008) on the Australian innovation system all highlight the need to develop better innovation metrics and data collection methods. This is because traditional indicators for R&D or patents are not sufficient to capture the diversity and complexity of innovation. This particularly applies to what NESTA (2007, 2008) refers to as 'hidden innovation', consisting of innovative activities that are not captured in R&D statistics.

The purpose of this report is to fill the gaps in the available innovation metrics for Australia by identifying new innovation metrics that can capture neglected aspects of the Australian innovation system. The new metrics are inspired by recent advances in innovation research. Some of the new metrics, including composite indicators, can be created from existing Australian data, particularly the Australian innovation surveys. The report also identifies where new data collection exercises might be necessary, assesses the international comparability of Australian data, and uses econometric research to help identify key innovative activities. A major goal is to provide useful data to innovation policy analysts that can be used to strengthen the Australian innovation system. This requires indicators that can provide fine-grained results where needed, such as at the sector level, and general indicators that can provide an overview of national innovative capabilities.

1.1 ADVANCES IN INNOVATION RESEARCH

Up until the 1980s, most innovation research was limited to case studies or to what is now seen as 'traditional' indicators on the creation of new knowledge, as measured by R&D investments, scientific publications, patented inventions, and the stock of scientists and engineers. The dominant perspective viewed innovation as synonymous with the use of R&D by manufacturing firms to develop technical inventions. Policy was usually based on linear science-push models in which increased support for inputs such as R&D expenditures or training of scientists and engineers led to increased outputs of publications or patents.

The re-discovery of Schumpeterian theories in the late 1970s and early 1980s led to the development of modern innovation theory, in which innovation was defined as the commercialization of a new product or the implementation of a new process. This definition created two major differences with science push models. First, both invention and commercialization were seen as essential steps in the innovation process. This introduced demand as a key factor. Second, as innovation is defined by commercialization, firms can innovate with limited or even no creative effort on their part, as when a firm purchases new production technology. This highlighted the need for data on the diffusion and adoption of new products or productivity enhancing processes.

Early experiments with innovation surveys in the United States, Italy and Scandinavia showed that innovation was measurable, along with a range of supporting activities. Best practice was summarized in the OECD's first Oslo Manual of 1992, which provided guidelines for how to measure technological innovation in the manufacturing sector. The second and third Oslo Manuals (OECD, 1997, 2005) extended innovation measurement to the services sector and to non-technological innovation, respectively. The third Oslo Manual currently provides the theoretical basis for innovation surveys within OECD countries.

The availability of innovation survey data has helped researchers to study the relationship between R&D inputs and sales of innovative products by manufacturing firms, in addition to the traditional research model based on R&D inputs and patent outputs. Innovation surveys also provide a wealth of useful data on ancillary activities such as cooperation and knowledge sources. This permitted a substantial *deepening* of our understanding of R&D and related activities. Yet fully exploiting the potential of innovation surveys also requires a *broadening* of our understanding of innovative activities. Research is required on innovative activities that do not require R&D and by firms outside of the manufacturing sector.

Several recent overviews of innovation research have emphasized the need to broaden our understanding of innovation. Veugelers (2007) comments that we need to develop indicators that go beyond knowledge creation and provide a balanced approach that covers not only creative capacity, but also diffusion capacity and absorptive capacity. Colecchia (2007) notes that there are two main targets for innovation research: invention based activity and diffusion based innovation.

A broader approach to innovation has developed slowly. Research using the first CIS verified the importance of diffusion and incremental innovation that did not require R&D. This research also noted that innovation was widespread, rather than concentrated among a small number of R&D performing firms in 'high technology' sectors (Smith, 2002; 2005), and that aggregate innovation expenditures in 'low technology' sectors were similar to those in high technology sectors. The difference was that the former spent a higher share of their innovation 'budget' on technology acquisition while the latter spent a higher share on R&D (Evangelista et al, 1997).

Much of the leading edge research in innovation today concerns the broadening of our understanding of innovation and the implications for economic growth, productivity and competitiveness. Some of the results of this research are as follows:

- Innovation is based on what Smith (2002) terms 'distributed knowledge bases', with learning and knowledge distributed across all economic sectors. Firms need to be able to draw on these widely dispersed information sources, although they can often use intermediaries such as suppliers or consultants for this purpose.

- A significant share of innovative activity does not involve R&D. This is true for both creative and inventive innovation and of innovation through the diffusion of new technology. R&D indicators fail to capture all investments in invention and the different methods that are used by firms for creative innovation (NESTA, 2007).

- A competitive high technology manufacturing sector is insufficient. In most OECD countries, this sector accounts for only a small percentage of GDP and this percentage has declined over the past decade (see Table 2). Economic prosperity depends on the innovative capacity of other sectors, particularly services.

Of note, none of the above results are due to new developments in the innovative strategies of firms. Most of the contents of the current 'tool kit' of innovative strategies are not new. Firms have been collaborating, forming networks, drawing on external knowledge sources, obtaining innovative ideas from clients, joining global value chains and participating in many other innovative activities for decades. It is possible that only a few entirely new strategies, driven by technological developments or emerging markets, have emerged over the past fifty years. For example, the internet has made it possible for groups of independent inventors to work on a common problem, such as open source software. Emerging markets can also change the emphasis that firms place on specific types of innovation strategies.

The danger in positing that a long-standing activity is new is that it diverts attention from a broad or systemic approach to innovation to the latest academic fad. This can be a hazard to both policy and the development of metrics. Indicators need to be robust, cover all of the main factors, and retain their relevance over time.

Although innovation policy continues to focus on R&D and supporting activities, the policy community has long recognized that innovation is more than invention (Arundel, 2007). Yet for several understandable reasons, innovation policy analysts have struggled to adequately incorporate a broader view of innovation. One reason is that there are fewer policy levers for innovative activities that are not based on R&D. This reduces policy interest in other forms of innovating, even though the latter could have a substantial influence on the innovative capabilities of a sector, region or nation. A second factor is that academic research on innovation is still dominated by an R&D mindset, so that the characteristics and drivers of non-R&D based innovation continues to be neglected. A third problem, which is most relevant to this study, has been a lack of good indicators to describe the full range of innovative activities in modern economies. Better indicators on these activities would complement our understanding of R&D, increase awareness of the prevalence of innovative activities that are not based on R&D, and permit research on their effects on economic performance.

2.   THE AUSTRALIAN CONTEXT

What are the key characteristics of the Australian Innovation System and what new indicators are required to guide policy development and analysis?

Australia has a proven capacity for economic development driven by creative innovation (WEF, 2009). Australia performs reasonably well in several international comparisons that focus on innovation inputs such as R&D intensity, tertiary education levels, and the number of scientists and engineers, research institutions, patents, scientific publications and internationally authored papers per capita. In five such exercises, Australia averages in 5th place, behind the United States, Finland, Sweden and Canada (Archibugi and Coco, 2005). These results attest to the high quality of the scientific and technological capacity of Australia, defined as 'the ability of a country to absorb and retain specialized knowledge and to exploit it to conduct research, meet needs and develop efficient products and processes'.

Yet many of the strengths of the Australian innovation system are based on the rapid adoption of inventions that were developed outside of Australia, rather than the development of Australian inventions that are then marketed abroad. This feature of the Australian innovation system has been in place since the 19th century (Barlow, 2006), reflecting the competitive advantages of Australia in natural resources and the problems created by both its distance from foreign markets and the relatively small size of its domestic market. The declining cost of telecommunications has reduced the significance of both distance and a small domestic market, creating new opportunities for inventive innovation based on 'new to world' products and processes, but Australia will always need to acquire and build on new technology developed abroad, for the simple fact that the Australia produces only 2% to 3% of global knowledge, based on Australia's share of patents and publications. Australia needs to maintain and further develop both a capacity to develop new to world innovations and a capacity to rapidly acquire useful knowledge and technology developed elsewhere (Commonwealth of Australia, 2009).

Understanding, tracking, and enhancing the Australian innovation system requires more than input indicators for R&D or new PhDs in science and engineering. Instead, as noted in the Cutler report, Australia needs indicators for absorptive capacity, 'linkages, relationships and information flows', and specific innovation strategies. The indicators should also be useful for research on the role of specific innovative strategies in improving productivity and attaining environmental goals.

In addition to the recent Cutler report, several other studies have reviewed the structure and performance of the Australian innovation system (Scott-Kemmis 2004, Roos 2005). A similarly comprehensive review is outside of the scope of this report and not attempted here, though we draw on the findings of previous work. The objective is to provide a broad analysis of the Australian Innovation System and to identify the key characteristics that inform the review and selection of appropriate metrics.

We begin by considering key elements of the Australian economic structure over time, comparing Australia's economy, innovation system and technological trajectory to a sample of comparable countries of similar size and industrial structure, plus the United States. We then draw on the results of previous reviews of the Australian innovation system, before drawing some of the implications for innovation metrics.

2.1   THE STRUCTURE OF THE AUSTRALIAN ECONOMY

Over the past thirty years Australia has experienced rapid growth, increasing levels of productivity, and ranked consistently above the OECD average for GDP per capita. Over the same time period, there have been three major changes in the Australian economic structure.

Economic structure

Two of these changes concern the distribution of value-added in the economy. First, as shown in Figure 1, the share of manufacturing in the Australian economy fell by 7.2 percentage points from 17.9% of GDP in 1978 to 11.7% in 2001 and 10.7% in 2008. The share for 2001 is the lowest within the group of comparator countries, with the exception of Norway (see Table 1). Australia also has an above average contribution of mining and agriculture to GDP.

Figure 1:   Australian Gross Value Added (GVA) by industry, 1978-2008

Legend:
- Agriculture, forestry and fishing
- Mining
- Manufacturing
- Transport and storage; electricity, gas and water supply
- Construction
- Retail and wholesale trade, accommodation and hotels
- Knowledge intensive business services
- Government services, defence, health and education
- Cultural, recreational, personal, and other services
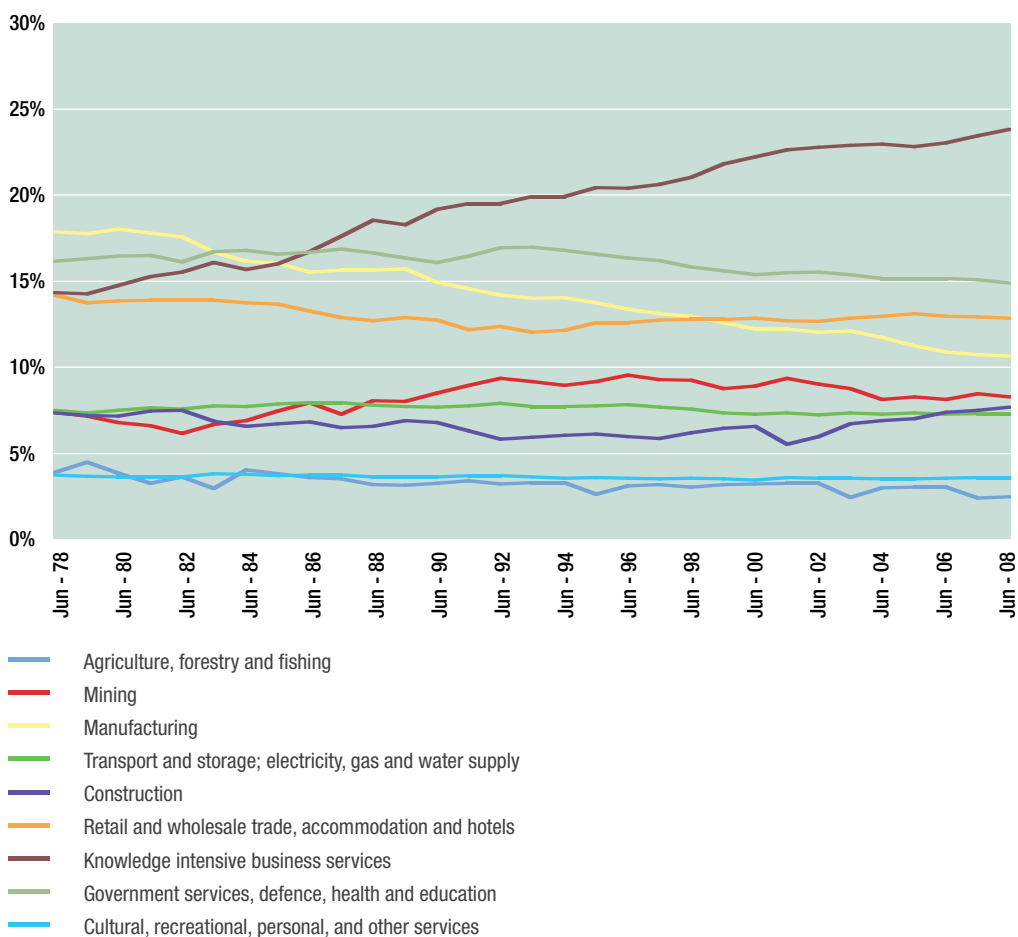
Source: ABS 5204.0, 2007-2008. Table 5. GVA by industry.

The second major change in national GDP has been the increase in the share of Knowledge Intensive Business Services (KIBS), which grew by 9.4 percentage points from 14.4% of GDP in 1978 to 23.8% in 2008. The share of the service sectors now accounts for 70.2% of GDP[1].

Australian manufacturing continues to be dominated by low and medium-low technology activities, with food, beverages and tobacco, wood and paper, petroleum, coal and chemicals, non metallic minerals and metal products accounting for 71% of total manufacturing GVA in 2008, and an average of 62% over the last twenty years. Over this time, the largest decline in relative share within manufacturing has been in textile, clothing and footwear.

TABLE 1: SECTOR CONTRIBUTIONS TO GROSS VALUE ADDED, SELECTED COUNTRIES-2001

Industry	Contribution to Gross Value Added (%)						
	Australia	Canada	Denmark	Netherlands	New Zealand	Norway	United States
Agriculture, Hunting, Forestry And Fishing	3.8	2.2	2.9	2.7	9.2	1.8	1.0
Mining and Quarrying	5.3	5.7	2.6	3.0	1.2	22.6	1.2
Total Manufacturing	11.7	18.3	15.7	15.3	16.1	10.8	14.4
Electricity, Gas and Water Supply	2.5	2.9	2.1	1.5	2.5	2.2	2.0
Construction	6.2	5.3	5.0	5.9	4.4	4.1	4.6
Wholesale and Retail Trade; Restaurants and Hotels	13.5	13.6	13.6	14.8	15.4	10.3	15.4
Transport and Storage and Communication	8.2	7.0	8.0	7.2	7.1	9.1	6.3
Finance, Insurance, Real Estate and Business Services	28.8	25.4	24.1	26.6	26.8	18.1	32.0
Community Social and Personal Services	20.1	19.6	26.1	23.0	17.3	20.9	23.0

Source: OECD STAN Database for industrial analysis 2005.

1   KIBS includes Communication services, finance and insurance, and property and business services - ANZSIC 93 Divisions J, K, L. Service sectors includes all industries apart from agriculture, mining and manufacturing.

Australia has developed a high-technology manufacturing sector, with rapid growth in pharmaceuticals and precision instruments. However, all high technology sectors combined account for less than 1% of GVA and for 0.7% of GVA for 2005 (the most recent year for which data are available). Yet countries with similar size and resource structures have maintained and developed larger high-tech manufacturing sectors than Australia, as shown in Table 2.

TABLE 2: HIGH-TECH MANUFACTURING AS A SHARE OF TOTAL GROSS VALUE ADDED, 1978-2005						
	1978	1988	1998	2001	2003	2005
Denmark	1.2%	1.6%	2.1%	2.6%	2.4%	2.2%
Australia	0.7%	0.7%	0.9%	0.8%	0.8%	0.7%
Netherlands	1.8%	1.4%	1.3%	1.3%	1.0%	0.9%
Canada	1.2%	1.6%	1.7%	1.5%	NA	NA
United States	5.0%	5.1%	4.7%	4.4%	3.9%	3.8%

High technology manufacturing includes pharmaceuticals (ISIC 24.4), computer and office equipment (ISIC 30), Radio, TV and telecommunications equipment (ISIC 32), scientific instruments (ISIC 33), and aerospace (ISIC 35.3).

Source: Calculations by the authors using the EUKLEMS database, except for Canada which uses the OECD STAN Database for industrial analysis.

Canada, which resembles Australia in terms of its resource base, economic structure, and high immigration rate, managed to increase its share of high technology manufacturing since 1978, in part due to a concerted government effort to reduce dependence on resources by supporting the aerospace, ICT, and telecom equipment sectors. Yet Australia's per capita income in purchasing power parities (PPP) grew from 88% of Canada's in 1990 to parity in 2004[2]. This suggests that a concerted strategy to develop a high technology sector does not, by itself, always result in an improvement in this key indicator of economic performance. Table 2 also shows that the share of high-technology manufacturing sectors in GVA has declined in all countries. For example, the share of high technology manufacturing declined in the United States from 5.1% of GVA in 1988 to 3.8% in 2005 and from a peak of 1.8% in the Netherlands in 1978 to 0.9% in 2005.

2   Based on data in the EUKLEMS database.

Exports

The third major change to the Australian economy has been a shift in merchandise exports from unprocessed or lightly processed agricultural commodities (mostly food, live animals, textile fibres and their wastes) to mineral resources, largely coal and iron ore. Figure 2 shows that the share of agricultural exports fell from 32.6% of total exports in 1990 to 13.3% in 2009, while the share of mineral exports increased from 29.7% to 50.2%. The share of all manufactured exports decreased from 19.4% to 15%. Low technology export goods have accounted for the majority of total merchandise exports over the last twenty years.

Figure 2:   Merchandise exports, 3 year moving average, 1990-2009

- Beverages and tobacco
- Machinery and transport equipment
- Unprocessed/lightly processed agricultural products
- Mining products
- Other manufactured goods
- Commodities and transactions not classified elsewhere in the SITC
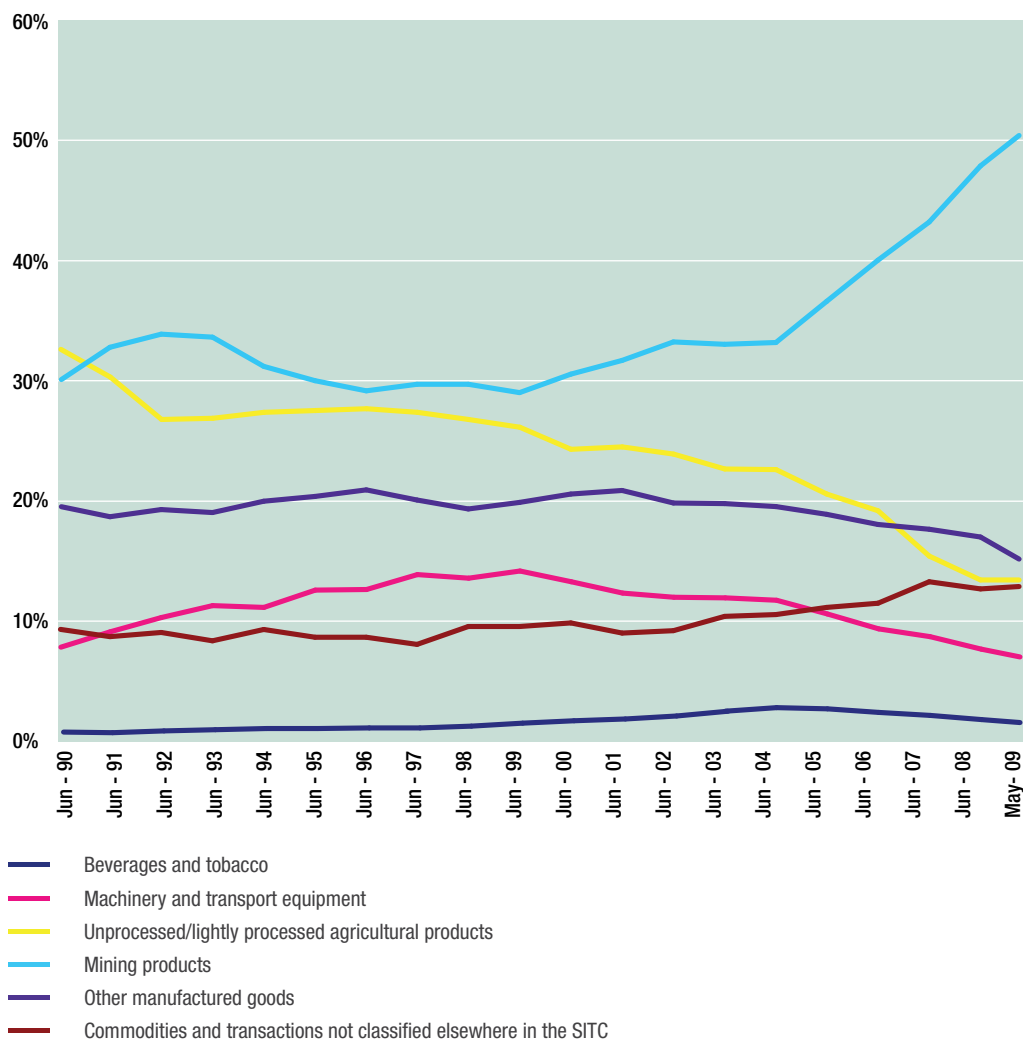
Source: ABS 5368.0 Mar-2009, Table 12a. Merchandise exports. Categories constructed from SITC 2 digit categories. Note that the data for the final period ends in May 09.

Exports of services have been steadily increasing in volume over the past twenty years. The top three contributors to current service exports are travel services (55.2%) transportation services (17.4%) and other business services (14.4%)[3].

Australia is a net importer of medium and high technology goods and has run a trade deficit over most of the past twenty years. However, the distribution of imports between capital goods for investment, intermediate goods, and consumption goods has remained relatively stable since 1990, as shown in Figure 3, implying that Australia has avoided dissipating the advantages of the past decade from favourable terms of trade on consumption goods only. In 2009, 23.6% of merchandise imports were capital goods, 21.3% intermediate goods and 23.4% consumption goods.

Figure 3:   Imports by broad economic category, 3 year moving average, 1990-2009
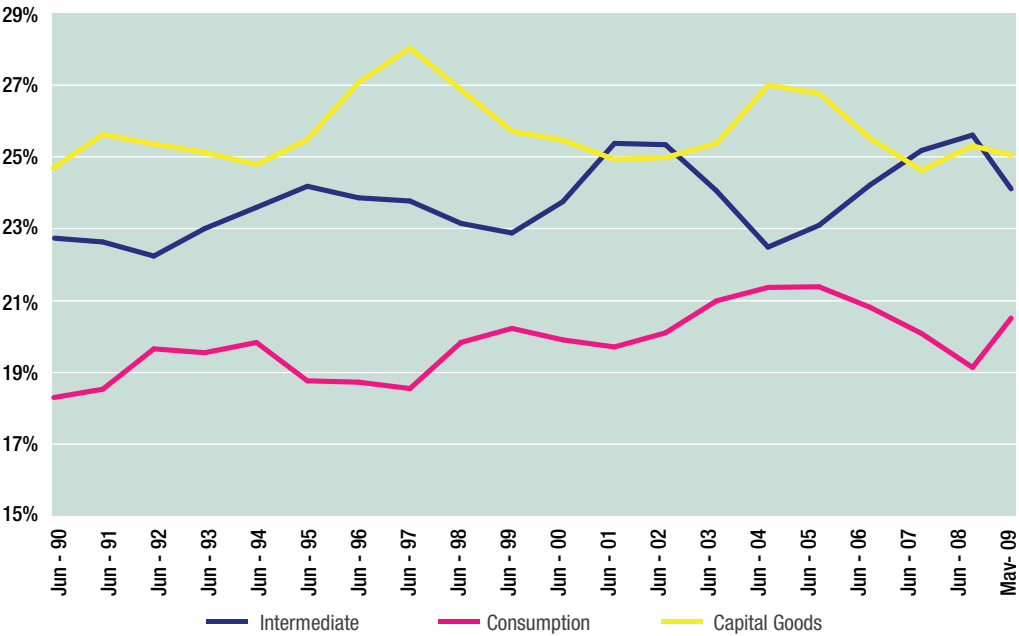
Source ABS 5368.0 Mar-2009, Table 33. Merchandise imports, broad economic category. Note that data for the final period ends in May 09.

Trade plays a smaller role in Australian GDP than in many other small and medium sized open economies such as Canada, Denmark, the Netherlands, New Zealand and Norway. Only the US has a lower share of trade intensity, as shown in Table 3. The low trade share partially protects the Australian economy from foreign competition and economic turmoil.

3   Based on ABS 5368.0.55.004 2008, Table 9. International Trade in Services, Calendar Year by Detailed Service.

Compared to other OECD countries, Australia has an above average share of small firms. Out of 26 OECD countries with available data, Australia ranks second in the total share of value-added produced by firms with 1 to 9 employees, and seventh in the total share of value-added produced by firms with less than 250 employees (ranking higher than Denmark and the Netherlands though slightly lower than Norway). In 2005, firms with less than 50 employees accounted for just under 50% of GVA, while firms with more than 250 employees accounted for just under 40% (OECD, 2008). The population of firms has experienced consistent net growth in recent years, with an average yearly increase in the number of new firms of 35,700 from 2003-4 to 2006-7. Most of this growth is due to an increase in the number of small firms, with the share of micro-businesses (firms with 0-4 employees) growing by around 5 percentage points, accounting for 84.5% of all firms in 2007[4].

TABLE 3: EXPORTS AND IMPORTS AS A SHARE OF GDP, 2001

Country	Exports Share of GVA	Imports Share of GVA
Australia	15.1%	17.7%
Canada	36.6%	32.4%
Denmark	33.8%	30.4%
Netherlands	47.6%	46.2%
New Zealand	25.5%	26.6%
Norway	38.4%	21.2%
United States of America	6.9%	11.1%

Source: OECD STAN Database for industrial analysis 2005.

Labour force characteristics

Key changes in the structure of Australian employment over the past twenty years have mirrored the industrial structure, with a decline in the manufacturing share of total employment by 5.5 percentage points and an increase in the services sector share of total employment by 3.4 percentage points, with employment gains in knowledge intensive business services, retail, wholesale trade and accommodation, and government and other services[5].

4   Source: Dr Michael Shaper ACCC, calculated using ABS 8165.0. (2000, 2002, 2007). Figures for shares by firm size exclude agricultural enterprises.
5   Based on ABS 6291.0.55.003 Labour force Australia, Detailed, Quarterly Feb, 2009.

The share of skilled employees in the workforce is increasing, particularly in service sectors. The share of persons with a bachelor degree in service sectors increased by an average of 13.1 percentage points between 2001 and 2006, and 9.6 percentage points in non-service sectors over this period. Over the same time, the share of employees with a postgraduate degree increased by an average of 3.3 percentage points in service sectors and 2.1 percentage points in non-service sectors[6].

Services sectors have been key contributors to the growth in Australia's productivity from the 1990's, with wholesale trade, communications and finance sectors the top contributors to increasing productivity. Adoption of new technologies has been an important factor influencing service sector productivity improvements (Davis and Rahman, 2006; PMSEIC, 2008) as well as productivity improvements in the wider economy (Scott-Kemmis, 2004).

2.2   KEY CHARACTERISTICS OF THE AUSTRALIAN INNOVATION SYSTEM

Early attempts to map Australia's innovation system and science and innovation capacity have predominantly featured traditional innovation indicators including R&D, patent and bibliometric data, influenced by a science-push policy focus of the time (Marsh and Edwards, 2009) as well as lack of available innovation data and analyses.

The 2002 and 2004 Australian innovation scorecards compared indicators for Australia against other OECD countries and identified relative strengths in the areas of government and higher education funding for R&D, a strong education system reflected in high education levels in the workforce, high proportions of foreign affiliates in manufacturing R&D, high take up of ICT and sustained and high multi-factor productivity growth. The main weaknesses were low levels of business expenditures on R&D and international collaboration in science and engineering (Backing Australia's Ability, 2004-2005).

The Australian innovation system shows a specialisation in traditional low technology resource intensive industries (agriculture and mining), as shown by the strength of Australian science in related disciplines. These strengths are probably responsible for high productivity levels in the resource sectors. Another characteristic of Australia's innovation system is internal fragmentation (influenced largely by geography and a geographically dispersed population), and the importance of non-R&D based innovation inputs including design.

An important strength of the Australian innovation system is its success in adapting knowledge and technology from outside Australia to the requirements of the Australian economy (Scott-Kemmis, 2004). The success of Australia's resource based industries and exports are an example. These sectors are often seen as a systemic weakness, but firms and other organizations active in these sectors have been able to draw on complex distributed knowledge bases and import, upgrade, and apply technology and R&D to industry specific problems. These capabilities have provided sustained innovation and growth (Smith and West 2007; Smith 2008).

6   Based on ABS 2068.0 Level of education by industry of employment Census tables 2001, 2006.

Tressel (2008) identifies the importance of the diffusion of ICT, increasing skill levels, and R&D on the growth in multi-factor productivity (MFP) in Australia between 1980 and 2003. Over these years, MFP growth in Australia increased by 1.5% per year between 1980 and 2003, compared to the OECD average of 1.3% per annum. Skill levels had a larger estimated effect on MFP than R&D. Doubling R&D would increase MFP growth by 0.04 percent per year, while increasing the number of high-skilled workers in the labour force by 13% would increase MFP by 0.5 percent per year. The main benefits of R&D were indirect: it improved the ability of Australian firms to successfully adopt foreign technology.

The perceived weaknesses of the Australian innovation system include poor linkages between firms and the science and technology infrastructure (universities, research institutes) (Cutler, 2008; Roos, 2005), low levels of early stage venture capital[7], and insufficient entrepreneurial and management expertise (Commonwealth of Australia, 2009). Despite consistently large numbers of new and innovative businesses entering the market, Smith and West (2005) argue that a shortage of high level entrepreneurial capabilities – those required to grow a business beyond a specific critical mass and develop and capture value from developing global markets - present an ongoing problem for Australia. An example of this is the Australian wine industry, where intensive innovation resulted in rapid growth over the last twenty years. However, a lack of global marketing and distribution capabilities led to a series of mergers and acquisitions and to majority ownership of the industry by foreign multinational companies (Smith and Marsh, 2007).

The OECD STI Outlook for 2008 (OECD, 2008) provides a comparison of 13 innovation indicators for Australia with the OECD average (see Figure 4). Ten of the 13 are traditional indicators, while three are drawn from innovation surveys (percent of firms collaborating, percent non-technological innovators, percent with new-to-market product innovations). Australia performs notably better than the OECD average for scientific publications, co-patenting, venture capital, and science and technology occupations.

7   Although Australia ranks relatively well on some recent venture capital indicators as in Figure 9, the low level of venture capital directed to early stage funding is seen as a systemic weakness (Scott-Kemmis, 2005) and is not picked up in this indicator.

Figure 4: Australian performance on 13 innovation indicators compared to OECD average
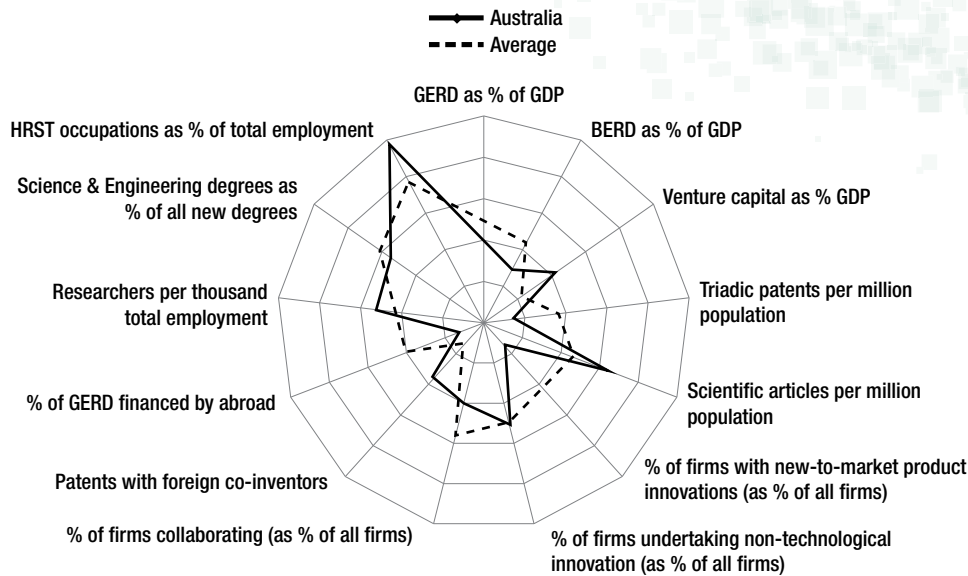
Source: OECD STI Outlook 2008

Australia is below the OECD average for triadic patents, new to market product innovations, and collaboration.

