Examining the Characteristics of Innovative Firms in Australia

A Report for the Australian Government Department of Innovation, Industry, Science and Research

by

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16-June-2010

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Introduction

Innovation determines productivity and productivity determines real incomes. Governments can affect this process of change via rigorous, evidence-based industry policy. However, there is currently limited empirical analysis about which Australian firms are innovating and the effects of innovation on performance at the firm level. This report aims to fill this gap via a systematic analysis of innovative firms in Australia, with a special focus on the manufacturing industry. To achieve this, we have used data from the Business Longitudinal Database (and the BLS 1994–97), IBISWorld, the Australian Inventor Survey, and the IPRIA R&D Scoreboard.

A major part of our focus will be on the manufacturing industry, which accounts for 40 per cent of Australian business R&D expenditure ($3.9 billion in 2005-06) and is a major force in terms of value-added, employment and exports. We also compare our results with similar results from the United Kingdom and Europe.

Innovation is defined as the introduction of new forms of production (processes and products) into the workplace. Innovation may be conceptualised either as a change in the input-output algorithm, or as a form of firm investment. As a result, there are many different proxies used to measure innovation including: expenditure data (such as R&D expenditure); count-based data (such as patent and trade mark applications, and new product launches); and qualitative innovation assessments (such as surveys). Some measures are more suited to capturing product rather than process innovations (such as counts of trade marks and new product launches), while others are more suited to measuring radical rather then incremental innovation (such as patents).

Review of the literature

<u>Determinants of innovation</u>

Internal sources of finance, a large and growing market, and firm-specific management choices—in terms of competitive posture, internal work routines and attitude towards learning and communication—are consistently found to be associated with innovative firms. There is only limited evidence that plentiful opportunities from science cause firms to be more innovative. The dominant view is that the behaviour of the individual firm matters more. Firms in 'low-tech' sectors can be very innovative, especially with respect to process and incremental innovations. Evidence that size and the number of competitors in the firm's output market are contributory factors to firm innovation is weak and inconsistent.

Knowledge sources of innovation

The sources of knowledge used to underpin innovation vary considerably and it is difficult to generalise. However, most studies point to the importance of both formal and informal networks for innovation. In addition, collaboration has been found to be related to the propensity of Australian firms to attempt innovations.

Determinants of success

The most successful innovations: pay attention to the special needs and circumstances of users; integrate development, production and marketing activities; link with external sources of scientific and technical information; favour high-quality R&D resources; put high-status, experienced business managers in charge of the project; and have strong commitment from top management and the board. A mature understanding of, if not active support from, financiers has also been cited as significant. Importantly, persistence in innovation appears to improve the success rate of innovative activities, and may underlie the skewed distribution of innovative effort across firms (see the section *Innovative Activity in Australia* below).

Firm performance

As we would expect, observed innovation is not linearly related to either positive or negative profits. If that were so then, by deduction, firms would spend 100 per cent or 0 per cent of their resources on innovation. Given this we are not surprised to find the absence of an empirical relationship between innovation and profitability or firm survival. Some innovations are highly profitable, while others lead to firm closure. There is some evidence, however, that high-risk inventive activity leads to a higher probability of firm death in the early stages of the inventive life cycle, but once past this point, firm survival rates are enhanced. More innovative industries appear to be more export intensive.

Australian innovation surveys

Australian innovation surveys from 2001 to 2005 suggest that businesses in the manufacturing sector were significantly more innovative than comparable businesses in other sectors. This result holds for each of product, process and organisational innovation. Implementing organisational processes and new operational processes appears to be more important than the introduction of new goods and services.

Defining and Measuring Innovation

Defining Innovation

Innovation which means the introduction of new forms of production (processes and products) into the workplace, may be conceptualised either as a change in the input-output algorithm, or as a form of firm investment.

Commonly-Used Innovation Proxies

Commonly-used innovation proxies include: expenditure data (such as R&D expenditure); count-based data (such as patent and trade mark applications, and new product launches); and qualitative innovation assessments (such as surveys). Some measures are more suited to capturing product rather than process innovations (such as counts of trade marks and new product launches), while others are more suited to measuring radical rather then incremental innovation (such as patents).

Innovative Activity in Australia

Our original analysis on Australian firms reveals that:

- Amongst SMEs, those in the manufacturing industry have the highest probability of engaging in innovative activities.
- Amongst large firms, those in the manufacturing industry have the highest tendency to engage in R&D activities.

- R&D expenditure per firm (by innovating firms) increased between 2003–04 and 2006–07 in all industries.
- More than half of innovating firms in the services industry are ‘one-time’ innovators; while around half of innovators in the resources industry can be considered as ‘sporadic’ innovators.
- Innovation is very concentrated and ‘persistent’ innovators account for the bulk of innovative activity in each industry.
- Manufacturing SMEs are more likely to export than service and resource sector SMEs.
- While about 80 per cent of firms are able to obtain debt finance, innovators are slightly more able to obtain debt finance, with the exception of the largest SMEs in manufacturing.
- Innovating SMEs are more likely to report increased profits in the most recent year.
- Overall, firms which receive grants are more likely to be innovators, particularly those in the resources and services industries.

Comparisons with Top EU and UK R&D Firms

Our original comparative analysis finds that:

- Australian top R&D spenders are much smaller than UK- and EU-based top R&D spenders.
- R&D expenditure by Australian firms increased during 2003–04 to 2006–07 by 20–30 per cent p.a. – more than double the UK and EU rates.
- R&D intensity varies widely across industries. Similar to the United Kingdom and the European Union, Australian firms in the manufacturing industry are more likely to spend a higher proportion of sales as R&D expenditures.

Factors Affecting Australian Inventors

Our original analysis on Australian inventors finds that:

- About 30 per cent of manufacturing firms attempted to license or spin off their invention compared, with over 60 per cent of organisations from the other industries.

- About 90 per cent of all organisations, regardless of their industry, attempted one or more development stage.
- Manufacturing firms were considerably more likely than other organisations to attempt other downstream commercialisation stages.
- 40 per cent of manufacturing firms were exporting compared with 20 per cent of firms in other industries.
- Inventors from manufacturing establishments were more likely to be aware of the occurrence of copying than inventors from other industries. Manufacturing employers were also more likely to send the alleged infringer a ‘cease and desist’ letter.
- Internal funds are the most common way R&D is financed.
- ‘Finding a partner’ was the most commonly-cited barrier to commercialising an invention, except in the manufacturing industry where uncertainty over the ability of their IP to prevent infringement and over the feasibility of the technology were commonly-cited problems.

Determinants and Impacts of Innovation

Finally, our limited economic modelling on the determinants and impacts of innovation reveal that:

- The presence of international competition is associated with a 12 percentage point higher probability of carrying out R&D.
- Firms engaged in formal networks are on average 13 percentage points more likely to carry out R&D.
- Whether or not a business received financial assistance (for any reason) from the Australian Government, is associated with around 5 percentage point increase in the probability of conducting R&D.
- The correlation between product innovation and productivity is not as clear cut as theory suggests. The estimated correlation coefficient is only significant at the 10 per cent significance level. Nonetheless, it is positive and large in size relative to the findings from other countries.

1. Introduction

This report provides a descriptive analysis of the characteristics of innovative firms in Australia and a preliminary multivariate analysis of the determinants and impact of innovative activities. While much is known about the importance of innovation for economic growth and prosperity, little is known in Australia about which firms are actually innovating and what factors drive or hinder their innovative performance. Even less is known about the firm-level effects of innovation on the performance of Australian firms.

Part of the difficulty with documenting this issue at the firm level has been the availability of suitable, robust and comprehensive data. Rather than relying on case studies or industry analysis, this report is based on a systematic analysis of the characteristics of innovative firms in Australia using available datasets including: the Australian Bureau of Statistics (ABS) Business Longitudinal Database (BLD), which covers firms with less than 200 employees; the Intellectual Property Research Institute of Australia (IPRIA) R&D and Intellectual Property Scoreboard data, which is based on IP Australia's intellectual property rights application database; the IBISWorld database, which covers large Australian enterprises with annual revenues of more than $50 million; and the Melbourne Institute's Australian Inventor Survey, which covers Australian inventors who applied for a patent at IP Australia between 1986 and 2005.

Australian federal and state governments spend large amounts of resources on the promotion of innovation. A good example is the program 'Backing Australia's Ability – Building our Future through Science and Innovation,' a package that commits $5.3 billion of public funds over seven years from 2004–05. It builds on the initial 2001 investment of $3 billion under the program 'Backing Australia's Ability - An Innovation Action Plan for the Future,' which took place over five years to 2005–06. In addition, there are other major programs such as the Federal Government's new R&D tax credit and state-based programs which aim to increase the rate of innovation among local firms. More recently, the current government has shown an increased interest in promoting innovation, as evidence by the Cutler, Bracks and Green Reviews of Australian industry.

These programs highlight the importance of innovation policy in a modern economy, for it is widely recognised that innovation is closely linked to productivity growth and successful innovation is the only way a developed economy can maintain its competitive position in the world economy. It is therefore important to gain an in-depth understanding of factors that influence Australia's ability to generate ideas and undertake research, accelerate the commercial application of these ideas, and develop and retain skills. In the absence of a sound evidence base on these issues, policy making will be driven by anecdote and rent-seeking by vested interest groups.

There are many relevant issues that need to be examined in order to understand the link between innovation activities and economic performance. There is evidence, for example, that in developed countries—which are mostly net exporters of technology—innovation is a key determinant of firm and national economic performance. On the other hand, in developing countries—which are mostly net importers of technology—innovation activities are secondary to the ability to access international markets and sources of technology in terms of the performance of the firms and the economies. Therefore, it is important to understand where Australian firms stand with respect to innovation.

Relevant questions include:

- What are the determining characteristics of the innovating firms? Do size, ownership, market orientation, or availability of skilled labour matter? How important are internal managerial factors?
- Do innovating firms have better economic performance in terms of productivity, profitability, or exports?
- How do Australian firms compare to other countries?

The rest of this report aims to provide some answers to the above questions. In Chapter 2 we summarise the findings from existing theoretical and empirical studies which evaluate the questions in various settings. Specifically, we discuss factors which influence firms' decisions to undertake innovation, the intensity of innovative activities and the effects on performance. In Chapter 3 we discuss important problems in studying these issues, particularly the problem of measuring innovation.

In Chapter 4 we present descriptive analysis of innovative activities by Australian firms, mainly between 2003 and 2007 depending on data availability. We investigate how many and which firms innovate and how the pattern has changed over time; who are the persistent innovators and how important they are; how many resources firms have devoted to innovative activities and the role of size and financial factors in this respect; how widespread the innovative phenomenon is within the industrial structure; and the importance of different sources of innovation. In this chapter, and the following two chapters, we relate the lessons learned from theories and empirical findings from other countries to empirical information on Australian firms. This sets the stage for a more robust discussion of policy implications. Chapter 4 also considers the link between Australian firms' innovation and their economic performance. For example, whether there is any systematic difference between the innovators and the non-innovators in terms of growth in employment and sales, productivity and profitability and what the underlying determinants of this difference are.

Chapter 5 provides a direct comparative analysis between top Australian R&D spenders (based on annual firm-level data contained in IPRIA's *R&D and Intellectual Property Scoreboard*), top European R&D spenders (based on annual firm-level data in the European Commission's *EU Industrial R&D Investment Scoreboard*) and the top R&D spenders in the United Kingdom (based on annual firm-level data contained in the Department for Business Innovation & Skills' *R&D Scoreboard*). In this chapter, we look at the relative performance of Australian firms in terms of both innovative activities, such as intensity of R&D, and economic outcomes such as sales growth.

In Chapter 6 we look more deeply into the issues by utilising data from the Australian Inventor Survey. In the survey we asked the inventors what happened to their invention beyond the formal patenting process, and what factors affected their commercialisation of the invention. In this chapter we provide a deeper characterisation of the innovative performance of Australian firms at the individual innovation project level. The analysis is intended to complement and enlighten the firm-level analyses discussed in the other chapters. For example, information on the commercialisation stages of specific invention is not available from the firm-level survey, yet such information is crucial in understanding the link between innovation and economic performance.

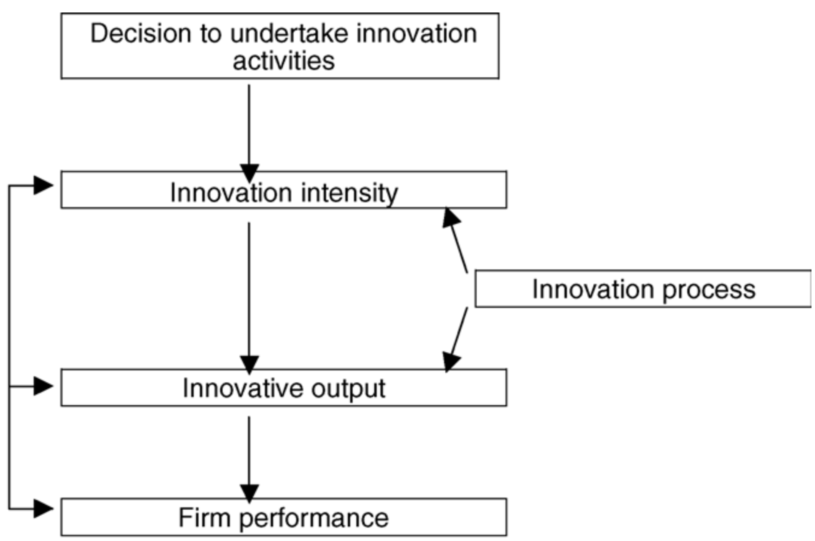
Chapter 7 presents some preliminary findings from a multivariate analysis of the determinants of innovative activities and their outcomes based on the BLD data of Australian small and medium-sized enterprises. While the descriptive analyses in the previous chapters seem to provide evidence for a systematic link between R&D, innovation and performance for Australian enterprises and the importance of factors such as firm size and access to finance, the multivariate analysis of this chapter aims to refine the analyses by controlling for the influence of all other factors when examining the relationships.

Finally, in Chapter 8 we provide conclusions and draw some policy implications. In addition, we discuss the limitations of the report as well as directions for further research.

2. Review of the Literature

Why do firms innovate? What explains the superior innovative performance of some firms relative to others? What promotes innovative behaviour among firms? What are the economic outcomes of innovative activities and what determines these outcomes? For years, providing answers to these and similar questions has been the main objective of numerous theoretical and empirical papers in the field of economics and management. This chapter provides a brief summary of this literature in order to help with the interpretation of the empirical findings presented in the next three chapters. To provide some structure to the discussion, we first refer to a stylised diagram, such as the one shown in Kemp *et al*. (2003), of the link between firms' decision to innovate, their innovative activities and outputs, and the their economic performance.

Figure 2.1: Innovative Behaviour, Innovation Process and Firm Performance



Source: Kemp *et al* (2003).

2.1 Determinants of innovation

As indicated in Figure 2.1, a good starting point is to look at studies which try to understand what makes firms decide <u>and</u> able to undertake innovation activities. In a recent article, Woerter (2008) summarised a number of hypotheses that have been proposed to address the issue:

- The Schumpeterian hypotheses (Schumpeter 1912, 1975) which focus on the size of the firm and the level of concentration in which the firm operates as key factors determining its innovative behaviour;[1]
- The demand-pull hypothesis (Schmookler 1966) which proposes the significant role that market conditions such as the size of the market and changes in prices;
- The technology-push hypothesis (Phillips 1966; Rosenberg 1976) which argues that conditions underlying knowledge production processes are essential;
- The financial-constraints hypothesis (Nelson 1959) and the related hypotheses which are based on issues surrounding the risks of R&D and the risk preferences of the institutions involved (Mansfield 1968); and
- The technology-related, supply-side factors hypothesis (appropriability, tacitness of knowledge, technological opportunities and uncertainties) (Dosi 1988).

Woerter (2008) then continued by citing recent empirical studies based on the European Community Innovation Survey (CIS) data aimed at providing formal tests of these hypotheses. The empirical studies discussed by Woerter (2008) are summarised in Table 2.1 below. As seen from the table, support for the 'firm size hypothesis' is at best inconclusive, with a tendency for the effect to be negative. This is consistent with other non-CIS empirical studies which tried to sort out whether firms acquired market power <u>because</u> of successful innovation or whether market power <u>enabled</u> firms to make innovation profitable (i.e. Kamien and Schwartz 1982; Mansfield 1984; Levin and Reiss 1984; Acs and Audretsch 1987, 1988, 1991; Van Dijk *et al.* 1997). Many studies that do find market structure and/or firm size are a significant determinant of R&D intensity do not control for the underlying conditions of opportunity and appropriability. Intermingled with this issue is the question of whether firm size enabled or resulted from higher levels of R&D. Tests of these competing hypotheses were not helped by the lack of panel data sets, but the 'final' word on the issue appears to be that both size and market structure are unlikely to be the dominant determinants of innovation since the findings commonly depend on which control variables are included in the model (Phillips 1966; Sutton 1991; Scherer 1967; Cohen 1995; Bosworth and Rogers 2001).

[1] See also Cohen (1995) and Cohen and Levin (1989)

In contrast, both the demand-pull and technology-push hypotheses have some support. There have been a series of economic studies that have tried to estimate the role of more deep-seated determinants such as the opportunities proffered by the scientific sector and how easily firms can appropriate their R&D profits (Levin and Reiss 1984; Pakes and Schankerman 1980). This avenue of research appears to have found more consistent results than the earlier studies (Caves 1982; Jaffe 1986; Cohen, Levin and Mowery 1987; Dunning 1988; Cohen and Levinthal 1989; Sterlacchini 1994; Griliches 1995; Oltra and Flor 2003), in part because the theoretical direction of effects are less ambiguous. However, it still leaves open the question of what governs scientific opportunity and natural appropriability. For example, it may be that size, and the underlying financial resources it implies, enhances the scope of an enterprise's opportunity and appropriability sets.

Another smaller but concurrent stream of economic research has concentrated on the financial hurdle for firms which desire to invest in highly uncertain and collateral-free projects such as R&D (Branch 1974; Kamien and Schwartz 1978; Himmelberg and Petersen 1994; Cumming and Macintosh 2000; Hall 2002; Bloch 2005; Rafferty and Funk 2008). As with the scientific opportunity and appropriability theories, there is a clear a priori prediction of the effects of retained earnings and gearing levels, and therefore, not surprisingly, reasonably consistent empirical findings. Higher levels of retained earnings facilitate higher levels of R&D, *ceteris paribus*. A recent study by Scellato (2007) using Italian manufacturing firm data in 1995-2000 finds that firms with fewer financial constraints are more likely to be able to sustain their innovating activities. In particular, he shows that relative to the innovators, non-innovators are more significantly dependent on their last period cash flow when deciding on how much to spend on current investment. Based on his findings, he further argues that financial constraints due to imperfect Italian capital markets would delay the ability of especially medium-size firms to start their in-house R&D activities.

Somewhat separate from this economic stream, a range of studies have been undertaken in the management literature. Some of this has followed the resource-based theory of the firm which roots outcomes in firm capabilities – that is, the skills and knowledge of the workforce – (Grabowski 1968; Rothwell *et al*. 1974; Nelson and Winter 1982; Pavitt

1991; Souitaris 2002; Lee 2002; Murovec and Prodan 2009; among others); other studies have arisen from the strategic management side (Medina et al. 2005).