The 13 indicators in the OECD STI Outlook report are almost entirely input measures and heavily focused on R&D and related activities such as patenting and publications. Only two of the indicators measure innovation. Another R&D focused measure of Australia's innovative capabilities is from the IBM-Melbourne Institute's innovation index, which finds that Australia's overall innovation activity stalled in 2006. This is based on indicators for patents, trademarks, design, R&D, organisational/managerial innovation, and productivity.

R&D performance

Although Figure 4 shows that Australia has below average performance on R&D indicators, Figure 5 shows that R&D as a share of GDP has increased steadily over the past twenty years, mostly due to increases in business R&D (influenced by R&D tax concessions). Aggregate figures also indicate that Government expenditures on R&D have been increased in the recent 2009 Federal budget.

Recent government R&D expenditure has been directed towards research fields of relevance to traditional low technology sectors (agricultural and environmental sciences, earth sciences) and leading high technology sectors (biological and medical sciences, ICT), with an average of 38.8% of total expenditure per year going to the former and 28.8% to the latter from 2000-1 to 2006-7 (see Table 4). Given the structure of the Australian economy, the focus on supporting R&D in low technology sectors is reasonable, as well as the provision of a significant amount of R&D support for leading edge technologies. The latter can be essential to building up capabilities to assess and adopt knowledge developed abroad.

Figure 5:   R&D trends in Australia, 1981-2004
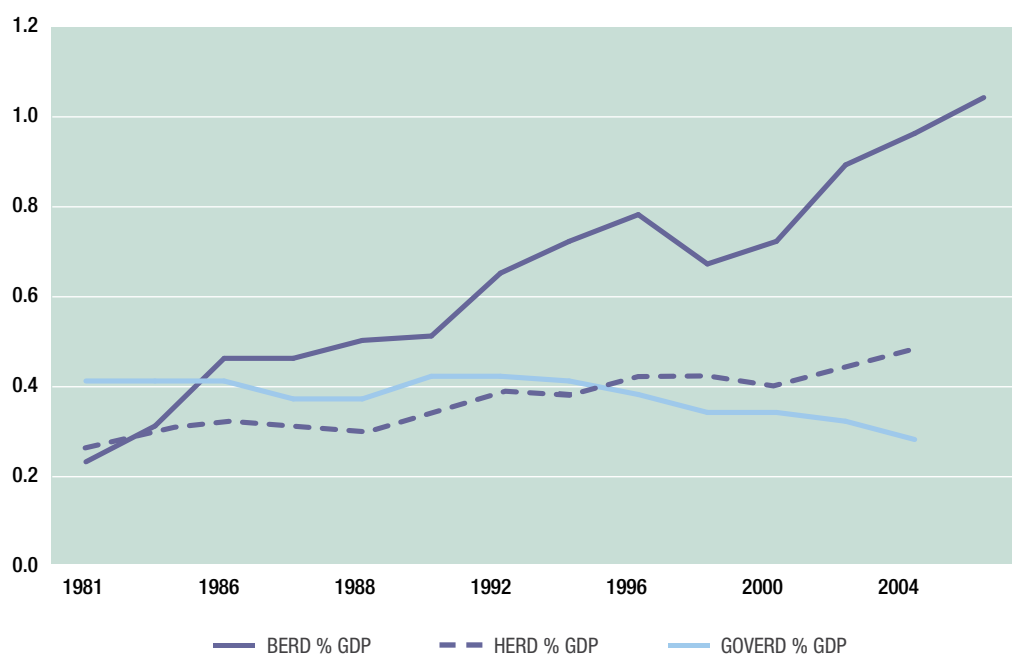
Source: OECD STI Outlook 2008

TABLE 4: GOVERNMENT EXPENDITURE ON R&D BY RESEARCH FIELD

Research field	Share of total government expenditure on R&D (%)			
	2000–01	2002–03	2004–05	2006–07
Mathematical sciences	1.13	1.45	1.53	1.44
Physical sciences	3.96	4.82	5.13	5.60
Chemical sciences	4.09	4.91	4.50	4.77
Earth sciences	9.36	9.77	7.09	6.84
Biological sciences	11.25	10.61	11.92	11.69
Information, computing & communication sciences	9.10	7.32	5.73	7.16
Engineering & technology	16.33	17.10	16.76	16.70
Agricultural, veterinary & environmental sciences	31.68	30.67	31.12	28.77
Architecture, urban environment & building	0.15	0.13	0.18	0.25
Medical & health sciences	7.84	7.99	11.57	12.85
Humanities	5.10	5.22	4.45	3.92
Total expenditure on R&D ($'000)	2,355,797	2,482,161	2,486,026	2,954,082

Source: ABS 8112.0. Gross expenditure on R&D, by sector by research field, 1992–93 to 2006–07.

International comparisons of R&D performance

Many of the traditional indicators such as R&D expenditures and patents capture capabilities essential to an innovation system, but comparisons of national aggregates for these indicators can be highly misleading. They can fail to capture what matters to an economy, which is the development of capabilities in economically important sectors. Sector based analyses can give very different results. This can be illustrated by comparing R&D data for specific business sectors between Australia and a group of comparator countries, as shown in Table 5 (see Annex A for further details)[8]. Due to a lack of data, agriculture and mining are excluded. Table 5 provides average R&D intensities by business sector, national R&D intensities for all business sectors combined, and industry-standardized business sector R&D intensities.

---

8   This can also be illustrated by reviewing R&D intensities at the finest level of sectoral detail. For example from 2001 to 2003 the average R&D intensity for high-tech sectors medical, precision and optical instruments, watches and clocks, and office accounting and computing machinery was higher in Australia than for the OECD, as well as in medium-high-tech sectors including motor vehicles (Balaguer, 2009).

TABLE 5: SECTOR R&D INTENSITY, BUSINESS SECTOR R&D INTENSITY, AND INDUSTRY-STANDARDIZED R&D INTENSITY FOR THE BUSINESS SECTOR, SELECTED COUNTRIES, 2004

Sector + average R&D intensity	Average contribution of each sector to business GVA	Business Sector R&D Intensities						
		Canada	Germany	Denmark	Norway	Holland	Australia	US
High-tech* 29.7%	2.6%	32.97%	22.65%	32.23%[2]	-	40.69%	20.08%	29.41%
Medium-high-tech* 7.8%	6.6%	2.63%	10.43%	9.72%[3]	-	7.96%	6.59%	9.48%
Medium-low-tech* 1.9%	5.0%	1.53%	1.85%	1.84%[4]	-	1.22%	2.65%	2.08%[8]
Low-tech* 1.7%	7.4%	1.88%	0.85%	3.25%[5]	-	1.36%	1.69%	1.45%[9]
Electricity, gas, water supply 0.5%	2.8%	0.91%	0.20%	0.14%	1.12%	0.40%	0.41%	0.10%
Construction 0.3%	6.9%	0.08%	0.04%	0.16%	0.52%	0.25%	0.64%	0.35%
Services 1 0.5%	29.1%	0.81%[1]	0.15%	0.47%[6]	0.48%	0.31%[7]	0.59%	0.71%
Services 2 (KIBS) 1.3%	37.6%	1.21%	0.50%	2.59%	1.65%	0.67%	1.20%	
	100.00%							
Standard R&D intensity		1.84%	2.63%	3.24%	1.71%	1.79%	1.39%	2.00%
Industry-standardized R&D intensity		1.96%	1.67%	2.93%	1.81%	2.10%	1.89%	2.11%
Percent difference		**+6.5%**	**-36.7%**	**-9.6%**	**+6.0%**	**+17.1%**	**+35.6%**	**+5.3%**

Source: Catalina Bordoy of UNU-MERIT, calculations using OECD STAN and ANBERD data.

Notes: * = manufacturing sector.

The results for the United States are biased downwards because separate R&D data for services 1 and 2 are not available.

Separate data for manufacturing are not available for Norway.

Sector 2423 (pharmaceuticals), as subset of chemicals, is included in medium-high-tech manufacturing because VA data at this level of disaggregation are available.

Sector 6420 (telecommunications), is included in services 1 because VA data are not available at a higher level of disaggregation than sectors 60 – 64 combined.

For some countries, sectors have been excluded from the calculation of R&D intensities because either VA or R&D data were not available:

1: Excludes sector 55 Hotels and restaurants.

2: Excludes sector 353 Aircraft and spacecraft.

3: Excludes sectors 352+359 Railroad equipment and transport equipment.

4: Excludes sector 351 Building and repairing of ships and boats.

5: Excludes sector 36-37 Manufacturing, n.e.c.; Recycling.

6: Excludes sector 55 Hotels and restaurants.

7: Excludes sector 55 Hotels and restaurants.

8: Excludes sector 351 Building and repairing of ships and boats.

9: Excludes sector 36-37 Manufacturing, n.e.c.; Recycling.

The left-hand column of Table 5 describes each sector and gives the average R&D intensity for the seven countries. For example, the average R&D intensity in high technology manufacturing sectors is 29.7% (R&D expenditures equal 29.7% of gross value-added or GVA) and 1.3% in the KIBS sectors. The second column gives the average contribution of each sector to total business sector GVA among the seven countries. For example, high technology manufacturing accounts for an average of 2.6% of business sector GVA while KIBS services account for 37.6% of business sector GVA. The data in each country column gives the sector R&D intensity. The R&D intensity of high-technology manufacturing in Australia is 20.08%, the lowest for this sector among the comparator countries. For medium-high technology manufacturing, the average R&D intensity is 7.8%, while the Australian result is 6.59% - lower than the average but not substantially below. However, for most sectors, the Australian R&D intensity is *very close to the average or substantially higher*. For example, Australia out-performs the average for medium low technology sectors, construction, and Services 1 (all business services with the exception of KIBS) and is only slightly below the average for low technology manufacturing and for KIBS.

These results show that business R&D intensities are high in sectors that make a substantial contribution to the Australian economy (KIBS, low and medium-low technology manufacturing, and other services). Unfortunately, there are no available data for agriculture and mining, but it is likely that Australia performs well here too.

The Australian weakness in medium-high and high technology manufacturing explains why Australia ranks poorly on international comparisons of R&D. This can be observed by comparing 'Standard R&D intensity' with the 'Industry standardized R&D intensity. The former is the standard method: R&D expenditures are summed over all sectors and divided by the sum of all value added in these sectors. On this metric, Australia has the worst performance among the comparator countries, with a business sector R&D intensity of 1.39%.

However, industry standardization tells a very different story. This method uses a standard industry distribution for all sectors, given in column 2. All countries are assumed to have this standard distribution, with their R&D expenditures in each sector weighted accordingly. Germany, with a very large medium-high technology sector, suffers because the average size of this sector is considerably smaller, so its adjusted R&D intensity declines. In fact, German performance is notably below average in all sectors except for medium-high and medium-low technology manufacturing. As a consequence, the industry standardized R&D intensity for Germany falls by 36.7%, from an average of 2.63% to 1.67%. In contrast, Australia's good performance in almost all sectors except for medium-high and high technology manufacturing gives it the largest boost, by 35.6% after standardization: from 1.39% to 1.89%. This is because medium-high and high technology sectors contribute little to the average total of business sector value added (only 9.2%), compared to the large contribution of sectors where Australia is close to or out performs the average.

Innovation

Innovation survey data show that fewer Australian firms collaborate or innovate compared to firms in many European countries, but part of the low rates for Australia are probably due to differences in the survey questions. As shown in Figure 6, a lower percentage of Australian than European firms report collaboration, but the data refer to any collaboration over the three years before the survey in Europe and to only *one year* before the survey in Australia[9]. Consequently the results are not comparable, particularly for an activity such as collaboration which is less frequent than innovation itself.

Results from the 2004-05 business survey of innovation in Australia show that innovation occurs in all sectors of the economy, but only 19.4% of firms introduced a product innovation over the previous two year period, 21.6% introduced a process innovation, and 24.9% introduced an organizational innovation. Again, these rates are lower than those observed in several European countries, where over 45% of firms innovate, (OECD, 2009b), but part of the difference is caused by varying reference periods. European innovation rates are based on any innovation or innovative activity in the previous three years, while in this case Australian innovation rates are based on innovations or innovative activity over the previous *two* years.

As in other countries, the propensity to innovate in Australia increases with firm size and varies by sector, though the distribution of innovation input activity is skewed, with R&D and innovation expenditure intensity concentrated amongst a small share of highly innovative firms. Interestingly this is a general characteristic of innovation in Australia and does not appear to simply reflect specific business size or industry characteristics alone (ABS and DITR 2006). Smith and O'Brien (2008) show this is also the case for innovation outputs measured by sales of innovative products, with small shares of firms accounting for the majority of innovation sales across all firm size classes.

In 2003, over two-thirds (69%) of innovation expenditures in Australia were for activities other than R&D. Organisational innovations are more common in the services sectors.

---

9   The data for Europe are based on the CIS-4 survey and covers collaboration between 2002 and 2004 inclusive, while he data for Australia are from the Innovation Survey 2003 and refer to collaboration 'during the calendar year 2003' (Question 13).

**Figure 6:   Share of all firms collaborating in innovation activities, 2002-2004
(or nearest available years)**
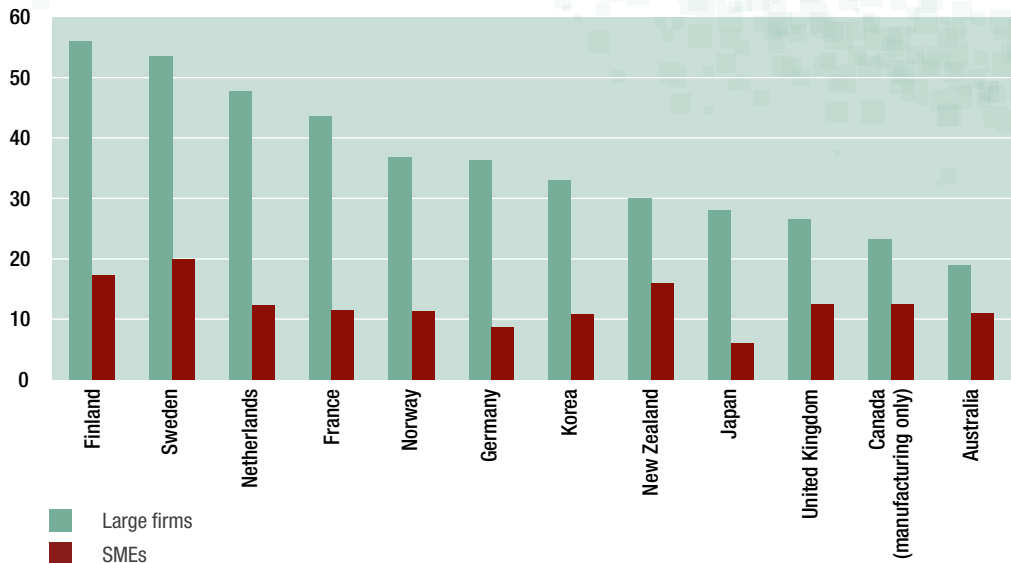
Source: STI Outlook 2008, OECD, 2009

Innovation data can be used to reveal more about the sectoral differences in innovation processes. As an example, Table 6 gives the share of Australian firms in three broad sectors that report positive innovation expenditures in 2007 for each of nine innovation activities. The most frequently reported activity is technology acquisition, while only 15.8% of manufacturing/mining firms and 13.4% of KIBS firms performed R&D.

TABLE 6: PERCENT OF FIRMS REPORTING SPECIFIC INNOVATION ACTIVITIES, SELECTED SECTORS

Innovation activity	Mining and manufacturing	Knowledge intensive business services	All other services (non-KIBS)
Acquisition of machinery, equipment or technology (including hardware or software) used for innovation related purposes	54.3	48.1	48.3
Training (including external) specifically for innovation related purposes	32.6	38.5	32.6
Marketing activities undertaken to introduce innovation(s) to the market	18.3	34.0	29.4
R&D Acquired from other businesses	8.2	6.7	4.1
R&D Undertaken by the business	15.8	13.4	7.9
Design, planning and testing needed for innovative activities	20.9	19.7	10.9
Acquisition of licences, rights, patents or other intellectual property	15.4	12.1	11.8
Operational processes	14.0	10.9	12.8
Organisational/managerial processes	10.7	12.9	13.1

Source: ABS 8158.0. Table 1 Types of expenditure for innovation purposes, by employment size, by industry–2006–07. KIBS includes information, media and telecommunications, financial and insurance services, rental hiring and real estate services, professional scientific and technical services and administrative and support services. Non-KIBS includes all other industry divisions apart from mining and manufacturing. Based on ANZSIC 2006. Agriculture is not included in 8158.0.

Note: Comparable data for Europe are not available, as the Australian innovation survey uses a one-year reference period compared to the three year reference period used in the European Community Innovation Survey. This difference will increase innovation rates in Europe compared to Australia. See Chapter 3.3 for a discussion of comparability issues.

The number of patent applications in Australia has been increasing in recent years (by 13.2% from 2003 to 2006), but Australia still accounts for a relatively small share of world patenting activity, ranking tenth for patents granted to foreign based applicants to the USPTO in 2006. Areas of Revealed Technological Advantage for Australian patents granted in the EU and US are agriculture and food machinery, civil engineering, building and mining, space technology and weapons, and biotechnology[10].

In the 2004 Australian innovation scorecard, Australia ranked 4th of 19 OECD countries in terms of the share of domestic R&D conducted by foreign affiliates. More recently, businesses with greater than 50% foreign ownership accounted for 36.6% of total BERD in Australia in 2006-2007[11].

2.3   FUTURE CHALLENGES

The goal of innovation policy is to strengthen the capacity and effectiveness of Australia's innovation system in the face of myriad current and future policy challenges that are both national and global in scale. Innovation metrics will need to be forward looking and capture the response of key system elements to particular challenges.

Climate change is possibly the greatest challenge facing Australia, both from its direct effects on the Australian environment and its indirect effects on the traditional resource based sources of export income. If governments worldwide introduce effective mechanisms to limit climate change from CO_2 emissions, coal exports, one of Australia's major sources of export earnings, will decline –perhaps precipitously[12]. Conversely, demand for agricultural, forestry and fisheries products are expected to increase due to rapid income growth in developing countries (OECD, 2009). The ability to take advantage of these markets could require renewed innovation to counteract the negative effects of climate change, such as drought, higher temperatures, and climatic variability. The challenge of climate change would therefore require a diversification of Australia's exports and new areas of innovative strengths. Options include developing Australia's geothermal and solar energy resources or diversifying into new export sectors with good terms of trade conditions.

The Government commitment to introduce high-speed broadband infrastructure will increase the potential for service sector innovation through access to new markets, introduction of new goods, services, and organisational methods. Metrics will need to be responsive to these types of innovation and the development of entirely new business models.

2.4   IMPLICATIONS FOR INDICATORS

To summarize the above review of the Australian innovation system, the Australian economy produces agricultural and mineral resources for export and depends on imports for most of its medium and high technology goods. The low share of trade in economic output reduces exposure to foreign economic turbulence, but requires support for competition in the domestic market to maintain productivity growth. Based on traditional indicators for innovation inputs, the innovation system performs well in the most economically important sectors of low and medium-low technology manufacturing and in services. This conclusion is supported by above average business R&D intensities in these sectors and government support for R&D in low technology export sectors. The main apparent weaknesses are low patenting rates and a high share of SMEs, with below average rates of innovation and collaboration compared to larger firms. The low patent rate is possibly explained by the structure of the economy, with strengths in sectors such as agriculture where patents are not an effective appropriation mechanism.

12   Effective carbon capture and storage (CCS) technologies would reduce the rate of decline in coal consumption, but would not stop it. This is because the cost of CCS technology is likely to be higher than the cost of many alternatives, including conservation. An effective cap and trade system for carbon would therefore result in a mix of low carbon energy technologies that would partly replace coal-fired electricity generation.

Collaboration and other forms of sourcing knowledge from both domestic and international sources are essential to the innovative capacity of the Australian economy. Consequently an innovation metric system for Australia needs to provide data on the innovative capabilities of Australian firms, including their ability to source knowledge from external sources[13].

There are four main implications of Australia's economic characteristics and future challenges for innovation metrics:

1. ***Capabilities and knowledge flows:*** Metrics are required that capture the innovative and absorptive capabilities of Australian businesses, government agencies, and public and private research institutions. Maintaining absorptive capacity requires R&D plus effective systems for sharing knowledge, such as informal and formal collaboration, both within Australia and between Australia and the rest of the world. These capabilities are built and maintained in specific sectors or product markets, such as the wine industry or the mining sector. This is due to the activities (or lack thereof) of research institutions, training programs, and business or professional associations in each sector.

2. ***Sectors:*** Firms compete in product markets characterized by different patterns of innovation and support systems. Consequently, metrics need to be available at the sector level. Many innovation indicators that combine all sectors, if used unwisely, can mislead policy, as shown in the example of R&D intensity. Key sectors of interest are the export sectors (mining, agriculture, other primary resources, educational services) and the service sectors that account for 70% of Australian GDP.

3. ***Firm size:*** Small firms account for a large share of Australian GDP but are perceived as less innovative than large firms. Innovation metrics need to be available for small firms so that their innovative capacities can be fully understood, as well as the drivers that encourage them to innovate. Many innovation indicators are biased by pure size effects. Understanding can often be improved by providing employment-weighted indicators for different size classes of firms.

4. ***Future technologies:*** Metrics need to be developed for emerging technologies that will shape Australia's future. These include biotechnology, nanotechnology, low carbon energy technologies, internet applications, and possible new export-oriented sectors. Although the small size of the Australian economy is often viewed as a barrier to the development of high-technology export-oriented manufacturing sectors, other small economies have been very successful in these markets, including Denmark, Sweden, and Finland.

Many of these four priority areas for innovation metrics match current priorities of the Australian Government (Commonwealth of Australia, 2009) and recommendations of the Australian Bureau of Statistics (ABS, 2008). These priorities include improving the innovative capacity of the public research sector, extending the skills of the labour force, tracking future industries, meeting the needs of SMEs, and improving collaboration between industry and the public research sector. The latter includes

---

13   The argument that Australian firms perform poorly on collaboration, compared to firms in other developed countries, is supported by data on co-publishing (NSF, 2008), but data on the share of innovative firms in Australia and Europe that collaborate are not comparable, due to large differences in the reference time period.

greater levels of international collaboration so that Australia can benefit from developments overseas. In addition, the ABS has identified a need for better indicators for environmental innovation, for emerging technologies, and for innovation in the public sector.

Three of these four priority areas guide the analysis of innovation indicators in the following sections – this report does not evaluate metrics for future or emerging technologies. The interested reader is referred to the OECD frameworks for collecting technology specific indicators of relevance to biotechnology applications in health, industry and primary production and to the overview in Box 1[14]. The same methods are currently being applied by the OECD to develop indicators for nanotechnology.

Chapter 3 evaluates methodological issues for developing and analyzing indicators. Chapter 4 covers indicators for firm capabilities, such as how firms innovate; while Chapter 5 evaluates indicators for knowledge sourcing, which is a key factor in building absorptive capacity. Both Chapters 4 and 5 concentrate on indicators that can be constructed from innovation survey data.

The remaining five chapters look at indicators for factors that shape innovation (entrepreneurship and demand) and specific topics of relevance to ongoing challenges: environmental innovation, the use firms make of innovation support programs, and innovation in the public sector. Some of the required data to construct indicators on these five topics are already available. The main requirements are to provide indicators in a form that is comparable with other innovation indicators and to assemble all indicators in the same document. Other indicators can be constructed from data collected in the Australian *Business Characteristics* surveys, while a third set of indicators could require new data collection.

Of note, this report does not cover all innovation metrics. For example, there is only limited discussion of patents and bibliometrics and as noted above the report does not cover indicators for future technologies. The focus of this report is on recent research into measuring innovation activities.

14   The OECD (2005) framework for measuring innovation activities in biotechnology can be applied to other emerging technologies such as nanotechnology or low carbon energy production. The publication *OECD Biotechnology Statistics 2009* (van Beuzekom and Arundel, 2009) and OECD (2009) provide a wealth of examples of how to produce indicators for an emerging technology, using both survey and non-survey data.

3. METHODOLOGY OF INDICATOR DEVELOPMENT

This chapter evaluates several methodological issues concerning the collection, presentation, and use of innovation indicators, including an evaluation of the international comparability of Australian innovation indicators constructed from the Business Characteristics Survey and indicators derived from innovation surveys in other OECD countries.

3.1 SELECTING INNOVATION INDICATORS

There are potentially hundreds of innovation indicators that can be constructed from available data sources. Innovation indicators of value to policy development need to meet one of two requirements: 1) the indicator is essential for econometric analysis, such as on the propensity to innovate, innovation strategies, or innovation performance, and 2) the indicator helps 'tell a story' or improve understanding of innovative activities, including appropriate methods of benchmarking performance over time or across sectors. The latter group includes many composite indicators for how firms innovate. The most useful indicators can serve both requirements.

There are two main sources of innovation indicators: surveys and an eclectic mix of other data sources. Surveys include Business Characteristics survey in Australia, R&D surveys, and specialized surveys, such as surveys of specific topics such as commercialisation.

As part of identifying relevant indicators, this report draws on national innovation surveys in Canada, New Zealand and the European Union (the Community Innovation Survey or CIS), in addition to the Australian Business Characteristics surveys. The United States does not conduct an innovation survey, but the 2008 R&D survey includes a few relevant questions.

This report also draws on specialized surveys from the European Union and Canada. The European Innobarometer surveys, with approximately 4,500 to 5,000 respondent firms, focus on specialized topics. The 2004 survey looked at the use of innovation support programs for firms, the 2007 survey examined how firms innovate without performing R&D, and the 2009 survey looked at changes in innovation strategies. Two Canadian specialized surveys are the 2007 Survey on the Commercialisation of Innovation and the 2004 Environment Industry Survey. A few one-off academic surveys are also evaluated for possible indicators.

The World Economic Forum (WEF) conducts an opinion survey of high level managers in over 100 countries, with the 2009 report providing results for 134 countries in all regions of the world. The survey does not follow good survey practice in asking respondents about conditions in their own firm, but instead asks them to give their opinion on national conditions. Good practice avoids this technique because respondents will often use general perceptions to answer the question, rather than conditions in their own firm. Nevertheless, the survey is a good source of ideas for indicators and the results often correlate well with other measures of national innovative capabilities, such as the European Innovation Scoreboard. The method may also be appropriate when a broad understanding of conditions across an economy is warranted.

Other data sources are available for publications, patents, and venture capital investments.

Each of the following chapters examines a different aspect of innovation and includes a table with a list of relevant indicators for Australia. These indicators are classified into two main categories:

1. The indicator can be calculated from non-survey sources or from survey data that is already collected for Australia.
2. Australian surveys would need to add new questions to produce the indicator.

The 'comment' column of the tables classifies indicators in the second category into three groups:

a) The survey questions have been tested in other surveys.
b) The survey questions have been partially tested in other surveys (same question but a different application, or there are significant differences in wording).
c) The survey question has not been tested in other surveys.

Indicators in group *b* and group *c* above would need further testing and evaluation before inclusion in Australian surveys. Group *b* indicators would require minor testing while group *c* indicators would require full evaluation, including cognitive testing to ensure that the proposed question can obtain reliable results.

3.2   INDICATORS BY SECTOR AND FIRM SIZE

An essential requirement for constructing an Australian innovation metrics system is to provide as many indicators as possible at the sectoral level, including indicators of R&D. With the rare exception of large diversified firms, firms compete in sectoral markets. Each market has unique characteristics in terms of the opportunities for innovation to improve performance. These sectoral conditions affect how firms innovate, the role of science-based knowledge, the importance of different types of intellectual property and other appropriation methods, opportunities for product or process innovation, the types of skills that are required to innovate, and many other innovation strategies.

To date, the majority of econometric research using innovation survey data has used general innovation models that only include the firm's sector as a control variable. This approach has identified broad features of innovation, such as the importance of collaboration, R&D, and appropriation strategies in innovation performance, or the effect of firm size on the propensity to innovate. Yet these results hide substantial variation across sectors. Understanding these variations is a key requirement for innovation policy.

A disadvantage of general innovation models is that they have focused on innovation inputs that are relevant to high technology manufacturing sectors, such as patents, R&D expenditures, and collaboration rates with universities, even though these sectors contribute, in most developed countries, to less than 3% of GDP, as shown in Table 2. These indicators are often assumed, incorrectly, to be good measures of innovative performance in all sectors, including low technology manufacturing (Arundel, 2007; DIISR, 2008). This ignores the sector specific nature of innovation.

Academic research is increasingly exploring more appropriate methods of measuring innovation at the sector level,[15] including identifying indicators that describe how innovation occurs in each sector. Even in high technology sectors, indicators that do not measure science inputs can be of value. As noted in the report *Powering Ideas*, high technology firms require both employees with science, technology, engineering and math skills, and employees with communication and business management skills (Commonwealth of Australia, 2009).

15   Examples are the Innova project funded by the European Commission and the report by Adams et al (2008) for NESTA.

Figure 7:   Potential sector breakdowns for presentation of innovation indicators
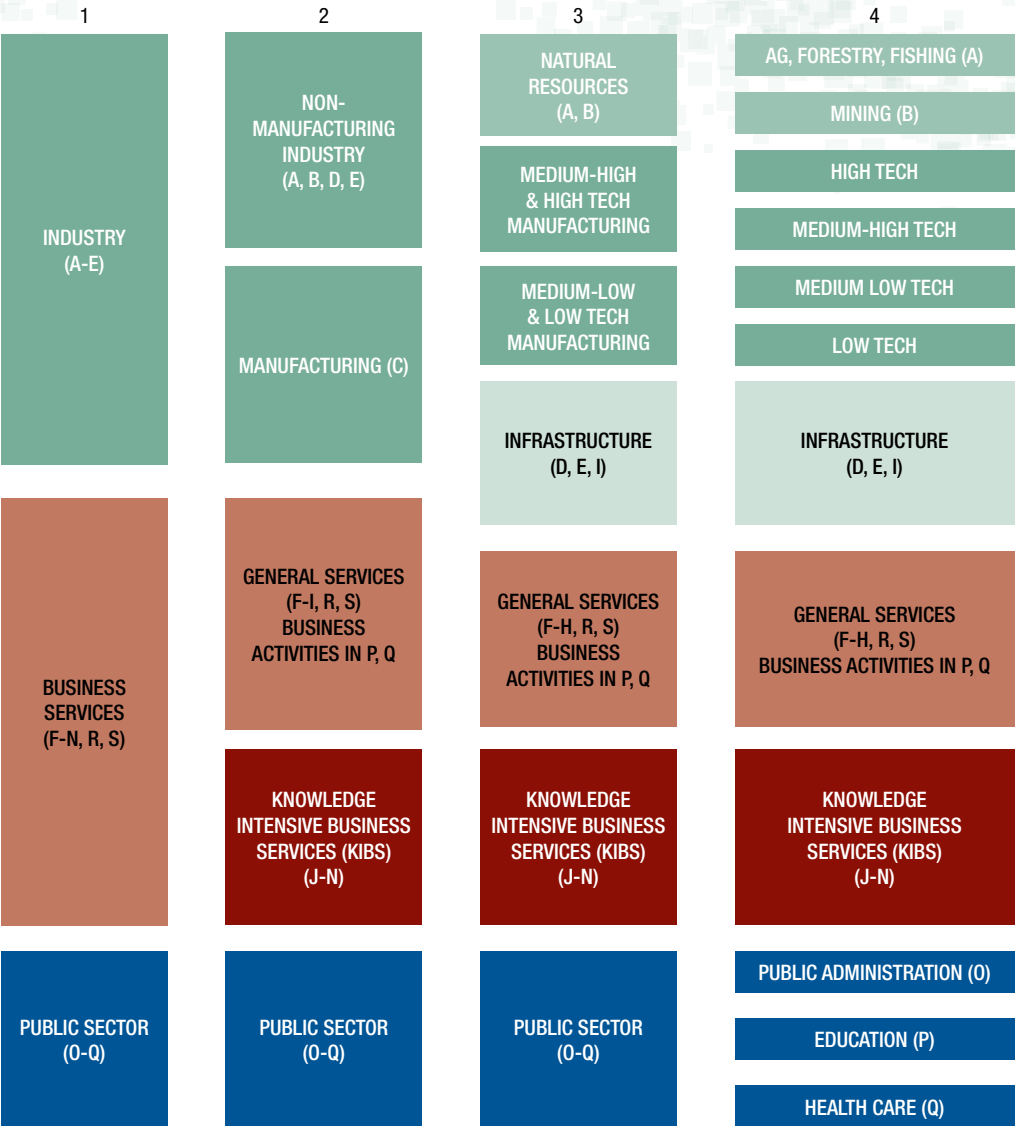
Notes: Letters refer to ANZSIC 06 Divisions. Some activities in sectors P and Q are part of the business services sector and are included under general services.

A sectoral approach needs to provide indicators for the most economically important sectors and identify indicators that capture how innovation occurs in each sector. For Australia, this requires building relevant indicators for medium-low and low-technology manufacturing and for the services sector.

The possible level of disaggregation by sector is constrained by the need to maintain confidentiality and statistical accuracy. This problem can be partly addressed by

increasing the sample size in innovation surveys[16], although this method is often not feasible because it increases costs. One compromise is to increase the sample size in sectors of major policy interest.

Figure 7 provides examples of possible sector breakdowns. Each option will provide more useful information than the preceding option, with option 3 preferred as a minimum. Although Figure 7 includes the public sector, robust innovation indicators for these activities are not yet available. Chapter 10 describes some of the current research to develop indicators for public sector innovation.

Firm size

In addition to the sector, indicators should be provided for different firm size classes and by a measure of innovative capability (see Chapter 4). An option for managing differences in firm size class distributions is to weight results by the number of employees. Employee weighting changes the interpretation of indicators from the percent of firms with a specific innovative activity to the percent of employees that work for firms with this activity. Table 7 gives examples of indicators with and without employment weighting, using data from the Tasmanian Innovation Census.

TABLE 7: EXAMPLES OF THE EFFECT OF EMPLOYMENT WEIGHTING					
	Innovative firms			Innovative and collaborative firms	
Full Time Equivalent (FTE) employees	Number of firms	Share of firms that innovate	Share of employees that work for innovative firms	Share of firms that collaborate & innovate	Share of employees that work for collaborative & innovative firms
5-9	599	65.4	65.5	28.5	28.7
10-19	465	67.7	68.5	29.0	29.2
20-49	323	74.0	74.4	36.5	35.3
50-99	108	79.6	79.7	40.7	39.9
100-249	62	85.5	84.7	40.3	37.5
250+	34	88.2	89.0	41.2	44.5
Total	1591	70.1	79.8	31.9	37.7

Source: Tasmanian Innovation Census 2007, calculations by the authors.

Generally, employment weighting increases the prevalence of an activity. For example, the unweighted results for all firms combined shows that 70.1% of firms innovate, but 79.8% of employees work for an innovative firm. Similarly, 31.9% of firms innovate and collaborate, but 37.7% of employees work for both innovative and collaborative firms.

---

16   Increasing the sample size, even to the point of surveying all firms, does not always solve the confidentiality problem. Confidentiality is also an issue when a small number of large firms account for a significant share of production.

The effect is due to higher rates of innovation or collaboration in larger compared to smaller firms[17]. In so far as a large firm is likely to apply innovative methods across all its operations, employee weighted results can provide a more accurate measure of the economic effect of innovation than unweighted results for firms.

3.3   INTERNATIONAL COMPARABILITY OF AUSTRALIAN INNOVATION INDICATORS

Policy analysts are often interested in benchmarking innovation indicators against performance in other comparable countries. The European CIS is the world's largest innovation survey, with results for 30 countries. Consequently, the CIS serves as a useful benchmark for innovation indicators drawn from the Australian Business Characteristics survey. Australian indicators can also be benchmarked against performance in Canada and New Zealand.[18] However, several factors reduce comparability between Australian and European innovation indicators, mostly in a way that will reduce Australian performance compared to European countries.

Reference period: The reference period is the time period over which a firm can report innovations or related activities such as collaboration. The Australian Business Characteristics surveys switched from a three-year reference period for innovation to a two-year reference period in 2005 and to a one-year reference period in 2006-07. The European CIS and the Canadian innovation surveys use a three year reference period while the 2007 New Zealand Business Operations Survey uses a two year reference period. The shorter reference period for Australia should produce lower rates of innovative firms or collaboration (see previous discussion of Figure 6 in Chapter 2.2) compared to surveys in other countries.

Minimum firm size: The Australian Business Characteristics survey uses a minimum firm size of zero employees, whereas the European CIS uses a minimum size of 10 employees and the New Zealand survey uses a minimum size of six employees (Statistics New Zealand, 2008). Australian data therefore need to be limited to firms with a minimum size of 10 employees to improve comparability with the CIS or to a minimum size of six employees to be comparable with New Zealand, since smaller firms are known to be less likely to collaborate or innovate than larger firms. Alternatively, results can be given for Australia that match the size classes used in other countries. For Europe, results are reported for three size classes: 10 to 49 employees, 50 to 249 employees, and 250+ employees.

Industry structure: Comparability at the national level will be affected by differences in industry structure and the size distribution of firms. As shown above for R&D in Table 5, this will reduce the performance of Australia on many indicators compared to countries with higher economic shares in medium-high and high technology manufacturing, such as Germany. Addressing this issue requires comparisons between firms of the same size category and within the same sector.

---

17   This effect is suppressed using Tasmanian data because very few Tasmanian businesses are large firms with thousands or even tens of thousands of employees.

18   The United States does not conduct a survey on innovation, although the 2008 R&D survey includes a few relevant questions. Within the OECD, Japan and Korea also conduct innovation surveys.

Service sector coverage: Comparability for service sectors is affected by national differences in the coverage of these sectors. European countries are not legally required to survey firms active in construction, retail trade, accommodation and food services, and film and television production, plus many knowledge intensive business services such as legal and accounting activities, advertising and marketing research, scientific research and development, other professional, scientific and technical activities; and real estate activities (Eurostat, 2009). Coverage of these sectors varies across the countries that participate in the CIS.

Questionnaire response categories: Many of the response categories for the Australian innovation questions are limited to a single 'yes' check box. Most CIS questions include a 'no' option so that non-responses to specific questions are not combined with 'no' answers. This difference will slightly reduce the frequency of specific innovative activities in Australia compared to CIS respondents, as the CIS results for non-respondents to these questions are imputed, increasing the number of 'yes' responses.

The response category for several CIS questions is scalar (not used; low, medium, high importance). Any positive answer to the CIS (low, medium, or high) may not be comparable to the Australian 'yes', particularly for Australian questions with a question qualifier to limit 'yes' responses. For example, the 2007-08 Australian question on barriers to innovation asks the respondent 'did any factors *significantly hamper* this business in the development or introduction of [innovations]'' whereas the CIS version does not limit responses to significant effects.

Question wording: Differences in the wording of a question, or the order of a list of questions, can affect results. However, some differences in wording are required to ensure that the meaning of a question is understood properly by national respondents. For example, the standard CIS questionnaire uses the term 'enterprise', whereas the Australian survey uses the term 'business', which is better understood by Australian respondents. In many cases, minor differences in wording are unlikely to have more than a mimimal effect on responses. Many of the Australian questions are very similar to the CIS equivalents. However, for other questions, a minor wording change can mask a large difference in meaning that will reduce comparability. For example, the questions on innovation expenditures in the 2006-07 Australian Business Characteristics survey refers to expenditures on activities to develop or introduce 'goods, services, processes or methods' and intentionally includes organizational and marketing methods. The equivalent CIS questions are limited to goods, services, and process innovations.

All of the above factors need to be taken into consideration when producing Australian innovation indicators for comparison with indicators for other countries. Comparability can be improved by producing indicators for identical firm size classes and sectors, particularly for indicators of service sector innovation. The most serious factors that will reduce comparability include large differences in the reference period between Australia and other countries and significant differences in question wording. Neither can be adjusted for. Of note, the international comparability of Australian innovation indicators derived from the Business Characteristics survey has been declining over time, as the reference period has been reduced from three, to two, and more recently to one year.

Since the Business Characteristics survey queries firms on their innovation activities every year, the advantage of a one-year reference period is that it minimizes recall problems and prevents double counting for firms that are included in consecutive surveys. For example, a firm that innovates in 2008 but not in 2009 would be counted as an innovative firm in 2008 but not as an innovative firm in 2009 when a one year reference period is used. If a two or three year reference period is used, the firm would be counted as an innovator in both 2008 and 2009 even though it had no innovative activities in the latter year. However, this example also shows that the length of the reference period defines what it means to be an innovative firm. Firms that are active in sectors where innovation occurs relatively slowly, for example over a three year cycle, are defined as non-innovators even though they could be among the most innovative firms in their business. One solution to this problem is to include a question that asks non-innovative firms if they actively scanned trade publications or market conditions to identify innovations that might benefit them.

3.4   USE OF INNOVATION INDICATORS IN ECONOMETRIC ANALYSIS

Innovation indicators include simple indicators constructed from a single survey question and composite indicators constructed from two or more survey questions. Both are used in descriptive analyses of how innovative activities vary across sectors, regions, or by the size of the firm. In addition, both types of indicators can be used in econometric analyses where the dependent variable of interest is a strategy (what factors affect the probability that a firm will apply for a patent or collaborate with other firms?) or an outcome (what factors increase the share of sales from innovative products or labour productivity?).

Simple indicators have been more frequently used in econometric analysis, but the use of composite indicators has been increasing because they can capture related or complex strategies. One type of composite indicator is a scalar variable that sums the number of positive responses to a set of related variables, such as a "breadth" indicator for the number of different types of knowledge sources used by a firm. This indicator was used by Lausen and Salter (2006) in an econometric analysis of the factors influencing the share of sales from new to market innovations. A second type of composite indicator consists of nominal variables, such as whether or not the firm develops innovation in collaboration with other firms. This indicator is positive if a firm either developed innovations 'together with other firms or institutions' or through collaboration. Nominal composite indicators have been used by Bloch (2008b) in econometric analyses of innovation outputs and productivity. A third type of composite indicator is categorical, such as for how firms innovate (see chapter 4.2). These can be disaggregated into nominal indicators for econometric analysis or included as categorical variables.

Econometric research using innovation survey data has mostly constructed models based on firm-level data, but an alternative approach is to construct databases at the sector level and across countries or regions. This permits analyses of sectoral changes in productivity or the factors that affect progress towards the technological frontier, defined as the country or region with the highest labour productivity in a given sector. The Eurostat-OECD EUKLEMS data can be used for this purpose, but this dataset only includes an indicator for R&D, while lacking indicators for other innovative activities.

The University of Urbino has constructed a Sectoral Innovation database using ten national innovation indicators from CIS-2, CIS-3 and CIS-4. Bogliacino and Pianta (2009) have used this database to explore the factors that influence the distance from the technological frontier, including technological strategies based on knowledge generation and cost saving strategies. Van Wiel et al (2008) use both innovation indicators at the firm level and sector data from EUKLEMS to define the technological frontier in an econometric study of the factors that influence 'catching up' by Dutch firms. A third approach is used by Hollanders and Esser (2007). They use a non-parametric data envelopment analysis (DEA) to estimate an unobservable efficiency frontier and the distance of each of 37 countries (including Australia) from this frontier. The efficiency frontier is estimated from the correlation between indicators for innovation inputs and innovation outputs, using innovation indicators obtained from a range of sources, including the European CIS.

3.5   POLICY USE

Indicators can be used by firm managers to benchmark their activities against best practice, but their primary value is for policy development and assessment, either when used directly or through econometric research. In either case, a single indicator can only tell part of the story. Therefore, multiple indicators need to be evaluated in order to obtain a balanced picture. For example, only using indicators for R&D can be misleading if most innovative activity in a sector occurs via engineering activities or through combining existing knowledge in new ways. Indicators for inputs into the innovation process, such as R&D or technology acquisition, should also be combined with indicators for outputs, such as the sales of innovative goods and services or productivity.

Innovation is also a non-linear process – more of something is not always better – and it requires time. It is often difficult to determine the optimum level of an input such as R&D or of an intermediate output such as patents. Evaluating complementary indicators for other innovative activities and indicators for outputs can help, as well as tracking innovative inputs and outputs over time.

4.   CAPABILITIES: HOW FIRMS INNOVATE

Economic growth depends on the diffusion of new technology and access to codified knowledge, driven by national innovation systems that can absorb and implement knowledge, either embedded in capital equipment or in intangible forms (Freeman and Soete, 2009). The adoption and exploitation of existing technology is often more relevant to productivity improvements than invention.

In high income countries such as Australia, the challenge is to maintain a flexible innovation system that can both create knowledge and absorb it from elsewhere. All methods of innovating will play a role in absorptive capacity – even the adoption of new technology can require careful assessment of different options and the ability to incorporate new technology in existing organizations and production processes.

Indicators are required to measure a sector's ability to generate innovations, incentives and processes for developing and diffusing innovations, and its 'absorptive capacity to identify and draw them in from elsewhere' (NESTA, 2007).

In the United States, Hicks and Hedge (2005) report that small innovative firms play an important role in developing new technologies for niche markets and in trading specialized technology. These types of firms could play a valuable role in developing and licensing specialized technology to address Australian requirements, for instance in areas such as managing drought, developing new types of energy, or providing services to farmers over the internet.

"Traditional" innovation indicators largely cover invention, or inputs into invention and innovation, rather than innovation itself. They include indicators for scientific publications, educational levels, R&D and patents. Innovation surveys based on the Oslo Manual provide direct measures of innovation activitie.

The third edition of the Oslo Manual defines innovation as *"the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations.* It further notes that an innovation only needs to be new to the firm. This means that the firm itself does not need to be the original developer of a product, process, marketing method, or organizational method that it introduces to its market for the first time (OECD, 2005, p. 46).

This definition of an innovation has been criticized for being overly broad because it includes everything from a multi-billion dollar R&D program to develop new technology to firms simply buying new technology, such as a software program or production equipment, 'off the shelf'. Von Hippel (2007), for example, argues that a better definition of innovation is 'anything novel that creates value for its users', where the creation of novelty requires inventive activity.

Indicators based on the Oslo Manual, such as the percentage of firms that innovate, can also highlight the problems with the Oslo Manual's definition. The results of the third CIS for Europe found, for instance, that 46% of firms in Portugal introduced a product or process innovation between 1998 and 2000, compared to 45% of firms in Finland. This type of result attracts skepticism, since Finland performs far better than Portugal on indicators for R&D, publications, tertiary education, and a range of other innovation input and output measures. The problem is that the indicator for the percentage of firms that innovate combines firms with disparate methods of innovating and disparate innovative outputs. This raises the question: How relevant to understanding is a single indicator that combines all firms, no matter how they innovate, their size, or their sector of activity? Our view is that such an indicator is of limited value.

The problem is not due to the Oslo Manual's definition of innovation, as suggested by von Hippel and many others, but in a failure to adequately exploit the potential of innovation surveys to produce disaggregated indicators that identify *how* firms innovate. An example is given in Figure 8, which assigns innovative Finnish and Portuguese firms to one of four discrete categories that define how firms innovate: strategic innovators, intermittent innovators, technology modifiers, and technology adopters. The vertical axis gives the percentage of all firms that are either strategic or intermittent innovators. These firms have in-house capabilities to invent new or improved products or processes, although the former perform R&D on a continuous basis while the latter only perform R&D as needed. The horizontal axis gives the

percent of innovative firms that do not perform R&D, but either use other methods to modify technology or primarily acquire innovations developed by other firms. The light blue diamond in the middle gives the average distribution for all European firms. The sum of the four axes gives the percentage of all firms that innovate in each country.

Figure 8:   Innovation modes for Finland and Portugal
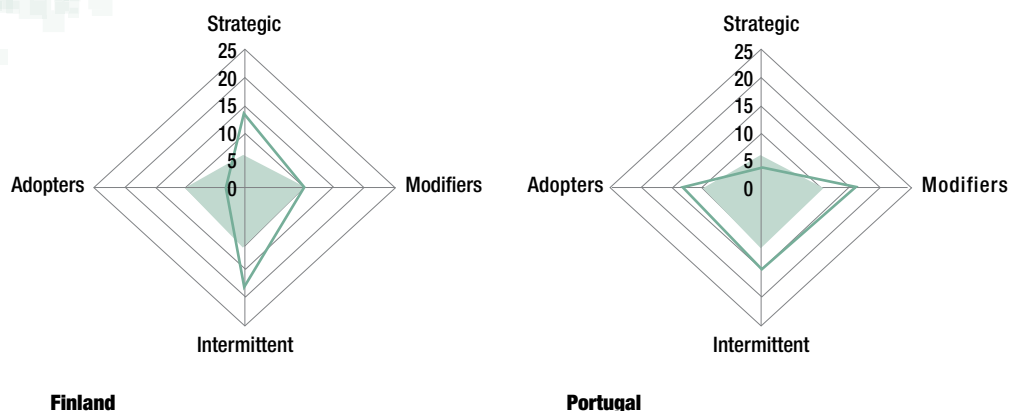
Finland

Portugal

One can see at a glance that the distribution of innovative Finnish firms is compressed along the vertical axis (14% are strategic innovators and 19% are intermittent innovators), while the opposite is true for Portuguese firms, where 14% are technology adopters and 16% are technology modifiers. A much higher percentage of Finnish firms innovate through in-house creative capabilities, whereas considerably fewer Portuguese firms have these capabilities. Once the data are disaggregated, the similarity in the percentage of Finnish and Portuguese firms makes sense, given what we know from other data sources. The disaggregated results are also more informative for policy. In Portugal, the most cost-effective policy might be to encourage technology adopters to develop the ability to modify technology and intermittent innovators to become strategic innovators.

Of course, many firms do not innovate solely through R&D or through technology adoption - there is a continuum of creative activities between these two end points. Freeman and Soete (2009) note that R&D statistics do not capture many creative activities such as applying knowledge in new ways, design and engineering, consultancy, project feasibility studies, production engineering and quality control, training and information services.

In practice, the innovation literature divides the 'innovative' continuum into five main methods that firms use to innovate:

1. *Technology adoption*: Firms acquire innovative products and processes from sources external to the firm, with little or no further work required. For example, a computer assembler can purchase faster hard drives or wireless cards from specialist firms, to include in a notebook computer, or a food processing firm can purchase improved packaging equipment. CIS data used by Evangelista and Mastrostefano (2006) show that the acquisition of new machinery and equipment is one of the most common innovation activities across firms. Similarly, firms could acquire the ideas for organisational innovations from other firms.

2. *Modifications or incremental changes*: Modifications can be made to both purchased products and processes or to technologies or organisational methods that were developed by the firm itself in a previous time period. These innovative activities are particularly common for process innovation (Evangelista et al 2002; Nascia and Perani 2002). Lhuillery and Bogers (2006) estimate that 15% of overall cost reductions are from incremental innovations made by employees to production processes. The importance of incremental process innovation to efficiency has been recognized for a long time, with an in depth study by Hollander (1965) on the role of incremental innovation in improving the efficiency of Du Pont rayon plants. Incremental change can depend on learning by doing (Cohen and Levinthal, 1989) and on engineering expertise (Kline and Rosenberg, 1986).

3. *Imitation including reverse engineering*: This includes many activities to replicate products or processes that are already available, including some solutions to circumvent a patent (Kim and Nelson, 2000). The PACE survey of Europe's largest industrial firms in the early 1990s found that reverse engineering was one of the most common sources of knowledge for innovation (Arundel et al, 2005). Presumably, much of this knowledge would have been used to develop innovations.

4. *Combining existing knowledge in new ways*: This can include some types of industrial design and engineering projects (Grimpe and Sofka, 2007; Huston and Sakkab, 2006). The Italian 'informal learning systems', characterized by SMEs in traditional industries and mechanical and electrical/electronics sectors, use these methods to create new products (Evangelista et al. 2002). These systems build on tacit knowledge, engineering skills and cumulative learning processes, where the necessary knowledge is located in the system, rather than in a specific firm (Gottardi, 1996).

5. *Research and experimental development (R&D)*: R&D is a more complex concept that is defined by the OECD's Frascati Manual (OECD, 2002) as "...creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications (page 30)." 'Systematic' refers to the requirement for effort, rather than accidental discovery, whereas the reference to culture and society includes research in social sciences. Some of the boundaries between what is accepted as R&D and what is not accepted are confusing. To address this issue, the Frascati Manual provides a basic criterion for identifying R&D, which is an 'appreciable element of novelty and the resolution of scientific and/or technological uncertainty, i.e. when the solution to a problem is not

readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned (page 34)." Due to the complexity of the definition, some R&D activities, particularly outside of formal R&D labs, are probably not reported to official R&D surveys and are consequently missed in national statistics.

Firms can undertake technology adoption with very little creative activity or learning, but each of the three other types of non-R&D based innovation will require some creative effort on the part of the firm's employees and consequently develop the firm's in-house innovative capabilities. These capabilities are likely to lead to productivity improvements, improved competitiveness, and to new or improved products and processes that could be adopted by other firms. For these reasons, the activities of firms that innovate without performing R&D should be of interest to policy.

Hidden innovation

Several NESTA reports define creative innovative activities that do not involve R&D as 'hidden innovation' because they are poorly captured by R&D and other innovation statistics (NESTA, 2007; 2008). According to NESTA, hidden innovation includes small scale incremental innovations (option 2 above), combining existing knowledge in new ways (option 4), research outside of formal labs that may not be counted as R&D, and organizational and business model innovations that are not based on science and technology and therefore missed by R&D statistics.

How firms innovate varies substantially across sectors and by firm size. Innovation processes in low and medium technology (LMT) industries are often less formal and more related to modification and incremental change, design and process optimization, rather than identifiable R&D (Hansen and Serin, 1997; DIISR, 2008). These informal methods are not confined to LMT sectors. A series of case studies of how British firms innovative in six high technology sectors (pharmaceuticals, aerospace, automotive engines, telecom services, software and IT services, and electronics) found that technological innovation was not captured by R&D alone. Other methods in widespread use by high technology firms included combining existing knowledge and small scale incremental improvements (NESTA, 2008).

Service sector firms innovate in a continuous, incremental manner, in part based on improvements to ICT systems (David and Foray, 1995), with many people from different divisions involved. This manner of innovating makes it difficult to identify specific non-technological innovations (Tether, 2004; Gellatly and Peters, 1999).

User innovation

The concept of user innovation, as originally developed by von Hippel (2005), concerned the development of innovations by independent users that were not employed by a firm. Classic examples are scientists that develop specialised equipment for their research, sport enthusiasts who modify bicycles or other sporting equipment, and open source software developers. This type of user innovation thrives when there are methods for sharing information between a community of users and opportunities to break down a problem into components. These enable users to innovate without new

R&D and to combine and coordinate their efforts, for instance over the internet.[19] This form of innovating does not fit well within the above model of five innovation methods, except when a firm adopts solutions developed by users (with users possibly doing unreported R&D work). Von Hippel (2005) argues that manufacturers do not spot these types of user innovations very often, and when they do, it is normally by accident.

Gault and von Hippel (2009) and de Jong and von Hippel (2009), in respective surveys of Canadian and Dutch firms, extend the concept of user innovation from individuals or communities of individuals to firms that modify process equipment produced by a manufacturer. This is a variant of the second innovation method described above (modifications or incremental changes) and has been understood for decades as an important means of innovating that also applies to products (Arundel *et al*, 2007). The research by de Jong and von Hippel (2009) find that 32% of the sample of Dutch SMEs report modifying process equipment. Both studies with von Hippel also determine if these 'user' innovations are adopted by the original manufacturer. In both Canada and the Netherlands, 25% of the user innovations had been transferred to the original equipment manufacturer by the user firm. In the majority of cases, the user firm did so informally, with no expectation of license revenues.

For both types of user innovation, by individuals and by firms, manufacturers and society at large could benefit if manufacturers actively seek out user modifications that appeal to larger markets.

4.1   INDICATORS FOR HOW FIRMS INNOVATE

There are many opportunities for developing new indicators for how firms innovate from existing innovation surveys, possibly supplemented with a few additional questions. Most of the research in developing indicators for how firms innovate concentrates on 'innovation modes'. These are discrete categories where each firm is assigned to only one mode, as in Figure 8 above. Since innovation occurs along a continuum of creativity, the standard is to assign each firm to its highest position along the continuum. For example, a firm that both adopts new technology *and* performs R&D is assigned to the category of R&D performing firms.

Different criteria are used to develop innovation modes. Firms can be classified on the basis of *output* measures such as the novelty of their innovations or on *input* measures such as their innovative capabilities, for instance whether or not they perform R&D. In addition, innovation modes can be constructed from two different scales, such as novelty and innovative capabilities, plus additional data, such as the firm's market, which is commonly used as a proxy output measure. As a result, most innovative mode indicators are composite indicators (indicators that combine answers to two or more survey questions).

The decision to construct an input or an output measure of innovation modes depends on how the indicator will be used. Output modes are not suitable as independent variables in econometric analysis of the factors that determine outcomes such as innovation novelty (for example whether or not the firm develops a world first

19   This is obviously a link between user innovation and open innovation. Von Hippel (2002) also uses the term horizontal user innovation networks to describe groups of user innovators each freely revealing their innovations.

innovation), since the output mode will not be independent of the dependent variable. In this case, input modes should be used, for instance to determine if *how* firms innovate affects their ability to introduce world-first innovations.

The first examples of innovation modes are from Tether (2001) and Arundel and Hollanders (2005), but both of these examples (such as in Figure 8) use questions with high missing value rates for several questions, requiring complex analytical routines. Arundel (2007) describes innovation modes that avoid these problems. Other innovation modes were developed by Bloch *et al,* (2008), using the fourth CIS survey data for five Scandinavian countries. These modes were then applied to 16 countries as part of an OECD project, using national innovation survey data (Bloch and Lopez-Bassols, 2009). Unfortunately, innovation modes were not developed for Australia.

Four examples of innovation modes are described below:

1. *Product innovation novelty by markets* (Bloch et al, 2008): based on whether or not the firm introduces a 'new to market' product innovation (output indicator) by activity on international markets. The market data adds an extra dimension to novelty, assuming that firms that compete on international markets (compared to domestic markets only) are more likely to have highly novel innovations. The version developed by Bloch and Lopez-Bassols (2009) contains a category for technology adopters and consequently has five innovation modes.

2. *'Who developed' novelty by markets* (Bloch et al, 2008): This indicator builds on option 1 above by adding information on 'who mainly developed' the firm's product innovations. The product innovation could have been developed in-house (either 'mainly' by the firm itself, or 'in cooperation with others') or it could have been 'mainly developed by others', which defines technology adoption. Four innovation modes are produced.

3. *Innovation status* (Bloch and Lopez-Bassols, 2009): Novelty is based on evidence of formal inventive activity (R&D or applied for a patent) and whether or not the firm develops innovations through collaboration. The purpose of this innovation mode is to link novelty with an important measure of knowledge flows. Four innovation modes are produced.

4. *Novelty by breadth of innovation* (Bloch et al, 2008): Novelty is measured as in option 2 above, but information is added on the type of innovation (technical or non-technical organizational or marketing innovations). The method produces five innovation modes: integrated innovators, technological innovators, modifiers, technology adopters, and soft innovators (no technical innovation).

Other options for defining how firms innovate include indicators for technological versus non-technological innovation and 'dual innovators'. The latter produces three innovation modes for product innovation: firms that only introduced a goods innovation, firms that only introduced a service innovation, and firms that introduced both goods and services innovations.

Factor analysis and innovation modes

An alternative method of constructing innovation modes is to use factor analysis to assign firms to one of two or more categories. This method is used by Frenz and Lambert (2009) to identify different patterns of how firms innovate in nine OECD countries. The method uses the results to 16 innovation survey questions. In most countries, three distinct innovation types were identified: new-to-market product innovators, wider innovators (primarily non-technological innovations), and process modernizers. Some of the modes increased productivity, defined as the log of sales turnover per employee, but the effect was not consistent across the nine countries.

Two advantages of the use of factor analysis to define innovation modes is that it does not require an *a priori* theory of how firms innovate and it can include information from a large number of variables. Three disadvantages are the need to make a subjective decision over the number of categories (which has a strong influence on the structure of each category), firms in different categories can share similar innovative activities, making interpretation more complex, and the categories may not be stable over time or across sectors.

4.2   DEVELOPING INNOVATION MODE INDICATORS FOR AUSTRALIA

As far as we are aware, composite indicators for innovation modes have not been calculated using Australian innovation survey data. Previous Australian studies have examined the relationships between classification variables (business size, sector) and a few dimensions of innovation activity such as collaboration and novelty and type of innovation and novelty (DITR 2006, ABS and DITR 2006). Modes can reveal a lot more than these methods about how firms innovate and the intensity of innovation activities, particularly by sector and firm size within a country.

It is not possible to construct examples of the innovation modes developed by Bloch *et al* (2008) for Australia because several key variables, while collected in the ABS 2003 survey, are not included in the CURF microdata available to the public. Consequently, we use microdata from the AIRC Tasmanian Innovation Census (TIC) to demonstrate the potential value of modes as system metrics and make recommendations on constructing composite indicators using the ABS data.[20]

20   The Tasmanian Innovation Census (TIC) surveyed all Tasmanian firms with five or more employees, across all business sectors, on their innovative activities. The survey focuses on the development and implementation of new products, production processes, organisational methods and marketing methods. Responses were received from 1,591 firms out of 2,807 eligible firms, for a response rate of 56.7%. The TIC questionnaire was administered using Computer Assisted Telephone Interviews and was conducted in 2007, covering innovation activities between 2004 and 2006.

Output-based modes

Figures 9 and 10 give an example of an output-based innovation mode that follows the description given in Box 2. It was not possible to fully replicate the version given by Bloch and Lopez-Bassols (2009), due to differences between the TIC and the European CIS used by Bloch and Lopez-Bassols.[21]

BOX 2: OUTPUT MODE BASED ON MARKETS

New to market international innovator: Introduced a product innovation that is new to international markets.

New to market domestic innovator: Introduced a product innovation that is new to domestic markets.

International modifiers: Develops innovations in-house, but its innovative products or processes are already available on international markets.

Domestic modifiers: Only operates on domestic markets, products or processes only new to the firm.

Adopters: Firm has no in-house development – it acquires technology from others.

Source: Based on Bloch and Lopez-Bassols, p. 33, 2009.

Figure 9 gives the distribution of innovative firms across the output-based mode described in Box 2 for two broad sectors of the Tasmanian economy: industry and services[22]. Each axis gives the percentage of innovative firms assigned to each modal category, with the sum of all shares in each category adding up to the total share of innovative firms for the relevant sector. As would be expected, there is a higher share of new-to-market international innovators and international modifiers in the more export oriented industry sector, while service sector firms are skewed towards domestic markets.

---

21 Questions 2.2 and 3.2 in CIS-4 ask whether product and process innovations were developed within the enterprise or in combination with other enterprises. The results to these questions are used to identify firms with in-house innovative capabilities. In the absence of these questions in the TIC questionnaire, R&D activity was used as a proxy for in-house capabilities when calculating the output-based modes shown in Figure 9.
22 Services include all sectors other than those in the level 1 'industry' category shown in Figure 7 (all ANZSIC divisions after E).

Figure 9:   Output based innovation modes for two sectors
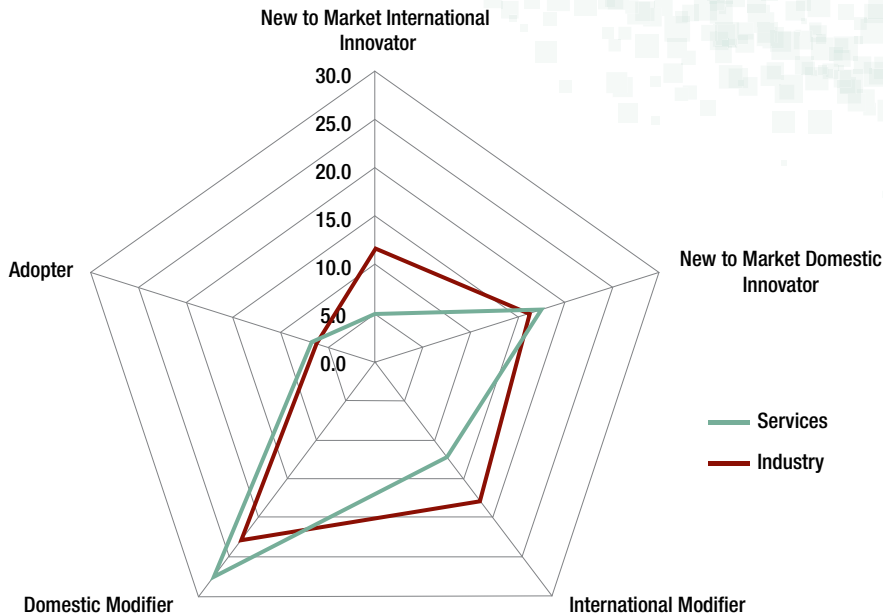
Notes: Industry includes ANZSIC Divisions A to E: agriculture, mining, manufacturing, construction, and electricity, gas, water and waste services. The services sector includes all other industry divisions, based on ANZSIC 2006.