While there are few Australian studies; exceptions are Griffiths and Webster (2010) and Thomson (2010). The former found that most of a firm's R&D activity is explained by internal factors such the managerial style and the competitive and appropriation strategies. The growth in the industry and internal sources of funds were significant, but smaller, in effect. The importance of the internal operation of the firm is also supported by Woerter (2008). He finds evidence in support of another hypothesis related to fifth point above, which argues that if firm innovation is driven by its perceptions about the problems it faces, and if the firm's perceptions depend on working routines which are influenced by the characteristics of the firm—such as the size of its employment and physical capital—then one could expect that industries with a greater variety in terms of firm characteristics would be relatively more innovative than industries with more homogeneous firms. Thomson (2010) used Australian data and did not find that working capital influenced the level of R&D.

Table 2.1 Determinants of Innovative Behaviour – Empirical Evidence from CIS

Study	Country	Finding
Arvanitis and Hollenstein (1996)	Swiss manufacturing firms	1. Supply-side factors (appropriability, technological opportunities) 2. Demand-pull factors (weak) 3. Schumpeterian (large firms more likely to innovate)
Raymond *et al.* (2004)	Dutch manufacturing firms	1. Demand-pull factors are more important 2. Negative size effect
Mairesse and Mohnen (2001)	French manufacturing firms	1. Positive size effect 2. Demand-pull factors for low-tech firms
Janz *et al.* (2003)	German manufacturing firm	1. Negative size effect
Crépon *et al.* (1998)	European manufacturing firms.	1. Demand-pull effect 2. Technology-push effect 3. No size effect

Source: Woerter (2008)

Some authors point out that there is tendency for the literature to suffer from 'high-tech myopia' i.e. the idea that economic growth and employment is mostly the result of research-intensive industries (Hirsch-Kreinsen *et al.* 2005; von Tunzelmann and Acha 2005). So called low-, medium- and high-technology sectors (as defined by their R&D intensity) are often composed of firms with varying technology intensity levels. Thus, it is important to look at the differences at the firm level when analysing how inter-sectoral patterns in innovative performance depend on the level of R&D intensity. For example, Kirner *et al.* (2009) study the 2006 German Manufacturing Survey data of 1663 firms and find that, while ‘low-technology’ manufacturing firms lag behind medium- and high-tech firms with respect to their product innovation, they may perform better at process innovation. This finding is perhaps explained by the tendency for low-tech innovations to involve processes which are not primarily based on formal research and technological development. Instead they tend to be practical and experience-based, usually involving implicit knowledge (Heidenreich 2009).

There is a view that variation between firms in innovative intensity depends on the maturity of the industry. However, the importance of this source of variation may alter from one setting to another, as illustrated by the finding of McGahan and Silverman (2001). In their study they investigate the activity of US publicly-traded firms during the 1980s through to mid-1990s. They find that firms’ patenting activity does not decrease as the industry in which they operate matures in terms of the underlying technology life cycle. They conclude that industry maturity does not appear to lead to a switch from product to process innovation, nor does it imply lower firm innovative activities compared to those in emerging industries.

2.2 Knowledge sources for innovation

There have been some recent studies on the sources of innovation. A recent study by Frenz and Ietto-Gillies (2009) looks at two main categories of knowledge sources, namely (a) own-generated innovation through R&D, and (b) externally-sourced innovation via knowledge transfer mechanisms, such as bought-in resources for the purpose of innovation or external R&D collaborations. Using data from the UK Community Innovation Survey, they did not find any clear benefit from joint innovation efforts in the form of cooperation. However, they did find that intra-company knowledge sources, own-generation, and bought-in resources are important in determining the outcome of innovative activities. In particular, they find that the international dimension of the firm’s internal networks is highly relevant, as are the interactions between the own-generation of knowledge and external sources.

Frenz and Ietto-Gillies (2009) also reviewed relevant studies and found that almost all them confirmed the significance of external collaboration with the users and external sources of technical expertise. The studies they reviewed also pointed to the importance of both formal and informal networks for innovation.

However, Tether (2002) argues that the relationship between innovation and research collaboration is not straightforward. In particular, the extent of co-operative research arrangements for innovation may depend on the type of firm, and on what is meant by innovation. For example, firms which conduct R&D in order to introduce innovation which is 'new-to-the-market' rather than 'new-to-the-firm' are much more likely to engage in co-operative arrangements for innovation. Otherwise, most firms still appear to develop their new products, processes and services without forming (formal) co-operative arrangements with other firms or institutions.

Collaboration is one of seven National Innovation Priorities. 'Powering Ideas – An Innovation Agenda for the 21st Century' (see DIISR, 2009) specifies the policy framework and outlines how several government initiatives aim at promoting the links and collaborations between individual businesses and groups of firms, between university-based researchers and the private sector, and between businesses and their customers, suppliers and competitors. The rationale behind these programs is that collaboration, whether formal or informal, enables innovating firms to reduce costs by eliminating duplication and by achieving economies of scale. Another benefit is that collaboration facilitates the process of finding, adapting and acquiring information relevant for innovation, as well as spreading the risk and maximising the rewards associated with innovation.

An econometric analysis conducted by the Department of Industry, Tourism and Resources investigates how collaboration and other factors influence innovation novelty in Australian businesses. The analysis uses information from the Innovation Survey 2003, presented in ABS (2005a). The database comprises only innovating firms, which are identified with a variable that is constructed by counting the number of different innovation related activities such as the acquisition of machinery and equipment, training related to new goods or services and substantial new design work. The analysis employs an ordered categorical probit model with the probability of introducing the highest degree of novelty (new to the world innovation) as the dependent variable.

The model predicts that collaboration, while controlling for other firm characteristics such as size, foreign ownership and R&D intensity, is associated with a statistically significant increase in the chance of achieving new-to-the-world novelty. Collaboration was found to be more common and important to frontier and creative innovation than to relatively minor modification of goods, services and processes and purely adoptive innovation. The principle conclusion is that, in comparison to non-collaborating businesses, collaborating firms are more likely to introduce new-to-the-world innovation.

2.3 Determinants of success

Freeman (1991) summarises an interesting list of characteristics which make for successful innovators. According to this list, successful innovators are those who:

- Pay attention to the special needs and circumstances of users;
- Integrate the development, production and marketing activities;
- Link with external sources of scientific and technical information and advice even when they typically have their own in-house R&D;
- Concentrate high quality R&D resources on the innovative project; and
- Have high status, wide experience and seniority of the ‘business innovator’ and, particularly in large organisations, have the strong commitment of top management.

Terziovski et al. (2002) conduct a case study of a product development project (the “Bushranger” Project) at Varian Australia Pty Ltd (a company with $140M turnover which exports 95 per cent of its products). They find that Varian Australia focuses on optimising two critical success factors of product innovation, namely (a) meeting and exceeding customer needs and expectations by innovating new products and accelerating the cycle time from conceptualisation to market launch, and (b) establishing cross-functional, multi-disciplinary teams. Cebon (2008) summarises the findings from 11 Australian case studies and finds that successful innovators: paid attention to the market needs rather than the technology; managed risks, including IP risks, well; attuned corporate governance to innovation needs; had active support from, and at least considered understanding of their situation by, financiers; and were able to launch the product into the Australian market before going overseas. These success factors seem to confirm items (1), (2) and (5) in Freeman's list above.

An important issue in the study of what determines the outcomes of innovative activities is persistence in innovation. Specifically, the focus is no longer merely the number of innovation outputs, such as patents. Rather, it is the frequency and consistency of innovation produced by a particular firm which are the primary points of interest. In theory, there are a number of reasons why particular firms become persistent innovators. First is the 'success-breeds-success' phenomenon (Nelson and Winter 1982). That is, innovative success yields profits that are reinvested in R&D. The second possible source of persistence is related to the idea that knowledge accumulation is intrinsically cumulative. If we look at Freeman's list above, one may expect that successful innovators who satisfy the identified characteristics at one period of time may indeed satisfy the list at different periods.

Cefis (1996) uses a transition probability matrix approach to study the importance of persistence in UK firms' innovation performance and finds that there is little persistence in innovation among most firms. However, she also finds that there is significant heterogeneity across sectors and size, with significant persistence exhibited by the largest and the smallest innovating firms. Geroski et al. (1997) link the length in patenting spell and the initial level of patenting and, after controlling for various factors (such as parent/subsidiary status, ownership status, growth in manufacturing output, employment, and innovation spillovers), find that very few firms are persistent innovators and that the threshold level to become a persistent innovator is very high. They also find that persistently innovative firms account for a very large share of total patents produced by the firms in their sample. Finally, Cefis and Orsenigo (2001) use (1) autoregressive parameters and (2) dynamics of cross-section distribution functions, i.e. transition probabilities matrix, as extensions to Cefis (1999) and find that: (a) there is a low degree of persistence in innovative activities at the firm level which declines overtime; (b) there are important differences across countries, sectors and firm size; and (c) that because inter-sectoral differences are rather invariant across countries, persistence is (at least partly) a technology-specific.

2.4 Firm performance

The last part of Figure 2.1 refers to the benefits that firms can derive from their innovative activities. There are a number of perspectives from which the effects of innovation on firm performance can be examined. In addition, it is likely that any economic benefit of innovation may feed back into future decisions and the ability to innovate, as illustrated by our earlier discussion regarding the persistence in innovation.

The first way innovation affects performance is through employment. Product innovation, for example, may lead to increased employment at the firm, sector and national level because it creates either entirely new goods or services, or significantly differentiated products, both of which require different factors of production, particularly labour. However, such innovation may lead to substitution effects by displacing the demand for existing products so the net effect is unclear. Unlike product innovation, process innovations in general have a direct negative employment effect as they typically reduce labour requirements. However, there might be compensating mechanisms that work against the negative effects of labour reductions, such as where there is technological change involving the use of new machinery, and price and income effects due to the resulting increased productivity of labour. Innovation may also affect employment indirectly through embodied technological change, which can be expansionary if it increases the capacity to produce.

These employment effects should go hand-in-hand with changes in productivity, and there are many studies which have investigated the extent to which and ways that innovative activities lead to improved productivity. For example, Chudovsky *et al.* (2006) —who use the so called CDM framework[2]—find that the probability of introducing new products and/or processes to the market is positively related to both in-house R&D and expenditures for acquiring external technology. More importantly, they find that

[2] CDM refers to the framework by Crépon, Duguet, and Mairesse which, unlike other approaches, uses each block of the entire innovation process shown in Figure 2.1.

innovators have higher productivity levels compared to non-innovators. In addition, they also find that larger firms are more likely to engage in innovation activities.

Using business-level information from the 2003 Innovation Survey, ABS (2007a) is the first study to apply the CDM model to Australian data. The results show that the propensity to innovate is related to firm size, initial market share and other firm-specific attributes. In terms of innovation intensity, the regression results are less straightforward and rather inconclusive. The second stage of the model empirically establishes a relationship between innovative output (measured with dummy variables for product, process and organisational innovation and the ratio of sales attributed to such innovation) and innovation intensity and a set of firm characteristics, such as collaboration, level of IP protection and firm size (but, interestingly, not to age and degree of foreign ownership). In the third stage the study demonstrates that product, process and organisational innovation output, as well as firm size and market share, positively influence firm performance.

The study conducts a series of robustness tests. The presented results prove to be pervasive for sub-samples of the manufacturing and service sectors. Further, the direction of findings is unaffected by the use of four different measures of innovation output, or by using the level of labour productivity instead of growth as the dependent variable. Nevertheless, the findings should be interpreted with care. Unlike the original CDM model, discussed in Crépon *et al.* (1998), the three stages are estimated separately and not as a system of equations, implying that cross-equation correlations cannot be accounted for. Lastly, the lack of panel data means that the analysis reveals relationships but cannot identify causality.

A small number of existing studies investigate how innovative activity affects profitability. One such study by Koellinger (2008) examines data on 7,302 European enterprises and finds that innovative activity is not necessarily associated with higher profitability. In contrast, an Australian study by Buddelmeyer *et al.* (2010) found that new patenting activity leads to firm death, *ceteris paribus*, most likely because of the risk associated with high-end innovation. However, once past the initial high-risk time frame, firms with larger stocks of active patents are more likely to survive that those without patents.

Other studies try to understand the way innovative activities can lead to better economic performance via exports. One of the earliest studies by Pavitt (1982) finds that at the country level, per capita exports is positively associated with per capita patents. A more recent study, which looks at the micro-level relationship between innovation and export propensity, finds that the probability of becoming an exporter is positively related to innovative activities such as the amount of expenditure on design, engineering and pre-production developments (Sterlacchini 1999).

Kafourous *et al.* (2008) further argue that not all firms reap rewards from innovation because of the need to have a sufficient degree of internationalisation say due to limited scale of the domestic market. Based on their theoretical and empirical models they find that the ability to operate internationally enhances the firm's capacity to improve performance through innovation and those below the threshold internationalisation level may not be unable to benefit from their innovation activities. However, in a later study, Wang and Kafouros (2009) find that factors such as international trade, FDI and R&D do not always have positive consequences on the innovation-economic performance nexus and that their effects may be moderated by technological opportunities and the level of foreign presence.

2.5 Australian innovation surveys

Building on the Oslo Manual and European Community Innovation Surveys, the ABS conducted Innovation Surveys in 2003 and 2005 covering the Australian economy in calendar years 2002–03 and 2004–05, respectively. There is a series of reports, for example ABS (2005 a,b) and ABS and DITR (2006), which use these data to document the patterns of innovation among Australian businesses. Innovation is measured in terms of implementing new goods and services, new operational processes or new organisational and managerial processes. A business is classified as innovative if it reports as having introduced at least one type of innovation in at least one of the calendar years in question. However, we caution the reader from drawing too much inference from this measure as it does not distinguish between a firm which instigated one small innovation from one that instigated many large innovations. This measure will also be inherently linked to firm size, because as firms become larger, they do more activities. It does not mean that large firms are innovation intensive. Nonetheless, while bearing these caveats in mind, the reports produce a range of interesting bi-variate correlations.

The principal finding is that about 29 and 34 per cent of firms were innovative in 2003 and 2005, respectively, suggesting that Australian firms are becoming more innovative. Both surveys suggest that implementing organisational processes and new operational processes are more important than the introduction of new goods and services. A comparison by state and territory demonstrates that (in all four calendar years) South Australia and Western Australia are the most innovative states, whereas ACT and Tasmania are the least innovative. Looking at differences between industries, it becomes evident that Manufacturing and Electricity, Gas and Water Supply have the highest proportion of innovative businesses, whereas Retail Trade and Property and Business Services appear to have the lowest share of innovative businesses.

The higher the degree of foreign ownership (measured in categories of wholly Australian owned, a foreign share of greater than or equal to ten per cent, less than or equal to 50 per cent and greater than 50 per cent), the greater the likelihood a given business will undertake innovative activities, although this correlation may be due to firm size.

Similarly, DITR (2007) draws on business-level data collected in the 2003 Innovation Survey and focuses on the manufacturing sector. Again, we warn the reader that this survey uses the simple binary measure of ‘innovative’. Bearing this in mind, the key finding is that, during the period 2001–03, businesses in the manufacturing sector were significantly more innovative than comparable businesses in other sectors. Manufacturing firms have a higher propensity to innovate, a result which is shown overall and for each of the three types of innovation (product, process and organisational). In comparison to non-manufacturing firms, more innovating manufacturing firms introduced innovation encompassing a high degree of novelty, such as products and processes that are new to the world or new to Australia. Overall, the manufacturing sector has the largest share of any Australian sector in terms of innovation expenditures.

Somewhat unique is the study by Smith and O’Brien (2009), which investigates innovative activity in Tasmania. The analysis employs data from a census (not a survey) which was conducted through telephone interviews in August 2007 and aimed to cover all firms in all sectors. The authors pay particular attention to potential non-response and sample selection biases. The major finding is that 70 per cent of firms in the census introduced new or improved goods, services or processes in one of the three calendar years 2004-2006. The result is pervasive across industries and firm size classes in Tasmania.

This finding is, however, not consistent with previous research, such as ABS (2005 a,b), which ranks Tasmania second lowest in Australia in terms of the proportion of businesses innovating. A likely explanation for the discrepancy is the definition of innovation, which in Smith and O'Brien (2009) refers to small-scale and non-radical changes of products or processes and imposes a low threshold. In contrast to most of the related literature, in their paper it is sufficient to have implemented minor upgrades to existing products or processes or have introduced technology that are new-to-the-firm to qualify as innovative.

The study also shows that the most common types of innovative activity are investments in, and acquisition of, R&D and internal or external training, whereas the use of new designs and the purchase of IP appear to be less important. The analysis also reveals inequality of innovative activity in terms of an uneven distribution of innovative sales and R&D expenditure—20 per cent of the firms in the census account for about 80 per cent of total innovative sales and about 90 per cent of total innovative expenditure.

3. Defining and Measuring Innovation

In the preceding discussions, we use the word ‘innovation’ in a general sense without providing any precise definition. In fact as will be discussed below, innovation is a complex, multi-faceted process which presents challenges in terms of how it is defined and measured. Reflecting this and depending on the types of innovation related data available, the studies cited earlier use a number of different measures of innovation. Rather than describing the different measures used by these studies, below we discuss how innovation can be defined and measured more generally.

3.1 Defining innovation

Innovation refers to the introduction of new forms of production into the workplace, and can be conceptualised either as a change in the input-output algorithm, or as a form of firm investment. Early economic thought did not directly analyse innovation but adopted the first view which relegated it to being an exogenous shift of the isoquant.[3] More recent thought, however, regards innovation as an outlay made by firms in the expectation of future benefits, i.e. an investment (Webster 1999).[4] Innovation, under this latter notion, is not just a workplace modification or the possession of a novel idea, but is about testing, refining and polishing this idea so its inclusion into the production process results in positive net benefits for the firm, such as an increase in productivity.

According to Jensen and Webster (2009), the lens through which the researcher views innovation determines the appropriate measure of innovation. If the algorithm view is used, then output measures of the innovation process – such as the number and type of new products and processes introduced – are most apt. However, if the investment view is used, then what matters is the total amount of resources committed to developing new products and processes. Either view can be represented as aggregated cardinal indices (ratio of inputs to outputs, change in the value of a product, total monetary outlays) or as a series of qualitative efforts on behalf of the firm (number and type of new products

[3] Isoquant is the set of input(s) quantity used to produce the same quantity of output. Thus, an outward shift of the isoquant, for example, is equivalent to an increase in the output quantity while holding the quantity of inputs constant.
[4] It is generally accepted that to constitute an investment, the benefits from undertaking an activity must extend beyond a year.

launched, number and type of new processes introduced). Typically, the algorithm view uses outcome indicators while the investment view relies on inputs.

Separate from this distinction is the type of innovation under consideration. Following Schumpeter (1934), five dimensions are commonly referred to: product, process, organisational, input and market innovation. Product innovation refers to the creation of new (or improved) goods or services that are launched on to the market. Whilst both goods and services are included in this aspect of innovation, much of the literature is dominated by innovation in physical goods. Process innovation refers to changes in the way in which goods and services are produced. This includes new technology that improves the productivity of a production line or softer technological improvements. Organisational innovation refers to changes in the architecture of production and accounts for innovations in management structure, corporate governance, financial systems or changes in the way workers are paid. Input innovation refers to improved ways of sourcing supplies of raw inputs or intermediate goods and services, while market innovation refers to opening up new market opportunities.

Ideal cardinal indices, from either the algorithm or investment perspective, do not exist. Input-output tables do not exist at the firm level – at best we have monetary values for the broad groups: output, labour, capital and materials. Not enough firm-level price information exists to reduce these to accurate constant-price values. The ideal cardinal investment index is expenditure by the firm on innovative activities. This measure is analogous to tangible investment – that is, a firm-level accrual of monies spent. However, this information is not easy to extract since intangible expenditure is usually expensed and pooled with current costs of production. At present, intangible expenditure is neither systematically categorised nor distinguished from other expenses.