Source: Authors, using the 2007 Tasmanian Innovation Census.

Figure 10 provides results for the output based mode using a more detailed industry breakdown that corresponds to level 2 in Figure 7[23]. Separating manufacturing out from other industrial sectors reveals that the larger share of new-to-market international innovation and modification resides in manufacturing, while domestic modification activity is more important for non-manufacturing industry sectors (agriculture, mining, electricity, gas, water and waste services and construction). Figure 10 limits services to Knowledge Intensive Business Services. This sector group shows a higher share of new-to-market international innovation and international modification than for all services combined.

23   Using three of the five industry categories in level 2 of Figure 7.

The key point here is that generating modes at a finer level of industry detail improves the usefulness of composite innovation metrics. The finer the level of industry classification, the more informative the modes are in terms of identifying the spread and importance of particular types and intensities of innovative activities by sector. This improves the value of these indicators for understanding innovation and consequently their value for policy analysis.

Figure 10: Output based innovation modes for three sectors
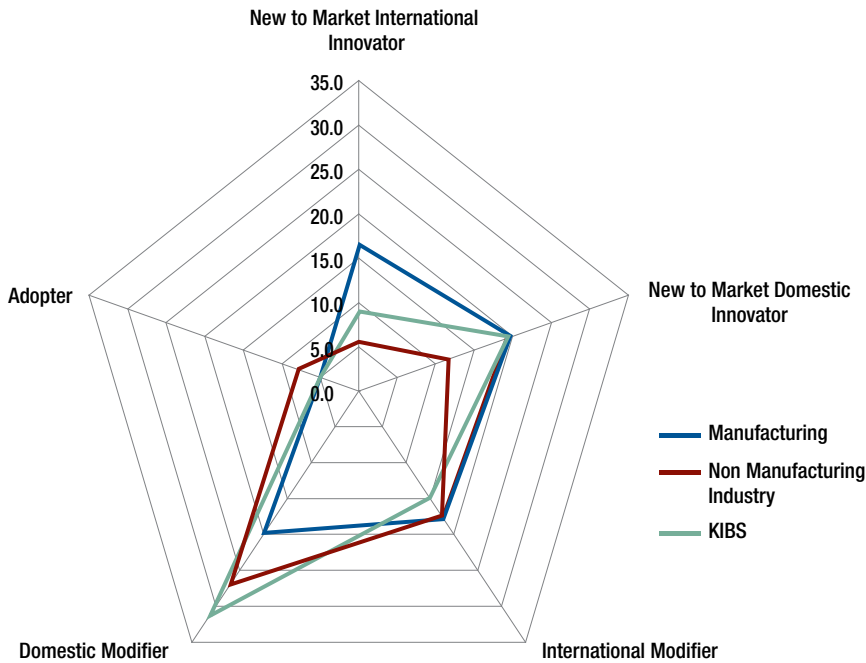
Notes: Manufacturing consists of ANZSIC Division C, non manufacturing includes ANZSIC Divisions A, B, D, and E (agriculture, forestry, fishing, mining, construction, and electricity, gas, water and waste services). The KIBS services sector includes ANZSIC divisions J,K,L,M and N.

Source: Authors, using the 2007 Tasmanian Innovation Census.

Innovation modes can also be generated for other classification variables. Figure 11 provides the output-based mode for different size classes of innovative firms[24]. An interesting point is that for the two modes representing the highest level of innovation intensity (new to market international innovator and international modifier) the share of firms increases monotonically with firm size. Conversely, the share of firms classified to the domestic modifier category decreases monotonically as size class increases. In the remaining two modal categories the share of firms does not track directly with size.

Figure 11: Output-based innovation modes by firm size class
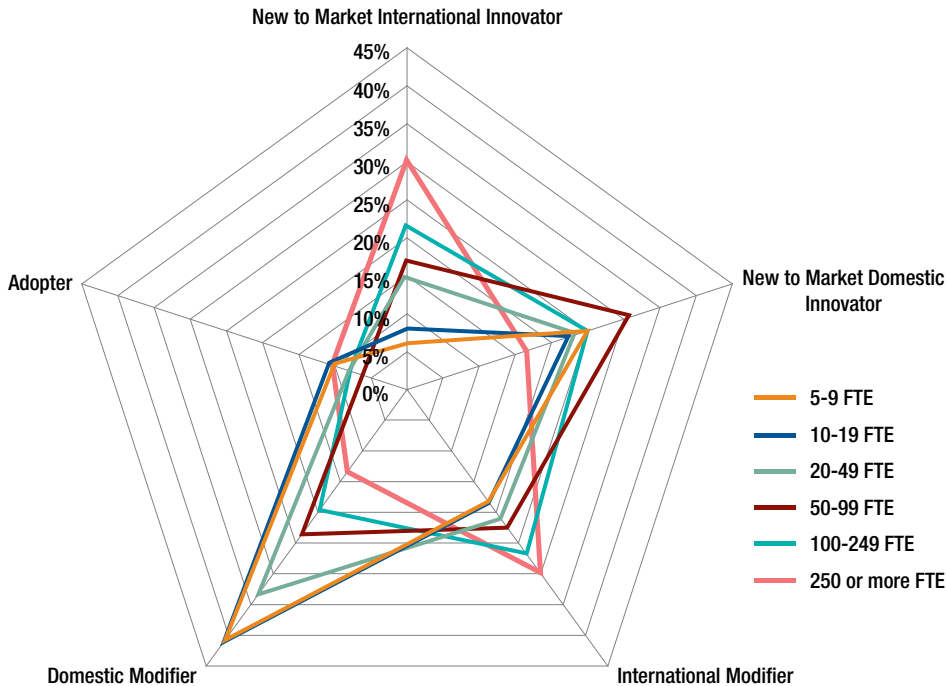
Source: Authors, using the 2007 Tasmanian Innovation Census.

24   The axis points in Figure 11 add to 100%, as the firms in each mode are expressed as shares of innovative firms only, rather than shares of all firms as in Figures 9 and 10.

New sets of modes can also be constructed, creating modal categories of relevance to particular industry sectors or national innovation systems, or of a specific policy interest. As an example Figure 12 presents a simpler output based mode using the four modal categories described in Box 3 below.

BOX 3: ADDITIONAL OUTPUT MODE

International novel innovators: Active in overseas markets and introduced new-to-market product or new-to-industry process innovation.

Domestic novel innovators: No overseas markets sales but introduced new-to-market product or new-to-industry process innovation.

Modifiers: Only new-to-firm innovations but acquired R&D or knowledge from other firms or active in design.

Adopters: Product or process innovator but only reports acquisition of new technology.

Figure 12: Additional output based innovation mode for two sectors
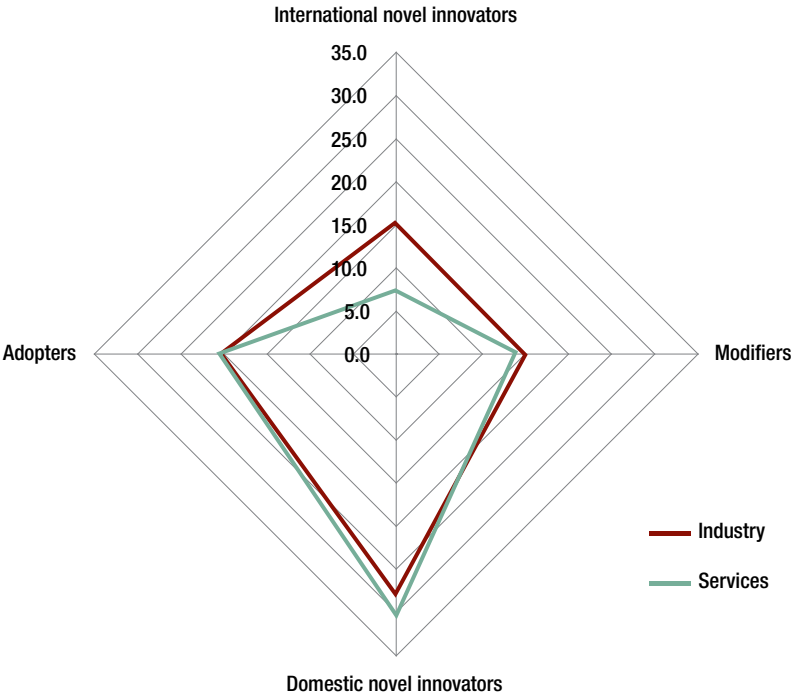
Notes: Industry includes ANZSIC Divisions A to E. The services sector includes all other industry divisions, based on ANZSIC 2006.

Source: Authors, using the 2007 Tasmanian Innovation Census.

Figure 12 shows the distribution of innovative firms for industry and services sectors. Using a simpler mode system shows a slightly different picture than in Figure 9, with greater levels of simple adoption (innovation through simple buying in of technology). Again characteristic differences are further borne out with an additional level of industry detail in Figure 13. There is more international novel innovation in manufacturing and KIBS, with adoption more important for general services and non-manufacturing based industry sectors. Key points of note here are that the type of mode used needs to be carefully considered in relation to the specific innovation characteristics of interest, that various modes need to be generated, tested and analysed to determine those most appropriate for analysis and use, and that new modes can be created to better suit specific analytical purpose.

Figure 13: Additional output mode for four sectors.
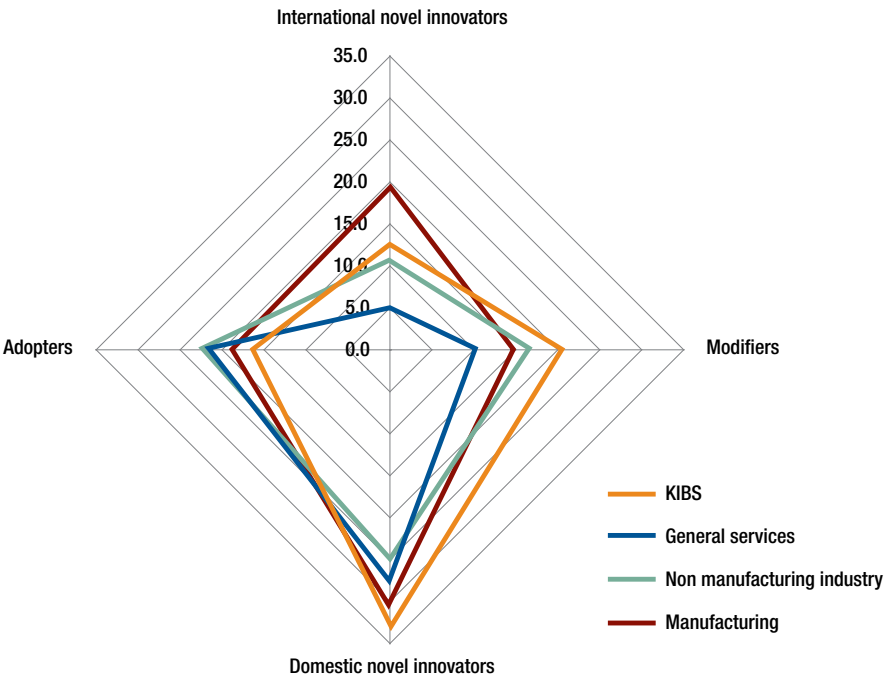
Notes: KIBS includes ANZSIC divisions J, K, L M, N, General services includes F-I, R, S, non-manufacturing includes A, B, D, E.

Source: Authors, using the 2007 Tasmanian Innovation Census.

Input or 'innovation status' modes

Input modes classify firms based on inventive or creative activities (indicated by in-house R&D or patent applications) and diffusion (indicated by collaboration or external involvement in developing product and/or process innovations). An example is a mode for innovation status based on how firms innovate:

• **R&D collaborators** both carry out high-level in-house creative activities and collaborate in their innovation activities.

- **R&D non-collaborators** carry out creative in-house activities, but do not actively collaborate to access external knowledge.
- **Informal collaborative innovators** do not carry out high-level creative in-house activities but they collaborate on innovation.
- **Informal non-collaborators** do not have high-level creative in-house activities, nor do they actively access external knowledge.

The term 'informal' is used to define innovation without high-level creative abilities in-house, as indicated by R&D. The modes are generated using the TIC data[25].

Input modes for how firms innovate are relevant for polices to encourage creative and inventive activities and collaboration. As shown in Figure 14, the manufacturing sector has the highest share of R&D collaborators while informal collaborators are most frequent in the KIBS sector. As with the output-based modes, sector differences become more apparent when using a finer level of industry detail.

Figure 14: Innovation status or input mode for how firms innovate
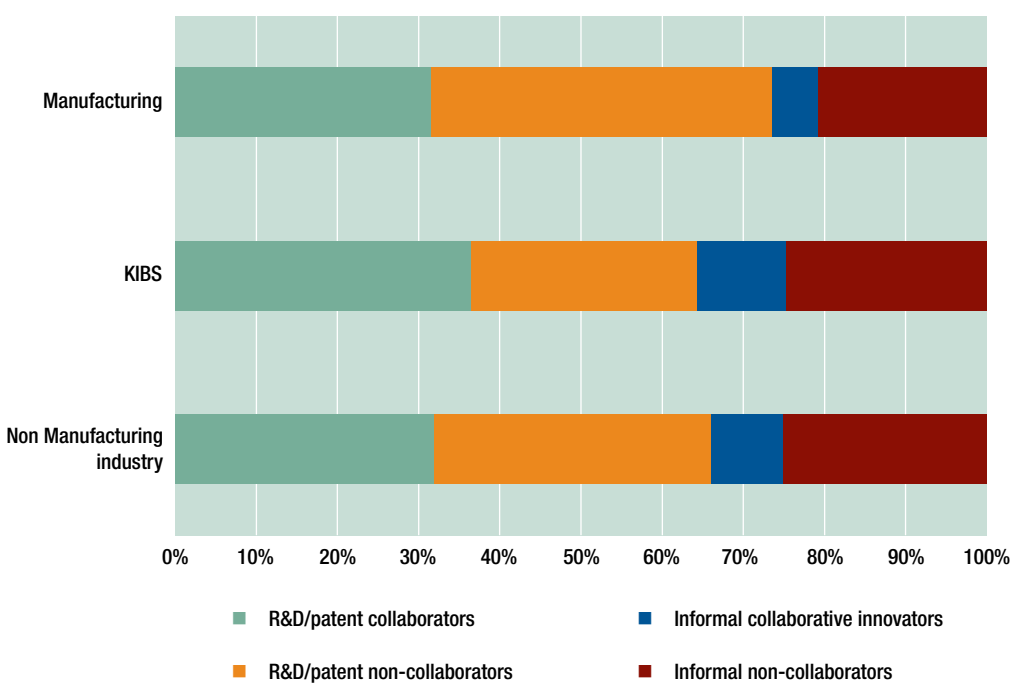
Notes: For sector definitions, see Figure 10.

Source: Authors, using the 2007 Tasmanian Innovation Census.

25 The OECD version defines high-level innovative activity as either R&D or patenting. Collaboration includes firms that develop innovations together with other firms or institutions.

Figure 15 gives the input mode for how firms innovate by firm size class. The level of creative and inventive innovation increases with firm size class, while informal collaboration decreases, with the exception of firms with between 100 and 249 employees. It would also be possible to generate modes using cross classifications (industry/size/location), for example by firm size class within industry sector. This type of more in depth analysis of input modes may be of use in assessing different applications for metrics and for informing policy evaluation and support for creative and collaborative activities.

Figure 15: Innovation status or input mode for how firms innovate by firm size class
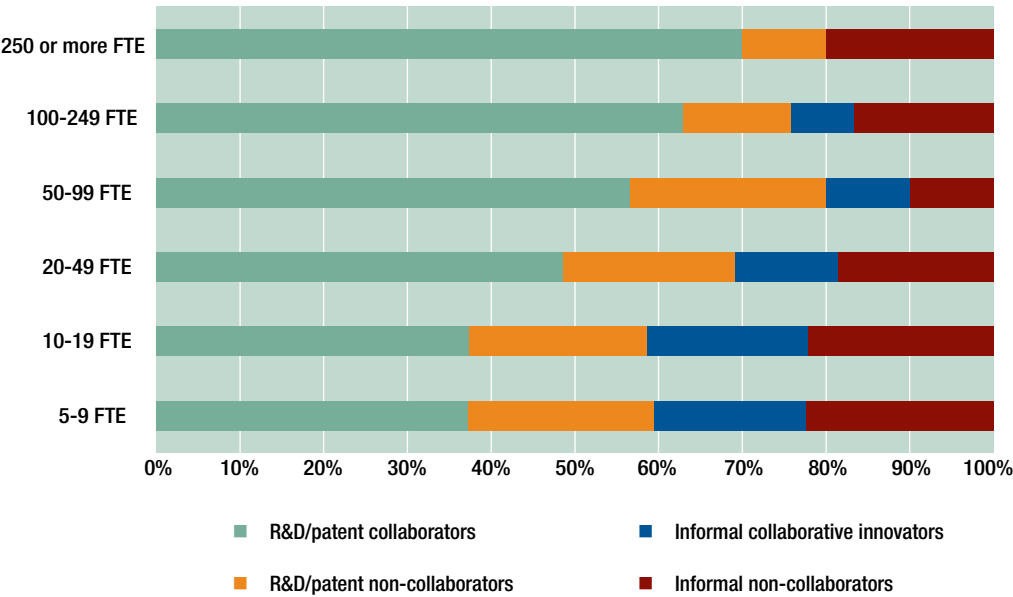
Source: Authors, using the 2007 Tasmanian Innovation Census. FTE = full time equivalent employees.

Dual innovator modes

The 'dual innovator' classification mode has been developed in response to an increasing trend towards services activities in manufacturing sectors and the need to better understand the challenges this presents for firms. It also shows that service sector firms also develop innovative goods. The share of firms with dual (both goods and services) innovations can indicate a shift towards services based innovation in other sectors. Figure 16 shows a relatively large share of dual innovators in manufacturing, as well as in knowledge intensive business services.

Figure 16: Dual innovators
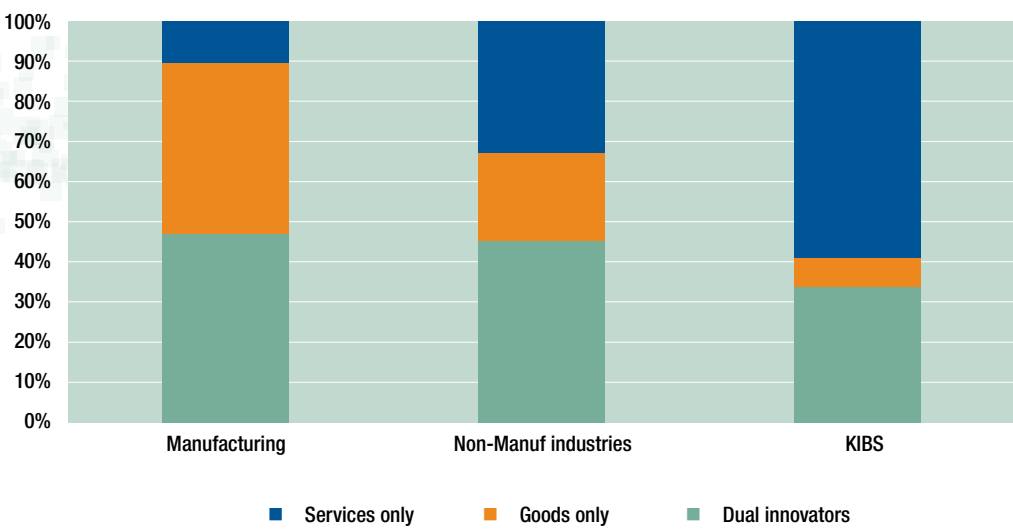
Source: Authors, using the 2007 Tasmanian Innovation Census.

Analysis of dual innovator firms, particularly at the subsector level, could be useful as service innovations (such as those related to supply and value chains) become increasingly important for traditional goods producing sectors such as mining and agriculture. It would be useful to track changes in the share of dual innovators over time.

Modes as metrics for the Australian innovation system

Innovation modes, based on composite indicators, could contribute to a more robust and relevant set of metrics for the Australian innovation system. They can provide a useful picture of differences in how firms innovate across sectors or firm sizes. If produced for consecutive surveys, they could illustrate how innovation activities change over time.

There are a large number of potential methods for calculating output and input modes, in addition to other innovation modes for dual innovators or for technological and non-technological innovators (results not shown). Identifying the most useful innovation modes for Australia requires generating and assessing different options, using ABS innovation survey data.

Most of the CIS4 survey questions that have been used by the OECD to develop innovation modes are included in the ABS innovation surveys. Where relevant questions are missing, it is often possible to approximate the innovation mode using other questions or develop new categories. Table 8 maps the availability of existing ABS data in terms of the requirements for calculating the three types of innovation modes discussed above, plus a fourth mode for technological and non-technological innovators. It is possible to produce all of these innovation modes using the ABS 2006-7 innovation survey data, three modes using the 2003 innovation survey, and two modes from the 2005 and 2007-8 surveys.

TABLE 8: ABS DATA AVAILABILITY FOR INNOVATION MODES

Mode	Survey questions	Survey year			
		2003	2005	2006-2007	2007-2008
Output-based	Source of innovations	Yes	Yes	Yes	No
	Novelty	Yes - ommitted from CURF	Yes	Yes	No
	Exports	Yes - ommitted from CURF	No	Yes	Yes
Innovation status	R&D	Yes - ommitted from CURF	Yes	Yes	No
	Application for Patent	Yes	Yes	Yes	No
	Collaboration	Yes	Yes	Yes	Yes
	Source of innovations	Yes	Yes	Yes	No
Dual innovators	Goods/Services separately	No	No	Yes	Yes
Technological and Non-technological	Product/Process	Yes	Yes	Yes	Yes
	Market/ Organisational	Yes	Not directly, but proxy Q	Yes	Yes

The most useful modes to generate might be the output and innovation status or input modes. Output-based modes could be generated for 2003 and 2006-7, and status based modes for 2003, 2005 and 2006-07. Annex B1 provides examples of how to produce these innovation modes using the ABS 2006-07 survey results.

Innovation modes cannot be constructed without access to ABS microdata. This would require some form of collaborative arrangement between the Department of Innovation, Industry, Science and Research and the ABS. This collaboration could also help to ensure that the necessary questions to construct useful innovation modes and other composite indicators are included in future surveys.

User innovation

User innovation, in the sense of firms altering technology received by other firms, can be measured by adding a sub-question to question 38 in the Business Characteristics Survey. Question 38 asks "Who developed the new goods, services, processes or methods reported in question Questions 33 to 36?". The sub-question, inserted after option a (This business or related company only), would be:

> "This business through customizing or modifying technologies or methods originally developed by other business(es) or institution(s)"

Table 9 summarizes innovation indicators for how firms innovate.

Category	Indicator description(s)	Survey	Source	Last date	Comments
TABLE 9: PROPOSED INDICATORS FOR HOW FIRMS INNOVATE (INNOVATION MODES)					
Output mode	Five mutually exclusive categories ranging from new-to-market international innovators to technology adopters.	Yes	BCS	2007-07	*Composite indicator*
Input 'innovation status' mode	Four mutually exclusive categories based on in-house creative activities by collaborative activities	Yes	BCS	2007-07	*Composite indicator*
Dual innovators	Three mutually exclusive categories for type of product innovation (service innovations only, goods innovation only, both)	Yes	BCS	2007-07	*Composite indicator*
Technological/ non technological innovators	Three mutually exclusive categories for type of innovations: technological product or process only, non-technological (organizational or marketing innovation only), or both	Yes	BCS	2007-07	*Composite indicator*
Technology adopters	Share of firms that innovate only through technology adoption.	Yes	BCS	2007-07	*Composite indicator*
Diffusion	Share of firms that depend on the active diffusion of ideas or technology for innovation.	Yes	BCS	2007-07	*Composite indicator*
User innovation	Share of firms that innovate via customizing or modifying technologies or methods originally developed by other businesses or institutions	Yes	-	-	Q tested IB[1]

BCS: Business Characteristics Survey. Annex B1 gives full descriptions of how to calculate each indicator using BCS data.

1: Innobarometer survey, 2007

5.   KNOWLEDGE FLOW INDICATORS

Innovation builds on existing knowledge. Consequently, innovative performance is linked to the flow or diffusion of knowledge among different actors and the ability of these actors to successfully apply this knowledge to their own innovative activities. The latter is often referred to as 'absorptive capacity'. Knowledge flows occur at the local, regional and state level, throughout a national innovation system, and between national actors and knowledge sources in other countries.

Knowledge flows are often a determinant of *how* firms innovate. For example, firms that only innovate through technology adoption are entirely dependent on obtaining innovations from other firms or from research institutes.

There are multiple characteristics of knowledge flows. The first characteristic is the type of tradable knowledge. Knowledge can be embodied in equipment and materials that firms purchase, or knowledge can be contained in intangible forms such as publications, patents, organizational routines, and in the minds of scientists, technicians and engineers. Intangible knowledge can be acquired through personal contacts, reading the literature or searching patent databases, or hiring skilled employees.

These two types of knowledge are related to two perspectives on knowledge diffusion: the uptake and successful adoption of new technology by firms and by the public sector (embodied technology diffusion), and the diffusion of knowledge itself (disembodied knowledge diffusion), linked to the capabilities to efficiently use this knowledge in innovative activities.

A second characteristic is where knowledge is produced. The two main loci are the business sector (firms) and the public research sector (universities, research institutes and government agencies), but private individuals are also a source of knowledge for innovation. An example is patenting by private inventors. Business sector sources can be further disaggregated into internal sources from other parts of the same firm or enterprise group and into external sources such as customers, suppliers, and consultants. An innovation system needs to enable the flow of knowledge both within these loci and between them (Veugelers, 2007).

The third characteristic consists of the mechanisms that are used to circulate knowledge. Active mechanisms involve personal contacts and include collaborative activities such as co-patenting, co-publishing, and collaborative development of innovations. Passive mechanisms do not require personal interaction and involve accessing open information sources where the information is free or available at a minimal cost. These include scientific and trade journals, patent databases, specialized databases such as for clinical trials, and attending trade fairs.

All of these characteristics are examined in the third Oslo Manual (OECD, 2005, chapter 5). Relevant questions on the type, location, and mechanisms to circulate knowledge have been included in innovation surveys since the 1980s, attesting to the importance given to knowledge flows in current innovation theory.

Open innovation

'Open innovation', a concept popularized by Chesbrough (2003), concerns knowledge flows as well as enabling conditions, such as the use of intellectual property to support trading knowledge. The concept fits in with the long history of empirical research on the importance of knowledge flows to the innovative activity of firms. For example, the SAPPHO study of the early 1970s found that links 'with the outside scientific and technological community' and the 'use of outside technology to help production' were important determinants of successful innovations compared to unsuccessful innovations in the chemical and instruments sectors (Rothwell *et al.*, 1974). Chesbrough argues that what makes his open innovation model unique in comparison to previous research is that it places sources of knowledge from outside a firm on an equal level with internal sources. Chesbrough uses cases studies of American firms to illustrate his thesis that firms are increasingly adopting 'open innovation' as a business strategy. However, case studies often fail to provide an accurate picture of strategies across all firms and sectors (if they did representative surveys would not be necessary).

Knowledge sourcing strategies

Since the SAPPHO study by Rothwell *et al.* (1974), there have been many other empirical studies on the strategies that firms use to obtain external knowledge and the effect of knowledge sourcing strategies on firm performance. The UNU-MERIT database of papers that used the European CIS identifies 32 papers up to the end of 2007 that looked at knowledge sourcing, of which six examined the effects of this activity on performance. The main topics have been innovation cooperation and linkages between firms and the public research sector. The main results of this literature are summarized below.

The knowledge sourcing strategy of firms is constrained by external factors and is not an entirely endogenous choice of firm managers. Instead, sourcing strategies vary by the firm's sector of activity and the type of technology that it uses (Acha, 2007) and by the size of the firm, with small firms more likely than large firms to depend on external knowledge sources, whereas large firms are active in both making and buying technology (Cassiman and Veugelers, 1999).

Although some sourcing of external knowledge improves firm performance, as measured by the share of product sales from new to market innovations and from new to the firm innovations, too much external knowledge sourcing decreases firm performance (Laursen and Salter, 2005). This is as expected, since an over-emphasis on external knowledge could distract firms from identifying and exploiting their own competitive advantages.

The types of external sources that are used by firms also differ by the firm's sector of activity. Tether and Tajar (2008) examined knowledge sourcing from 'specialised knowledge providers' (SKP), consisting of consultants, private research organizations, and public research institutes (universities, and government research institutes). Service sector firms were more likely than manufacturing firms to use consultants, but less likely to use public science, with the exception of technical service firms. One of the determinants of the use of public research institutes was the percentage of science and engineering graduates on staff. Performing R&D increased the use of all types of specialized knowledge providers.

In the Australian context, specialized knowledge providers could play an important role, particularly for innovative firms that do not perform R&D. Both specialized knowledge providers and the public research sector could provide the main conduit to technology and knowledge developed outside Australia.

An Australian study (DITR, 2006) used the results of the 2004 Australian innovation survey to examine the effect of innovation cooperation on innovation novelty. Firms that collaborated on innovation, or used several different types of collaborative agreements[26], had a higher probability of introducing a 'new to the world' innovation compared to firms that did not collaborate or used only one type of collaborative agreement. In contrast, the number of different collaborations[27] had little effect on the probability of introducing a new to world innovation. Small firms consistently benefited more from collaboration than large firms. Very similar results were found for collaboration in Canada.

Knowledge flows from the public research sector

In the last decade, knowledge flows or transfers from the public research sector to firms has received considerable attention, as part of national efforts to improve the rate at which public investments in research are commercialized. Several countries, including Australia, Canada, Denmark, the United Kingdom and the United States have produced indicators of formal technology transfer activities of public research institutes by surveying affiliated technology transfer offices.

Most of the research on knowledge sourcing from the public research sector is based on innovation surveys or on surveys of technology transfer offices (TTO). Landry et al (2007) surveyed 1,554 university researchers funded by government research grants in Canada. The respondents reported more 'non commercial' than commercial knowledge transfer activities, but no information is available on whether or not these activities led to innovations. The most important factors in explaining knowledge transfer was the frequency of the researcher's personal contacts with private firms, government, and industrial associations and a reported 'focus on user needs'. Publications were also positively correlated with self-reported knowledge transfer activities.

5.1   INDICATORS FOR KNOWLEDGE FLOWS

Key areas for indicator development for knowledge flows include collaboration, knowledge flows from the public research sector to firms, and knowledge flows that connect Australian firms and universities to knowledge produced outside of Australia. Many of these key areas can be directly influenced by policy, such as through subsidies for collaborative research or funding of the public research sector.

Indicators on knowledge flows have been constructed using traditional indicators such as patents and bibliometrics, innovation surveys of firms, surveys of TTOs affiliated with public research institutes, and from data on human capital mobility.

26   Examples include joint ventures for R&D, joint marketing or distribution agreements, and licensing agreements.
27   This was defined in the paper as collaboration intensity but the number of different collaboration partners is more commonly defined as the *breadth* of collaboration, with intensity referring to the importance of collaboration to the firm.

Patents, bibliometrics, and R&D

All three of these data sources can be used to produce indicators of knowledge sourcing from sources outside of the domestic country or on the impacts of global knowledge chains. Relevant indicators are:

1. The percentage of total domestic business R&D funded from abroad (OECD, 2004).
2. Co-patenting by individuals in different countries. Data are available from the OECD[28].
3. Co-authorship share for international scientific articles. Data are available from the American National Science Foundation for 2005.[29]

A subset of indicators can be created by looking at the innovative activities of firms by domestic and foreign ownership, using three groups of firms: subsidiaries of foreign-owned MNEs, domestic owned MNEs, and domestic firms that are only involved in the domestic market. R&D, patent, or innovation survey data can be used to address questions such as the share of national innovation activity that is due to MNEs (either domestic or foreign owned) and differences in the propensity of domestic and foreign-owned firms to innovate.

One drawback is that innovation surveys do not provide very reliable data on the enterprise group or country of headquarters. This information would need to be obtained from other sources and linked to innovation survey data.

Knowledge sourcing

Many of the indicators from innovation surveys are simple shares, such as the percentage of firms that collaborated with 'clients or customers' or with 'universities or other higher education institutions'. Recent work has been using innovation surveys to construct composite indicators for knowledge sourcing that measure either the *breadth* of external knowledge sources that are used or the *depth* (intensity) with which they are used.