These shortcomings in company accounting standards have lead researchers to rely either upon pre-existing data, or to develop second-best proxies such as R&D expenditure, counts of intellectual property (IP) rights, or surveys of management. Attempts by economists to measure innovation in this way date back at least to the 1960s with the development of the OECD's Frascati Manual, and subsequent work on the definition of concepts such as R&D (see Freeman and Soete 1997). Patent application data have also been used since the 1960s and managerial surveys such as the European CIS – which require managers to quantify or rate the firm's innovative activities during a defined time period – have been developed and refined since the 1980s.

Figures 3.1 and 3.2 are stylised examples of product and process innovations as they pass through successive stages of commercialisation success. These figures illustrate the coverage of these various second-best indicators. The figures show that the sequence runs from R&D expenditure indicators, to patent applications, design applications, trademark applications and then to product launch. The further along this spectrum the measure lies, the more it is defining a successful outcome rather than innovation *per se,* since the propensity to apply for, request examination of, and renew an IP title depends on the perceived commercial value of the invention.

Because of the ad hoc nature of much innovation data, researchers are heavily limited in their choice of dataset. What is available either narrows the research question or forces researchers to 'shoe-horn' available data into their preferred economic model (which typically results in estimates with large standard errors). However, it also means we have no way of distinguishing between the absence of an economic relationship and measurement error. To overcome this problem, work continues on developing new and improved measures of innovation. The papers by Dodgson and Hinze (2000) and Kleinknecht *et al.* (2002) advocated the use of multiple indicators of innovation in order to overcome the problems of single indicators.

Figure 3.1: Success Spectrum of a Product Innovation

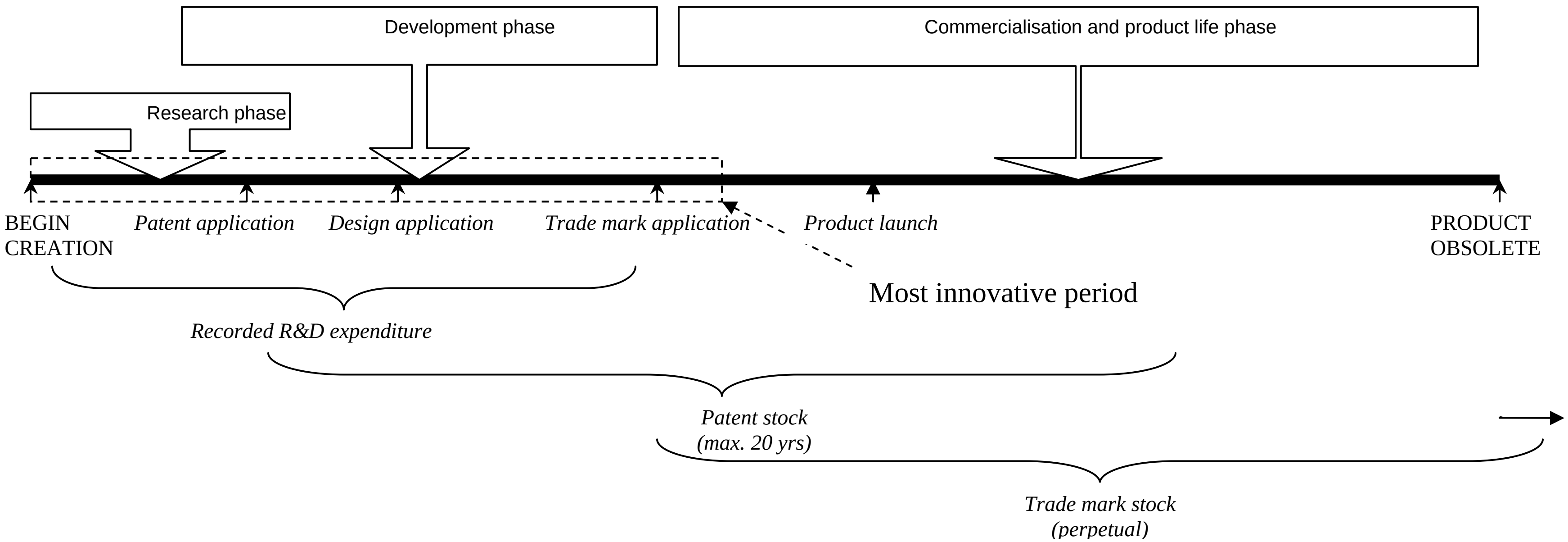
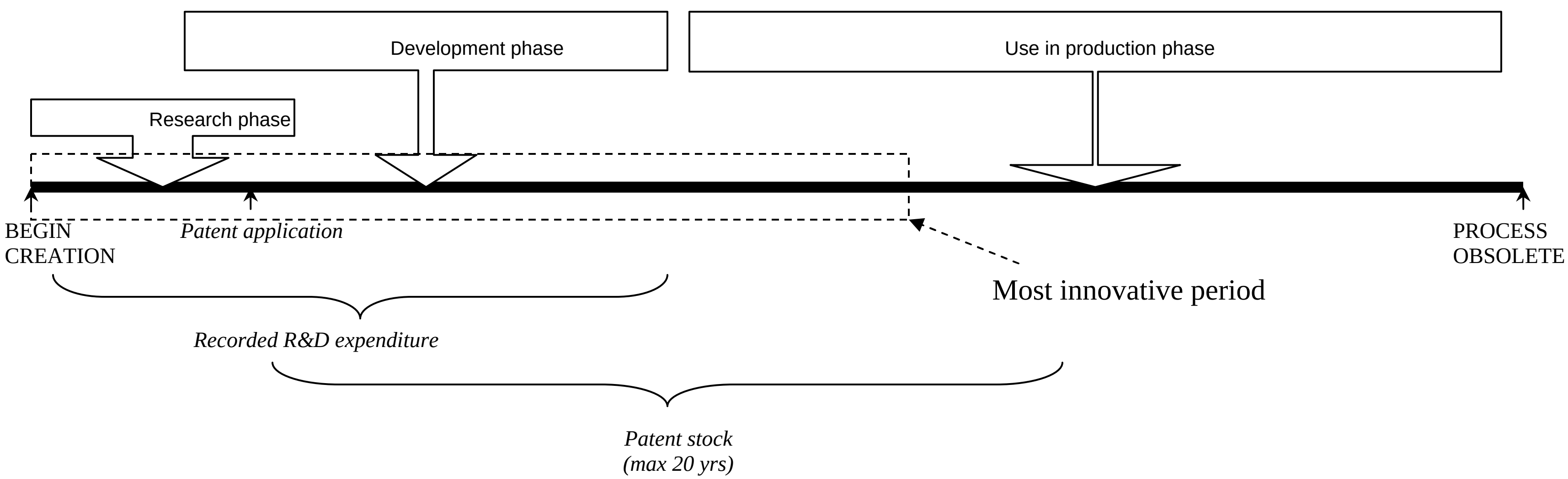


Figure 3.2: Success Spectrum of a Process Innovation



3.2 Commonly-used innovation proxies

Below we discuss the coverage of commonly-used proxies of innovation including: expenditure data (such as R&D expenditure); count-based data (such as patent and trade mark applications, and new product launches); and qualitative innovation assessments (such as surveys). Each innovation proxy has its relative strengths and weaknesses in terms of coverage. That is, some proxies are more suited to capturing product rather than process innovations (such as counts of trade marks and new product launches), while others are more suited to measuring radical rather then incremental innovation (such as patents). We draw upon a review by Jensen and Webster (2009) here in order to aid the interpretation of the results in the subsequent empirical chapter.

R&D data

R&D expenditure and employment data have been frequently used to measure innovation. These data come from two main sources: census data (R&D employment – e.g. Scherer 1965) and accounting data (R&D expenditure – e.g. Grabowski and Mueller 1978; Griliches 1986). The use of R&D expenditure as a proxy for innovation is first and foremost problematic because the lack of mandatory reporting for R&D expenditure precludes systematic data collection. Secondly, whether or not R&D expenditure is reported, and what is reported, will vary according to a firm's strategic motivations. Depending on how the firm wants to temporally distribute their earnings and profits (for tax benefits and to inform the stock market), they may or may not avail themselves of the opportunity to capitalise rather than expense R&D. Finally, not all firms that collect R&D data formally report it in their annual reports. As a result, it is unclear whether the apparent high incidence of missing R&D data from most accounting-based firm data sets is due to: the intentional exclusion of R&D data for strategic reasons; the fact that R&D spending is positive but below a certain threshold; or is that R&D truly zero.[5]

From time to time, national governments operate R&D incentive programs which require formal documentation of R&D activities. Often the R&D that is required to be recorded

[5] Griffiths & Webster (2004) found that over the period 1989 to 2004, 8.3 per cent of large firms file for a patent but never report R&D expenditure. Abrahams and Sidhu (1998) also report information on this.

is a subset of the accounting definition; in some countries, such as currently in Australia, the current tax rebate program is skewed towards research rather than development. The empirical literature also suggests that larger firms more accurately report R&D than small firms, and that listed companies are more likely to report R&D due to the fact that they are subjected to a higher level of regulatory scrutiny. Brouwer and Kleinknecht (1997) argue that R&D has a manufacturing bias. Nevertheless, R&D typically relates to innovative activities undertaken in the early and middle stages of the product/process life cycles identified in Figures 2.2 and 2.3. The other major problem with using R&D data is that its coverage is limited to product and process innovations. That is, R&D expenditure typically excludes organisational and market innovations.

IP counts

Counts of IP administrative data—such as patents and trade marks—have also been commonly used in the innovation literature (e.g. Griliches 1981; Greenhalgh and Longland 2001). IP applications—patents, designs and trade marks—are popular measures of innovation, but it is widely accepted that '…patents appear to be a good indicator for …inventive activity…[only] at a very aggregated level' (Griliches 1995, p.54). Nonetheless, using administrative data on IP provides certain benefits for the researcher since long time series of firm-level datasets can be merged in and simple counts of applications for registration of IP at the firm level provide information on inventions that are both new-to-the-firm (trade marks) and new-to-the-world (patents, designs).

Proxies for innovation based on registered IP also have problems, since particular types of registered IP tend to be used more intensively in some industries than others. For example, it is well documented that patents are infrequently used by firms working in technical fields that are not well covered by patent laws (e.g. services); where inventions can easily be protected by other methods (e.g. secrecy, unregistered copyright or keeping ahead of competitors); and where inventions are otherwise hard to imitate (e.g. knowledge is tacit). In fact, Arundel and Kabla (1998) claim that patents are reasonable as a measure of innovation only in sub-sectors of manufacturing (pharmaceuticals, chemicals, machinery and precision instruments). Similarly, firms without the resources to support litigation and enforcement (such as smaller firms) are expected, a priori, to have a relatively lower correlation between patents and innovation (see Griliches 1990; Arundel and Kabla (1998), however under-use by SMEs was not found in Australia (Jensen and Webster 2006).

Beyond this, each type of IP right differs in what it purports to measure. Patents and design applications are only granted for inventions or designs the inventor believes are new-to-the-world. Trade marks, on the other hand, can be used to herald the formal launch of a product which is merely new-to-the-firm, or to the local market. While registered designs and trade marks are most clearly applied to product innovations only, there is also some evidence that the use of patents for process innovations is low (see Levin *et al.* 1987; Cohen *et al.* 2000).

Applications for patents, trade marks or registered designs represent an unknown proportion of the original set of ideas developed by a firm. As such, we expect that IP counts are biased towards *successful* innovation, as highlighted in Figures 1 and 2. Furthermore, IP count is not a measure that can be meaningfully aggregated since we know from our limited information that the distribution of patent value is highly skewed.[6] While hedonic indexes can be used in relation to heterogeneous goods and services, this is only possible where there is enough of the old in each successive activity to splice onto the new. This is difficult to achieve with patents since there are no established ways of combining products that, in addition to heterogeneity, may have no overlap with the previous period's activities or products.

Moreover, IP data do not cover all innovative activities – for instance, patents almost totally exclude organisational and market innovations. Furthermore, patents can only apply to an idea that is 'manufacturable', which accordingly excludes most industries,

6 As a result, there have been several moves to systematically value-adjust patent applications by weighting applications counts according to whether they have been granted (sealed), how often they had been renewed (Lanjouw *et al.* 1998) or how often they have been cited by subsequent patents (Jaffe *et al.* 1998). In practice, weighting individual firm patents by forward-citations or renewal rates is not without difficulties because citation rates for recent patents may be unreliable (see Narin 1999) and renewals can take several years to occur. The Australian patent office does not systematically record prior art citations and therefore our data set cannot be used in the same was as the US patent data.

particularly service sector industries. While trade marks may obtain some coverage of product and market innovations, they would rarely apply to organisational and process innovations. Registered designs apply only to a select group of goods and therefore exclude services.

Surveys of managers

Since the 1980s, a number of survey-based innovation measures have been devised—the most well-developed of which are the European Community Innovation Surveys (CIS) (see Baldwin et al. 2002). These surveys require managers to quantify or rate the firm's innovative activities during a defined time period, using measures such as the number of new products, the extent of introduction of new processes and technologies, and the type of R&D activity.

Responses from surveys of management have broad coverage across all of the dimensions of innovation since surveys can be addressed at any aspect of the firm's activities, whether it be organisational innovation or the proportion of money spent on R&D. This is one major attraction of innovation surveys since activities such as changing the work culture can have a demonstrable effect on productivity, but are almost impossible for the economist to detect through administrative data. Most surveys do not ask for details of money spent on innovative activities since the absence of consistent accounting standards across firms means that a reliable figure would either be impossible to extract or impose an undue response burden. Accordingly, surveys often seek qualitative Likert-scale responses, which cannot strictly be aggregated and moreover do not represent flows over a given time period.[7]

While surveys can have much broader coverage than other innovation proxies, there are some inherent problems with survey-based proxies. The main problems are potential sample selection and non-response bias—it is often difficult to identify the population of firms to be surveyed, and more successful innovators may be more likely to respond to the survey than unsuccessful innovators. Such selection and non-response bias can be dealt with in a couple of ways—one is to survey the population of firms rather than a

[7] Arundel *et al.* (1998) discuss ways to account for Likert-scale biases in modeling approaches.

sample (i.e. conduct a census of firms), and the other is to undertake surveys of non-respondents in order to detect the magnitude of any non-response bias. Both steps have been undertaken by Smith *et al.* (2007) in their census of innovation in Tasmania.

New product launches

This measure of innovation counts the number of new product launches by searching for product launch announcements in trade journals. The oldest example of trade journal-based innovation counts is the US Small Business Administration's Innovation Data Base compiled in 1982 by the Futures Group and used by Acs and Audretsch (1993). The method has subsequently been employed in the Netherlands, Ireland, the United Kingdom and Austria [see the collection of papers in Kleinknecht and Bain (1993) and see Brouwer and Kleinknecht (1996)]. The advantages of this measure are that it does not require firm compliance (which introduces considerable selection bias); it is relatively cheap to collect; and a time series can be collated ex post since historic records are usually available. Furthermore, journal-based counts are not subject to the same technical and economic bias that shape the patenting decision (the cost of being reported in a journal is negligible and articles are not limited to patentable innovations).

Nonetheless, this measure also has several shortcomings. First, it is unlikely that these measures can distinguish between true inventions and imitated products and thus market leaders. In addition, while journal counts can be reasonable records of product innovation, they are considered to represent relatively poor sources of information about process innovation. Firms have clear incentives to publicise product innovations but also to conceal new processes. Given this, Kleinknecht (1993) suggests that these data should be primarily regarded as sources of product innovation and that attention should be paid to possible bias across industry or market areas and over time arising from varying journal coverage rates. This type of measure typically does not adjust for quality and generally represents the successful end of the innovation pathway.

Summary of innovation proxy coverage

A summary of the dominant coverage of different innovation proxies is presented in Table 3.1. In this table, a cross indicates that the innovation proxy covers the innovation type listed in the first column. Note that the table is supposed to be indicative of the overall coverage rather than an exact representation. For instance, a specific trade mark may be new to the world, but in general trade marks are best considered as new-to-the-firm. Thus, we indicate that the coverage of trade marks is new-to-the-firm by placing a cross in the relevant cell of the table. There is one clear conclusion to be drawn from this table: the most difficult innovative activities to measure are process, organisational and market innovations. As a measure of innovation, surveys can be designed to have the broadest coverage of all innovation proxies.

Table 3.1: Summary of the dominant coverage of commonly-used innovation proxies

Coverage includes…	*R&D data*	*Patent applications*	*Trade mark applications*	*Design applications*	*Product launches*	*Survey of managers*
Type of innovation						
Product	X	X	X	X	X	X
Process	X					X
Organisation						X
Market			X			X
New to firm	X		X		X	X
New to world	X	X		X		X
Stage of innovation life cycle						
Early	X					X
Middle	X	X		X		X
Late			X		X	X
Firm characteristic						
Large firms	X	X	X	X	X	X
Small firms		X	X	X	X	X
Manufacturing firms	X	X	X	X	X	X
Service firms			X			X
Other features						
Selection/response bias						X
Cheap to collect	X	X	X	X	X	
Incremental/radical nature						X

4. Innovative Activity in Australia

This chapter discusses the innovative activities of small, medium and large Australian companies during the financial years from 2003–04 to 2006–07 based on currently available BLD data (for small and medium companies) and the IPRIA's R&D and Intellectual Property Scoreboard data (for large companies), in three broad industry groups: Resources, Manufacturing and Services.[8] The discussion focuses on a number of issues that have been shown to be relevant in the literature. These issues comprise: how many and which firms innovate as shown by the share of innovating firms; how this share has changed overtime; whether or not there is persistence in innovation; and how the activities vary across different industries. In our discussion we also investigate if size and financial constraints are important influences on firms' innovative activities.

In the analyses that follow, the characteristics of innovators and non-innovators are contrasted. Due to the use of different sources of data for small and medium companies (based on the ABS' BLD database) and for large companies (based on the IPRIA Scoreboard), our definition of innovator differ slightly depending on the type of information provided. For the small and medium companies (SMEs), an innovator is defined as any company which reported as having introduced a new product or process in the specified year. For the large companies, an innovator is defined as any company which filed at least one patent or design application in the specified year. Thus, the definition of innovator for large companies is more strict than that for the SMEs. In addition, within each of the two company groupings, the analyses also focus on the variation across size of employment. For the SMEs, the companies are classified into three groups: 1–4 employees, 5–19 employees and 20–199 employees. For the large companies, the size classifications are: less than 200 employees, 200–500 employees,

[8] In this report, we use the ANZSIC 1993 industry divisions to define these sectors as follows: resources (A&B), manufacturing (C), and services (E, F, G, H, I, J, L, P and Q). For the small and medium companies excluded from services are Electricity, Gas, and Water Supply (D), Finance (K), Government (M), Education (N), Health (O), and other services (92, 96, 97). These exclusions are due to the design of BLD survey used for these types of companies. For large companies based on the IPRIA's Scoreboard, however, utilities, health and finance are included in order to be consistent with the discussion in Chapter 5 when the companies are compared to large companies from UK and European Union, See the Appendices to this report for further details of the data.

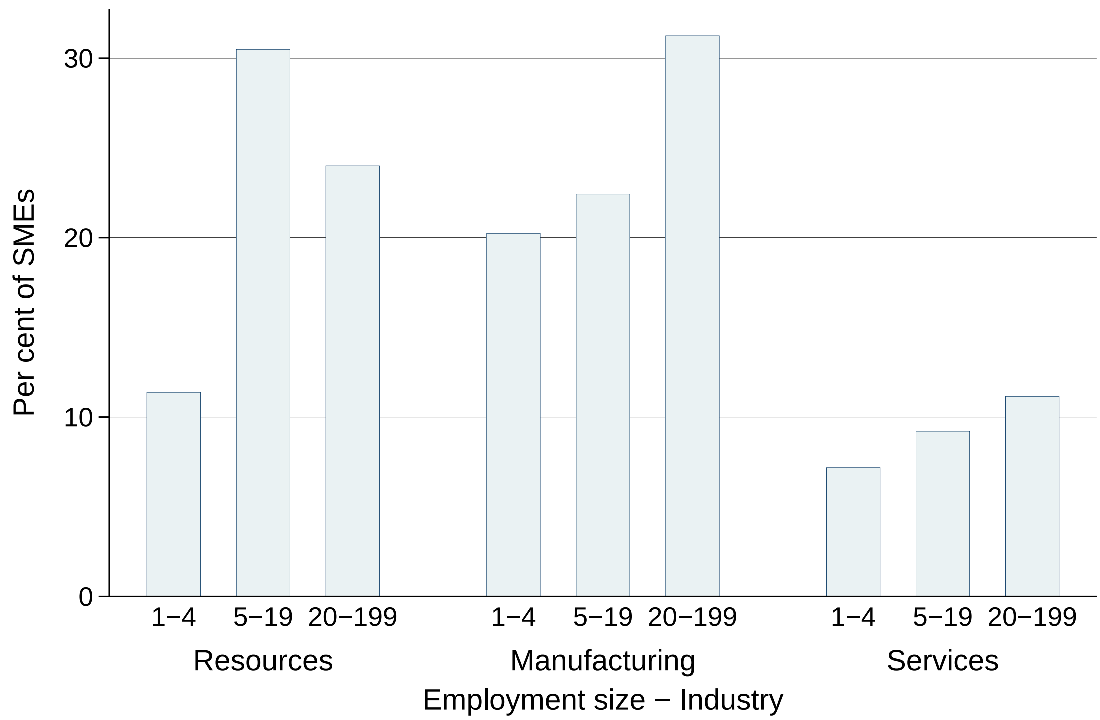
500-1000 employees, and more than 1000 employees. We note that the population of large companies with ‘less than 200 employees’ according to IPRIA Scoreboard data is different from the small companies in the BLD database, even though all BLD companies have less than 200 employees, and thus one should not make a direct comparison between the two groups.

We start by looking at the extent and patterns of resources used for innovation, particularly as reflected by R&D expenditure. The measure of innovation used here (positive R&D expenditure) is binary, as with the other Australian innovation surveys, and has the same drawbacks mentioned above in Chapter 2. Figure 4.1 shows the proportion of SMEs which reported having positive R&D expenditure in the financial year 2004–05, by industry group and employment size class. The figure shows that Manufacturing and Resources have significantly higher proportion of firms undertaking R&D than Service. A similar picture for large firms is shown in Figure 4.2. The Manufacturing sector followed by Resources is more likely exhibits higher tendency to report R&D expenditures compared to Service. This finding is in line with previous work using Australian data such as DITR (2007).

Two other important observations can be made regarding the propensity to undertake R&D shown by Figures 4.1 and 4.2. First, it appears that larger firms in the Manufacturing and Service industries are more likely to engage in R&D than small firms. This apparent positive size effect is in line with previous studies using Australian data, such as ABS (2005b). However, we note that this general the observation does not appear to hold for firm in the Resources industry. Second, as shown by Figure 4.2, there is in general a reduction in the proportion of large firms which report positive R&D expenditures during the financial years from 2003–04 to 2006–07.[9]

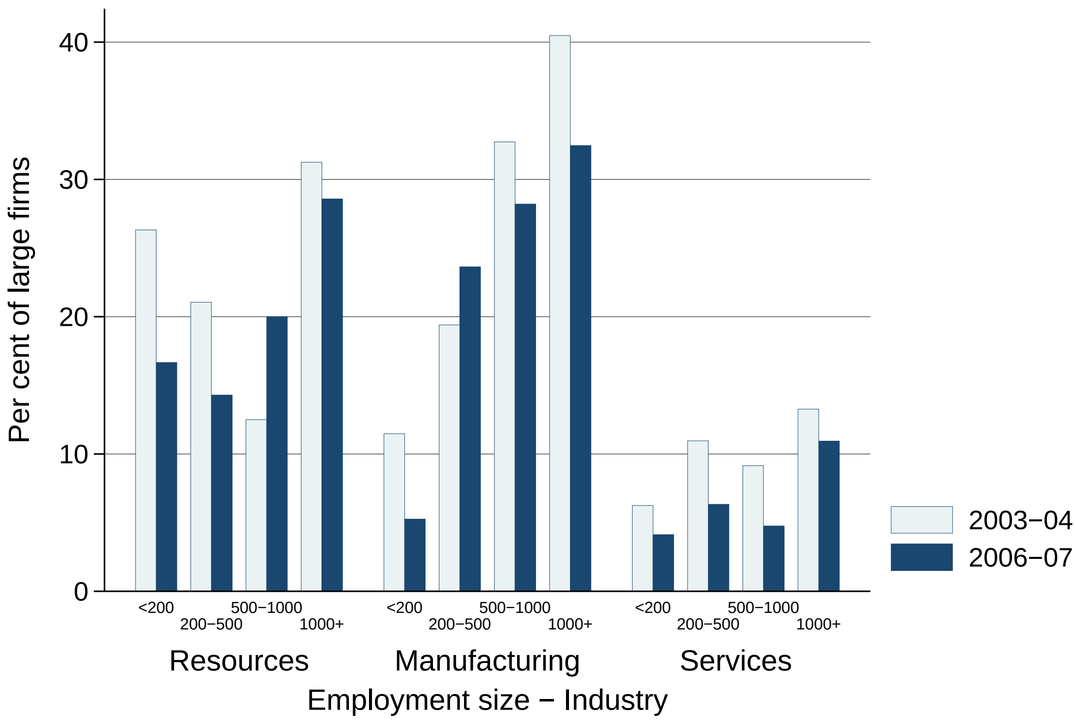
[9] Unfortunately, the BLD surveys did not ask the R&D question consistently over time so that we could not make any similar observation regarding the trend in R&D propensity of small and medium firms.

Figure 4.1: Proportion of SMEs with R&D expenditure 2004-05, by employment size class and industry group



Source: Processed from the BLD CURF database (see Appendix 2)

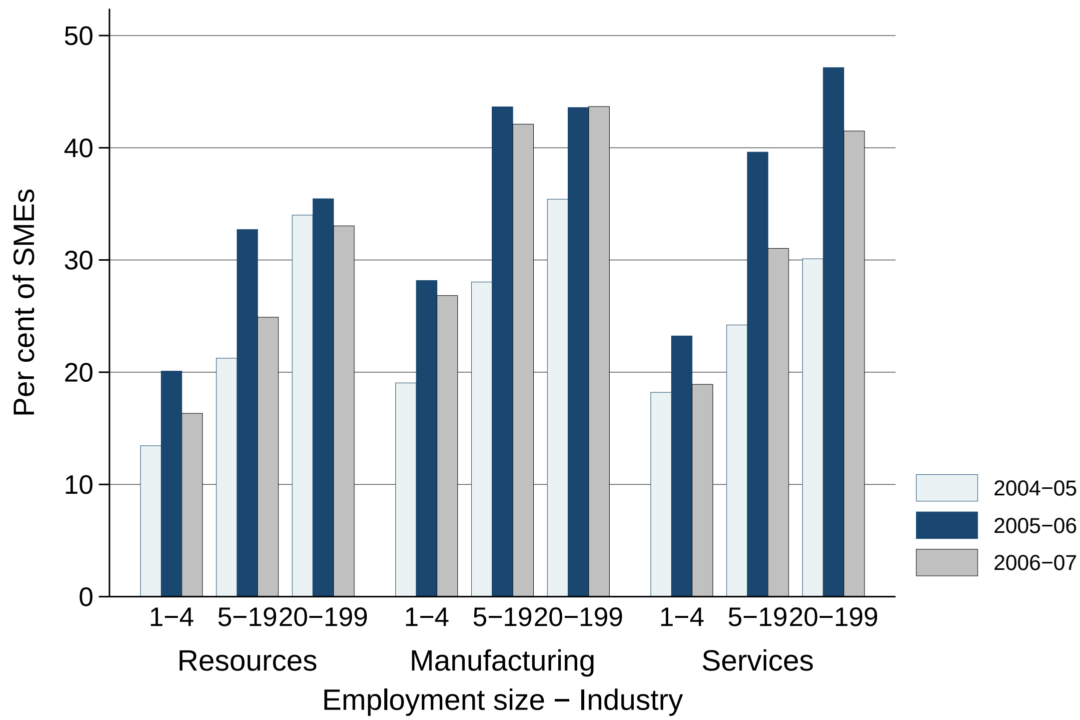
Figure 4.2: Proportion of large firms with R&D expenditure 2003-04 to 2006-07, by employment size class and industry group



Source: Processed from IPRIA Scoreboard database (see Appendix 3).

Figures 4.3 and 4.4 present the proportion of innovating firms, where innovation is defined as the introduction of a new product or process (for BLD firms) or having made at least one application for a patent or registered design (for R&D Scoreboard firms). Around 25 per cent of SMEs in the BLD report having introduced a new product or process in one of the financial years from 2004-05 to 2006-07. From Figure 4.3 a similar pattern becomes evident across the Resources, Manufacturing and Services industry groups. Figure 4.4 reveals that large manufacturing firms with more than 1, 000 employees are significantly more likely to apply for a patent or registered design compared to smaller firms.

Figure 4.3: Proportion of innovating SMEs 2004-05 to 2006-07, by employment size class and industry group

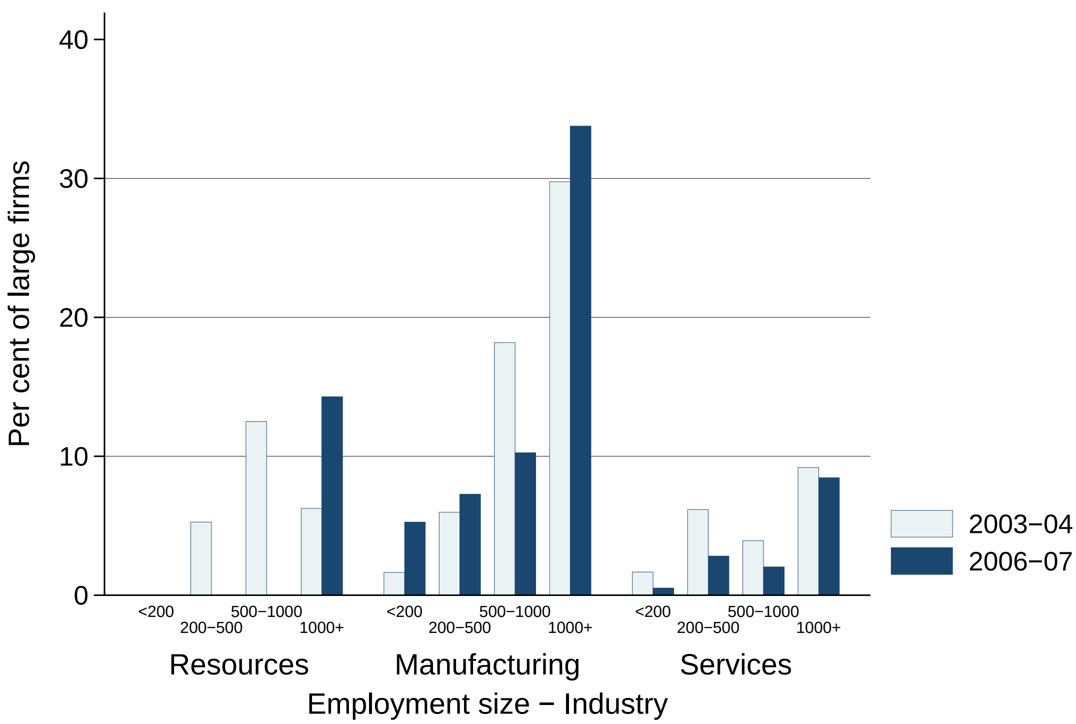


Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm, is a binary variable, =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise.

A comparison of Figures 4.3 and 4.4 suggests that the proportion of innovating SMEs is much higher than the proportion of innovating large firms (with the exception of large manufacturing firms). One possible reason for the difference is that the innovation question in the BLD survey refers new-to-the-firm products or processes while, in the R&D Scoreboard, a patent or design implies a new-to-the-world products or processes. Thus, caution should be used when attempting to make direct comparisons between the two graphs. The principal finding of a positive size effect, however, appears to be prevalent in both figures and all industry groups.

While Figure 4.2 shows the positive size effect on innovation inputs of large firms, Figure 4.4 shows the positive size effects on innovation outputs.[10] This suggests that there may be a positive relationship between R&D activities and innovation output. Interestingly, despite the general fall in the tendency of firms to engage in R&D overtime observed in Figure 4.2, Figure 4.4 shows that the tendency to innovate appears to have increased during the same period, especially for large manufacturing firms. One possible explanation for this is that those firms which reported having positive R&D in both periods may actually have increased the amount of R&D expenditure.

Figure 4.4: Proportion of innovating large firms 2003-04 to 2006-07, by employment size and industry group



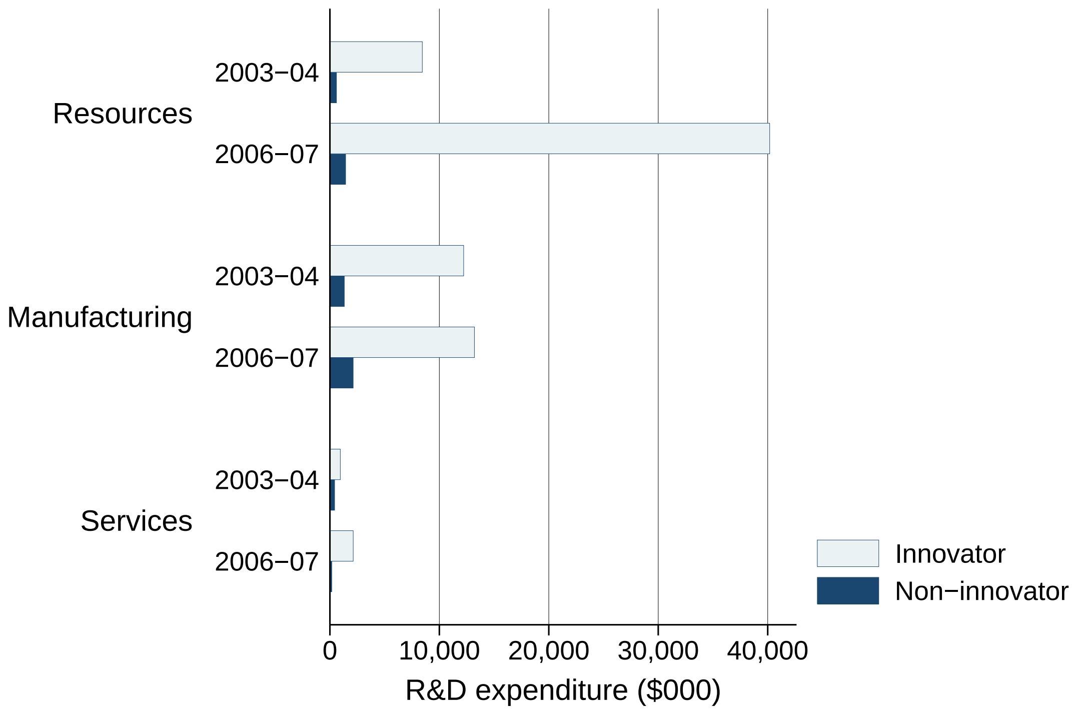
Source: Processed from the IPRIA Scoreboard database (see Appendix 3)
Note: An innovating firm is a binary variable = 1 if filed at least one patent or design application at IP Australia in the respective year; =0 otherwise.

Figure 4.5 confirms the above tentative conclusion regarding the cause of these seemingly contradictory observations. It shows that average R&D expenditure by large innovating firms actually increased between 2003-04 and 2006-07 in all industries

[10] In Figures 4.4, 4.6b, 4.7, 4.9 and 4.10, if there is no bar for a specific classification, then the percentage or the number of observation is 0.

(although the effect is quite small in the manufacturing industry).[11] The figure also shows that, overall, innovating large firms spent a lot more on R&D than non-innovating firms. We advise caution, however, for using this as solid evidence for a systematic relationship between firm size and innovation, since we have not held all other potentially confounding factors constant.[12]

Figure 4.5: Average R&D expenditure by large firms, 2003-04 to 2006-07, by industry group and innovation status



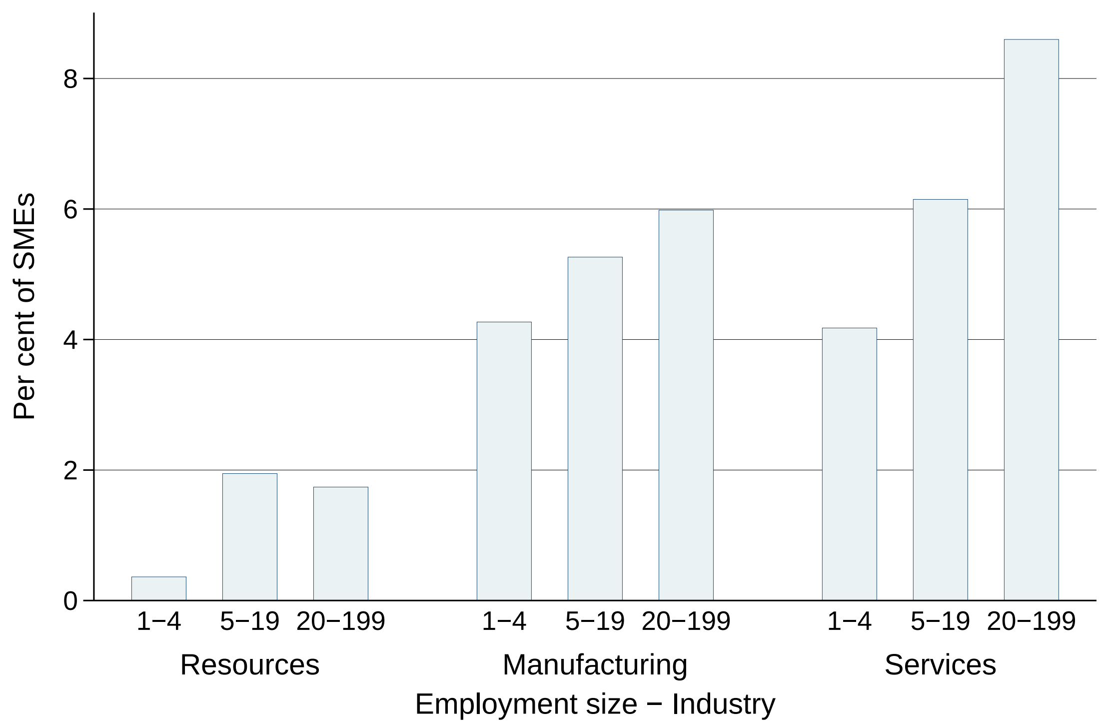
Source: Processed from the IPRIA Scoreboard database (see Appendix 3)
Note: An innovating firms, is a binary variable = 1 if filed at least one patent or design application at IP Australia in the respective year; =0 otherwise.