The breadth indicator used by Laursen and Salter (2006) is based on questions on the use of 16 information sources. The indicator varies from 0 (none of the 16 sources were used) to 16 (all 16 sources were used). Their depth indicator incorporates information on the importance of each knowledge source to each firm's innovative activities, with a score of '1' assigned if the firm reports that the source was of 'high importance' and a score of zero otherwise. The depth indicator also varies from 0 to 16.

Similar methods can be used to construct composite indicators for collaboration. Bloch and Lopez-Bassols (2009) suggest using the number of different types of collaboration partners (customers, suppliers, competitors, and specialised knowledge providers) as a measure of the breadth of collaboration. Using the CIS survey, the indicator can be developed for both domestic and international collaboration.

---

28 See OECD Science, Technology and Industry Scoreboard 2007, page 167.
29 National Science Foundation, 2008: Appendix Tables 5-23 to 5-26.

Bloch et al, (2008) propose indicators of passive or 'arms-length' knowledge sourcing and active sourcing. An 'arms-length' use of a source occurs when a firm cites a source as of medium or high importance, but does not report collaboration with the source. In active sourcing, the firm both cites the source as of medium or high importance *and* reports cooperation.

This method can also be used to develop indicators for specific sources, such as suppliers, or for categories of sources, such as market sources (customers, suppliers, or competitors), public research sources (universities or government research institutes), or information sources that are available at low or no cost (publications, journals, attending trade fairs, etc). The results of Bloch et al (2008) for high technology manufacturing, low technology manufacturing, and knowledge intensive service sectors show that most firms that source knowledge from public research sources collaborate, but there is a lot more 'arms-length' sourcing from market sources and suppliers.

User innovation: As noted in Chapter 4, user innovation can be both a method of sourcing knowledge and a form of how firms innovate. Most innovation surveys only include one relevant question, which is the importance of customers as a source of innovation. However, this question does not get to the central characteristic of user innovation because firms could be only identifying customer needs. A one-off survey by Gault and von Hippel, (2009) and a Danish experimental module on user innovation provide ideas for new indicators for user innovation. The Danish module asks firms about their use of data on consumer behaviour, focus groups on customer needs, and interviews with lead users (Bloch, 2008).

Absorptive capacity: One question from the 2008/2009 Global Competitiveness Report goes directly to the issue of absorptive capacity. The question asks if 'Companies in your country are (1 = not interested in absorbing new technology, 7 = aggressive in absorbing new technology)[30]. Australia ranks 17th on this indicator with a score of 5.8, compared to a score of 6.3 for the best performer (the United States). A national indicator of absorptive capacity would need to be supplemented by data at the sector level, as discussed in Chapter 2.

Knowledge transfer from the public research sector

Surveys of technology transfer offices (TTOs) can obtain information on formal methods of knowledge transfer from universities, research hospitals, government research institutes, and other institutions that form part of the public research sector. The methods are formal because they are based on reporting systems and/or contractual relationships with firms. Most surveys follow the American AUTM survey in obtaining data for six statistics: the number of invention disclosures, patent applications, patent grants, licenses executed, and start up firms established and the amount of licensing revenue earned (AUTM, 2008). This data can be converted to indicators at the level of the institution, state or country by adjusting for research effort (R&D expenditures or number of researchers) (Finne et al, 2009). A seventh indicator on the number of research agreements is increasingly added to reduce the emphasis on patented inventions.

30   WEF, Table 3.02, page 467, 2005.

The main drawback to this group of indicators is well known – they fail to capture the effect of the public research sector on innovative activities through non-formal information flows, such as when firms read the scientific literature or develop informal contacts with university staff (Hawkins, 2007). Consequently, it is essential to also draw on innovation surveys for measures of the importance of knowledge produced by the public research sector and the frequency of use.

Mobility of skilled people

Local labour pools of highly skilled people are known to be a major factor behind the development of sectoral clusters of firms and institutions. Under these conditions, knowledge can move from firm to firm through the mobility of skilled experts and scientists and engineers. Some European countries can provide an indicator for job-to-job mobility of employed human resources in science and technology (HRST), but this requires extensive administrative databases[31]. An alternative is to use innovation surveys to collect relevant data, particularly on the movement of people from the public research sector, either on a permanent or temporary basis. Surveys can also identify spin-offs from businesses, including consulting services, which could provide a valuable route to sharing knowledge. An example of such an indicator is included in Chapter 6 on entrepreneurship.

If a direct measure of physical mobility is desirable, it might be worth either 1) surveying a random sample of research staff to determine the frequency of physical mobility (for instance if they temporarily took up a position within a firm in the previous five years) or 2) determining if Technology Transfer Offices can answer such a question.

Mobility has a negative side: highly skilled people can leave a country, or too much mobility could be economically inefficient. The WEF has a relevant 'brain drain' indicator for the impact of the first negative factor. The question asks 'Your country's talented people (1 = normally leave to pursue opportunities in other countries, 7 = almost always remain in your country). The higher the WEF score, the less likely talented people are to leave the country. The United States ranks highest on this indicator, with talented people least likely to go abroad (score of 6.1). Australia ranks 38th, with a score of 4.1.

5.2   KNOWLEDGE FLOW INDICATORS FOR AUSTRALIA

Table 10 summarizes the types of knowledge flow indicators for innovation that can be constructed to capture knowledge flows from the public research sector to firms and between businesses, both within Australia and with public research institutes and businesses located outside Australia. Indicators in bold font are already available for Australia, although not necessarily on a consistent basis over time. Several of the available indicators do not distinguish knowledge flows by the location of the knowledge or by sector (public research or business). The most comprehensive coverage is for collaboration (using the Business Characteristics Survey). Patent and publication analysis could also produce indicators by location and sector.

31   The indicator is *hrst_mob* in Eurostat's New Cronos database.

Table 10 omits one important form of knowledge flows: between the public research sector, particularly flows between Australian and foreign research institutes or universities. This is omitted from Table 10 because there are few options for constructing relevant indicators, except for analyzing co-publications.

TABLE 10: FRAMEWORK FOR INDICATORS FOR INNOVATION KNOWLEDGE FLOWS				
	Linkages within Australia		Linkages with sources outside Australia	
Type of knowledge / mechanism	Public research sector to businesses	Business to business	Businesses with public research sector	Business to business
Intangible				
Publications	Co-publications	Co-publications	Co-publications (Australia-foreign)[1]	
Inventions	Co-patenting **Patent grants Start-ups Licenses License income**	Co-patenting Licenses	Co-patenting (Australia-foreign)[1]	
R&D	Share of public sector R&D funded by business sector		Share of Australian business sector R&D performed outside Australia Share of Australian R&D funded by foreign organizations	
	R&D contracted out (yes or no)			
Embodied				
Technology acquisition	Yes or no Expenditures			
Mechanism				
Informal (passive)	Use of journals, conferences, industry associations etc. as a source of knowledge			
Informal (active)	Use of market knowledge sources (clients, suppliers, competitors) Use of external consultants, non-profit private research institutes, commercial labs			
Collaboration	With universities, government agencies	With clients, customers, competitors	With universities, government agencies	With clients, customers, competitors
Mobility of highly-skilled individuals			Share of foreign PhDs out of all PhDs working in Australia Number of foreign tertiary and graduate students in Australia that remain after graduation	

1. Possible to calculate separately for the public and business sectors.

Patents, publications and R&D as measures of knowledge flows

Patents and science and engineering publication data can be used to identify co-patenting and co-authorship between Australian inventors or authors and inventors or authors outside of Australia. These relationships measure knowledge sourcing from abroad. The OECD provides the share of Australian EPO patents between 2001 and 2003 with foreign co-inventors (20%). The indicator should also be provided for USPTO and for PCT patents.

In 2005, 41% of the 15,957 Australian publications in science and engineering fields had one or more co-authors located outside of Australia (NSF, 2008, Table 5-24), which is less than the co-authorship rate observed among almost all European countries, with the exception of Greece, and less than in Canada or New Zealand. Indicators of co-authorship should be provided over time and also by scientific field.[32] It is possible that Australian co-publication rates are much higher in fields where Australian scientists need to collaborate to stay at the leading edge of research, such as in medicine, while less co-authorship is required in fields such as agriculture or the environment where the unique characteristics of Australia could reduce the opportunities for collaboration.

The share of total R&D expenditures funded from abroad was less than 5% in 2004 in Australia, in comparison to an average of 10% for the EU-27 in 2005 and 14% in Canada (OECD, 2007, p 169). The indicator is only relevant if R&D funding by foreign MNEs is linked to knowledge transfer. A better indicator for knowledge flows might be the share of R&D by Australian firms that is conducted abroad.

General knowledge sourcing

The 2006-07 Business Characteristics survey can be used to construct useful indicators for the sources of ideas and information for innovation and for cooperation. These include indicators for the use of twelve specific knowledge sources and the share of firms that collaborate with at least one of eleven types of partners located in Australia and with at least one of eleven types of partner located overseas. The latter is a key indicator for bringing knowledge from overseas to Australia.

The Business Characteristics Survey does not collect data on the importance of each type of collaboration partner or information source (Question 42). Consequently it is not possible to calculate a composite indicator for the intensity of collaboration or knowledge sourcing, as used by Laursen and Salter (2006). Conversely, indicators for the breadth of knowledge sourcing or collaboration can be constructed, using the number of different information sources or collaboration partners.

The breadth of knowledge sourcing can range from zero to a maximum of twelve. Breadth indicators can also be calculated based on the use of at least one of four different types of knowledge sources: market based (at least one of clients, suppliers, or consultants), external commercial experts (at least one of consultants, private non-profit research institutes or commercial laboratories), the public research sector (at

---

32   There are seven fields: engineering, chemistry, physics, geosciences, mathematics, biological sciences, and medical sciences.

least one of universities or government agencies), and open information sources (at least one of websites, conferences, or industry associations).

Indicators for the breadth of collaboration for the total number of collaboration partners can range from zero to 22. Separate breadth indicators for collaboration can be calculated for domestic collaboration partners (with a range from 0 to 11) and for foreign collaboration partners (range from 0 to 11).

Knowledge transfer (KT) from the public research sector to firms

The public research sector, consisting of universities and government research institutes, plays an important role in the Australian innovation system and in 2006 was responsible for 39.8% of all R&D expenditures in Australia, above the OECD average of 28.6%[33]. An important policy goal is to improve the commercialization of public research sector inventions by private sector firms.

Several surveys of TTOs affiliated with Australian universities and government research institutes have been conducted over the past decade, such as the National Survey of Research Commercialisation (NSRC), although the last comprehensive survey appears to have been conducted for fiscal year 2003/2004 (CCST, 2005; DEST, 2007). These surveys can provide indicators of formal mechanisms of knowledge transfer[34].

CCST (2005) provides an extensive list of 40 possible metrics that cover inputs, outputs, and outcomes of the public research sector and a list of 14 'core' indicators. Not all are relevant to knowledge flows, five indicators could be difficult for TTOs to provide[35], and two indicators are available in a more accurate form from other sources (number of clinical trials and publications). Table 11 includes seven indicators of knowledge flows that could be obtained from surveys of TTOs.

Six of these seven indicators are widely used internationally (the exception is plant breeder's rights). To improve international comparisons, full definitions for these six knowledge transfer methods and for two denominator variables for calculating indicators are provided in Annex C. The definitions are obtained from a 2009 study for the European Commission on designing comparable metrics for knowledge transfer from public research organizations (Finne et al, 2009).

Indicators on formal knowledge transfer from the public sector via IP or contracts should always be presented with indicators on informal knowledge transfer to prevent biases from an overemphasis on formal transfer mechanisms. Current data sources are not perfect because they do not differentiate between informal and formal methods. The relevant BCS 2006-07 survey questions on sourcing 'ideas and information for the development or introduction of new goods, services, processes or methods' from 'universities or other higher education institutions' and from

---

33 Total R&D expenditures by the higher education and government sectors as a percentage of Gross Expenditures on R&D (GERD) (OECD, 2008c).

34 These surveys have been expensive, with the cost of the 2001/2002 survey estimated at over 400,000 dollars (CCST, 2005), although this included questionnaire development costs. Survey costs should fall considerably with experience and from using a shorter, standard questionnaire.

35 These primarily include data on activities that are not managed by TTOs: 1) research graduates employed in industry, 2) research postgraduate income, 3) research postgraduates employed in spin-outs, 4) new products or services created, and 5) repeat and flow-on business (of low relevance to innovation).

'government agencies' (Question 42) do not differentiate between formal and informal mechanisms. A second question (53) asked respondents if their firm 'collaborated to develop or introduce new goods, services, processes or methods' from 'universities or other higher education institutions', from 'government/public research institutions', and from 'government agencies'.[36] Although the question is limited to formal cooperation, it provides results for a representative sample of firms.

Surveys in Europe and the United States have included questions on the methods that firms use to obtain information for innovation from the public research sector. These questions ask about the importance or frequency with which the firm obtains knowledge from the public research sector via informal methods: 1) publications and technical reports, 2) public conferences and meetings, 3) hiring trained scientists and engineers, 4) informal personal contacts, and 5) temporary personnel exchanges. The results show that informal or 'open science' methods are more widely used and important to firms than formal methods based on contracts, joint research projects, or licensing (Arundel and Geuna, 2004; Cohen et al, 2002). Similar questions could be added to the business characteristics survey as a one-off module.

Mobility of skilled people

Foreign students, particularly at the PhD level, could form an important source of supply for hiring scientists and engineers. It should be possible to construct indicators for Australia on the share of foreign PhD students (ISCED 6) as a percentage of total PhD enrolment and out of science and engineering disciplines. An additional indicator is the number of foreign graduate students (tertiary and graduate level) that remain in Australia after graduation.

A version of the WEF 'brain drain' indicator could be included in innovation surveys, possibly linked to the question on innovation barriers, but this may be a case where the WEF respondents have a better grasp on the mobility of talented Australians abroad than innovation survey respondents, most of whom will represent small firms.

An alternative is to conduct a random survey of researchers in both the public and private sectors and ask if they had switched their sector of employment (from public to private and vice versa) in the previous five years or if they had temporarily worked in the opposite sector.

Table 11 summarizes possible knowledge flow indicators for Australia. Most of these indicators either currently exist or can be constructed from existing data. Nine are composite indicators that could be constructed from innovation data collected by the Business Characteristics Survey. A more complete description of how to construct these composite indicators is provided in Annex B2. Figure 17 provides a schematic representation of knowledge flows for the Australian innovation system. The indicators in Table 11 capture the flows represented by the arrows.

---

36   Neither question was included in the 2007-08 BCS survey.

TABLE 11: PROPOSED KNOWLEDGE FLOW INDICATORS

Category	Indicator description(s)	Data available			Comments
		Survey	Source	Last date	
International collaboration	Co-authorship of scientific publications with authors outside Australia	No	NSF	2005	Reanalyse[1]
International collaboration	Co-patenting by Australian inventors with inventors outside Australia	No	OECD	2001-03	Reanalyse[1]
International collaboration	Percent of Australian firms that collaborate with at least one source outside of Australia	Yes	BCS	2006-07	*Composite indicator*
International collaboration	Percent of Australian firms that collaborate with market based sources outside Australia (one of questions 53a – 53e)	Yes	BCS	2006-07	*Composite indicator*
International collaboration	Percent of Australian firms that collaborate with public research sector sources outside Australia (one of questions 53f – 53h)	Yes	BCS	2006-07	*Composite indicator*
International collaboration	*Breadth* of knowledge sourcing outside Australia (sum of positive responses to questions 53a – 53g): indicator can range from 0 to 11	Yes	BCS	2006-07	*Composite indicator*
Int'l knowledge flows	Share of Business R&D in Australia funded from abroad	R&D	OECD	2004	
Int'l knowledge flows	Share of Business R&D expenditures by Australian firms performed abroad	R&D	ABS[2]	2006-07	
Knowledge sourcing (location not specified)	*Arm's length knowledge flows:* Positive answer to the use of a specific source but no collaboration with the source reported. For instance, BCS 2006-7 question 42f (universities) is positive but 53f (collaboration with domestic and foreign universities) is negative. Seven indicators can be constructed (clients, suppliers, competitors, consultants, universities, private non-profit and government agencies).	Yes	BCS	2006-07	*Composite indicator*
Knowledge sourcing (location not specified)	*Breadth* of knowledge sourcing: number of 13 possible sources used (Question 42a -42m)	Yes	BCS	2006-07	*Composite indicator*

(Continued over)

TABLE 11: PROPOSED KNOWLEDGE FLOW INDICATORS

Category	Indicator description(s)	Data available			Comments
		Survey	Source	Last date	
Knowledge sourcing (location not specified)	Knowledge sourcing from market (any of 42b – 42e, 42i), public research (any of 42f – 42h) and open information sources (any of 42j to 42l).	Yes	BCS	2006-07	*Composite indicator*
Absorptive capacity	Number of positive responses to measures of the firm's in-house innovative capabilities (varies from zero to nine). Reports developing in-house goods, operational processes, organizational methods, new marketing methods (Q 42); reports in-house R&D, training, design and other activities (Q49); and a new question on modifying new technology developed by other firms.	Yes	BCS	2006-07	*Composite indicator*
Absorptive capacity	Indicator for interest by Australian firms in absorbing new technology	No	WEF	2008	
Domestic collaboration	Percent of Australian firms that collaborate with at least one source *within* of Australia	Yes	BCS	2006-07	
Domestic collaboration	Percent of Australian firms that collaborate with market based sources within Australia (one of questions 53a – 53e)	Yes	BCS	2006-07	*Composite indicator*
Domestic collaboration	Percent of Australian firms that collaborate with public research sector sources *within* Australia (one of questions 53f – 53h)	Yes	BCS	2006-07	*Composite indicator*
Domestic collaboration	*Breadth* of knowledge sourcing within Australia (sum of positive responses to questions 53a – 53g): indicator can range from 0 to 11	Yes	BCS	2006-07	*Composite indicator*
KT from public research	Number of invention disclosures	Yes	NSRC	2004	
KT from public research	Number of plant breeder's rights granted[3]	Yes	NSRC	2004	Q modification[4]
KT from public research	Number of technically unique patents granted[3]	Yes	NSRC	2004	Q modification[4]
KT from public research	Number of research contracts and consultancies[3]	Yes	NSRC	2004	

TABLE 11: PROPOSED KNOWLEDGE FLOW INDICATORS

Category	Indicator description(s)	Data available			Comments
		Survey	Source	Last date	
KT from public research	Number of licenses, options and assignments (LOA)[3]	Yes	NSRC	2004	
KT from public research	Total income earned from licenses, options and assignments[3]	Yes	NSRC	2004	
KT from public research	Number of spin-off/start-up companies formed[3]	Yes	NSRC	2004	
KT from public research	Share of firms that obtained useful knowledge for innovation from the public research sector.	Yes	BCS	2006/07	
KT from public research	Share of firms that collaborated with public research sector institutions to develop or introduce innovations.	Yes	BCS	2006/07	
KT from public research	Share of firms that use informal methods of accessing knowledge produced by the public research sector: 1) publications and technical reports, 2) public conferences and meetings, 3) hiring trained scientists and engineers, 4) informal personal contacts, 5) temporary personnel exchanges.	Yes	-	-	Q tested (PACE & CMS)[5]
Labour mobility	Difficulty in retaining talented people in Australia	No	WEF	2008	
Labour mobility	Percent research staff in the public and business sectors that have, within previous five years, switched from one to the other, or had temporary employment in one or the other.	Yes	-	-	Q not tested
Labour mobility	Difference in the number of new migrants with tertiary or graduate degrees minus the number of Australians with tertiary or graduate level degrees that emigrate	No	ABS[6]	2007	
Labour mobility	Share of foreign PhDs out of all PhDs working in Australia	Yes	ABS[7]	2005	
Labour mobility	Number of foreign tertiary and graduate students in Australia that remain after graduation	No	DEEWR[8]	2007	

NSF = US National Science Foundation, BCS = Australian Business Characteristics Survey, KT = knowledge transfer, NSRC = National Survey of Research Commercialisation, WEF = World Economic Forum.

1. Data on publications and patents can be reanalyzed to improve relevance, for example by calculating separate indicators for co-patenting and co-publishing with public and business sector partners or between the public research sector in Australia with research institutions abroad. Data can also be disaggregated by type of technology (patents) or scientific discipline (publications). 2: ABS 8104.0 3. Indicator should be provided per million AUD of research expenditures or per 1,000 research staff. 4: Current question would need to be modified to obtain the exact indicator as described here by including separate questions for plant breeder's rights and patents. 5: The PACE survey (Arundel et al, 2005) was conducted in Europe in 1993 and the CMS (Carnegie Mellon Survey) was conducted in the United States in 1994 (Cohen et al, 2002). 6. ABS 6250.0 has level of highest non-school qualification obtained before arrival for migrants (bachelor degree or higher is the highest category). 7. 6278.0.55.003 includes educational attainment (uses ASCED – 'postgraduate degree' highest education category) and data on migration status. 8. DEEWR award completions data includes tertiary awards by citizenship though no data on remaining after graduation.

See Annex B2 for a full description of how to calculate composite indicators for knowledge flows using the Business Characteristics 2006-07 Survey.

Figure 17: Schematic chart of indicators for knowledge flows
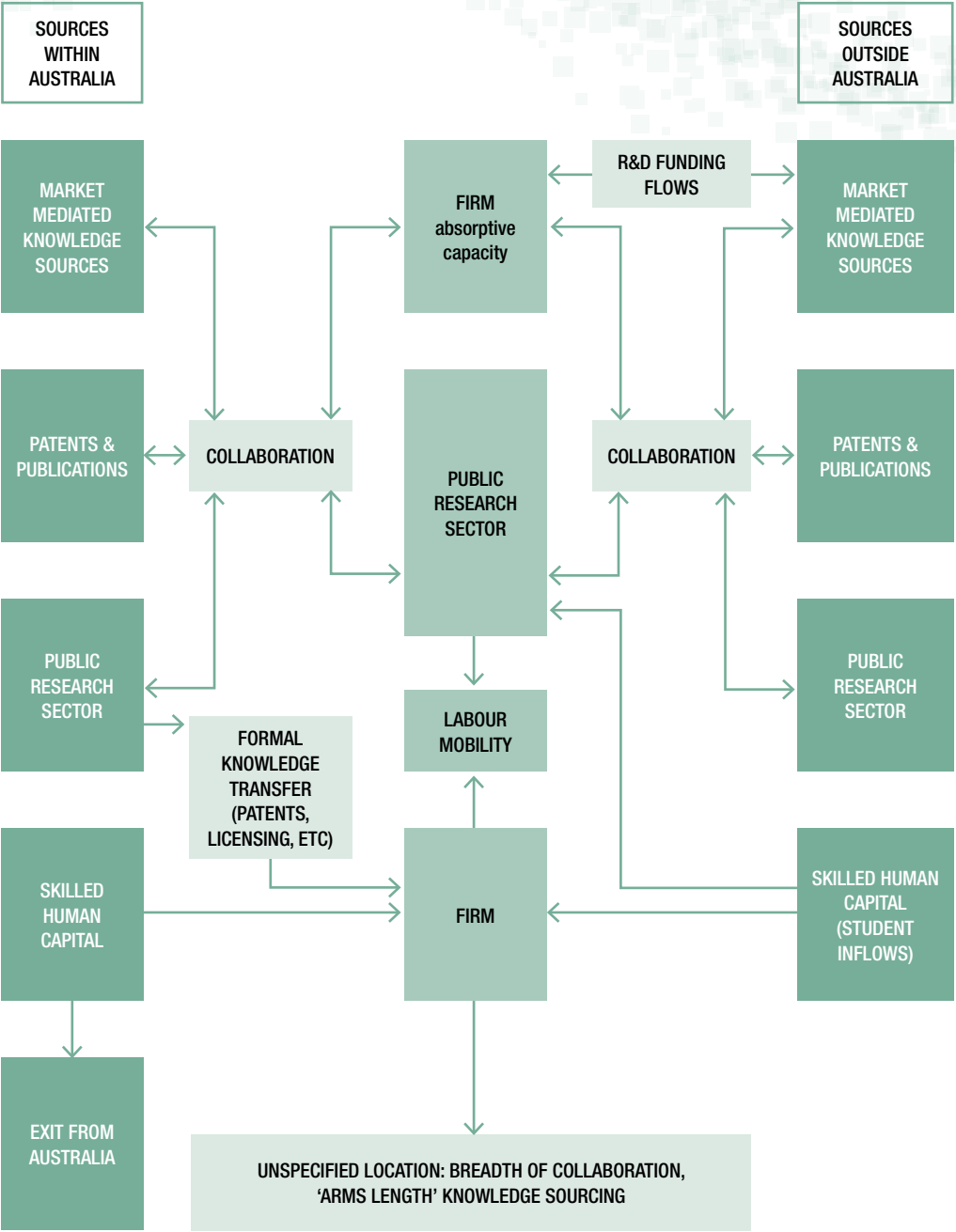
6.   ENTREPRENEURIAL INNOVATION INDICATORS

Entrepreneurial activity involves the founding and early-stage growth of new firms. New firms can be created by individuals or spun off from larger firms or from the public research sector. Entrepreneurship involves individual attitudes to risk, opportunities that reduce risk, receptiveness to new ideas, and access to capital. Entrepreneurship does not need to involve technological innovation, but can be based on franchising or establishing small businesses such as restaurants, hotels, retail stores, B&B accommodation, construction firms, web or consultant services, etc.

Innovation research is primarily interested in the creation of firms that develop new technology, use technology in new ways, for example new business models to exploit the capabilities of the internet, or which are based on new organizational structures. Indicators of entrepreneurship can cover the determinants of new firm formation (access to finance or an entrepreneurial culture of innovation and risk-taking), performance (number of new firm establishments and survival rates), and impacts (job creation and economic growth).

Indicators for entrepreneurship are hampered by the difficulty in separating non-innovative new firms from innovative new firms, or separating the interest of individuals in establishing 'mom and pop' firms from an interest in founding innovative firms. One argument is that all new firms are innovative in some way, but indicators built on this assumption will be of low value, in the same way that an indicator for the percentage of innovative firms is not particularly informative.

Interviews in 2005 and 2006 with 4,928 start-up owners drawn from random sample of approximately 250,000 firms founded in 2004 in the United States highlights some of the problems with identifying innovative entrepreneurship (Ballou et al, 2008). One year after establishment, 63.2% of the firms had one or no employees. Only 2.2% had a patent, although this increased to 4.1% of firms active in high-technology sectors. Only 10 percent of the firms obtained external equity and only 0.6% received venture capital funding, with 90% of firms funded by the owner or family members. Most of the firms were of micro-size and offered consulting or other services. Very few were likely to have been based on innovative business models or to have offered innovative products or services.

6.1   INDICATORS FOR ENTREPRENEURSHIP

There are only a limited number of indicators for entrepreneurship and almost all of them do not focus on innovation. A recent report by the OECD (2008) provides results for eight entrepreneurship performance indicators for 18 OECD countries (no results are provided for Australia), but the results are for all types of new firms, with no separation between innovative new firms and other types of new firms.

Indicators of relevance to innovative entrepreneurship include 1) churn (the sum of the number of firm births and deaths), 2) start-up formation by universities and businesses, 3) fast growing 'gazelles' (firms that are less than 5 years old and with sales growth of 20% per year)[37], 4) venture capital supply, and 5) management training.

Churn

The continual entry of new firms and the exit of established firms that no longer provide competitive advantages, or 'churn', can promote productivity growth. This occurs through the exit of less efficient firms and their replacement by more productive firms. Blanchard (2004) provides data to show that one of the main explanations for the rapid improvement of productivity in the United States versus France in the late 1990s was due to much higher churn rates in the retail sector in the former country.

The disadvantage of churn indicators is that they are not available for innovative firms alone, because of the difficulty in determining if new establishments meet innovative criteria. Nevertheless, the indicator could be useful, since high churn rates are likely to increase the number of innovative new establishments, in addition new firms that lack innovative characteristics.

Spin-off formation

Data have been collected for Australia and for many other OECD countries on the number of start-ups (or spin-offs) from universities and research institutes. This information is simple to collect from Technology Transfer Offices that serve these organizations. Indicators can be constructed from the annual number of start-ups per 1,000 researcher or per million dollars of research expenditures.

The Canadian *Survey on the Commercialisation of Innovation*, 2007 asks private sector firms if 'your enterprise [was] created as a spin-off' (question 27). If yes, the survey asks if it was a spin-off from a university, government agency or laboratory, from another enterprise, or 'other'. Combined with other data on the date of establishment of the firm, the results of this question can be used to identify the prevalence of start-ups, by age, in the private sector.

Gazelles

In addition to the role of entrepreneurship in establishing firms, the policy goal is for these firms to succeed and grow rapidly. Innovation survey data have been used to identify innovative fast-growing firms or 'gazelles'. Gazelles are often defined as SMEs

---

37   Research in Sweden on entrepreneurship takes advantage of the Scandinavian ability to link employer and employee datasets. There is also a cohort study in Germany of start-ups. The first method is unlikely to be feasible in Australia.

in the top quintile of employment or sales growth over the reference period of the innovation survey (three years in Europe and two years in Australia).

It is also possible to identify gazelles by innovation mode or 'highly innovative SMEs', such as fast-growing SMEs with R&D intensities above 5 or 10 percent. An alternative is to develop indicators for different types of innovative gazelles, such as gazelles that score highly on the efficient adoption of new technology. Depending on national and sector conditions, the fastest growing gazelles might be R&D intensive, technology adopters, or possibly firms that rely heavily on knowledge diffusion over in-house creative activities.

Venture capital

Venture capital data are available for most OECD countries, including Australia. A common indicator is venture capital investments as a share of national GDP. The indicator can be limited to investments that are most relevant to the establishment, survival and growth of new firms: seed, start-up, early development and expansion stage venture capital. Most countries also provide venture capital data by business sector, although these are not always comparable across countries. Data for Australia are available at an approximation of the ANZSIC division level, with some further disaggregation, such as for medical/health and biotechnology (Thomson Reuters, 2008). Data by sector permits the construction of venture capital indicators that are limited to 'high technology' and other innovative sectors.

A disadvantage of venture capital indicators is they do not measure the key issue of importance to entrepreneurship, which is the availability of start-up capital. Total venture capital does not provide this measure because a country could have a very high use of early stage venture capital, but if there are a large number of good ideas, a very high percentage of them could fail to receive funding.

The WEF includes an indicator that gets to the heart of the issue. It is based on answers to the question "How easy is it for entrepreneurs with innovative but risky projects to find venture capital (1 = impossible, 7 = very easy). The best performing country, the United States, has a score of 5.1, while Australia ranks 13th with a score of 4.4. This is an exceptional case in which it might be better to obtain data from experienced CEOs for conditions in their country than from managers for their own firm. The latter might either have no experience of the availability of venture capital, or base their evaluation on their own experience, without a realistic appraisal of the quality of their own innovative projects[38].

Management training

Venture capitalists and Technology Transfer Officers at universities and research institutes frequently complain that the problem they face is not a lack of ideas for the formation of innovative new firms, but a lack of experienced managers who can guide the development of a new start-up through to the commercialization of its ideas. The WEF report includes an indicator for the quality of national management schools, but

38   The best option might be to survey the managers of Venture Capital firms about both the availability of capital and the quality of funding proposals.

this does not provide an indicator for the supply of high quality management (partly because managers can be trained in other countries), nor a measure of the supply of entrepreneurial managers. Several options are possible:

1. Survey venture capital firms to obtain data on the supply of suitable managers.

2. Survey universities and research institutes to determine whether or not S&E students take classes on establishing a new business to develop an invention *(this is available for Australia)*.

The Canadian *Survey on the Commercialisation of Innovation, 2007* obtains data on the 'entrepreneur profile' of the firm's entrepreneur or CEO through three questions on the entrepreneur's age, highest level of education (college, bachelors, master's, doctorate and 'other; and training specialization (management, scientific, technical or engineering, sales or marketing, and 'other' (questions 29 – 31). This information can be linked to other data on the firm's size and date of establishment to obtain information on the skills and age of entrepreneurs.

6.2   ENTREPRENEURSHIP INDICATORS FOR AUSTRALIA

Table 12 provides a list of 10 possible indicators for entrepreneurship that could be assembled for Australia. The connections between the indicators are presented graphically in Figure 18. Many of the indicators are available. Two indicators could be produced through data linkage to the results of the Business Characteristics survey, while one indicator would require adding a new question to the Business Characteristics survey. No indicators are proposed for general social and cultural attitudes to entrepreneurship.