Figure 4.6 illustrates the propensity of BLD firms to collaborate with other businesses for innovation purposes.[13] Collaboration helps firms tackle some of the important barriers to innovation, such as the inability to obtain access to finance due to the uncertainty of

[11] Unfortunately, the BLD database does not provide any information on the amount of R&D expenditure so that it is not possible to look at the relationship for SMEs.
[12] In Chapter 7 we investigate how size is related to the propensity to conduct R&D for SMEs in the BLD database.
[13] The IPRIA Scoreboard database does not have any information on collaboration and therefore the analysis of collaboration-innovation link for large companies is not possible.

innovation and the inability to absorb external technology due to the partly tacit nature of the underlying knowledge. Collaboration can be especially important for smaller firms, which are more likely to face these difficulties. Despite these potential benefits, Figure 4.6 demonstrates that collaboration is not very common among innovating SMEs. On average across size categories and industry groups, only about four per cent of innovators report innovation-related collaboration. The figure also indicates that, in comparison to smaller innovating firms, larger innovators are more likely to collaborate in their innovative activities.

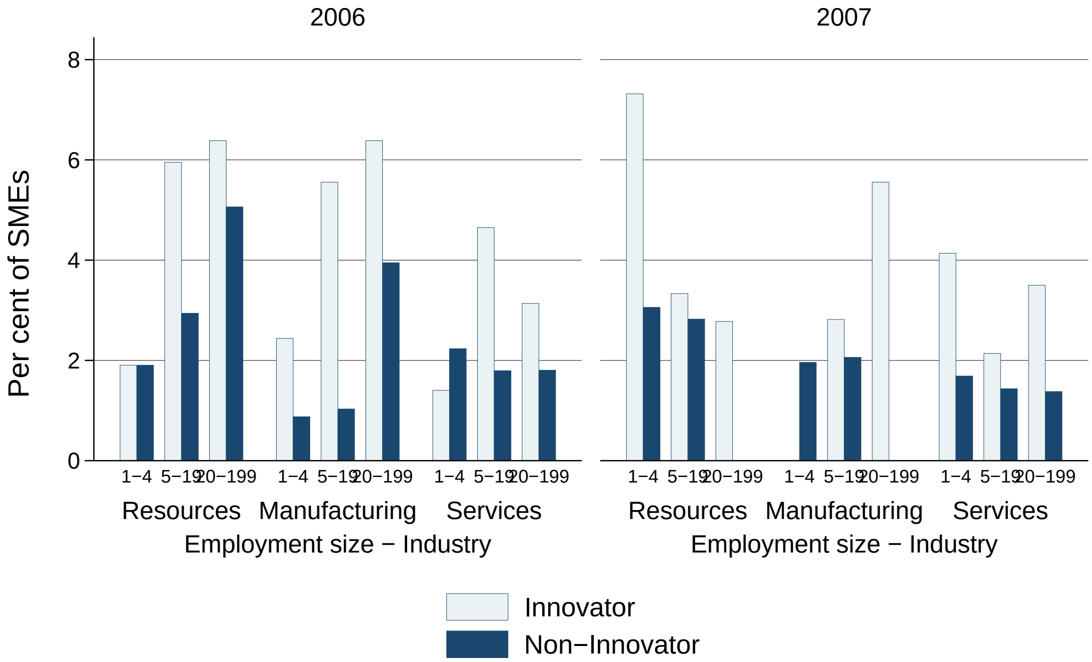
Figure 4.6: Proportion of innovating SMEs which collaborate with other businesses for the purpose of innovation 2006-07, by employment size class and industry group



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise.

Figure 4.7 shows the relationship between joint R&D and innovation. Overall, the proportion of SMEs engaging in a joint R&D arrangement is higher among the innovators than the non-innovators and this relationship appears to be stable across time, at least in the short run. As with collaboration, it becomes evident that only a minority of businesses report joint R&D arrangements. However, unlike the general collaboration data shown in Figure 4.6, there does not appear to be consistent relationship between joint R&D arrangements and size.

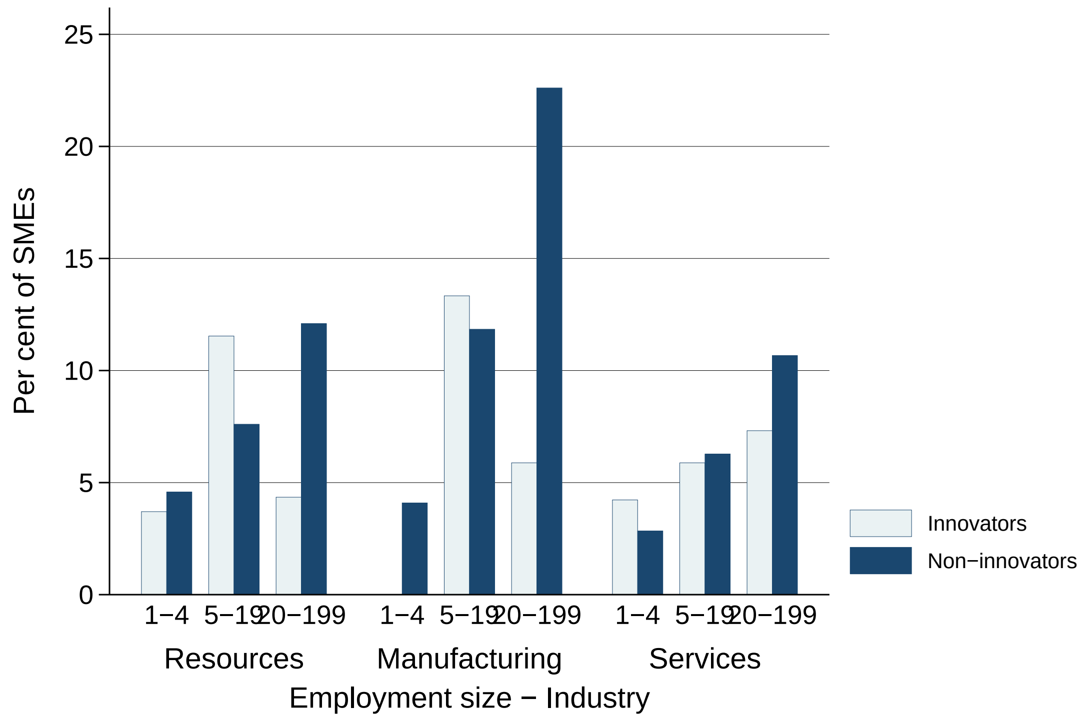
Figure 4.7: Proportion of businesses having a joint R&D arrangement, 2006-07, by employment size class and industry group



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable, =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise.

Figure 4.8 shows the proportion of SMEs which reported having received a grant from the Australian Government during the financial year 2006-07. Overall, firms which receive grants do not appear more likely to be classified as innovators. However, the tendency to receive a grant appears to increase with size, especially for non-innovators. The largest innovating SMEs in Manufacturing are considerably less likely to have received grants than non-innovating firms.

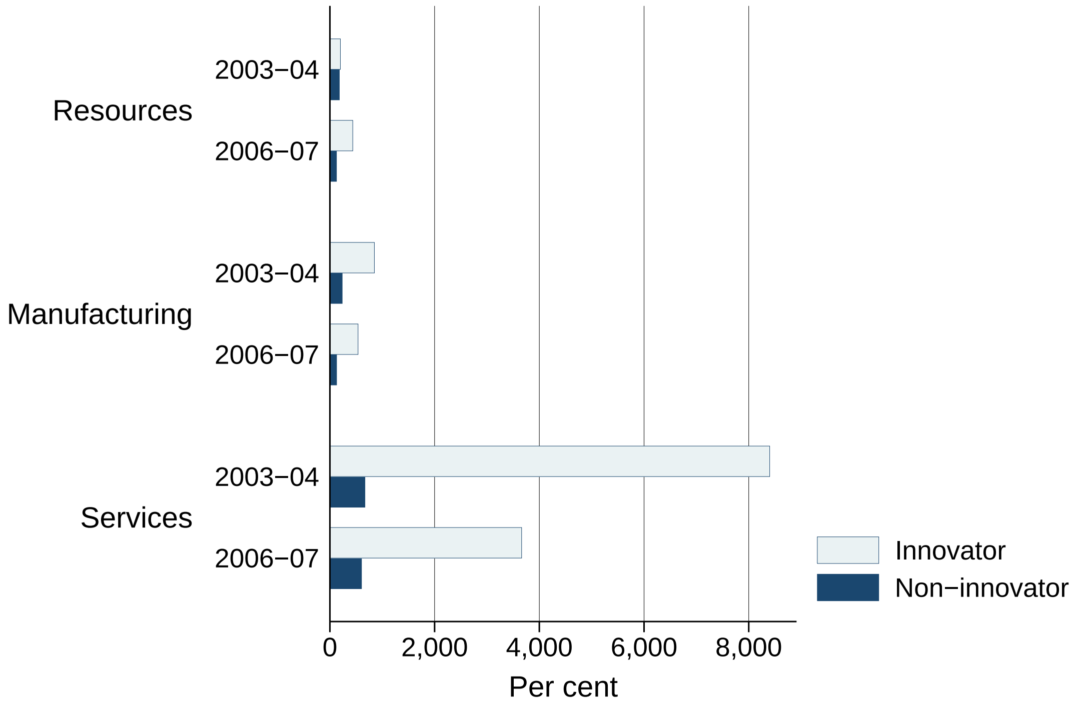
Figure 4.8: Proportion of SMEs which received grants, 2006-07, by employment size and industry group



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise.

Figure 4.9 shows the average ratio of total current-period investment expenditure to the previous period cash position. In Chapter 2 we discussed two recent studies which found that the amount of investment by non-innovators in one period is more dependent on the amount of cash in the previous period (Scellato 2007; Griffiths and Webster 2010). In terms of the investment to cash ratios presented in Figure 4.9, firms depend less on cash if the ratio is higher. The figure shows that innovators appear to depend less on cash than non-innovators across industries and years, indicating that they are less financially constrained. Interestingly, the ratios for innovators in the Services industry group are significantly larger than those in either Manufacturing or Resources. However, it is not possible to determine whether this captures the effects of 'lumpiness' in investment flows in Services, or whether there are genuinely lower financial constraints faced by innovating firms in that industry.

Figure 4.9: Total investment as a proportion of last year's cash, large firms, 2003-04 to 2006-07

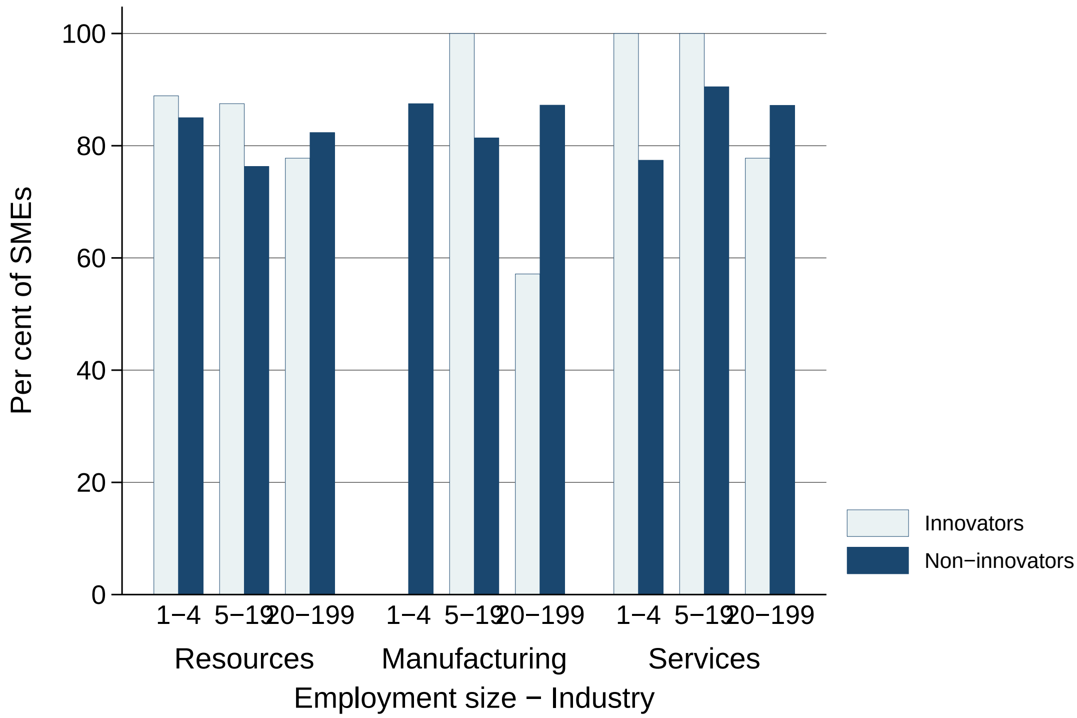


Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise.

Figure 4.10 shows the proportion of firms which sought and were able to obtain debt finance in the financial year 2006–07. It is evident that, across all size and industry groups (with the exception of large firms in Manufacturing and Services), about 80 per cent of firms rely on debt finance. However, this chart provides no indication about the extent to which debts was used in comparison with other finance. Furthermore, innovators appear to be slightly more able to access debt finance, in particular in the smaller size groups in the Resources and Services industries.

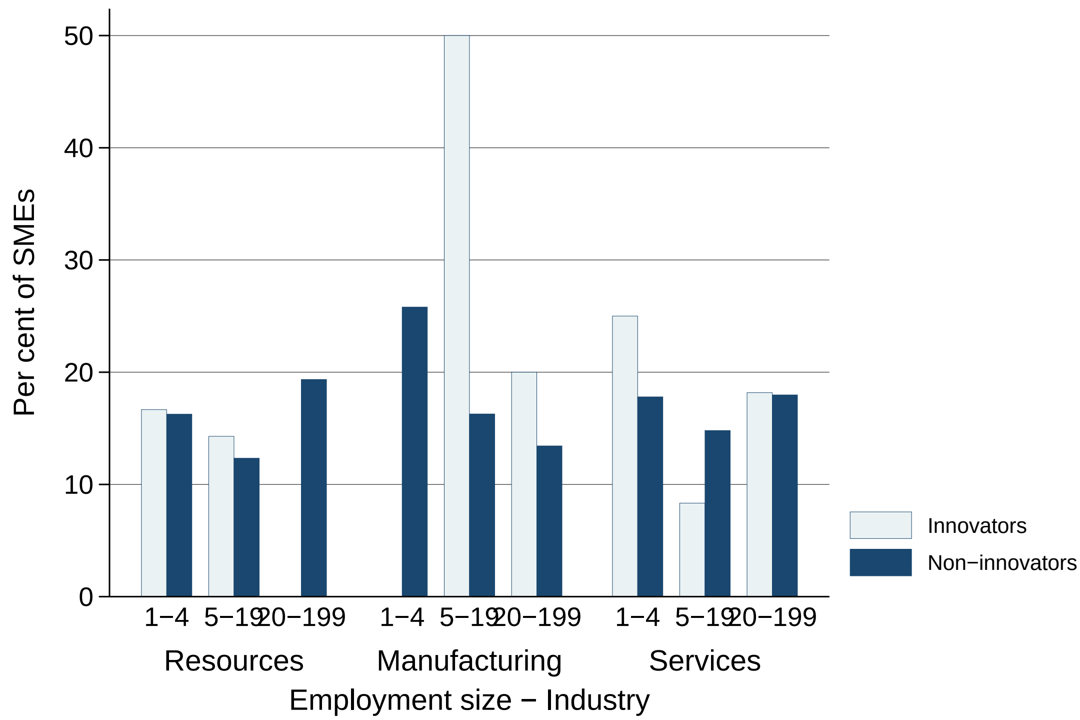
Figure 4.11 shows the proportion of firms which indicate that the cost and availability of finance are significant factors hampering their activity and performance. It appears that innovating firms have the strongest concerns regarding access to finance.

Figure 4.10: Proportion of SMEs which were able to obtain debt finance, by employment size class and industry group, 2006-07



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable, =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise.

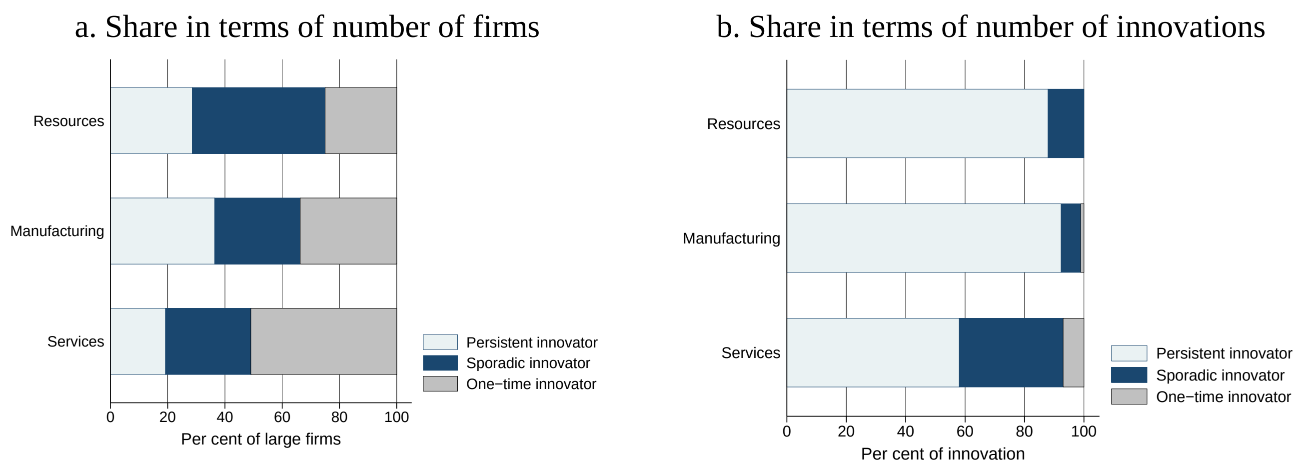
Figure 4.11: Proportion of SMEs which indicated that obtaining finance was a significant barrier to innovate, 2006-07, by employment size class and industry group



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise.

Another important finding from existing studies relates to persistence in innovation. In Figures 4.12a and 4.12b we look at large companies and define ‘persistent innovators’ as those firms which have at least one patent or design application in at least three consecutive years over the period from 1996 to 2007. ‘One-time innovators’ are defined as those firms which had only one patent or design application during the period. The third category is ‘sporadic innovators’, and covers the remaining firms (i.e. firms with two patent or design applications over the period, as well as three or more applications which were not made in consecutive years).

Figure 4.12: Persistent innovators, large firms, 2003-04 to 2006-07



Source: Processed from the IPRIA Scoreboard database (see Appendix 3)
Note: An innovating firm is a binary variable = 1 if filed at least one patent or design application at IP Australia in the respective year; =0 otherwise. Persistent innovators are innovators in three or more continuous year in 1996-2007. One time innovators are innovators only in one of the years. Sporadic innovators are innovators who are not classified as persistent or one time innovators.

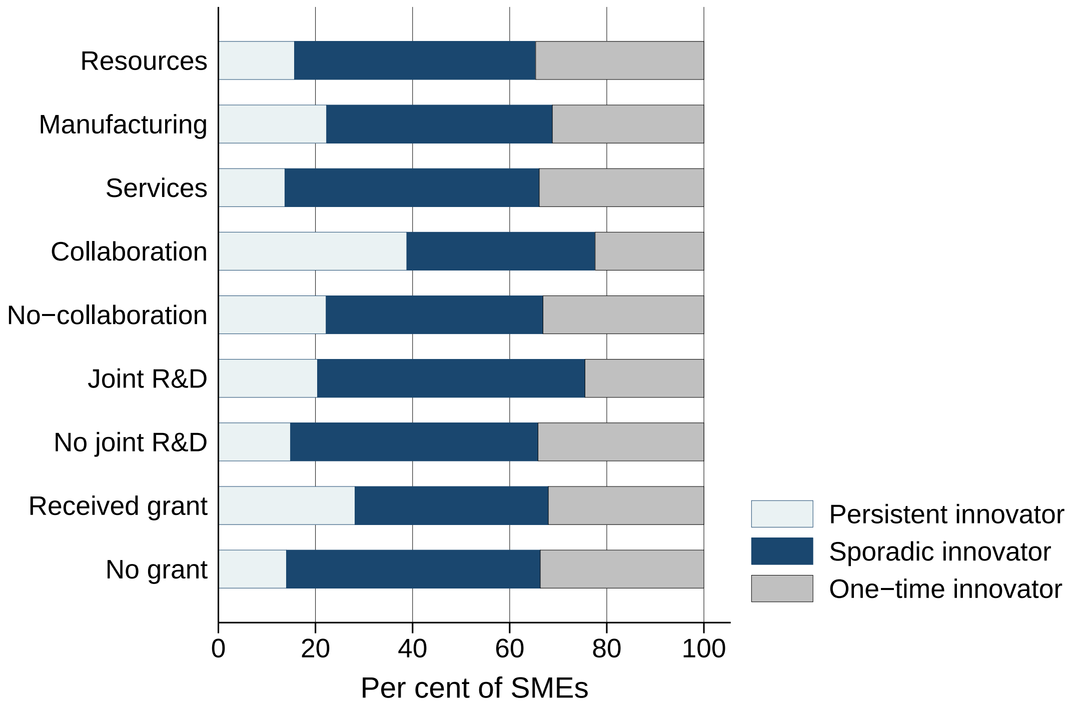
Figure 4.12a shows the distribution of innovating firms according to the above definition of persistent innovation. As shown, there is variation across sectors: more than half of the innovating firms in the Services industry are one-time innovators, while around half of the innovators in the Resources industry are shown to be sporadic innovators. For Manufacturing, the breakdown is almost even, with a slightly higher proportion of persistent innovators and one-time innovators than sporadic innovators.

Figure 4.12b looks at the same issue from a different angle, depicting the share of persistent innovators in terms of the total number of innovations (i.e. number of patent/design applications). For each industry group, persistently innovating firms account for the major number of innovations. For Resources and Manufacturing, respectively, more than 90 and 95 per cent of innovations are implemented by persistently innovating firms, while the number of persistent innovators in Services represents slightly more than two-thirds of the total number of innovations. This finding appears to be consistent with that of Geroski *et al.* (1997), Cefis (1999), and Cefis and Orsenigo (2001).

For the small and medium firms it is not possible to use the above definition of innovation persistence because the BLD data are only available for three years. Thus, in Figure 4.13, we use slightly modified definitions, as follows: ‘persistent innovators’ are those which innovate in all three consecutive years; ‘one-time innovators’ innovate in only one of the years; and ‘sporadic innovators’ are the rest of the innovating firms. In all cases ‘innovator’ refers to firms which indicated that they introduced new or significantly improved goods/services or operational processes.

In addition to showing the proportion of innovators in each industry according to their innovation persistence category, in Figure 4.13 we also give a breakdown according to the following three potentially important characteristics: whether or not the firms collaborate with other businesses in relation to innovation in any year; whether or not the firms have any joint R&D agreement with other firms in any year; and whether or not the firms received a grant from the Australian Government in any year. As can be seen from the figure, SMEs in manufacturing are more likely to be persistent innovators relative to the other industries (as is the case with large companies). Furthermore, it appears that firms which collaborate, engage in joint R&D agreement or received grant are also more likely to be persistent innovators.

Figure 4.13: Persistent innovators, small and medium firms, 2004-05 to 2006-07



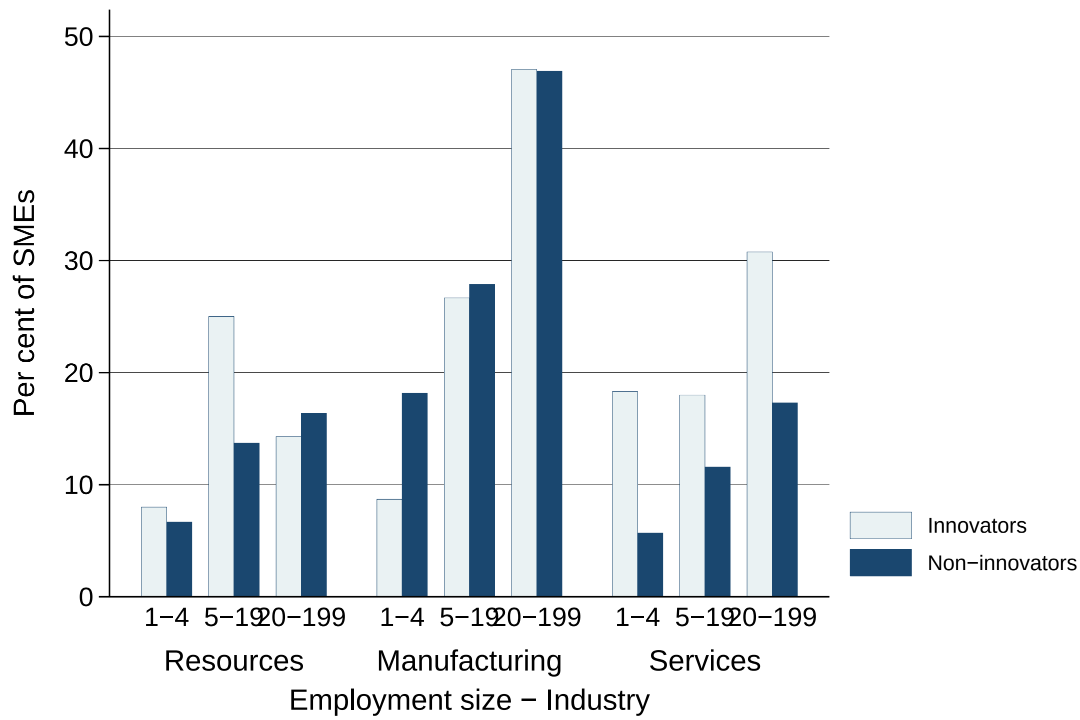
Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firms, is a binary variable = 1 if filed at least one patent or design application at IP Australia in the respective year; =0 otherwise. Persistent innovators are innovators in three or more continuous year in 1996-2007. One time innovators are innovators only in one of the years. Sporadic innovators are innovators who are not classified as persistent or one time innovators.

In Chapter 2 we discussed the importance of internationalisation with regard to firms' ability to gain economic benefits from their innovative activities. We also pointed out that the link between internationalisation and innovation is not straight forward, and probably depends on differences in technological opportunities and the extent of foreign presence in the domestic market. In Figure 4.14, we show the proportion of SMEs, by innovation status, which reported that they exported goods and/or services in the financial year 2006–07. The picture overall suggests that regardless of the innovation status larger firms are more likely to export.[14] Potential explanations for this are the existence of minimum size requirements to compete internationally and that large firms are more likely to cover (potentially) sunk costs associated with entering foreign markets. More interestingly, however, it can be seen that innovators in the Services industry (and to a lesser extent in

[14] However, again, given that the variable 'exporter' is binary, this relationship with size is probably not as important as it seems once all other factors are controlled for.

the Resources industry) are more likely than non-innovators to engage in the international market, where as in Manufacturing, non-innovating firms are more likely to export than innovators, especially in small size firms. This suggests that the relationship between innovation and export market participation is possibly non-linear, varying from one industry to another.

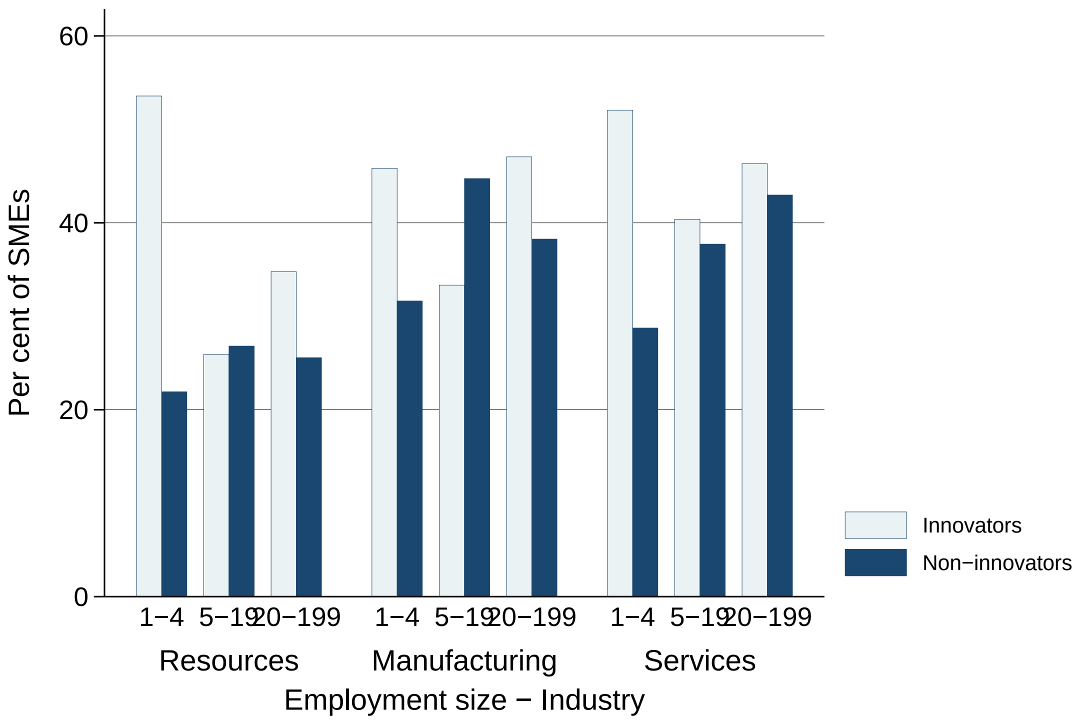
Figure 4.14: Proportion of SMEs who are exporters, 2006-07



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise. Exporters are firms which indicated having received any income from exports during the year.

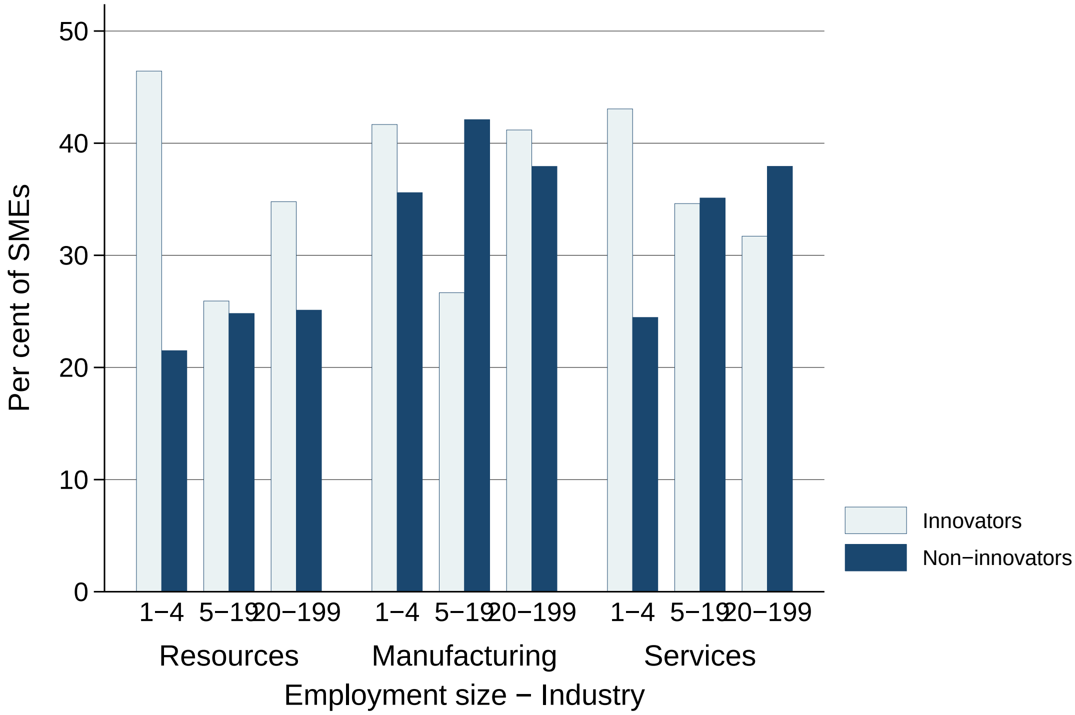
Figures 4.15 and 4.16 show the proportion of firms which reported higher profits and productivity respectively in 2006–07 compared to the previous year. While there is some variation across firm size and industry groups, innovating SMEs were generally more likely to report improvements in their economic performance than non-innovating SMEs. Bearing in mind that the information summarised in these two figures is based on subjective performance evaluation by the firm, it appears that there is a positive relationship between innovation and economic performance. However, it is not possible from these charts to make any conclusive statement on causality in terms of whether or not more innovation leads to higher performance.

Figure 4.15: Proportion of SMEs who reported increased profits 2006-07, by employment size class and industry group



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise. Increased profits reflect the subjective assessment of the firms..

Figure 4.16: Proportion of SMEs who reported increased productivity 2006-07, by employment size class and industry group



Source: Processed from the BLD CURF database (see Appendix 2)
Note: An innovating firm is a binary variable =1 if the firm has introduced any new or significantly improved goods/services or operational process in the respective year; =0, otherwise. Increased productivity reflect the subjective assessment of the firms..

5. Comparisons with Top EU and UK R&D Firms

As discussed earlier innovation is a complex and multi-faceted process, which complicates the measurement of innovation and therefore makes comparisons of the innovative performance of heterogeneous institutions such as firms or countries difficult. As a consequence, R&D Scoreboards have been developed in a number of developed countries in order to assess how innovative activities vary across firms. In the United Kingdom, for example, the Department for Business Innovation & Skills has published the UK R&D Scoreboard annually since 1991, with its 2009 edition covering the performance of the top 1000 UK-based firms in terms of R&D expenditure. Similarly, in every year since 2004 the Joint Research Centre and Research Directorates General of the European Commission has published the EU Industrial R&D Investment Scoreboard, with the 2009 edition providing comparisons of the top 1000 EU companies in R&D expenditure.[15]

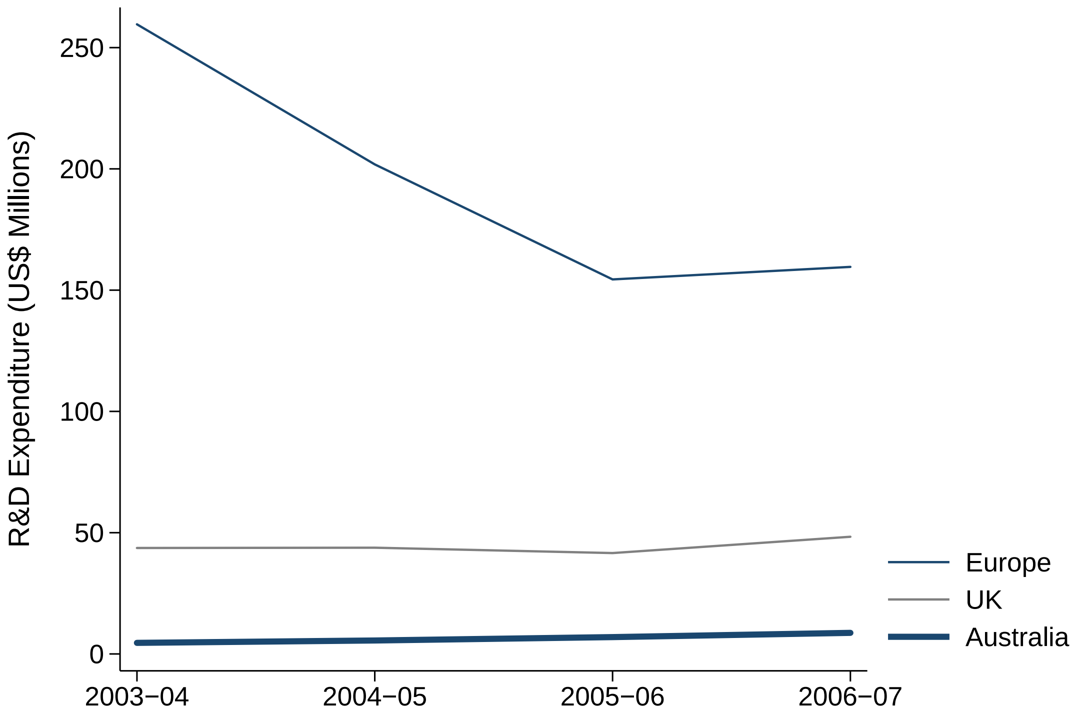
In Australia, similar R&D Scoreboard data for large firms with more than A$50 million total revenue per year are available for the period 1998–2007. These data are developed and published originally by the Melbourne Institute, and later by IPRIA, with collaboration from IBISWorld and IP Australia. The latest published version of the Scoreboard, i.e. 2007, covers as many as 3,400 Australian-based firms listed in the IBISWorld enterprise database. Of these firms, 291 firms reported positive R&D expenditure in the 2005–06 financial year and we refer to them as the top Australian firms. Similar numbers of R&D spenders have been reported in other years. While the number of companies in the Australian R&D Scoreboard is lower than those of the EU and UK Scoreboards, the Australian data cover the whole population of Australian large enterprises and we can treat the represented companies as the top R&D spenders in Australia. Because of this, it is the R&D performance of these firms that we report and compare with the top EU and UK R&D firms in this chapter.[16]

[15] It should be noted that the number of companies covered by the EU and UK Scoreboard varies across the years, increasing from 700 in 2004 to 1000 from 2006 on for the EU and from around 300 UK firms and 100 global firms in 1991 for the UK to 1000 firms in each category in 2009.

[16] Because the EU and UK Scoreboards exclude universities and publicly-funded research institution, we also exclude Australian universities and publicly-funded research institutions such as CSIRO.

Figure 5.1 shows the average R&D expenditure per firm of Australian-based, EU-based, and UK-based top firms for the period 2003-04 to 2006-07 in current US$.[17] Over the period, the average R&D expenditure of Australian firms increased from US$4.6m in 2003-04 to around US$8.7m in 2006-07.