TABLE 12: PROPOSED ENTREPRENEURSHIP INDICATORS					
Category	Indicator description(s)[1]	Gov't Survey	Data available		Comments
			Source	Last date	
Enterprise churn	Sum of new entrants and exits of firms	Yes	ABS[2]	2007	
Start-ups established	Number of start-ups from the public research sector[3]	Yes	NSRC[4]	2003/04	
	Number of start-ups in the business sector from an enterprise, a university, and a government agency/laboratory[5]	Yes	-	-	Q tested (Canada) [6]
Gazelles	Number of fast growing innovative gazelles that are SMEs. Can use BCS data to identify innovative firms, but identifying fast growing SMEs requires data linkage to obtain employment or sales data over a two or three year period.	Yes	BCS[6]	2006/07	*Composite indicator*
	Number of fast growing innovative gazelles that are R&D intensive, modifiers, and technology adopters. Requires determining innovation modes and data linkage, as above.	Yes	BCS[7]	2006/07	*Composite indicator*
Venture capital	Total seed, start-up, early development and expansion stage venture capital, plus as a percentage of GDP.	No	Thomson Reuters	2007	
	Total seed, start-up, early development and expansion stage venture capital venture capital investment *by technology field*, plus as a percentage of GDP.	No	Thomson Reuters	2007	
	WEF indicator on ease of raising capital for 'innovative but risky projects'	No	WEF	2007	
Capital availability	Share of new firms (younger than five years) that report 'lack of access to additional funds' for either innovation (Q 55a) *or* other business activities (Q 55b) as a hampering factor. [8]	Yes	BCS	2006/07	
Management training	Number of researchers and research students that take a class on management and the share that have taken such a class.	Yes	NSRC[3]	2003/04	

1. All indicators should be provided for a defined time period. 2. ABS 8165.0. 3. Indicator should be provided per million AUD of research expenditures or 1,000 researchers. 4. National Survey of Research Commercialisation. 5. Denominator can be per capita, per unit GDP, or as a share of all firms. 6. Question 27, Survey on the Commercialisation of Innovation 2007, Statistics Canada. 7: Australian Business Characteristics Survey. 8: Indicators should be provided by firm size class and sector.

Figure 18: Indicators for Entrepreneurship
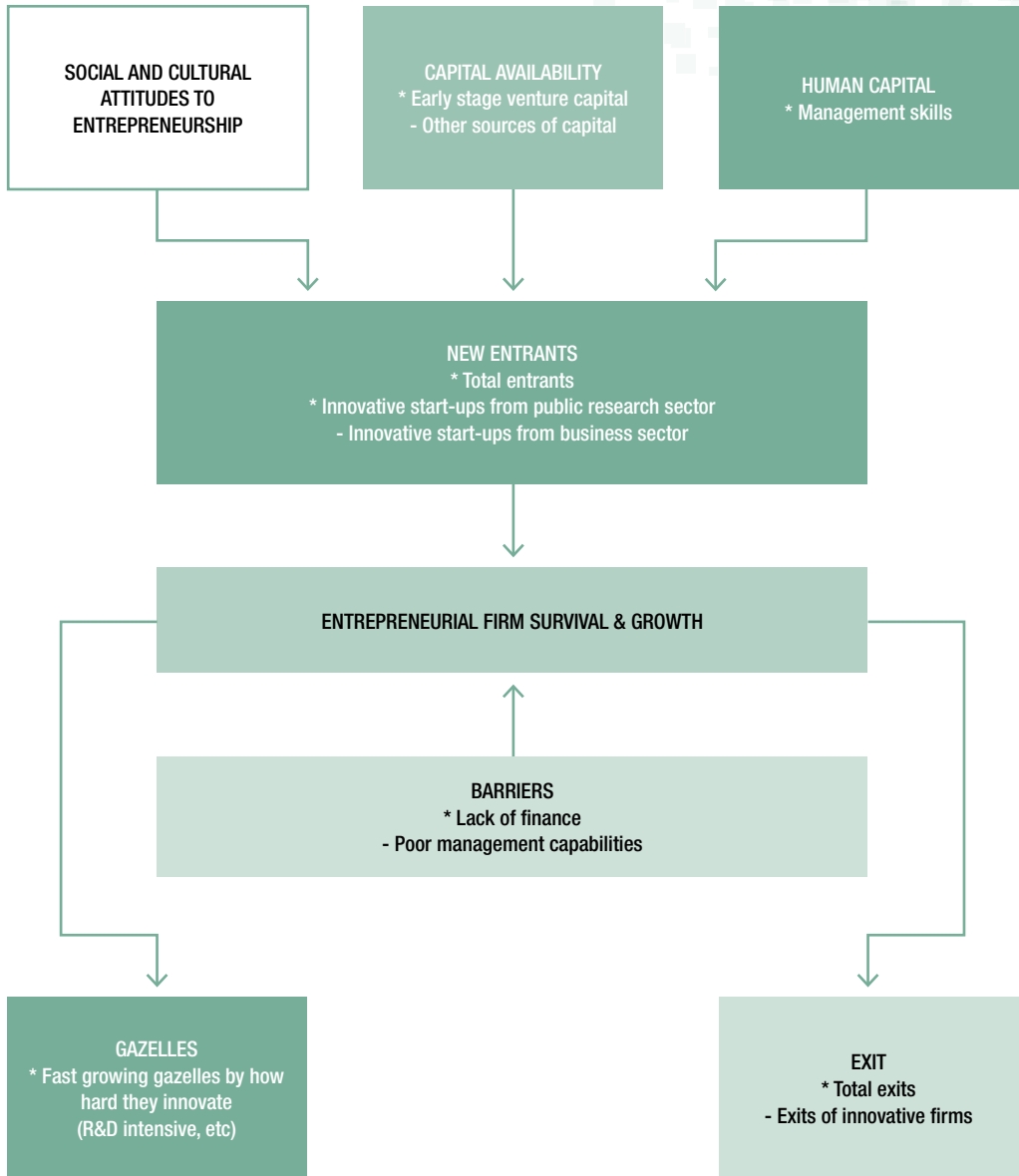
SOCIAL AND CULTURAL
ATTITUDES TO
ENTREPRENEURSHIP

CAPITAL AVAILABILITY
* Early stage venture capital
- Other sources of capital

HUMAN CAPITAL
* Management skills

NEW ENTRANTS
* Total entrants
* Innovative start-ups from public research sector
- Innovative start-ups from business sector

ENTREPRENEURIAL FIRM SURVIVAL & GROWTH

BARRIERS
* Lack of finance
- Poor management capabilities

GAZELLES
* Fast growing gazelles by how
hard they innovate
(R&D intensive, etc)

EXIT
* Total exits
- Exits of innovative firms

Unshaded boxes indicate areas where no innovation indicators are proposed in this report.

* = Indicator available or can be constructed from existing data. Darker boxes indicate greater indicator availability.

7.   DEMAND INDICATORS

In addition to framework conditions such as market competition, economic theory posits that innovation by firms is driven by supply side factors such as scientific research and technological opportunities and demand side factors that provide an economic incentive for investment (Utterback and Abernathy, 1975). Nevertheless, both innovation research and policy instruments focus on supply side factors. Policies to support demand for innovations, such as government procurement, tax incentives, and regulations and standards, are most likely to be implemented when a public good is involved, such as for environmental innovation (Edler and Georghiou, 2007).

Demand for innovative products can be divided into market driven demand and government demand. Market driven demand can be further subdivided by location (domestic and foreign) and by the type of customer (individual consumers or other businesses). In all cases, demand has both quality (buyer sophistication) and quantity aspects (expenditures).

A substantive body of literature argues that sophisticated *domestic* demand or 'lead users' for innovative products is an essential driver of innovation (von Hippel, 1986; Porter, 1990; Beise and Rennings, 2001; Morrison *et al,* 2002). Although there are many examples where this appears to be true[39], firms may be able to overcome a lack of sophisticated domestic markets by developing links with other lead markets with demanding consumers. In small market countries such as Australia, policy can create domestic market demand for innovative products by using the financial power of government procurement, implementing demanding regulations and standards, or by building opportunities for domestic consumer sophistication. An alternative is to help domestic firms to seek foreign lead user markets.

7.1   INDICATORS FOR INNOVATIVE DEMAND

National innovation surveys include several questions of relevance to demand, although none of them measure the importance of sophisticated demand:

1.   The firm's market. Innovation surveys often ask the respondent to indicate which of several markets they are active in: local, national, and international.

2.   The type of customer: governments, other businesses, general public.

3.   Responsiveness to customers or to meet regulations as an innovation objective.

4.   The importance of a lack of demand or uncertain demand for innovative goods and services as a barrier to innovation.

The first question could be used to construct an indicator for the effect of different types of markets on the firm's innovative status. One possibility is that innovative firms active in international markets could be much less likely than firms that are only active in local or national markets to find a lack of demand for innovations to be an important hampering factor. Conversely, local demand conditions could be essential to weakly

---

39   Examples include mobile telephones in Scandinavia, in early use because of large areas without land lines; pump technology in the Netherlands based on the need to pump water from land below sea level, windmills in Denmark due to feed in tariffs that created a market, and the pharmaceutical sector in the United States, due to higher drug prices (Georghiou, 2007a).

innovative firms. If international demand is an important factor, this also suggests using innovation surveys to construct an indicator for the share of firms that are active in international markets.

Lead markets and sophisticated demand

A direct question of relevance to sophisticated demand is used in the Global Competitiveness Report (WEF, 2009), which asks firm managers to rate the sophistication of buyers in their country. The question is: 'buyers in your country make purchasing decisions (1 = solely on the lowest prices, 7 = based on a sophisticated analysis of performance attributes). The leading country for this question is Switzerland, with a mean score of 5.4. Australia is in 19th place with a score of 4.8. The 2009 Innobarometer survey also included a direct question on this topic, with the response options including 'in your country', other European countries, outside of Europe, and 'no notable differences by market area':

> "Firms often think in terms of lead markets, where customers demand or have higher interest in certain innovative features of products or services. Where are your most demanding customers located?"

To produce useful results, the answers to this question need to be linked to a question on the firm's markets. Firms that are only active in a domestic market are unlikely to be able to evaluate the qualities of foreign markets.

Government procurement

Theoretically, procurement could be an effective policy lever to create demand for innovation, if the procurement criteria are demanding and if the demand is large enough (relative to the size of the market) to either spur innovation investment or reward innovators. National innovation survey questions on the type of customer could be used to construct indirect indicators on the effect of different customers (including governments) and innovative capacity.

The 2009 Innobarometer survey determines if firms have experience in responding to a government procurement contract. The results can be linked to another question on the role of procurement in innovation:

> "For a company to be successful in public procurement, do you consider that:
> 1. Low cost is more important than innovation for winning a public tender
> 2. Innovation is more important than low cost for winning a public tender
> 3. Cost and innovation have equal importance for winning public tenders"

Governments can also create demand for innovative products through regulation and financial incentives, for example through product safety standards or carbon cap and trade rules. The WEF indicator for the stringency of regulatory standards in 27 European countries is positively correlated with patent applications at the European patent office, indicating that stringent regulations could drive inventive activity (or at least showing that stringent regulations do not act as a barrier to innovation).

Demand barriers

A lack of demand due to small markets or consumer unwillingness to pay high prices for innovative products or services can act as a major barrier to innovation.[40] A second factor is uncertain demand (the size of the potential market is not known) that increases risk. It would be useful to be able to distinguish between these two types of demand barriers. National innovation surveys usually ask about one or the other.

Demand via capital expenditures

A potential aggregate measure of demand by businesses is Gross Fixed Capital formation (GFCF), which consists of the acquisition of fixed capital by firms and institutions (due to purchases or production by the firm or institution itself) minus disposals (sales, depreciation and losses) of fixed capital. The result gives the change in fixed assets during a given period.

The value of GFCF as a measure of demand for innovative products depends on the reasonable assumption that almost all new capital equipment will contain technical improvements over existing stock. The disadvantage of GFCF is that it includes expenditures that are less likely to be related to innovation, such as investment livestock or dwellings[41] and ownership transfer costs.

The Australian System of National Accounts provides, on an annual basis, two relevant sub-categories of GFCF that are better measures of innovative demand: 1) investment in machinery and equipment and 2) investment in non-dwelling construction (ABS, Series 5204.0, Table 51). Of the two, investment in machinery and equipment is probably a better measure of demand for innovative goods, but investment in non-dwelling construction could also provide demand for innovative construction methods. The data are available for three sectors: private businesses, public corporations, and the general government. Since the government, as the major shareholder in public corporations, could influence purchasing decisions, GFCF by public corporations is listed under government procurement. This assumption may not be valid, however, for all public corporations.

7.2   DEMAND INDICATORS FOR AUSTRALIA

Six indicators of demand for innovation or its effects on innovation activities can be obtained from currently available data sources, as shown in Table 13 and graphically illustrated in Figure 19, while an additional four indicators could be created by including short additional questions in the *Business Characteristics* survey. These indicators should be provided by sector and firm size. An alternative option is to add a module to the *Business Characteristics* survey on demand, with a focus on government procurement and lead users. An example of a possible module is provided in Box 4. Question 5 is also relevant to the concept of user innovation.

---

40   Consumers can include individuals, other firms, or governments. Examples of a lack of demand are common in health care, where additional incentives, such as through orphan drug legislation, have been required to provide an incentive for firms to invest in developing medicines to treat rare diseases.

41   New livestock varieties and innovative dwellings do reach the market, but the rate of innovation for these forms of capital investment is likely to be much slower than the rate of innovation for capital equipment.

Figure 19 also includes a box for the amount and type of competition, but no indicators are proposed for competition because it can both increase and decrease investment in innovation, depending on the structure of each product market. The effect of competition on demand is left here as an undefined framework condition.

BOX 4: SURVEY MODULE FOR INNOVATION DEMAND

1. Public procurement is the purchase of goods and services by local, state, and federal governments and by government funded bodies such as universities, hospitals and schools. In 200x, did your business:

    Investigate applying for a public contract without submitting a bid? ☐

    Apply for a public procurement contract? ☐

    Win one or more public procurement contracts? ☐

    None of the above (go to question 4) ☐

2. For your most recent bid or winning application, did the public procurement tender require your business to provide innovative products or services?

    Yes ☐   No ☐

3. In your opinion, does the selection process for public procurement contracts favour:
    (select one option only)

    Low cost over innovative products or services ☐

    Innovative products or services over low cost ☐

    Both are of equal importance ☐

4. Businesses often think in terms of lead markets, where customers demand or have a high interest in innovative products or services. Where are your most demanding customers located? *(select one option only)*

    Within the state where this business is located ☐

    Elsewhere in Australia ☐

    Overseas ☐

5. In 200x, has your business improved your products or services as a direct result of suggested improvements made by your customers?

    Yes, with minor improvements made. ☐

    Yes, with significant improvements made. ☐

    No ☐

TABLE 13: PROPOSED INDICATORS FOR INNOVATION DEMAND

Category	Indicator description(s)	Data available			Comments
		Survey	Source	Last date	
Lead markets	Share of firms that report "meet requirements of your most demanding customers" as an innovation objective. This question could be added to the BCS survey (2006-07) question 43b.	Yes	-	-	Q tested (IB[1])
	Share of firms that report each type of location for their most demanding customers for innovative products: local, state, Australia, overseas.	Yes	-	-	Partial Q test (BCS)[2]
	National rating for sophisticated domestic customers.	No	WEF[3]	2008	
	Type of most demanding customer: Combine results to a question on the location of the firm's most demanding customers with BCS 2006-07 question 27 on the firm's main type of customer (Government, large businesses, small businesses, general public).	Yes	-	-	*Composite indicator*
Government procurement	Share of firms that report 'meet requirements of a government procurement contract" as an innovation objective. This question could be added to the BCS survey (2006-07) question 43b.	Yes	-	-	Partial Q test (IB[3])
	Total GFCF for machinery and equipment and non-dwelling construction by the general government as a percent of GDP measured in current prices.	No	SNA	2007-08	
	Total GFCF for machinery and equipment and non-dwelling construction by public corporations as a percent of GDP measured in current prices.	No	SNA	2007-08	
	Share of firms that report 'In response to government regulations or standards' as an innovation objective.	Yes	BCS	2006-07	
Barriers	Share of firms that report 'uncertain demand for new goods or services' as a barrier to innovation.	Yes	BCS	2006-07	
	Share of firms that report 'small markets due to high cost of innovative goods or services' as a barrier to innovation.	Yes	-	-	**Q not tested**
Business sector demand	Total GFCF for machinery and equipment and non-dwelling construction by private businesses as a percent of GDP measured in current prices.	No	SNA	2007-08	

1. Innobarometer Survey, 2009, question 14 (EC, 2009). 2. Business Characteristics Survey 2006-07 includes a general market question (Q 26) that could be adapted for querying the location of the firm's most demanding customers. 3. WEF, 2009, question 6-15, page 436. 4. Innobarometer Survey, 2009, question 16e (EC, 2009). NA = national accounts.

Figure 19: Indicators for innovation demand
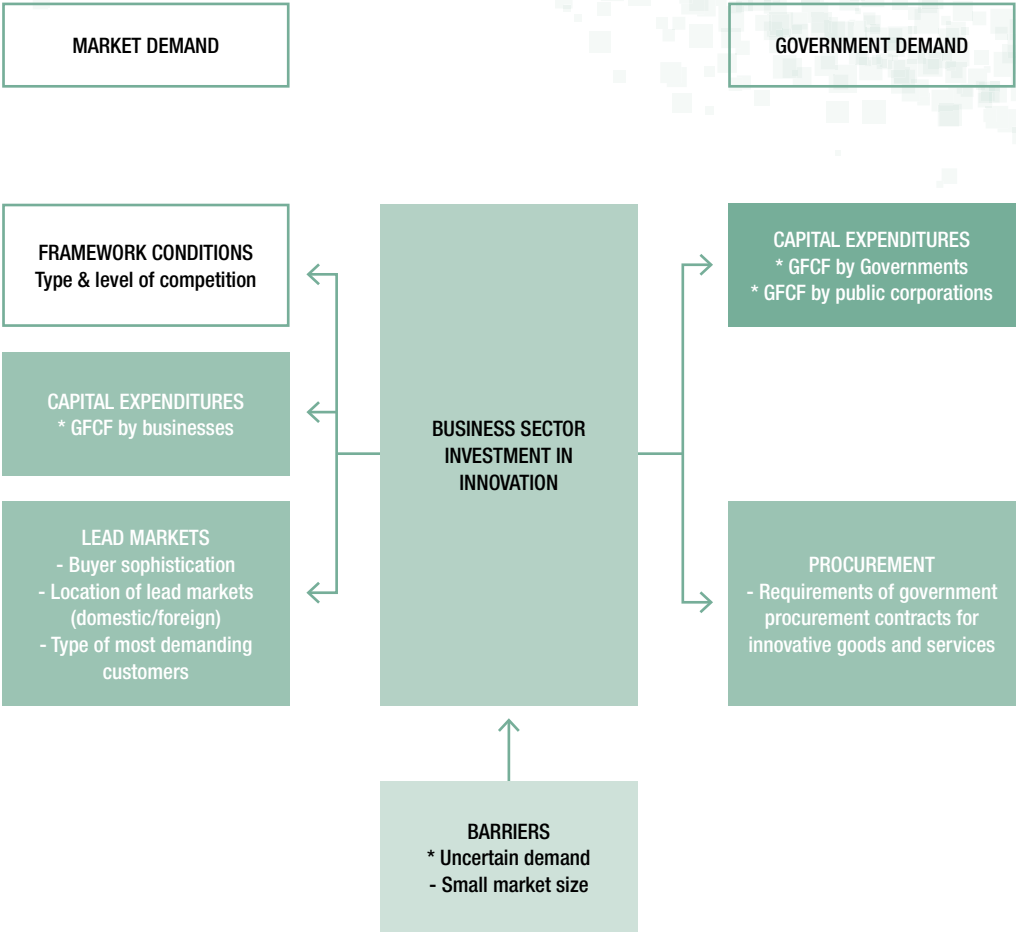
Unshaded boxes indicate areas where no innovation indicators are proposed in this report.

* = indicator available or can be constructed from existing data. Darker boxes indicate greater indicator availability.

8. ENVIRONMENTAL INNOVATION INDICATORS

Environmental innovation can be defined as new or significantly improved products, processes, and business methods that avoid or reduce harmful environmental impacts or which create environmental benefits compared to alternatives.

Relevant environmental indicators include indicators of the innovative activities of the Environmental Goods and Services Sector (EGSS) and indicators of environmentally beneficial innovations in all sectors. Several recent documents review the types of indicators that can be constructed from a range of data sources, including innovation surveys (See Arundel et al, 2006; Arundel and Kemp, 2009; Reid and Miedzinski, 2008).

The EGSS is an artificial sector constructed from four-digit sector classification systems[42]. Eurostat (2007) defines the 'core' EGS sectors as recycling and waste treatment activities: tire recycling, recycling; collection, purification and distribution of water; wholesale of waste and scrap, and sewage and refuse disposal. The 'non-core' EGS sectors include firms that are partly active in environmental services or in sectors that manufacture environmental equipment, such as renewable energy, pollution control technology, environmental sampling, etc. Many of the activities included in the non-core sectors could have dual uses in either environmental or other applications. The accuracy of many environmental innovation indicators is reduced by dual use, with the indicator capturing inventions, innovations, or innovation activities that may or may not be related to environmental innovation.

There are three main benefits from measuring environmental innovation:

1. Benchmark trends in environmental innovation, including shifts in the types of innovations. The past trend has been from end-of-pipe solutions to integrated clean production (Frondel et al, 2004). Data on specific product categories, such as wind turbines or solar energy, are relevant for measuring progress towards specific goals, such as low carbon energy.
2. Identify drivers and barriers to environmental innovation in order to improve incentives.
3. Raise awareness and encourage greater investment by industry and government, through a better understanding of the risks and benefits of environmental innovation.

There is a large economic literature on environmental innovation that, unfortunately, is not matched by a comparable supply of environmental innovation indicators. The main research interest is in the efficiency of different incentive structures, policy and other drivers, and management strategies. Environmental innovation indicators are primarily relevant to the latter two topics: what factors drive firms to invest in

---

42 The OECD defines the EGS sector as "consisting of activities which produce goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco systems. This includes cleaner technologies, products and services that reduce environmental risk and minimise pollution and resource use" (OECD 2005b).

environmental innovation, including regulation, and if clear management strategies in support of environmental innovation improve environmental performance. Both issues were investigated using the German CIS panel data (Horbach, 2006). Positive drivers included regulation, cost savings and if the firm also introduced an organizational innovation. The latter could partly depend on new management strategies.

Indicators of environmental indicators are needed to address three issues:

1. *Drivers and barriers*: Environmentally beneficial innovations can be intentionally developed to meet environmental goals or regulations, or the environmental benefits can be a side-effect of other goals such as cost reduction or product quality improvement. Surveys need to cover both intentional and unintentional environmental innovations and the drivers and barriers of different types of innovations.

2. *How firms eco-innovate*: Many environmental innovations are based on adopting new process technologies and organizational or business methods. Therefore, survey questions need to cover both the development of environmental innovations in-house and their acquisition from other sources.

3. *Outputs*: Positive and negative environmental effects occur during the entire life cycle of a product, from the sourcing of inputs, through manufacture and distribution, to after sales use. Do innovators conduct life cycle analyses of the environmental impacts of their goods and services? What are the environmental, cost, and other effects of different types of innovations? Are the environmental benefits obtained during the production phase or from after sales use of a good or services?

Of note, this report does not include indicators of environmental impacts. These require environmental quality indicators, such as CO_2 production, biological diversity measures, or air quality data.

8.1   INDICATORS FOR ENVIRONMENTAL INNOVATION

Indicators for environmental innovation can be constructed from R&D data, patents and bibliometrics, and innovation surveys. There are also several other secondary sources of environmental innovation indicators.

Environmental R&D

The only consistent data on environmental R&D across the OECD is for government budget appropriations (GBAORD) allocated to 'control and care for the environment' and R&D expenditures on low carbon and renewable energy technologies. Although useful, GBAORD data miss public sector R&D expenditures with environmental benefits in many other fields.

Government expenditures on renewable energy R&D and other forms of environmentally beneficial energy are available from the International Energy Agency (IEA). The most recent data are for 2007, but the last update for Australia was in 2003. There are four relevant categories: energy efficiency, CO_2 capture and storage linked to fossil fuels, renewables, and hydrogen/fuel cells. The renewable group is further subdivided into solar, wind, ocean, bioenergy and geothermal.

Business sector R&D surveys can ask respondents to estimate the share of their firm's R&D expenditures that address environmental concerns. For example, the 2008 business R&D and innovation survey in the United States (US Dept of Commerce, 2008) asks firms:

"What percentage of the domestic R&D performed by your company in 2008 … had environmental protection applications, including pollution abatement R&D?"

The reference to 'environmental protection' and 'pollution abatement' could restrict responses to intentional environmental innovation and end-of-pipe solutions. This is useful, but an additional question on R&D expenditures on projects with some environmental benefits other than protection or pollution abatement would improve coverage[43].

Environmental patents and bibliometrics

Patent counts of environmental innovations can measure research and inventive activity and the direction of research over time. The main difficulty is identifying an 'environmental' patent. This is usually done by assigning all patents in specific IPC (international patent classification) codes as relevant to environmental innovation, such as IPC codes for renewable energy or automobile pollution control patents. This will introduce many inventions with no environmental benefits.[44] Patents are also poor measures of inventions with non-intentional environmental benefits, where the environmental component may be undetectable in standard patent classification systems.

The OECD (2008) provides data for Patent Cooperation Treaty (PCT) patent filings between 2003 and 2005 for renewable energy and automobile pollution control while Johnstone *et al* (2008) provide EPO patent data for renewable energy patent applications between 1978-2003. The advantage of using PCT patent filings is that firms only apply to the PCT if they expect to apply for a patent outside of their home country (an indicator of the expected patent value) and PCT filings avoid the home country bias for patents. Using PCT filings, Australia ranks fifth in the world in the number of renewable energy patents. A more internationally comparable indicator is the number of patents per population or unit of GDP. By the unit of GDP measure, Australia ranked 12th out of 25 OECD countries in EPO patents for all types of renewable energy combined and in fourth place for solar patents (Johnstone *et al*, 2008).

Bibliometric data can be based on the number of publications in specialized environment and ecology journals covering fields such as 'environmental contamination and toxicology', environmental technology', 'water resources research and engineering' and 'environmental monitoring and management' (Reid and Miedzinski, 2008). The disadvantage of bibliometric data is that they often cover research that is far from the market or which has no foreseeable commercial applications.

---

43 The US survey asks a series of question on the share of R&D for different purposes, such as for defense, health, energy and agricultural applications, and by technology, such as software, biotechnology, and nanotechnology. Given the long list of questions, it would be impractical to include several questions on different types of environmental R&D.
44 Agricultural biotechnology patents are a good example. Patents for crop varieties or genes that reduce fertilizer or water use can have environmental benefits, but the same IPC codes that cover these patents will also include many other patents without direct environmental benefits.

Current official innovation surveys

Most official innovation surveys only include one or two questions of relevance to environmental innovation. Questions on innovation objectives or impacts, particularly for product and process innovations, often ask about 'reducing environmental impacts' and 'reducing material or energy use per unit output'. These questions can identify firms that intentionally innovated to reduce environmental impacts and firms that unintentionally created environmental benefits, for instance by recycling heavy metals as part of a cost-saving strategy. However indicators constructed from these two questions alone will only scratch the surface of environmental innovation.

Other survey options

Environmental innovation can be covered in a module added to an existing survey or in specialist surveys. The former option has been used in the most recent European CIS (see Box 5). The questions cover environmental benefits during production and during after sales use, different types of environmental innovation, drivers (regulations, subsidies, market demand and industry codes of practice) and management strategies to identify the firm's environmental impacts.

Management strategies such as the introduction of environmental reports, audits, ISO 14000 accreditation, or management programs to support innovation are common, reported by 49% of 1,581 European firms that had introduced an environmental innovation between 1997 and 1999 (Rennings and Zwick, 2003).

Statistics Canada (2004) surveyed the EGS sector to obtain data on revenues from different types of product sales and services, the sector and location of clients, export revenues and obstacles to developing environmental goods and services.

Specialized surveys on environmental innovation have been conducted in Europe, Canada, the United States and Australia (Arundel and Kemp, 2009). Most of these surveys have fewer than 500 respondents. The focus is often on motivations and drivers for environmental innovation.

BOX 5:   ECO-INNOVATION MODULE OF THE EUROPEAN UNION CIS 2008

10.   Innovations with environmental benefits

An environmental innovation is a new or significantly improved product (good or service), process, organizational method or marketing method that creates environmental benefits compared to alternatives.

- The environmental benefits can be the primary objective of the innovation or the result of other innovation objectives
- The environmental benefits of an innovation can occur during the production of a good or service, or during the after sales use of a good or service by the end user

10.1   During the three years 2006 to 2008, did your enterprise introduce a product (good or service), process, organisational or marketing innovation with any of the following environmental benefits?

Environmental benefits from the production of goods or services within your enterprise	Yes	No
Reduced material use per unit of output	☐	☐
Reduced energy use per unit of output	☐	☐
Reduced CO_2 'footprint' (total CO_2 production) by your enterprise	☐	☐
Replaced materials with less polluting or hazardous substitues	☐	☐
Reduced soil, water, noise, or air pollution	☐	☐
Recycled waste, water, or materials		

Environmental benefits from the after sales use of a good or service by the end user	Yes	No
Reduced energy use	☐	☐
Reduced air, water, soil or noise pollution	☐	☐
Improved recycling or product after use	☐	☐

10.2   During 2006 to 2008, did your enterprise introduce an environmental innovation in response to:

	Yes	No
Existing environmental regulations or taxes on pollution	☐	☐
Environmental regulations or taxes that you expected to be introduced in the future	☐	☐
Availability of government grants, subsidies or other financial incentives for environmental innovations	☐	☐
Current or expected market demand from your customers for environmental innovations	☐	☐
Voluntary codes or agreements for environmental good practice within your sector	☐	☐

10.3   Does your enterprise have procedures in place to regularly identify and reduce your enterprise's environmental impacts? (For example preparing environmental audits, setting environmental performance goals, ISO 14001 certification, etc)

☐ Yes: Implemented before January 2006

☐ Yes: Implemeted or significantly improved after January 2006

☐ No

Source: Eurostat, 2008. Final harmonized CIS-2008 questionnaire

Other environmental innovation indicators

Two alternative indicators are product announcements in the trade literature for environmental innovations and Pollution Abatement and Control Expenditures (PACE). The former is difficult to collect while the latter are limited to only a narrow range of innovations. Consequently they are not discussed here.[45] Trade data for EGS products can be used, but they suffer from the problem of dual use.[46] Venture capital data could be used to produce indicators of investment in environmental firms or technologies, but most venture capital organizations, including for Australia (Thomson Reuters, 2008) do not provide a sufficient level of detail. Accordingly, the European Venture Capital Association (EVCA) is exploring the possibility of producing venture capital data for EGSS firms (Kanerva et al, 2007).

8.2   ENVIRONMENTAL INNOVATION INDICATORS FOR AUSTRALIA

Table 14 summarizes key environmental innovation indicators that are either available or could be produced for Australia while Figure 20 provides a graphic overview of the factors influencing environmental innovation and indicator availability. Indicators are available or could be constructed from existing data for 'Government actions' and for 'Intermediate outputs'. New survey questions are required to obtain indicators for the drivers of and barriers to environmental innovation, business sector inputs, and environmental innovation outputs. This chapter does not provide suggestions for how to collect indicators on all aspects of the environmental innovation system. However, business sector impacts could be investigated by linking environmental innovation data to administrative data on firm sales and exports.

45   Both literature based methods and PACE are discussed in Arundel et al, 2006. PACE data focus on capital expenditures for pollution abatement equipment and do not differentiate between purchases of innovative technology and equipment to expand production.
46   The OECD also produces a list of environmental goods for trade statistics (Steenblik, 2005). Many of the products have dual uses, such as pumps, compressors, filters, centrifuges, valves, kneading machines, etc.

TABLE 14: PROPOSED ENVIRONMENTAL INNOVATION INDICATORS

Category	Indicator description(s)	Data available			Comments
		Survey	Source	Last date	
Publications	Environmental publications[1]	No	Thomson		Analysis required
Gov't research investment	GBAORD expenditures on 'control and care' for the environment[1]	No			-
Gov't research investment	Expenditures on low carbon and renewable energy[1]	No	IEA[4]	2003	-
Business sector research	Share of BERD for environmental research[2]	R&D	-	-	Q tested (US[6])
Invention	Environmental patents (PCT filings)[1]	No	OECD	2005	-
Eco-innovation	Share of firms that report 'reduce environmental impacts' as a main reason for introducing an innovation.[2, 3]	Yes	BCS[5]	2006-2007	-
Organisational eco-innovation	Share of firms that have introduced environmental performance systems; conduct life cycle analysis meeting ISO 14040, meet ISO 14001.[2, 3]	Yes	BCS[5]	2006-2007	-
Eco-innovation drivers	Share of firms that introduced 1) environmental innovations because of regulations, 2) financial incentives, 3) market demand, 4) best practice codes, 5) image, etc.[2, 3]	New	-	-	Q tested (CIS 2008[7])
How firms eco-innovate	Share of firms that developed an environmental innovation 1) in-house, 2) in cooperation with others, 3) obtained from other firms or institutes.[2]	New	-	-	Partial test (BCS[5])
Eco-innovation investment	Total expenditures on 1) environmental innovation, 2) share of environmental innovation expenditures on technology acquisition, R&D, other development activities.[2]	New	-	-	Q *not* tested
Type of eco-innovation	Share of firms that introduced innovations with defined environmental benefits: 1) reduced material use, 2) reduced energy use, 3) reduced CO_2 production; 4) recycling, 5) reduced soil, water, noise or air pollution.[2, 3]	New	-	-	Q tested (CIS 2008[7])
Barriers to eco-innovation	Share of firms that report barriers from 1) high cost, 2) high risk, 3) type of regulation (inadequate long-term incentives), 4) market demand.[2, 3]	New	-	-	Partial test (BCS[5])

1. Indicator should be produced for trends over time; denominator can be per capita or per unit GDP. 2: Indicators should be provided by firm size class and sector. 3: Indicators should be provided by firm innovative capability. 4: International Energy Agency. 5: Australian Business Characteristics Survey. 6. US 2008 R&D survey. 7: European Community Innovation Survey 2008 (environmental innovation module)

Figure 20. Indicators for environmental innovation
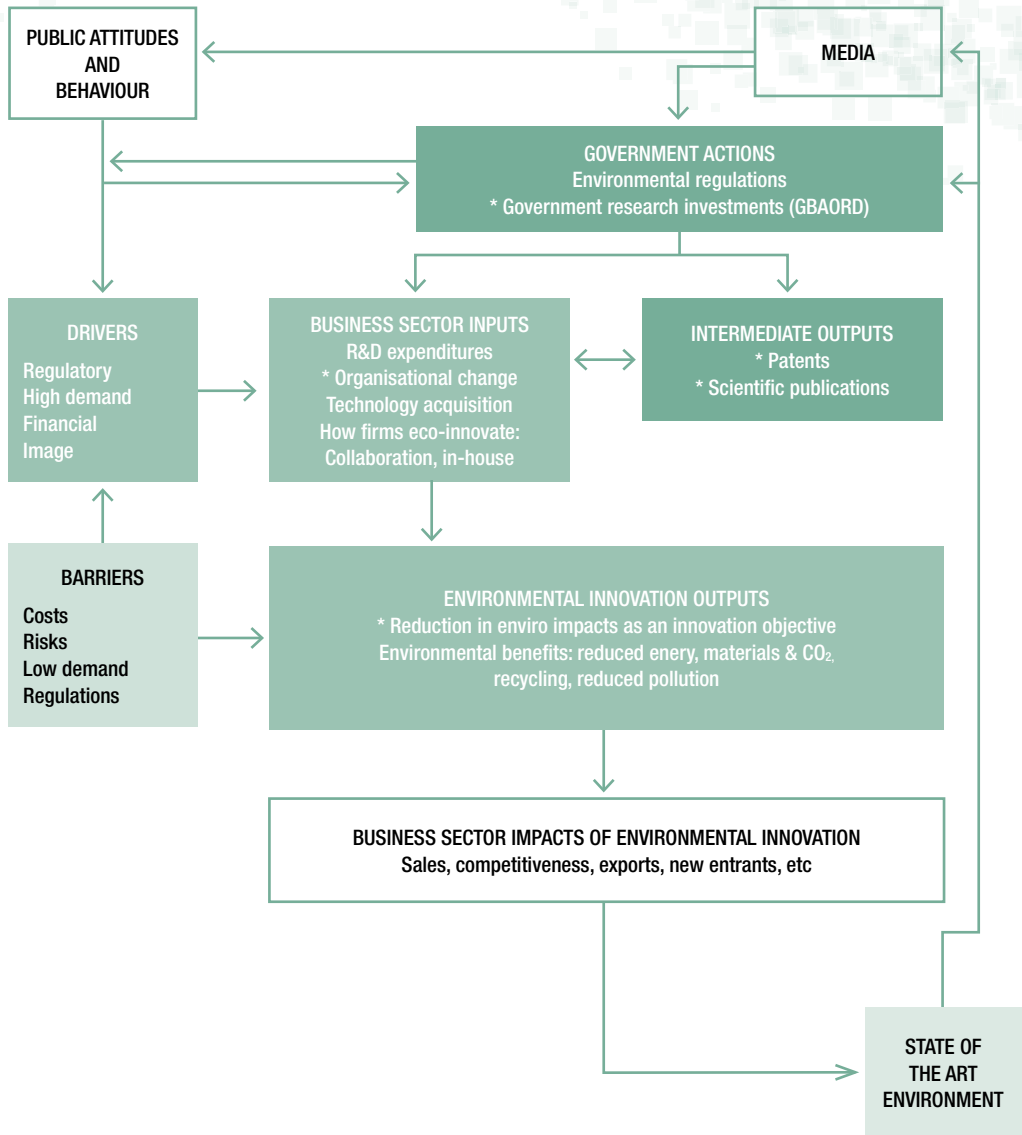
Unshaded boxes indicate areas where no innovation indicators are proposed in this report. However, supplementary indicators could be developed for public attitudes and for business sector impacts. 'State of environment indicators' are available from other sources.

* = indicator available or can be constructed from existing data. Darker boxes indicate greater indicator availability.

PROJECT 1

9. INDICATORS FOR USE OF INNOVATION SUPPORT PROGRAMS

A key policy interest is in the effectiveness of programs to support innovation by firms. Research in this area is often based on surveys of firms that are known recipients of an innovation support program, such as R&D subsidies. A second option is to use innovation surveys to obtain data for all innovative firms on the use of innovation support programs. As noted by Pattinson (2009), a major advantage of the second option is that it includes a comparator group of firms that did not apply for or receive government support for innovation.

Descriptive and econometric analyses of firms that did and did not receive government support can be used to investigate three issues of relevance to the design and administration of these programs:

1. Is innovation support going to firms that can benefit from it? This is an issue of the effective *targeting* of support programs.
2. Does government support *increase* innovative activity or performance?
3. Are public and private sources of funding for innovation substitutes or complementary: does government support for innovation simply cause firms to reduce their own private investments in innovation, or does it lead to *additional* private expenditures on innovation?

Almost all innovation surveys include questions on whether or not the firm received financial support for innovation from different levels of government (local, state, national, or supra-national). A few official innovation surveys collect information on the amount of government support, either in units of currency or as a percentage of total external funding (Statistics Canada, 2008), or on the types of government programs that the firm used (Statistics Canada, 2005; Arundel, 2004). These questions have been used to explore each of the above topics.

The issue of targeting can be explored by using innovation survey data to compare the characteristics of firms that use and do not use government support programs. The best results are likely to be obtained from analyzing data on use of specific types of innovation support programs, although most innovation surveys do not collect this data. Arundel (2004) uses an Innobarometer survey to investigate the frequency of use of eight types of innovation support programs among European innovative firms with different levels of innovative capability. With the exception of subsidies to hire university graduates and innovation advice services, the frequency of program use increases with the innovative capability of the firms. This is an acceptable result if the policy intention is to assist the most capable firms, but it would be a sign of program inefficiency if the goal was to improve the innovative capabilities of less innovative firms.

The second application is to determine if government support for innovation has a positive effect on innovative activity or performance. Criscuolo and Haskel (2002) find that government support in the United Kingdom has no effect on the incidence of process or product innovation while Janz *et al.* (2004) find that Swedish firms that receive government support have a lower sales share from innovative products compared to firms that receive no government support. Other studies find a positive effect of government support on the R&D intensity of Dutch firms (Van Leeuwen and

Klomp, 2006), the probability of introducing a new-to-market product innovation for firms in high-technology sectors in France (Mairesse and Mohnen, 2005), patent applications (Czarnitzki and Fier 2003; Czarnitzki *et al,* 2006, Czarnitzki *et al,* 2007), the sales share of innovative products (Garcia and Mohnen, 2004), and the number of world-first product innovations in Canada (Berube and Mohnen, 2009).

Econometric research on the additionality question usually focuses on R&D investments and assumes that government is an endogenous variable, since governments could be more likely to support successful innovators or innovation performance could be correlated with greater experience in applying for government support (as suggested by the results of Arundel, 2004). These studies find that government support in Germany or Austria does not simply substitute for the firm's own R&D investments but leads to additional R&D (Licht and Stadler, 2003; Czarnitzki and Fier, 2002; Aerts and Czarnitzki, 2004; Garcia and Mohnen, 2004).

9.1   INDICATORS FOR USE OF INNOVATION SUPPORT PROGRAMS

The companion report by Pattinson (2009) evaluates how current Australian data sources, including the *Business Characteristics* survey, can be used to examine the effect of government programs on innovation outcomes, with a focus on R&D tax concessions. The relevant questions from the *Business Characteristics* questionnaire asks if the business received 'any financial assistance from Australian government organizations' for its innovations (question 47) and if yes, if the financial assistance came from the 'federal government' or from the 'state/territory or local government' (question 48). An earlier question that is not limited to innovation assistance asks if the firm had received financial assistance through six mechanisms: grants, ongoing funding, subsidies, tax concessions, rebates, or 'other'.

This Chapter complements Pattinson's report by identifying survey questions and indicators on the *types* of innovation support programs used by firms. The use of eleven different types of programs were queried in either the 2004 Innobarometer survey, the 2007 Innobarometer survey, or the 2005 Canadian Innovation Survey. The eleven program descriptions are as follows:

1. *Advice services* or assistance with business plans, market research, patenting, finding innovation partners, or adopting new technology.
2. Assistance to conduct *market research* for new products or services.
3. Public support for in-house or contracted out *R&D.*
4. Public support for *collaborations* with other firms, universities, or research institutes.
5. Public subsidies for *hiring new university graduates* to support innovation.
6. Public support for *staff training* courses on innovation.
7. Public assistance or subsidies to participate in an *innovation networks.*
8. Subsidies for *technology acquisition* for new or improved processes.
9. Government *venture capital*
10. Subsidies for *buildings or infrastructure*
11. Subsidies to *attend or participate in trade fairs* or missions

Questions on the types of innovation support programs in use permit the construction of three indicators:

1. The percent of all innovative firms that use one or more innovation support programs.
2. The *average policy uptake rate*, or the average percent of firms that use specific programs for which they are eligible. To be eligible, the program must be available and the firm must have innovation activities that could be supported by the program. The 2004 Innobarometer questionnaire determines the firm's eligibility through filter questions. For example, only firms that sent staff to formal training courses are eligible for training subsidies. The average policy uptake rate is calculated for all innovation support policies combined.
3. The *policy uptake rate* for each specific innovation support program.

In the 2004 European Innobarometer survey, the percent of innovative firms that used at least one innovation support program varied between 16% and 58%, while the average policy uptake rate varied between 6% and 21%. The highest policy uptake rate for a specific program category was for training (11%) and the lowest for hiring (3%) (Arundel, 2004).

Ideally, questions on programs or funding methods should cover all available options. A list of program categories should also include examples that are open to firms that do not perform R&D in order to increase the relevance of the questions and to obtain good quality data for the majority of innovative firms that do not perform R&D. As an example, the Innobarometer 2007 survey specifically asked if the firm had obtained support for innovation projects that did and did not require R&D:

Direct support to finance R&D based innovation projects [yes or no]
Direct support to finance innovation projects with no R&D involved [yes or no]

Tax reductions for R&D expenditures [yes or no]
Tax reductions for innovation expenditures other than R&D [yes or no]

Impacts

The main impact issue is if government support leads to additional innovation that would not have occurred otherwise. This can be estimated econometrically. An alternative is to include a direct question. Both the 2004 and 2007 Innobarometer surveys ask respondents about the impact of government programs:

Was public support in the last two years crucial to any of your innovation projects, such that the innovation would not have been developed without the support?

The responses to the 'crucial' question can be linked to the use rates for each program category. This permits the identification of the most useful support policies, defined as the estimated percentage of program users that report each program category of crucial value. The most useful programs in the 2004 Innobarometer survey are support for collaboration (32% of the 'crucial' responses), followed by support for R&D (25%) and innovation advice (14%). The most widely used program, training support, only receives 3.5% of the 'crucial' responses. However, to interpret these results for policy evaluation, it would be necessary to adjust results for the cost of specific program categories, with data on costs obtained from other sources. Training support, for

instance, could be more effective in terms of the number of 'crucial' responses per million dollars of government investment.

The 2004 Innobarometer survey also contained questions on the impacts of innovation support. These are similar to survey questions on the objectives or effects of innovation: reducing the time to innovate, reducing costs, improving quality, reducing risks, and 'no notable effect'.

9.2   INNOVATION SUPPORT INDICATORS FOR AUSTRALIA

Survey questions on the types of innovation support programs used by firms must be limited to innovative activities that are supported by existing programs. Survey questions can either refer to specific innovation support programs by name (such as Enterprise Connect or COMET) or to the function of the support program, such as to subsidize R&D or support collaboration with the public research sector. The second option is preferred for innovation surveys. A single program often covers multiple functions, so only asking about the use of named programs will fail to identify the types of support sought by the firm. For analysis, it is often the function of a program that matters, such as the use of programs to support collaboration. Furthermore, asking about the function of programs could reduce the number of required questions. Many more questions would be required to cover all innovation support programs offered by all levels of government.

Table 15 provides examples of indicators that are relevant to Australia. Many of the questions refer to 'assistance' instead of 'financial assistance' since the firm may not receive a direct financial benefit, such as when it uses advice services.

Many of the indicators listed in Table 15 are based on asking the respondent if their business 'uses' a specific type of program, but it may also be worth asking if they 'considered applying' for a specific program. This would capture the extent to which firm managers are aware of programs that might be of benefit to their business. The proposal to create a composite indicator indicator for the use of innovation support programs that are open to firms that do not perform R&D is of particular relevance to Australia, since 69% of Australian innovative firms do not perform R&D.

TABLE 15: PROPOSED INDICATORS FOR USE OF INNOVATION SUPPORT PROGRAMS BY FIRMS

Category	Indicator description(s)	Data available			Comments
		Survey	Source	Last date	
Innovation advice services[1]	Use of government advice services for business plans, market research, patenting, finding innovation partners, or finding new technology.	Yes	-	-	Q tested (IB[2])
Skills development[3]	Use of government assistance for staff training for your innovation activities.	Yes	-	-	Q tested (IB[2])
Hiring researchers[4]	Use of government assistance to identify or hire researchers from universities or research institutes to work on your innovation projects.	Yes	-	-	Partial test (IB[2])
ICT capacity[5]	Use of government assistance for Information and Communication Technologies (ICT), such as computerization, robotics, and e-commerce.	Yes	-	-	Q *not* tested
Technology acquisition[6]	Use of subsidies to acquire new or improved processes or organizational methods	Yes	-	-	Q tested (IB[2])
R&D[7]	Use of subsidies or tax credits for R&D performed by your business.	Yes	-	-	Partial (IB[2])
Commercialisation[8]	Use of subsidies to help commercialize new technologies or for venture capital.	Yes	-	-	Partial test (Statcan[9])
Business collaboration[10]	Use of government assistance to identify collaboration partners in the business sectors or to assist with collaboration and networking.	Yes	-	-	Partial test (IB[2])
Public research sector collaboration[11]	Use of government assistance to identify collaboration partners at universities or public research organisations or to subsidize collaboration and networking with public sector researchers.	Yes	-	-	Q *not* tested
Impacts	Share of innovative firms that report that government assistance in the last *x* years was crucial to one or more of the firm's innovation projects, such that the innovation would not have been developed otherwise.	Yes	-	-	Q tested (IB[2])
Policy uptake rate	Percent of innovative firms that use one or more innovation support programs (such as above list of nine programs).		-	-	*Composite indicator*
Average policy uptake rate	Percent of all support programs that are used by firms for which they are eligible.		-	-	*Composite indicator*

TABLE 15: PROPOSED INDICATORS FOR USE OF INNOVATION SUPPORT PROGRAMS BY FIRMS

| Category | Indicator description(s) | Data available | | | Comments |
		Survey	Source	Last date	
Uptake rate for non-R&D programs	Percent of R&D performing and non-R&D performing firms that use one or more innovation support programs that do *not* require R&D.		-	-	*Composite indicator*

1. Relevant programs include Enterprise Connect. 2. Innobarometer Survey (2004). 3. Relevant programs include Enterprise Connect and Innovation and Business Skills Australia. 4. Relevant programs include the Researchers in Business Program of Enterprise Connect and the National Research Flagships program of CSIRO. 5. Relevant programs include Small Business Online and Small Business and General Business Tax Break. 6. Relevant programs include the Small Business and General Business Tax Break. 7. Relevant programs include the R&D Tax Credit. 8. Relevant programs include COMET, the Venture Capital Limited Partnerships Program, the Early Stage Venture Capital Limited Partnership Program, and the Innovation Investment Fund. 9. Support for venture capital was included in the 2005 Canadian innovation survey (Statistics Canada, 2005). 10. Relevant programs include Enterprise Connect, the Industry Innovation Councils, Cooperative Research Centres Program, and the Joint Research Engagement Scheme. 11. Relevant programs include several run by CSIRO, the Researchers in Business Program of Enterprise Connect, and the Royal Institution of Australia.

10.   INDICATORS FOR PUBLIC SECTOR INNOVATION

The public sector accounts for between approximately 30% and 50% of GDP within most OECD countries (Koch and Hauknes, 2005) and for 22% of GDP in Australia in 2007-08. Its economic significance, combined with good opportunities for performance enhancing innovation, has attracted academic and policy interest in measuring innovation in this sector. Public sector innovation is defined by Mulgan (2007) as 'new ideas that work at creating public value'. It can include new services, organizational methods, or regulations. Outcomes are measured in terms of efficiency, effectiveness or quality.

Research on innovation in the 'public sector' generally excludes the public research sector, where the output is new ideas and inventions. The main public sector activities of interest concern health, social work, education, culture, and government administration, but the public sector can also innovate in other areas, such as in public and private transport infrastructure and services. An example of the latter is the introduction of congestion charging in London, or the first introduction of mandatory seat belt use in the state of Victoria[47].

---

47   Bloch (2009) notes that some experts believe that politically mandated changes should be not be included as public sector innovations, which would omit significant innovations such as congestion charging, safety regulations, or the establishment of the Open University in the UK in the 1969 to offer distant learning (Mulgan and Albury, 2003; Mulgan 2007). Perhaps the problem is how to exclude changes that are simple reorganisations from innovations with substantial effects on the provision of services or public behaviour.

Organisational or process changes are believed to be particularly important in the public sector, including new models for delivering services or regulatory functions, such as Business Enterprises in Australia (Armstrong and Ford, 2002). A survey in the United Kingdom of 85 government agencies asked respondents to answer questions on up to three recent innovations of their own choosing. The respondents reported 125 innovations, of which 38% improved service delivery, 22% improved services to citizens, and 34% improved performance management (NAO, 2006). One third of the innovations involved new IT or web services. Half did not require any new technology.

As almost all public sector organizations are large, there are enormous opportunities for productivity gains through linking technology adoption, particularly ICT, and organizational innovations. Earl (2004) provides data for Canada showing that a higher percentage of public sector organizations than private sector firms adopt new technology, although there is little difference in the technology adoption rates by the public and private sector for organizations with over 50 employees.

10.1   INDICATORS FOR INNOVATION IN THE PUBLIC SECTOR

There are almost no internationally comparable indicators for innovation in the public sector. The exception concerns the e-economy, such as the percentage of firms and individuals that access public services on-line. These are measured in surveys of firms and individuals rather than surveys of public agencies. Eurostat publishes results for these two indicators for many European countries on New Cronos (indicators polindd2 and polindd3).

Experimental surveys on one or more aspects of public sector innovation have been conducted in Canada (Earl, 2004), France (Statistiques Publiques, 2007), the United Kingdom (NAO, 2006, Audit Commission, 2007) and Korea (MGAHF, 2005). Due to limited knowledge on how public sector organizations innovate, several of these surveys used open ended questions, with respondents able to describe what they believe was an innovation. A collaborative project by the Nordic European countries to develop and test a questionnaire on measuring public sector innovation began in November 2008 and should produce a draft pilot questionnaire by November 2009. A final report, including guidelines for data collection, is planned for 2010 (Bloch, 2009).[48]

To date, there is no agreement on a framework for measuring public sector innovation, or if the Oslo Manual guidelines for measuring private sector innovation can be directly applied to the public sector. The European PUBLIN research project on measuring innovation in the public sector concluded that applying metrics developed for the private sector would not be appropriate, commenting that 'the direct application of any notions of 'private sector' technological or non-technological, product or process innovation to 'public sectors' does not address the key characteristics of any non-private, non-market activities' (Koch and Hauknes, 2005). The opposite perspective is taken by Clark *et al* (2008), who propose adapting private sector innovation surveys for use in the public sector. In either case, it is too early to tell what will work, due to insufficient experience in measuring public sector innovation. The available innovation surveys on the public sector have used questions that were specifically designed for

48   The project website for MEPIN (Measuring Public Innovation) is http://www.mepin.eu/.

public sector organizations. Many of these questions are neither comparable nor similar to questions used in business sector innovation surveys.

The main challenges for developing indicators for public sector innovation are as follows:

1. Survey questionnaires need to be applicable to public organizations that vary substantially in size, the services they provide (such as government administration, health or education) and the level of government (local, state, or national).

2. Identifying who should respond, plus the statistical unit. For instance, should surveys of education cover individual high schools, school boards, or education ministries?

3. How to produce results that are comparable across the level of government and across different types of services.

One approach to avoiding these three problems is to conduct specialized surveys of only one type of service, such as health service organizations or educational establishments. For example, a French survey of hospitals adopts a business methods approach and asks about the use of a variety of technologies and organizational methods that are relevant to health care (Statistiques Publiques, 2007).

General questions that could be applicable to all types of public sector organizations include questions on IT use, involvement in networks, the attitudes of staff to change, the drivers and enablers of innovation, and the use of external sources such as consultants to assist with improvements to services and administrative functions.

Obtaining indicators for public sector innovation will require survey questionnaires that are relevant to all types of public sector organizations and which can be collected regularly over time. This will require a much better understanding of several key components: the types of innovations that are relevant to the public sector, the enablers and barriers to innovation, and how to measure the outcomes of public sector innovation. These are currently not well understood, which has led to exploratory questionnaires that are, by necessity, too long for regular use.

An example of the current lack of knowledge is the large number of survey questions that have been tested on the enablers of innovation. Case study and other research suggest that public sector organizations differ in several important ways from private sector organizations, including the absence of market incentives, a reluctance to fire staff or promote on the basis of merit, and the use of non-financial methods of measuring outcomes. All are thought to make innovation less likely than in the private sector, but there is a lack of knowledge on what does drive or enable public sector innovation. Consequently, the few surveys of public sector innovation ask multiple questions on these 'enablers', including policy changes, staff and management attitudes to change, the methods in use to learn about innovation in similar organizations (the presence of a 'horizon scanning team', for example), and the presence of an innovation 'culture' in the organization. The latter is explored through questions on the presence of a unit responsible for innovation, a mission statement for innovation, or evidence of routines to support innovation. As an example, the questionnaire for the Audit Commission of the United Kingdom (RBAresearch, 2006) includes 32 questions on enablers (Question groups 1, 7a, and 8).

10.2   INDICATORS FOR PUBLIC SECTOR INNOVATION IN AUSTRALIA

Table 16 lists some of the main types of innovation indicators that could be collected for public sector organizations through surveys. The table does not provide further details because of a lack of consensus and experience with measuring public sector innovation. An alternative source of data is to implement a system in which public sector organizations are requested to regularly report innovations to a government agency. This could follow current systems where universities and research institutes report inventions (invention disclosures) to their technology transfer offices.

Data on public sector innovation can also be obtained by asking employees about their working conditions (CEE, 2007). These surveys take a sample of all employed individuals, but because government employment is common, the survey will capture a large number of public sector employees. These surveys can ask about organizational innovation through questions on changes in the use of IT, workplace flexibility and control over work routines, training, and consultation over change. Results for public sector workers can be compared against different types of private sector workers in order to identify differences in how change is managed, its influence on work practices, and the types of organizational or process changes that have been introduced.

TABLE 16: INNOVATION INDICATORS FOR THE PUBLIC SECTOR

1. Enablers

Long-term innovation planning

Mission statements for innovation

Dedicated staff responsible for innovation

Dedicated time to search for innovation ideas

2. Types of innovation

IT / web-based services

Other product or services using new technology

Cost-reducing service innovations

Quality-enhancing service innovations

Administrative: new instruments, regulations, etc.

New organizational forms

Implementation of government policy or directives

3. Implementation methods

Formal 'brainstorming' sessions

Pilot project or small scale trial

Evaluation of similar innovations in use by others

Direct to full-scale implementation

4. Inputs

Expenditures

Number of people involved with implementation

Time required for implementation

5. Sources of ideas/knowledge for innovation

Conferences/seminars on innovation

Networks /contacts with other government agencies

Academic / journal articles

External consultants or experts

Own front-line staff

Own managers

Surveys of or discussions with users of your services

Ministerial level

6. Impacts

Reduces costs

Improves speed or quality of delivery to customers

Offers new or extended services

Improves responsiveness or flexibility

7. Barriers

Costs

Opposition by front-line staff

Opposition by management

Risk of failure

Lack of evidence for efficacy of proposed innovations

Conflicts with regulatory requirements

Lack of an incentive structure to reward success

Lack of trained or experienced staff

REFERENCES

ABS (Australian Bureau of Statistics). Goods and services innovation, by status, employment size, and industry. *Report 81580DO002_200607*, Table 1, August 2008.

ABS (Australian Bureau of Statistics). *ABS Submission to the Review of the National Innovation System*, ABS, Canberra, April 2008.

ABS (Australian Bureau of Statistics) and DITR (Department of Industry, Tourism and Resources), Patterns of Innovation in Australian Business, ABS cat 8163.0, 2006.

Acha V. *Open by Design: The role of design in open innovation*, Department for Innovation, Universities and Skills, London, 2007.

Adams R, Neely A, Yaghi B, Bessant J. Proposal for measures of firm-level innovation performance in 12 sectors of UK industry. *NESTA Innovation Index Working Paper*, September 2008.

Aerts, K. and D. Czarnitzki. "Using innovation survey data to evaluate R&D policy: The case of Belgium", *ZEW Discussion Paper No. 04-55*, 2004.

Archibugi D, Coco A. Measuring technological capabilities at the country level: a survey and a menu for choice. *Research Policy* 34:175-194, 2005.

Armstrong J, Ford R. Public sector innovation and public interest issues. *Innovation Journal*, March 13, 2002.

Arundel A. The Knowledge Economy, Innovation Diffusion, and the CIS. *Proceedings of the 21st CEIES Seminar, Innovation Statistics – More than R&D Indicators*, Athens, April 10-11, 2003, Eurostat, General Statistics, European Commission, Luxembourg, 2003.

Arundel A. The use of innovation support programs by European SMEs: An analysis of the Innobarometer 2004 survey. *2004 Trend Chart Statistical Paper Series*, DG Enterprise, European Commission, Brussels, December 15, 2004.

Arundel A. Innovation survey indicators: What impact on innovation policy? *In Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs*. OECD, Paris, pp 49-64, 2007.

Arundel A, Geuna A. Proximity and the use of public science by innovative European firms, *Economics of Innovation and New Technology*, 13:559-580, 2004.

Arundel A, Hollanders H. EXIS: *An Exploratory Approach to Innovation Scoreboards*, TrendChart, DG Enterprise, March 2005.

Arundel A., van de Paal G., Soete L. I*nnovation Strategies of Europe's Largest Industrial Firms: Results of the PACE Survey for Information Sources, Public Research, Protection of Innovations and Government Programmes*, EIMS Publication 23, Directorate General XIII, European Commission, 1995.

Arundel A, Kemp R and Parto, S. Indicators for Environmental Innovation: What and How to Measure, in Dora Marinova, David Annandale and John Phillimore (Eds), *International Handbook of Environmental Technology and Management*, pp 324 – 339, Edward Elgar, Cheltenham, 2006.

Arundel A and Bordoy C. *Non R&D based innovation: Results of an analysis of the Innobarometer 2007 survey No. 215*, TrendChart, DG Enterprise, Brussels, December 15, 2007.

Arundel, A, Kemp R. *Sustainable manufacturing and eco-innovation: Part IV: Existing methods for macro-level measurement of Eco-innovation*. OECD, DSTI/IND(2009)5/Part4, Paris, 2009.

Audit Commission, *Capacity to innovate questionnaire*, Audit Commission, London, 2006.

Audit Commission, *Seeing the light: Innovation in local public services*, Audit Commission, London, 2007.

AUTM (Association of University and Technology Managers). *AUTM Licensing Survey: FY 2007*, AUTM, Deerfield, 2008.

Backing Australia's Ability: *The Australian Government's Innovation Report* 2004-05, 2005.

Backing Australia's ability 2004; *Inquiries into pathways to technological innovation*, 2005.

Balaguer, A. Unpublished R&D sectoral intensities using data from the OECD STAN database, 2009.

Ballou J, Barton T, DesRoches D, Potter F, Reedy EJ, Robb A, Shane S, Zhao Z. *The Kauffman Firm Survey: Results from the baseline and first follow-up surveys*. Kauffman Foundation, Kansas City, March 2008.

Barlow T. *The Australian Miracle*. Sydney: Pan Macmillan Australia Pty Limited; 2006.

Beise M, Rennings K. *Lead markets of environmental innovations: A framework for innovation and environmental economics*. ZEW, Mannheim, 2001.

Beuzekom van, Arundel A. OECD *Biotechnology Statistics 2009*, OECD, Paris, 2009.

Berube, C, Mohnen P, Are firms that received R&D subsidies more innovative?, *Canadian Journal of Economics*, 42:206-227, 2009.

Bloch C. *Changes and additions to the Danish CIS2006 questionnaire as part of the experimental module on user-driven (or people centred) innovation*. Draft, Centre for Studies in Research and Research Policy (CFA), University of Aarhus, Denmark, 2008.

Bloch C. *Innovation indicators and performance - An analysis for Danish firms*. Danish Centre for Studies in Research and Research Policy, June 4, 2008b.

Bloch C. *Measuring public sector innovation in Nordic countries: Towards a common statistical approach*, DSTI/EAS/STP/NESTI(2009)13, OECD, Paris, 2009.

Bloch C, Mortensen PS, Foyn F, Salte V. *Development and analysis of innovation indicators in the Nordic countries,* Report for NIND (Policy Relevant Nordic Innovation Indicators), Danish Centre for Studies in Research and Research Policy (CFA), University of Aarhus, Denmark, 2007.

Bloch C, Lopez-Bassols V. Innovation Indicators. In *Innovation in Firms: A Microeconomic Perspective*, pp. 21-68, OECD, Paris, 2009.

Bogliacino F, Pianta M. *Innovation performance in Europe: A long term perspective.* Pro Inno, DG Enterprise, February 2009.

CCST (Coordination Committee on Science and Technology). *Metrics for research commercialization.* http://www.dest.gov.au/NR/rdonlyres/E3170A75-79D5-4737-955E-BE41714948E8/16499/FinalMoCReport15April2006.pdf, April, 2005.

CEE (Centre d'Etudes de L'emploi), *Questionnaire for 'Organisational Changes and Computerisation 2006 Workers: Main worker questionnaire*, CEE, Paris, 2007.

Chesbrough H. *Open Innovation.* Harvard University Press, Cambridge, MA, 2003.

Clark J, Good B, Simmonds P. Innovation in the Public and Third Sectors, *Innovation Index Working Paper*, *NESTA,* September 2008.

Cohen WM, Nelson RR, Walsh JP. Links and Impacts: The Influence of Public Research on Industrial R&D. *Management Science*, 48, 1–23, 2002.

Colecchia A. Looking ahead: What implications for STI indicators development? *In Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs*, pp. 285-298, OECD, 2007.

Commonwealth of Australia, *Powering Ideas: An Innovation Agenda for the 21st Century*, 2009.