Figure 5.1: Average R&D expenditures per top firm, 2003-04 to 2006-07

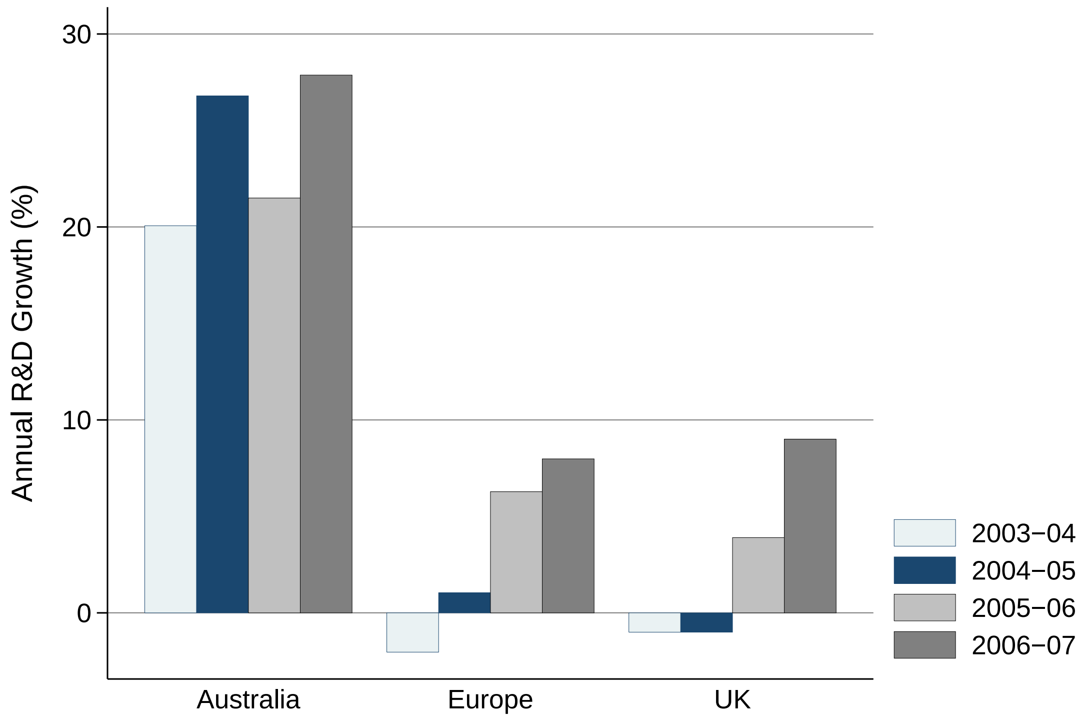


Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

As shown in Figure 5.2, R&D expenditure by Australian firms has increased at an average annual growth rate of 20-30 per cent p.a., more than double the growth rate in the other two regions.[18] However, the Australian top R&D spenders are much smaller than the UK and EU-based top R&D spenders.

[17] The period is chosen so that data are available for all of the three regions.
[18] These are nominal growth rates.

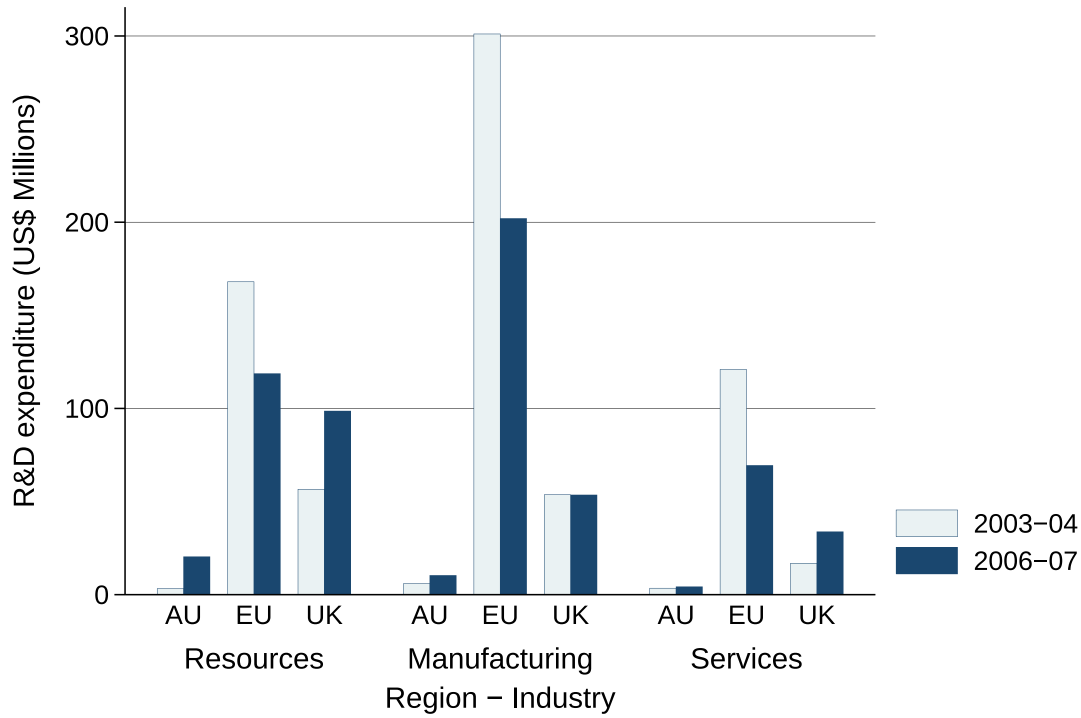
Figure 5.2: Annual growth rate in R&D expenditure, 2003-04 to 2006-07, by top firms



Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

Figure 5.3 shows the same average R&D expenditure per top firm summarised in Figure 5.1 according to broad industry groups: Resources, Manufacturing and Services. In 2006-07, Australian-based firms in the Resources industry group spent significantly more on R&D than those in the other industries, unlike Resources firms from the other two regions. However, this reflects the larger size of Australian Resource firms compared to those in Manufacturing and Services, rather than a higher propensity to do R&D (see the end of this chapter for more on this issue). Another interesting point to note from Figure 5.3 when comparing the three regions is the relatively large R&D spending by the EU's manufacturing firms.

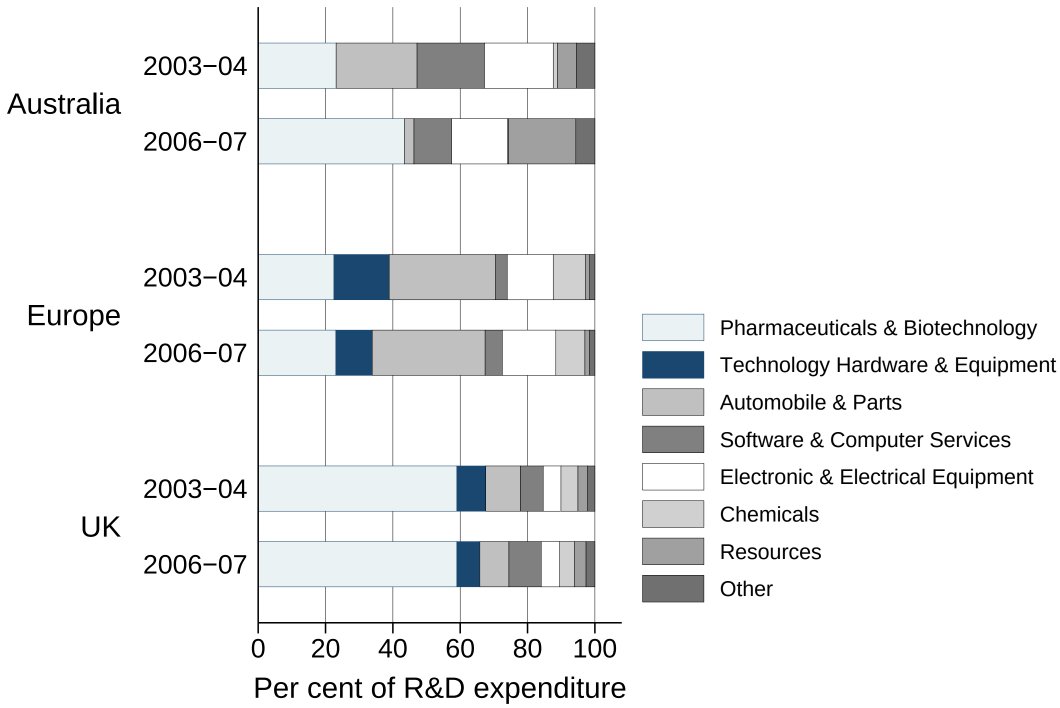
Figure 5.3: Average R&D expenditure per firm, 2003-04 and 2006-07, by industry



Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

In Figure 5.4, the shares of total R&D expenditure by sector in each region are shown. From the figure it can be seen that Pharmaceutical and Biotechnology firms are amongst the most important R&D performers, especially in Australia and the United Kingdom, where they account for more than 40 per cent of total R&D spending in 2006–07. While the Automobile and parts sector was important in Australia in 2003–04, its share dropped significantly in 2006–07 and was taken over by Resources. EU firms in the Automobile and parts industry made the most important contribution to R&D expenditure in both years. In contrast to the United Kingdom and European Union, there appears to be no R&D expenditure by Australian firms in the technology hardware equipment sector.

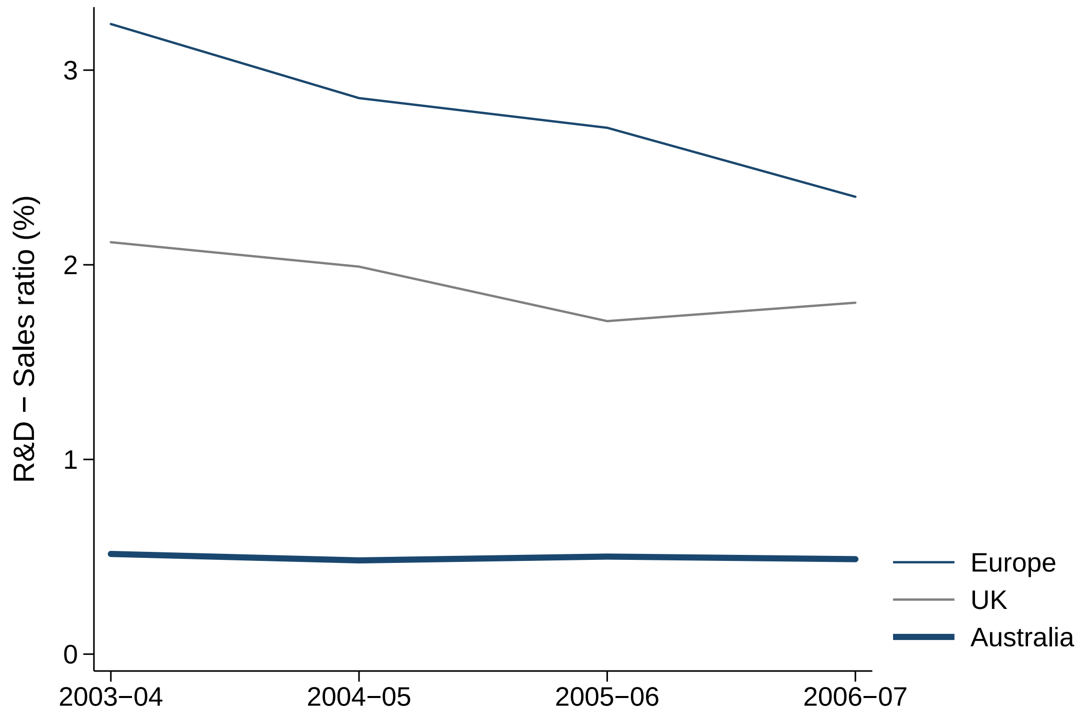
Figure 5.4: Distribution of R&D expenditure, 2003-04 and 2006-07, by sector



Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

Figure 5.5 shows the trend in R&D intensity—which we define as R&D expenditure as a proportion of sales revenue. It reveals that the R&D intensity of Australian firms is much lower than that of firms in the European Union and the United Kingdom and appears to be unchanged between 2003–04 and 2006–07. The relatively flat R&D intensity over the years for the case of Australia indicates that the increased in R&D expenditure shown in Figure 5.1 earlier may reflect the stronger economic performance of Australian firms in that period, rather than a higher propensity to conduct R&D.

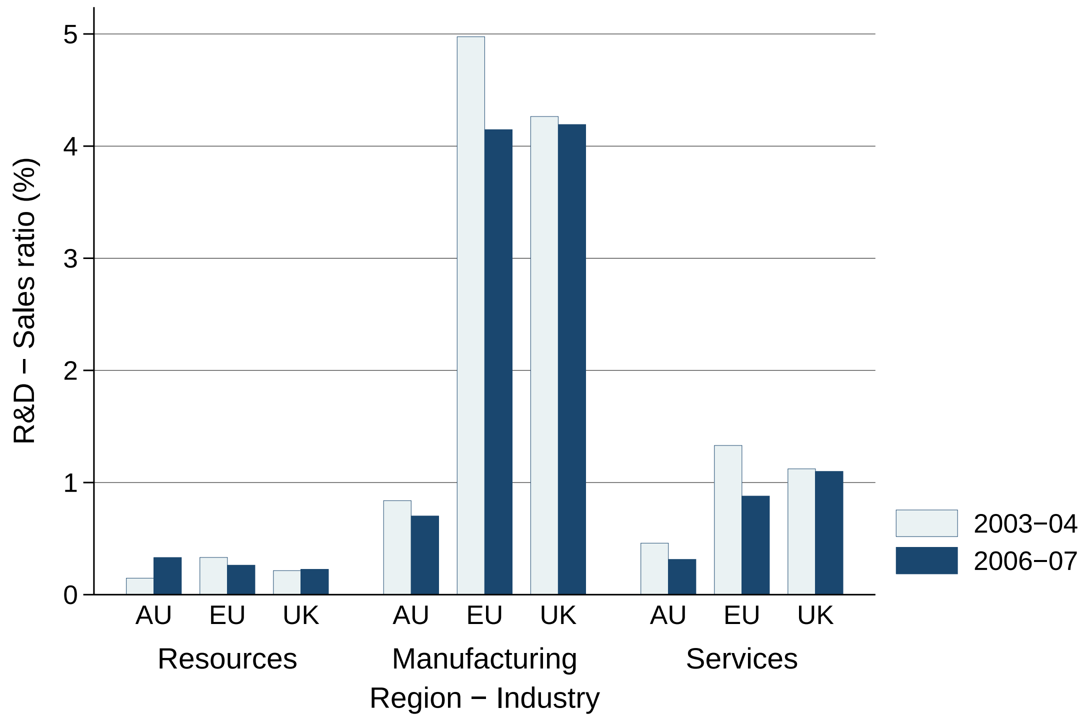
Figure 5.5: R&D intensity, 2003-04 to 2006-07



Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

However, as shown in Figure 5.6, R&D intensity varies widely across industries. As in the other two regions, Australian firms in the manufacturing industry are more likely to have higher R&D intensity. While firms in the Australian Resources industry have a higher level of R&D expenditure than those in Manufacturing and Services, their R&D intensity appears to be the lowest. Another to note in Figure 5.6 is the significantly lower R&D intensity of Australian firms in the Manufacturing industry than those in the same industry in the European Union and the United Kingdom. UK-based firms in Manufacturing, in particular, spend less than one-third of the total expenditures on R&D by top EU companies (see Figure 5.3) and yet they were able to match the R&D intensity of those European firms.

Figure 5.6: R&D intensity, 2003-04 and 2006-07, by region

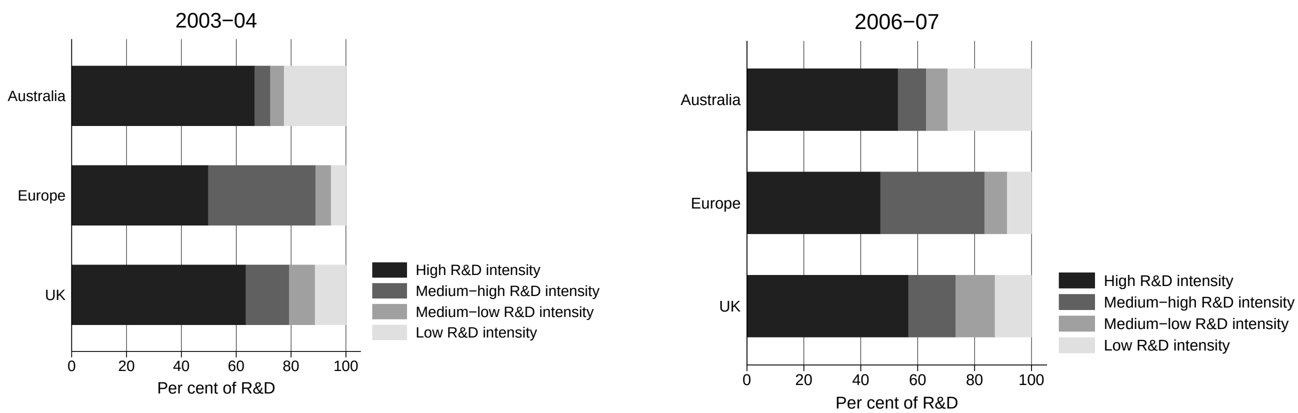


Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

In order to provide a deeper understanding of the propensity of Australian firms to conduct R&D, we divide the firms into four categories: high R&D intensity (intensity >5 per cent), medium-high R&D intensity (intensity between 2 per cent and 5 per cent), medium-low R&D intensity (intensity between 1 per cent and 2 per cent), and low R&D intensity (intensity <1 per cent).[19] Figure 5.7 shows the R&D expenditure shares of the firms in each of these categories. For Australia, most R&D expenditure is accounted for by firms which belong to the high R&D intensity group, followed by those which belong in the low intensity group. Thus, it appears that a small number of high intensity firms account for the bulk of R&D spending by Australian firms; the rest is picked up by a large number of low intensity firms. Unlike in Australia, firms with medium intensity play a more significant role in the United Kingdom and especially in the European Union, possibly indicating a broader base of R&D activity in these regions.

[19] This classification follows the 2008 E.U. Industrial R&D Investment Scoreboard.