Criscuolo, C. and J. Haskel, "Innovations and productivity growth in the UK", *CeRiBA discussion papers*, 2002.

Cutler T. *Venturous Australia: building strength in innovation.* Cutler and Company, 204 pp. 2008.

Czarnitzki, D. and A. Fier, "Do innovation subsidies crowd out private investment? Evidence from the German service sector", Konjunkturpolitik – *Applied Economics Quarterly* 48(1), 1-25, 2002.

Czarnitzki, D. and A. Fier "Publicly funded R&D collaborations and patent outcome in Germany", *ZEW discussion paper No. 03-24*, 2003.

Czarnitzki, D., B. Ebersberger and A. Fier, "The relationship between R&D collaboration, subsidies and patenting activity: Empirical evidence from Finland and Germany", *Journal of Applied Econometrics*, *22:* 1347-1366, (2007).

David P, Foray D. Accessing and expanding the science and technology knowledge base. *STI Review* 16: 16-38, 1995.

DEST. *National survey of research commercialization: 2003 and 2004*. August 2007.

DIISR (Department of Innovation, Industry, Science and Research). *Innovation, growth and policy in low and medium tech industries: A review of recent research*. Commonwealth of Australia, Canberra, 2008.

DITR (Department of Industry, Tourism and Resources). *Collaboration and other factors influencing innovation novelty in Australian businesses: An econometric analysis.* DITR, Canberra, April 2006.

EC (European Commission) Innobarometer 2007: Analytical Report. Flash EB Series #215, DG Enterprise, Brussels, http://www.proinno-europe.eu/admin/uploaded_documents/Fl215_Analytical_Report_2007.pdf, January 2008.

EC (European Commission) Innobarometer 2009: Analytical Report. Flash EB Series #267, DG Enterprise, Brussels, http://ec.europa.eu/enterprise/policies/innovation/files/innobarometer_2009_en.pdf.pdf, April 2009.

Edler J, Georghiou L. Public procurement and innovation – Resurrecting the demand side. *Research Policy* 36:949-963, 2007.

Evangelista R, Perani G, Rapiti F, Archibugi D. Nature and impact of innovation in manufacturing industry: some evidence from the Italian innovation survey. *Research Policy* 26:521-536, 1997.

Earl L. Technological change in the public sector, 2000-2002, *Statistics Canada Working Paper 88F0006XIE, No. 008*, Statistics Canada, Ottawa, March 2004.

Eurostat, *Draft compilation guide on environmental sector, version 4*, European Commission, Luxembourg, 2007.

Eurostat. *The Community Innovation Survey 2008: Methodological Recommendations*. Eurostat, Luxembourg, March 4, 2009.

Finne H, Arundel A, Balling G, Brisson P, Erselius J. *Metrics for Knowledge Transfer from Public Research Organisations in Europe: Report from the European Commission's Expert Group on Knowledge Transfer Metrics*, DG Research, European Commission, Brussels, 2009. http://ec.europa.eu/invest-in-research/pdf/download_en/knowledgde%20transfer_web.pdf.

Freeman C, Soete L. Developing science, technology and innovation indicators: What can we learn from the past? *Research Policy* 38:583-589, 2009.

Frenz M, Lambert R. Exploring non-technological and mixed modes of innovation across countries, In *Innovation in Firms: A Microeconomic Perspective*, pp. 69-110, OECD, Paris, 2009.

Garcia, A. and P. Mohnen, *Impact of government funding on R&D and innovation*, UNU-MERIT, mimeo, 2004.

Gault F, Von Hippel E. The Prevalence of User Innovation and Free Innovation Transfers: Implications for Statistical Indicators and Innovation Policy, *MIT Sloan Research Paper 4722-09*, 2009.

Gellatly, G. and V. Peters, 1999. Understanding the innovation process: Innovation in dynamic service industries, *Research Paper Series*, No. 127. Statistics Canada.

Georghiou L. *Demanding Innovation: lead markets, public procurement and innovation*. NESTA Provocation 02, NESTA, London, February 2007.

Graeme D, Jyoti R. *Perspectives on Australia's Productivity Prospects*. Treasury Working Paper 2006-4; September, 2006.

Hansen, P.A. and G. Serin, 1997. Will low technology products disappear? The hidden innovation processes in low technology industries. *Technological Forecasting and Social Change,* 55, pp. 179-191.

Hawkins RW, Langford CH, Sidhu KS. University research in an innovation society, pp 171 – 191. *In Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs*, pp. 171-192, OECD, Paris, 2007.

Hicks D and Hegde D. Highly innovative small firms in the markets for technology. *Research Policy* 34:703-716, 2005.

Hippel E von. Lead users: a source of novel product concepts, *Management Science* 32:791-805, 1986.

Hippel, E. von. *Democratizing innovation: The evolving phenomenon of user innovation. State-of-the-art-article*. MIT Sloan School of Management, 2005.

Hippel, E. von. Democratizing innovation: The evolving phenomenon of user innovation. *In Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs*, pp. 125-138, OECD, Paris, 2007.

Hippel E. von. *Ideas for the NESTA Index Project*, Sept 5, 2008.

Hollanders S. *The sources of increased efficiency: A study of the Du Pont rayon Plants*. MIT Press, Cambridge, Mass., 1965.

Hollanders H, Esser FC. *Measuring Innovation Efficiency*. Inno-Metrics Thematic Paper, DG Enterprise, European Commission, December 2007.

Horbach J. Determinants of environmental innovation: New evidence from German panel data sources. *Fondazione Eni Enrico Mattei Working Paper*, January 13, 2006.

IBM-Melbourne Institute *Innovation Index of Australian Industry*, Melbourne Institute of Applied Economic and Social Research; 2006.

Koch P, Hauknes J. *Innovation in the public sector*. PUBLIN report, NIFU STEP, Oslo, 2005.

Janz, N., H. Lööf and B. Peters, ˝Firm level innovation and productivity – is there a common story across countries?˝, *Problems and Perspectives in Management,* 2, 184-204, 2004.

Johnstone N, Hascic I, Popp D. Renewable energy policies and technological innovation: evidence based on patent counts. *NBER Working Paper Series No. 13760*, NBER, Mass, January 2008.

Jong P de, Hippel E von. Transfer of user process innovations to process equipment producers: A study of Dutch high-tech firms. *MIT Sloan School of Management Research Paper No. 4724-09*, 2009.

Landry R, Amara N, Ouimet M. Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineering. *Journal of Technology Transfer* 32:561-592, 2007.

Laursen K, Salter A. Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms. *Strategic Management Journal* 27:131-150, 2006.

van Leeuwen G. and L. Klomp, "On the contribution of innovation to multi-factor productivity growth", *Economics of Innovation and New Technologies*, 15:367-390, 2006.

Licht, G. and M. Stadler, "Auswirkungen öffentlicher Forschungsförderung auf die private F&E-Tätigkeit: Eine mikroökonomische Evaluation", *Tübinger Diskussionsbeitrag Nr. 256*, 2003.

NESTA. *Hidden innovation: How innovation happens in six 'low innovation' sectors*. National Endowment for Science, Technology and the Arts, London, June 2007.

NESTA. *Total innovation: Why harnessing the hidden innovation in high-technology sectors is crucial to retaining the UK's innovation edge,* National Endowment for Science, Technology and the Arts, London, May 2008.

Mairesse, J. and P. Mohnen, The importance of R&D for innovation: a reassessment using French survey data, *Journal of Technology Transfer*, 30, 2005.

Marsh I, Edwards L. Dilemmas of Policy Innovation in the Public Sector: A Case Study of the National Innovation Summit. In press 2009.

MGAHF (Ministry of Government Administration and Home Affairs), *Government Innovation Index Questionnaire*, Seoul, Korea, December 2005.

Morrison P, Roberts J, Midgley D. The nature of lead users and measurement of leading edge status. *INSEAD Working Papers,* INSEAD, Paris, 2002.

Mulgan G, Albury D. *Innovation in the Public Sector*, Mimeo, October 2003.

Mulgan G. *Ready or not? Taking innovation in the public sector seriously.* NESTA, London, April 2007.

NAO (National Accounting Office), *Achieving innovation in central government organizations*, NAO, London, July 25, 2006.

NSF (National Science Foundation), *Science and Engineering Indicators*, Volume 2, 2008.

OECD. *Oslo Manual: Guidelines for collecting and interpreting innovation data.* OECD, Paris, 1992.

OECD, A Framework for Biotechnology Statistics, OECD, Paris, 2005.

OECD. *Oslo Manual: Guidelines for collecting and interpreting innovation data.* OECD, Paris, 1997.

OECD. *Frascati Manual: Proposed standard practice for surveys on research and experimental development*, OECD, Paris, 2002.

OECD. *Oslo Manual: Guidelines for collecting and interpreting innovation data.* OECD, Paris, 2005.

OECD. *Measuring Entrepreneurship: A digest of indicators*, OECD-Eurostat Entrepreneurship Indicators Program, OECD, Paris, 2008.

OECD. *OECD Compendium of Patent Statistics*, 2008, OECD, Paris, 2008b.

OECD. *Main Science and Technology Indicators (MSTI)*, 2008-2. OECD, Paris, 2008c.

OECD, *The Bioeconomy to 2030: Designing a Policy Agenda*, OECD, Paris, 2009.

OECD. OECD Innovation Strategy – Draft Interim Report, February 4, 2009a, OECD, Paris.

Pattinson B. *Metrics for the Evaluation of Government Assistance Programs*, Draft, Report for DIISR, Canberra, June 2009.

PMSEIC. *Science and Technology-Led Innovation in Services for Australian Industries, A Report for the Prime Minister's Science Engineering and Innovation Council*, Commonwealth of Australia 2007; 2008.

Porter, ME. *The Competitive Advantage of Nations*, Free Press, New York, 1990.

Reid A, Miedzinski M. *Eco-Innovation*. Europe Innova, DG Enterprise, Brussels, May 2008.

Rennings K, Zwick T (Eds). Employment impacts of cleaner production, *ZEW Economic Studies 21*, Physical Verlag Heidelberg, New York, 2003.

Roos G, Fernstrom L, Gupta L. *National innovation systems: Finland, Sweden and Australia compared*. Intellectual Capital Services Ltd, London, November 2005.

Rothwell R, Freeman C, Horlsey A, Jervis VTP, Robertson AB, Townsend J. Sappho updated – project Sappho phase II. *Research Policy* 3:258-291, 1974.

Scott-Kemiss D. Innovation Systems in Australia, *ISRN 6th Annual Conference Working Paper,* Vancouver, May 13-15, 2004.

Smith, K. What is the knowledge economy? Knowledge intensity and distributed knowledge bases. INTECH, *Discussion Paper Series 2002-6*, United Nations University, Maastricht, 2002.

Smith, K. Measuring innovation, in J. Fagerberg, D.C. Mowery and R.R. Nelson (eds.), *The Oxford Handbook of Innovation*. Oxford University Press, pp 148–77, 2005.

Smith, K. *Promoting innovation in Australia: Business and Policy Issues*, Discussion Paper, Australian Business Foundation, Sydney, 2006.

Smith K, Marsh I. Wine and economic development: technological and corporate change in the Australian wine industry. *International Journal of Technology and Globalisation* 3: 224-45, 2007.

Smith K, O'Brien K. Innovation in Tasmania: An innovation census in an Australian State: Australian Innovation Research Centre; 2008.

Smith K, West J. Australia's innovation challenges: building and effective national innovation system. *The Melbourne Review* 1: 15-22, 2005.

Smith K, West J. *Innovation Policy, Productivity and the Reform Agenda in Australia: A Framework for Analysis,* Australian Innovation Research Centre (AIRC), Hobart, January 26, 2007.

Statistics Canada, *Environment Industry Survey, 2004 (Questionnaire),* Statistics Canada, Environment Accounts and Statistics Division, Ottawa, September 3, 2004.

Statistics Canada, *Survey of Innovation 2005 (Questionnaire)*, Statistics Canada, SIEID Division, Ottawa, August 24, 2005.

Statistics Canada, *Survey on the Commercialisation of Innovation, 2007 (Questionnaire)*, SIEID Division, Statistics Canada, 2008.

Statistics New Zealand. *Innovation in New Zealand 2007*. Statistics New Zealand, Wellington, 2008.

Statistiques Publiques, Changement Organisationnels et Informatisation. Conseil National de L'information Statistique, Paris, 2007.

Steenblik R. *Environmental Goods: A comparison of the APEC and OECD lists*, OECD Trade and Environment Working Paper No. 2005-04, OECD, 2005.

Tether B. Identifying innovation, innovators, and innovation behaviours: A critical assessment of the Community Innovation Survey. *CRIC Discussion Paper 48*, UMIST, December 2001.

Tether, B.S., 2004. Do services innovate (differently)? *CRIC Discussion Paper No. 66.* Manchester: University of Manchester, Centre for Research on Innovation and Competition.

Tether B, Tajar A. Beyond university-industry links: sourcing knowledge for innovation from consultants, private research organizations and public science base. *Research Policy* 37:1079-1095, 2008.

Thomson Reuters. The Australian Private Equity and Venture Capital Association Limited: *Yearbook 2008*, 2008.

Tressel, T. Does technological diffusion explain Australia's productivity performance? *IMF Working Paper 08/04*, International Monetary Fund, Washington DC, January 2008.

Utterback J, Abernathy W. A dynamic model of process and product innovation. *Omega* 3:639-656, 1975.

Veugelers R. Developments in EU statistics on science, technology and innovation: taking stock and moving closer to evidence-based policy analysis. *In Science, Technology and Innovation Indicators in a Changing World: Responding to Policy Needs*, pp. 33-46, OECD, Paris, 2007.

Veugelers R, Cassiman B. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. Research Policy 28:63-80, 1999.

van der Wiel H, Creusen H, van Leeuwen G, van der Pijl E. *Cross your border and look around*. Working Paper, Statistics Netherlands, The Hague, November 2008.

World Economic Forum, *Global Competitiveness Report*, 2009.

ANNEX A: INDUSTRY STANDARDIZED R&D INTENSITY

Definition of sector groups for industry standardized R&D

- High-tech sectors:
    - 353 Aircraft and spacecraft
    - 30 Office, accounting and computing machinery
    - 32 Radio, TV and communications equipment
    - 33 Medical, precision and optical instruments

- Medium-high-tech sectors:
    - 31 Electrical machinery and apparatus, n.e.c.
    - 34 Motor vehicles, trailers and semi-trailers
    - 24 Chemicals (including pharmaceuticals)
    - 352+359 Railroad equipment and transport equipment, n.e.c.
    - 29 Machinery and equipment, n.e.c.

- Medium-low-tech sectors:
    - 351 Building and repairing of ships and boats
    - 25 Rubber and plastics products
    - 23 Coke, refined petroleum products and nuclear fuel
    - 26 Other non-metallic mineral products
    - 27-28 Basic metals and fabricated metal products

- Low-tech sectors:
    - 36-37 Manufacturing, n.e.c.; Recycling
    - 20-22 Wood, pulp, paper, paper products, printing and publishing
    - 15-16 Food products, beverages and tobacco
    - 17-19 Textiles, textile products, leather and footwear

- **Services 1**:
    - 50-52: Wholesale and retail trade-repairs;
    - 55: Hotels and restaurants;
    - 60-64: Transport, storage and communications;
    - 75-99: Community, social and personal services.

Sector 64.20 Telecommunications is included in Services 1 because value added data for this sector is not available.

- **Services 2** (KIBS):
    - 65-67: Financial intermediation;
    - 70-74: Real estate, renting and business activities.

For the calculation of R&D intensities, the following sectors have been considered: high-tech , medium-high-tech, medium-low-tech and low-tech manufacturing, electricity, gas and water supply, construction and business sector services. Sectors 1 – 15 (agriculture, fishing, forestry, mining and quarrying) and sectors 75 to 99 (government, education, health, personal services etc) are excluded.

For each sector $s = 1...N$, and each country $c = 1... M$, we have computed the sectoral contribution of this sector to the economy as:

$$SC_s^c = \frac{VA_s^c}{\sum\limits_{s=1}^{N} VA_s^c},$$

where VA_s^c is the value added in country c in sector s.

The average contribution of sector s is defined as follows:

$$\overline{SC}_s = \frac{\sum\limits_{c=1}^{M} SC_s^c}{M}.$$

In order to adjust for industry distribution, for each country, R&D expenditures in each sector s are multiplied by the correction factor

$$\frac{\overline{SC}_s}{SC_s^c}.$$

Finally, the industry-standardized R&D intensity in country c is computed as follows:

$$I_c = \frac{\sum\limits_{s=1}^{N} \left(\frac{\overline{SC}_s}{SC_s^c} \right) X_s^c}{\sum\limits_{s=1}^{N} VA_s^c},$$

where X_s^c are the R&D expenditures of country c in sector s.

ANNEX B: CONSTRUCTING COMPOSITE INNOVATION INDICATORS FROM THE ABS BUSINESS CHARACTERISTICS SURVEY 2006-07

B1: CONSTRUCTING INOVATION MODES

B1.1 OUTPUT-BASED MODES

New to market international innovator: Introduced a product innovation that is new to international markets.

A yes response to the following:

Q26d (Sold goods or services to overseas markets)

Q38a or Q38b (Product or process innovation developed by firm alone or together with other firms)

Q39a (New to the world *goods or services)*

New to market domestic innovator: Introduced a product innovation that is new to domestic markets.

A yes response to the following:

Q38a or Q38b (Product or process innovation developed by firm alone or together with other firms)

Q39b or Q39c (New to Australia/industry but not new to the world *product innovations*)

And a no response to:

Q26d (Sold goods or services to overseas markets)

International modifiers: Develops innovations in-house, but its innovative products or processes are already available on international markets.

A yes response to the following:

Q38a or Q38b (Product or process innovation developed by firm alone or together with other firms)

Q39b or Q39c or Q39d (New to Australia/industry/business *product process innovations*)

And a no response to:

Q39a (New to the world *product or process innovations*)

Domestic modifiers: Only operates on domestic markets, products or processes only new to the firm.

A yes response to the following:

Q39d (New to business product or process innovation)

And a no response to:

Q39a or Q39b or Q39c (New to world/Australia/industry *product or process innovations*)

Q26d (Sold goods or services to overseas markets)

Adopters: Firm has no in-house development – it acquires technology from others.

A yes response to the following:

Q38c (Product or process innovation developed by other firms)

And a no response to:

Q38a or Q38b (Product or process innovation developed by firm alone or together with other firms)

B1.2   INPUT (INNOVATION STATUS) MODES

R&D collaborators both carry out high-level in-house creative activities and collaborate in their innovation activities.

A yes response to the following:

Q49e (Undertook in house R&D) or Q54a (Patent activity)

Q52 (Collaboration) or Q38b or Q38c (Product or process innovation developed by firm alone or together with other firms)

R&D non-collaborators carry out creative in-house activities, but do not actively collaborate to access external knowledge.

A yes response to the following:

Q49e (Undertook in house R&D) or Q54a (Patent activity)

And a no response to:

Q38b and Q38c (Product or process innovation developed by firm alone or together with other firms)

Q52 (Collaboration)

Informal collaborative innovators do not carry out high-level creative in-house activities but they collaborate on innovation.

A yes response to the following:

Q38b or Q38c (Product or process innovation developed by firm alone or together with other firms) or Q52 (Collaboration)

And a no response to:

Q49e (Undertook in house R&D)

Q54a (Patent activity)

Informal non-collaborators do not have high-level creative in-house activities, nor do they actively access external knowledge.

A no response to:

Q49e (Undertook in house R&D)

Q54a (Patent activity)

Q52 (Collaboration)

Q38b and Q38c (Product or process innovation developed by firm alone or together with other firms)

B1.3 TECHNOLOGY ADOPTION ONLY INDICATOR

Firms that innovate through adoption of technology only.

A yes response to:

Q38c (Product or process innovation developed by other firms)

or Q49a or Q49d or Q49g (acquisition of advanced machinery, equipment or technology, acquisition of R&D, acquisition of knowledge).

A no response to:

Q49b Q49c Q49e Q49f Q49g Q49h (All innovation activities other than technology adoption).

Q52 (Collaboration)

Q38a or Q38b (Product or process innovation developed by firm alone or together with other firms)

Q54a to Q54f (other creative/inventive activities).

B1.4 DIFFUSION INDICATOR

A yes response to:

Q38b or Q38c (Product or process innovation developed by other firms or together with other firms)

or Q49a or Q49d or Q49g (acquisition of advanced machinery, equipment or technology, acquisition of R&D, acquisition of knowledge).

Q52 (Collaboration)

B2.   COMPOSITE INDICATORS FOR KNOWLEDGE FLOWS

B2.1 INTERNATIONAL COLLABORATION

Any collaboration with sources outside Australia:

A yes response to at least one of the following 'From Overseas':

Q53a (other related businesses) *or* Q53b (clients) *or* Q53c (suppliers) or Q53d (competitors) *or* Q53e (consultants) *or* Q53f (universities) *or* Q53gi (private non-profit) *or* Q53gii (government/public) *or* Q53giii (commercial) *or* Q53h (government agencies) *or* Q53i (other).

Any collaboration with market mediated sources outside Australia:

A yes response to at least one of the following 'From Overseas':

Q53b (clients) *or* Q53c (suppliers) *or* Q53d (competitors) *or* Q53e (consultants) *or* Q53i (other).

Any collaboration with public sources outside Australia:

A yes response to at least one of the following 'From Overseas':

Q53f (universities) *or* Q53gi (private non-profit) *or* Q53gii (government/public) *or* Q53giii (commercial) *or* Q53h (government agencies).

***Breadth* of knowledge sourcing outside Australia:**

Number of positive responses to the following Q53 options 'From Overseas':

Q53a (other businesses) *plus* Q 53b (clients) *plus* Q53c (suppliers) *plus* Q53d (competitors) *plus* Q53e (consultants) *plus* Q53f (universities) *plus* Q53gi (private non-profit) *plus* Q53gii (government/public) *plus* Q53giii (commercial) *plus* Q53h (government agencies) *plus* Q53i (other).

B2.2   KNOWLEDGE SOURCING (LOCATION NOT SPECIFIED)

Arm's length knowledge flows:

Clients: Q42b = yes and Q53b within = no and Q53b overseas = no.

Suppliers: Q42c = yes and Q53c within = no and Q53c overseas = no.

Competitors: Q42d = yes and Q53d within = no and Q53d overseas = no.

Consultants: Q42e = yes and Q53e within = no and Q53e overseas = no.

Universities: Q42f = yes and Q53f within = no and Q53f overseas = no.

Government agencies: Q42g = yes and Q53h within = no and Q53h overseas = no.

The breadth of arm's length knowledge flows can be calculated from the sum of the above results for clients, suppliers, competitors, consultants, universities and government agencies.

Breadth of knowledge sourcing:

Number of positive responses to the following Q42 options:

Q42a (other businesses) *plus* Q42b (clients) *plus* Q42c (suppliers) *plus* Q42d (competitors) *plus* Q42e (consultants) *plus* Q42f (universities) *plus* Q42g (government agencies) *plus* Q42h (private non-profit) *plus* Q42i (commercial labs) *plus* Q42j (websites) *plus* Q42k (professional conferences) *plus* Q42l (industry associations) *plus* Q42m (other).

Knowledge sourcing from market sources:

At least one positive response to the following Q42 options:

Q42a (other businesses) *or* Q42b (clients) *or* Q42c (suppliers) *or* Q42d (competitors) *or* Q42e (consultants) *or* Q42i (commercial labs).

Knowledge sourcing from public research sources:

At least one positive response to the following Q42 options:

Q42f (universities) *plus* Q42g (government agencies) *plus* Q42h (private non-profit).

Knowledge sourcing from open information sources:

At least one positive response to the following Q42 options:

Q42j (websites) *or* Q42k (professional conferences) *or* Q42l (industry associations)

B2.3 ABSORPTIVE CAPACITY

Number of positive responses to measures of the firm's in-house capabilities to innovate:

Q38a (new goods) *plus* Q38a (new processes) *plus* Q38a (new organizational methods) *plus* Q38a (new marketing methods) *plus* Q49b (training) *plus* Q49e (R&D) *plus* Q49f (design) *plus* Q49h (other activities).

B2.4 DOMESTIC COLLABORATION

Any collaboration with sources within Australia:

A yes response to at least one of the following 'From within Australia':

Q53a (other related businesses) *or* Q53b (clients) *or* Q53c (suppliers) *or* Q53d (competitors) *or* Q53e (consultants) *or* Q53f (universities) *or* Q53gi (private non-profit) *or* Q53gii (government/public) *or* Q53giii (commercial) *or* Q53h (government agencies) *or* Q53i (other).

Any collaboration with market mediated sources within Australia:

A yes response to at least one of the following 'From within Australia:

Q53b (clients) *or* Q53c (suppliers) *or* Q53d (competitors) *or* Q53e (consultants) *or* Q53i (other).

Any collaboration with public sources within Australia:

A yes response to at least one of the following 'From within Australia':

Q53f (universities) *or* Q53gi (private non-profit) *or* Q53gii (government/public) *or* Q53giii (commercial) *or* Q53h (government agencies).

***Breadth* of knowledge sourcing within Australia:**

Number of positive responses to the following Q53 options 'From within Australia':

Q53a (other businesses) *plus* Q53b (clients) *plus* Q53c (suppliers) *plus* Q53d (competitors) *plus* Q53e (consultants) *plus* Q53f (universities) *plus* Q53gi (private non-profit) *plus* Q53gii (government/public) *plus* Q53giii (commercial) *plus* Q53h (government agencies) *plus* Q53i (other).

ANNEX C

<table>
<tr><th colspan="3">DEFINITIONS OF CORE INDICATORS FOR KNOWLEDGE TRANSFER FROM THE PUBLIC RESEARCH SECTOR USING SURVEYS OF TECHNOLOGY TRANSFER OFFICES (TTOs)</th></tr>
<tr><th></th><th>Definition</th><th>Comments</th></tr>
<tr><td>Research expenditures (denominator)</td><td>Total expenditures on all types of basic and applied research (science and humanities) in the affiliated institution(s) from all funding sources: all levels of government, industry, non-profit foundations, etc. Include share of academic costs dedicated to research, costs of administrative support and capital expenditures on new equipment. Exclude cost of new buildings or land.</td><td>Expenditures on humanities research should be included because they can produce commercially useful outputs such as software or teaching materials.
The definition is in line with the Frascati manual (OECD, 2002).
If research expenditure data at the level of individual public research institutes are available from official sources , the question can be omitted from the questionnaire.</td></tr>
<tr><td>Number of researchers (denominator)</td><td>Average number of research personnel in the reference year in FTEs. Include time spent by academic staff on research, other researchers (post-docs, PhD students, researchers on fellowships, part and full time researchers), technicians and administrative support personnel. Exclude time spent by academic staff on teaching.</td><td>The number will fluctuate over the year. Surveys should ask for an average or for the number of personnel at the end or middle of the academic year or financial year.</td></tr>
<tr><td>1. Research agreements (may include consultancy contracts)</td><td>All contracts where a firm funds the public research sector institute to perform research on behalf of the firm. Include collaborative agreements where both partners provide funding and share the results. Exclude cases where the firm funds a research chair or other research of no expected commercial value to the firm.</td><td>Consultancy differs from research agreements in that it does not involve new research. In some countries consultancy could be an important method of knowledge transfer. It is not clear if the TTO is likely to be aware of all consultancy contracts, which could be drawn up between firms and individual research staff.</td></tr>
<tr><td>2. Invention disclosures</td><td>Descriptions of inventions or discoveries that are evaluated by the KTO staff or other technology experts to assess their commercial application</td><td>-</td></tr>
<tr><td>3. Patents granted</td><td>Technically unique patents granted. Count a patent grant for the same invention in two or more countries as one technically unique patent. If a technically unique patent grant has been counted in a previous year, it cannot be counted again.</td><td>The main problem is maintaining comparability across countries. It could be more difficult for respondents to give the number of technically unique patents than to give the number of Australian or USPTO patents. An option is to ask for both the number of technically unique patent grants and the number of Australian and USPTO patents.</td></tr>
<tr><td>4. Number of licenses executed</td><td>Include all licenses, options and assignments for all types of IP (copyright, know-how, patents, trademarks, etc). A license grants the right use IP in a defined field or territory. An option grants the potential licensee a time period to evaluate the technology and negotiate the terms of the license. An assignment transfers all or part of the right to the IP to the licensee.</td><td>There are national differences win survey definitions of licenses, with the AUTM in the United States excluding software licenses worth less than 1000 dollars.</td></tr>
</table>

(Continued over)

DEFINITIONS OF CORE INDICATORS FOR KNOWLEDGE TRANSFER FROM THE PUBLIC RESEARCH SECTOR USING SURVEYS OF TECHNOLOGY TRANSFER OFFICES (TTOs)		
	Definition	Comments
5. License income earned	Total income from all types of know-how and IP (patents, copyright, designs, material transfer agreements, confidentiality agreements, plant breeder rights, etc.) before disbursement to the inventor or other parties. Include license issue fees, annual fees, option fees and milestone, termination and cash-in payments. Exclude license income forwarded to other institutions than those served by the TTO or to companies	Corresponds with the AUTM definition, but difficult for TTO managers to answer. The question could benefit from cognitive testing to determine the cause of the problem. For instance, the definition could be too complex or leave out an important component of license revenue.
6. Start-ups established	A new company expressly established to develop or exploit IP or know-how created by the PRO and with a formal contractual relationship for this IP or know-how, such as a license or equity agreement. Include, but do not limit to, spin-offs established by the institution's staff. Exclude start-ups that do not sign a formal agreement for developing IP or know-how created by the institution.	A start-up is any new company involving either people (staff or students) from the public sector institute and based on knowledge transfer from the public sector institute. A start-up is often called a spin-off.

Notes: All indicators refer to a one year reference period. All data are count data unless otherwise indicated.

Source: Adapted from Table 5.1 and Table 5.3, Finne et al, 2009.

ABOUT THE AUTHORS

Anthony Arundel

Anthony Arundel is currently a Senior Researcher at UNU-MERIT in the Netherlands and an Honorary Fellow at the Australian Innovation Research Centre, University of Tasmania.

Anthony's research interests include questionnaire design and methodology, technology assessment, environmental issues, intellectual property rights, biotechnology, and knowledge flows between public research and firms. He has been active over many years in the design of survey questionnaires, including for the 1993 PACE survey of Europe's largest industrial firms, and assisted the European Task Force with the design and survey methodology in four of the six European Union's Community Innovation Survey (CIS-2, CIS-4, CIS-2006 and CIS-2008), and in econometric analysis of innovation survey data, particularly on patenting and on knowledge flows. He also has research interests in the development and analysis of indicators at the sector level, particularly for biotechnology and pharmaceuticals, and has also been very active in the interpretation of innovation surveys for policy and in the development of new indicators that better serve policy needs.

Anthony is currently engaged in research to improve innovation indicators, particularly the development of composite indicators, or "innovation modes", based on two or more innovation questions to describe *how* firms innovate, and on measuring innovation in services and 'soft' indicators for innovation, such as entrepreneurship, social, and demand factors.

Anthony's other work have included spending two periods as a consultant to the Economic Analysis and Statistics Division of the OECD (2004 and 2006), undertaking research for the SIEID division of Statistics Canada on biotechnology surveys and surveys of Advanced Manufacturing Technology, participation in Framework Research projects on composite indicators for a Knowledge Based Economy (KEI), sector level innovation (SYSTEMATICS), and on measuring organizational innovation (MEADOW). He has also been involved in research for the European Commission and the OECD on how to measure eco-innovation.

Kieran O'Brien

Kieran O'Brien is currently a Research Fellow at the Australian Innovation Research Centre (AIRC), University of Tasmania. Seconded from the Australian Bureau of Statistics, Kieran's work at AIRC has involved management of the Tasmanian Innovation Census (TIC) project; leading the data collection and processing, database development, analysis work, and collaborating in the design and implementation of an ongoing program of studies from the TIC data.

He has co-written the first three TIC working papers: *Innovation in Tasmania: An innovation census in an Australian State*; *Technical and Methodological Issues in the Tasmanian Innovation Census* and *Structure, Business demographics and Innovation in Tasmanian Manufacturing*. Prior to moving to the AIRC in 2007, Kieran worked as a Change Manager for the Federal Department of Education, Science and Training, working in areas of strategic management and policy analysis for the national skills and training system.

Previously, Kieran was the Manager of an Economic, Employment and Regional Statistics unit in the ABS Tasmanian Office, where he managed a project investigating the development of an Innovation scorecard for Tasmania in collaboration with the State Department of Economic Development and the AIRC, as well as working on research projects with other State agencies including the Department Treasury and Finance, and Infrastructure, Energy and Resources.