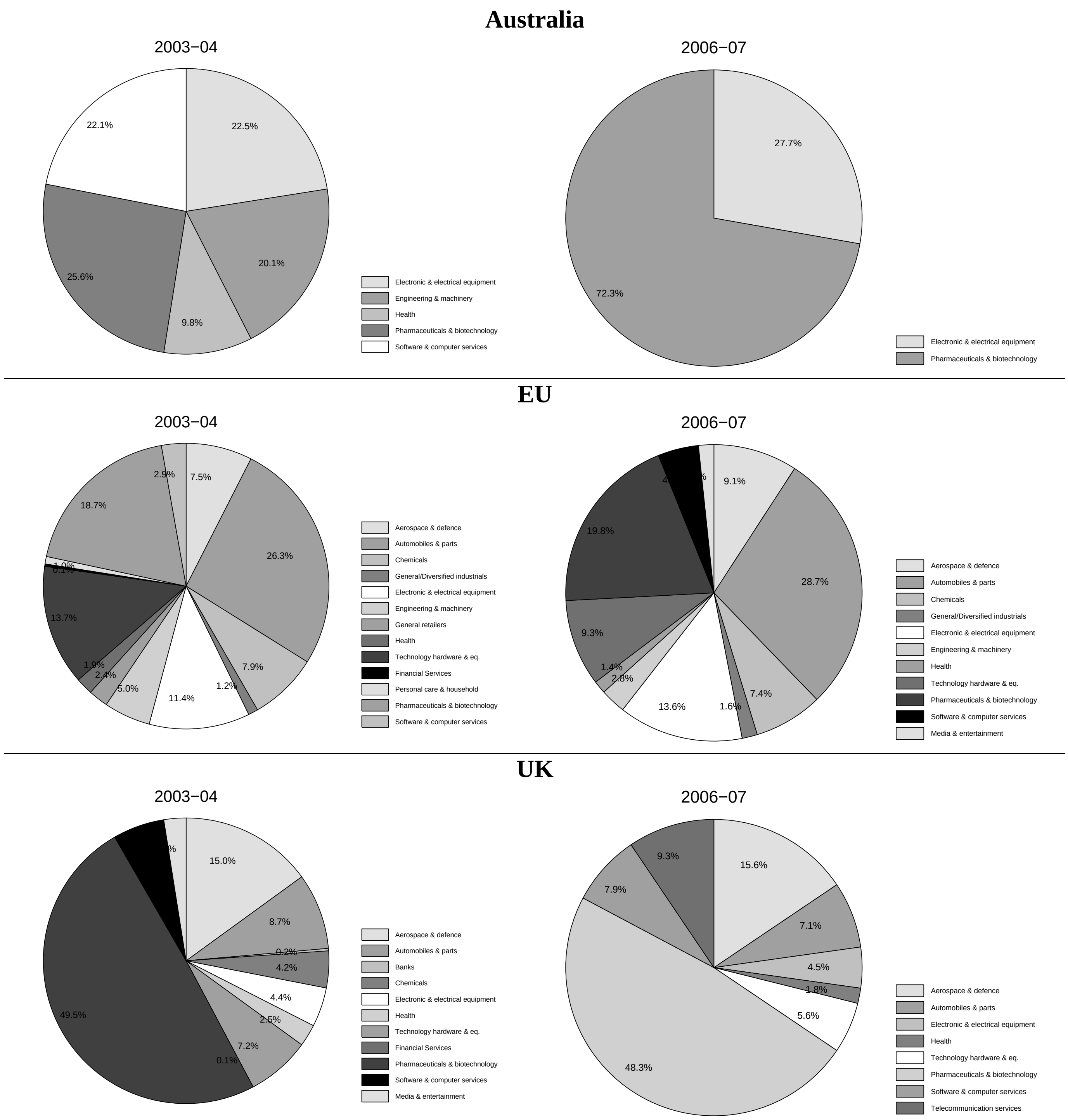
Figure 5.7: R&D expenditure share, 2003-04 and 2006-07, by R&D intensity category



Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

Figure 5.8 confirms our observation that R&D activities have a broader industry base in both the European Union and the United Kingdom than Australia. From this figure, it is apparent that the number of sectors in which firms have either medium-high or high R&D intensity is significantly greater in those two regions. In 2003–04, the spread of industries in Australia which included firms that can be classified as at least medium-high R&D intensity Australian covers Electronics and Electrical equipment, Engineering and Machinery, Health, Pharmaceuticals and Biotechnology, and Software and the Computer services sectors. However, by 2006–07, only Pharmaceuticals and Biotechnology and Electronics and Electrical equipment were represented in the most R&D-intense categories. The share of Pharmaceutical and Biotechnology firms in total Australian firms with at least medium-high R&D intensity is more than 70 per cent. In the United Kingdom, the comparable share of the firms in this sector is also significant, at close to 50 per cent. The industry concentration in Australia is not a negative and may indicate a sensible specialisation in our areas of comparative advantage.

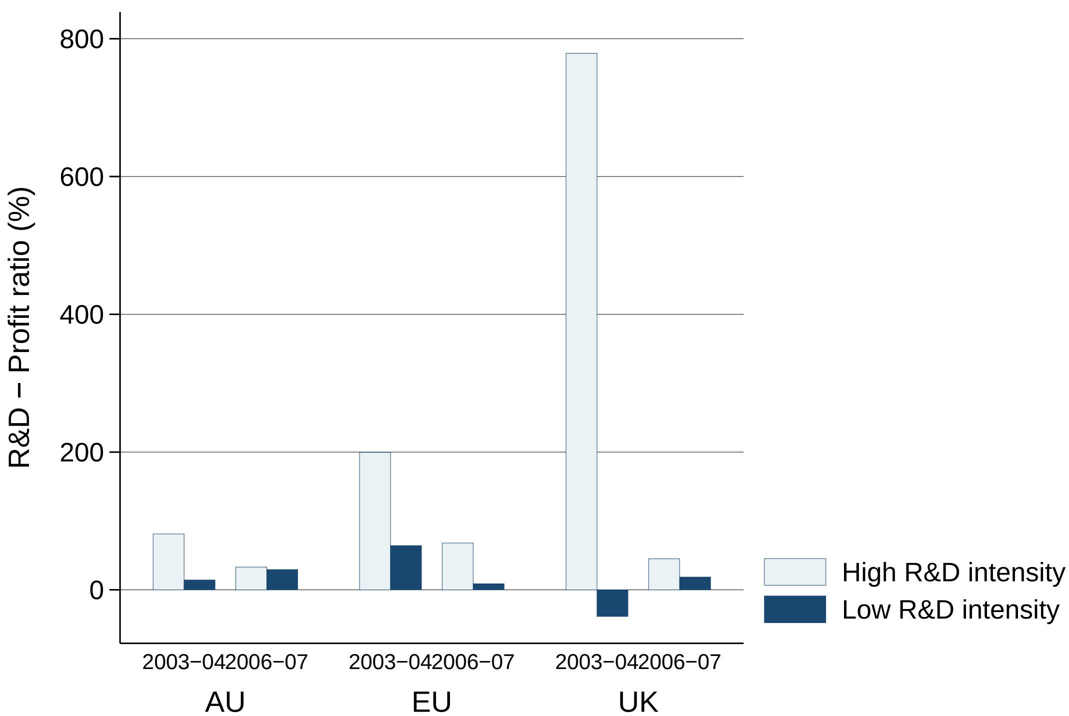
Figure 5.8: Distribution of R&D expenditure of firms with medium-high and high intensity, 2003-04 and 2006-07



Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

Finally, Figure 5.9 shows how R&D expenditure and profits are linked. In this figure, we classify firms with medium-high and high R&D intensity as 'high R&D intensity'; firms with medium-low and low R&D intensity are classified as 'low R&D intensity'. From Figure 5.9 we can see that on average, high R&D intensity firms devote a significantly larger share of their profits to R&D.

Figure 5.9: Average R&D expenditure as proportion of profit, 2003-04 and 2006-07, by R&D intensity



Source: Processed from IPRIA Scoreboard, EU Scoreboard, and UK Scoreboard (see Appendices 3, 5, 6)

6. Factors Affecting Australian Inventors

This chapter examines Australian innovation activities at the inventor/invention level. As suggested by two of the leading researchers in this area, “analyses at the individual innovation project level, whenever possible, can be of course extremely instructive and useful to complement and enlighten analyses performed at the overall level of firms” (Mairesse and Mohnen 2010, p.11). For example, information on the commercialisation stages of specific invention is not available from the firm level survey, yet such information is crucial in understanding the link between innovation and economic performance.

In 2007 IPRIA surveyed all named Australian inventors listed on patent applications between 1986 and 2005. This survey collected information on commercialisation outcomes of 3,736 inventions and the determinants of commercialisation success.[20] Essentially, the Inventor Survey provides us with a picture of innovation beyond that which can be provided by firm-level data such as R&D expenditure and patenting counts. Given the importance of the Manufacturing sector in innovation, and especially the more extensive use of patents by the sector, we structure our discussion by comparing Manufacturing as one sector and Resources and Services as the other combined sector. While patent applications are an imperfect measure of an organisation’s inventive output, since not all inventions are patentable or worth patenting given the organisation’s financial resources, patent data contain some useful information, especially for the Manufacturing sector.[21]

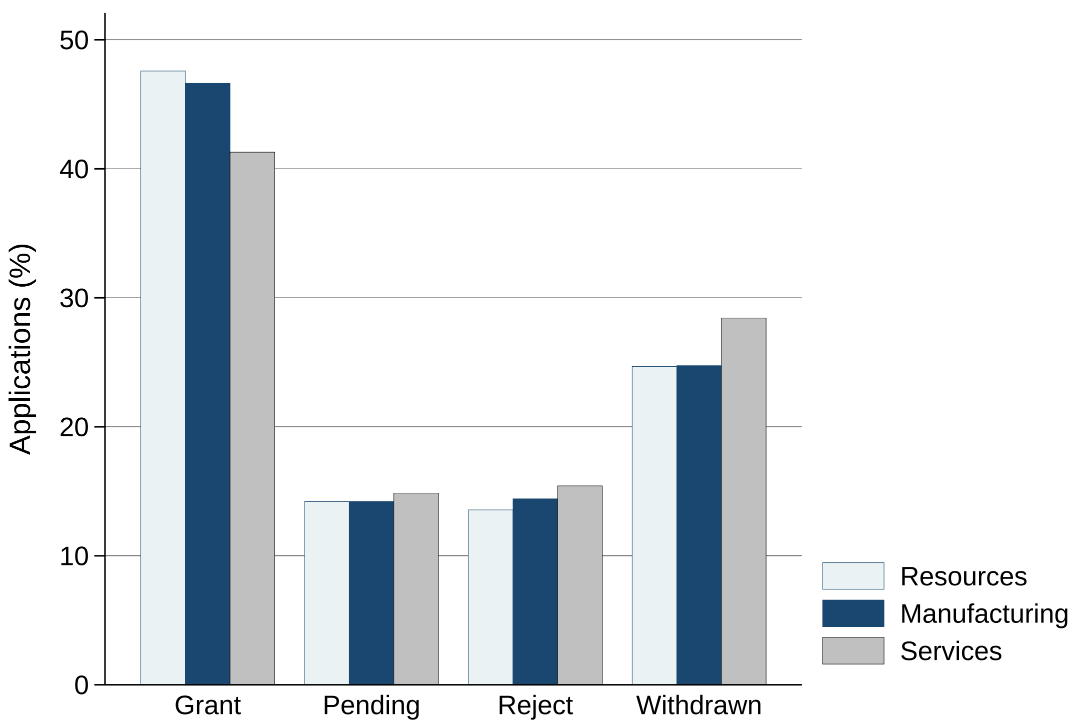
There has been an increasing trend in the number of patents filed by Australian organisations over the past two decades, and about half of these have come from the Manufacturing sector. SMEs that file for a patent are more likely than large firms to be in

[20] See Appendix 4 and Jensen and Webster (2009) for more details.
[21] It should be noted that the information from the survey is only accurate to the extent the inventor (a) knew about what happened to their invention after the patent application was lodged, (b) has an unbiased assessment of the facts and (c) is not subject to significant re-call errors and biases. There was some bias in the response to the survey: more recent inventors and those whose application had been granted were more likely to respond. However, the size of this bias is not large. Note that the analysis in this chapter excludes about one third of all Australian patent filings which are made by individuals rather than organisations.

the Manufacturing sector. Large firms are disproportionately more like to be in Mining or Wholesale Trade. Manufacturing industries are slightly more successful than other industries in obtaining a patent. Of all patent applications filed between 1986 and 2007, 45 per cent had been granted as of August 2009, 26 per cent had been withdrawn by the applicant, 14 per cent were rejected and the remaining 15 per cent were still pending an outcome.

According to Figure 6.1, the grant rate was highest for Resource firms and lowest for Service sector firms, although the difference between Resources and Manufacturing was small. In the Manufacturing industry, the grant rate was 47 per cent. The Services sector had the highest percentage of patent applications withdrawn, pending and rejected. Note that consistent with previous chapters, Services excludes the predominantly non-commercial government-owned sectors of Education, Health and the CSIRO (see fn 8).

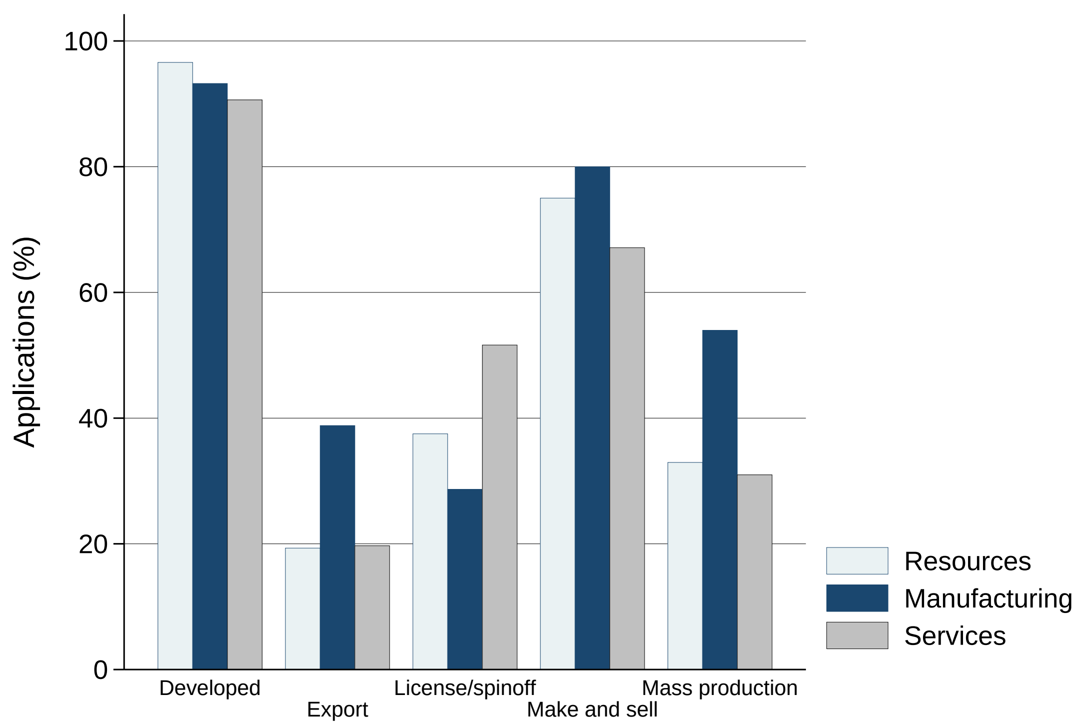
Figure 6.1: Status (as at April 2007) of patent applications filed by organisations located in Australia, 1986-2007, Manufacturing and Other industries



Source: Processed from Melbourne Institute's Australian Inventor Survey (see Appendix 4)

The data from the inventor survey provide us with information about what happens to the inventions beyond the formal patenting process. According to the data and as shown in Figure 6.2, about 30 per cent of Manufacturing-firms attempted to license or spin off their invention compared with 50 per cent in the service sector and less than 40 per cent in resources. About 90 per cent of all organisations, regardless of their industry, had attempted one or more development stages (such as proof of concept, testing and validation, or creating a prototype) reflecting the fact that development and filing for a patent often go hand-in-hand.

Figure 6.2: Commercialisation stages attempted (as at April 2007) for patent applications filed by organisations located in Australia, 1986-2005, Manufacturing and Other industries



Source: Processed from Melbourne Institute's Australian Inventor Survey (see Appendix 4)

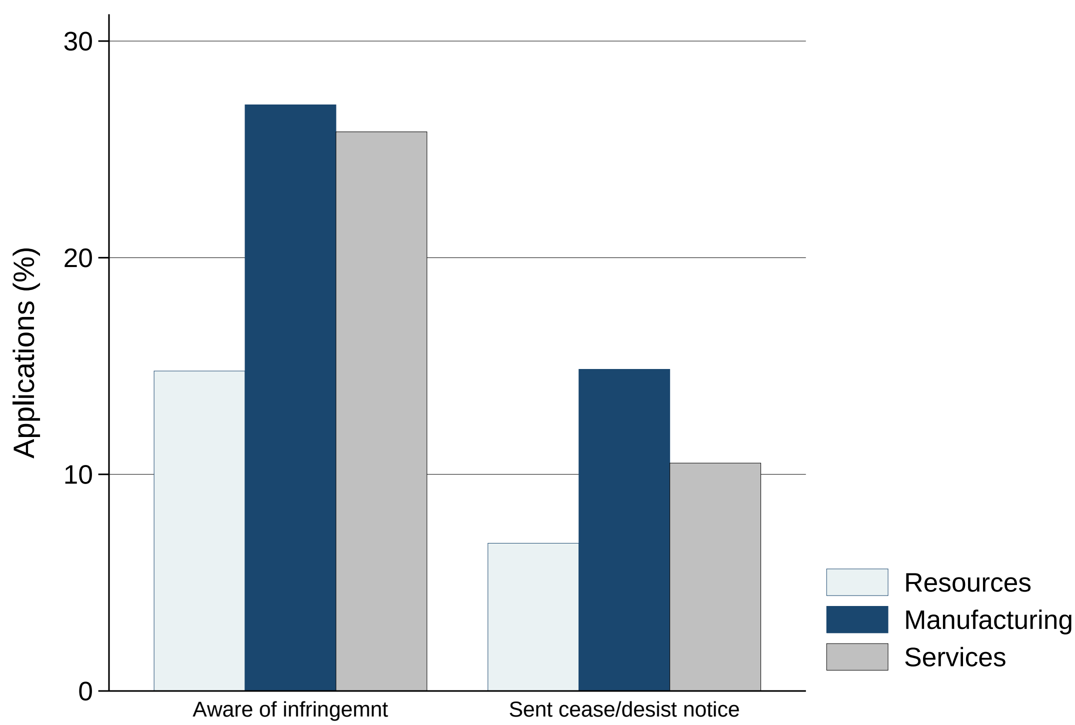
However, Manufacturing firms were considerably more likely than other organisations to attempt other downstream commercialisation stages. Eighty per cent of Manufacturing firms attempted the 'make and sell' stage (gathering market intelligence, validating commercial opportunity, trialling the manufacturing process and market launch) compared with about 75 per cent in the service sector and less than 70 per cent in resources. About half of Manufacturing firms attempted mass production compared with only a quarter of organisations from other industries. Finally, about 40 per cent of Manufacturing firms were exporting, compared with 20 per cent of firms in other industries. This higher rate of commercialisation possibly reflects the greater access private companies, especially large companies, have to the operation and marketing capabilities that are needed to take an invention to the final retail stage.

Organisations may file for a patent for several intermediate reasons. However, the primary motive is the desire to limit competitors' ability to copy their ideas. We have only been able to identify four surveys that have sought to quantify how much copying or infringement exists anywhere in the world. These are Kingston (2000), You and Katayama (2005), Rodwell *et al.* (2007) and Weatherall and Webster (2009). Kingston conducted a representative survey of 3,660 SMEs with EU-originating patents granted at the United States Patent and Trademark Office (USPTO) or European Patent Office (EPO). He received 549 replies (15 per cent response rate) and found that 67 per cent of SMEs alleged that another party had copied their inventions despite the presence of a patent.

A survey in 2000 of 98 Japanese-owned subsidiaries in China (You and Katayama 2005) estimated that 30 per cent of companies believed their patents were being infringed locally. A small survey of 143 firms with undisclosed bias and response rates was undertaken for the EU Directorate-General for Enterprise and Industry. The study, which only included SMEs in certain industries (Auto parts, Mechanical engineering, Textiles, and Toys), found that 27 per cent of firms believed they had been 'affected' by patent infringement. Although these studies provide valuable information about the extent of infringement, it should be noted that they are based on small, unrepresentative samples.

The Weatherall and Webster (2009) study is based on the Australian Inventor Survey (2007). Using survey responses from 3736 inventors who had applied for a patent, they estimated that inventors believed in 28 per cent of cases copying had occurred. Figure 6.3 presents this information disaggregated by whether the owner was in a Manufacturing industry or not. It shows that inventors from Manufacturing and Services sector establishments were considerably more likely to be aware of the occurrence of copying than inventors from resources. Manufacturing and Services sector employers were also more likely to send the alleged infringer a 'cease and desist' letter. Clearly, infringement is a more important issue for these industries than the Resources industry firms that use the patent system. This may be because more infringement is actually occurring, or because manufacturers consider it more worthwhile to devote resources detecting it.

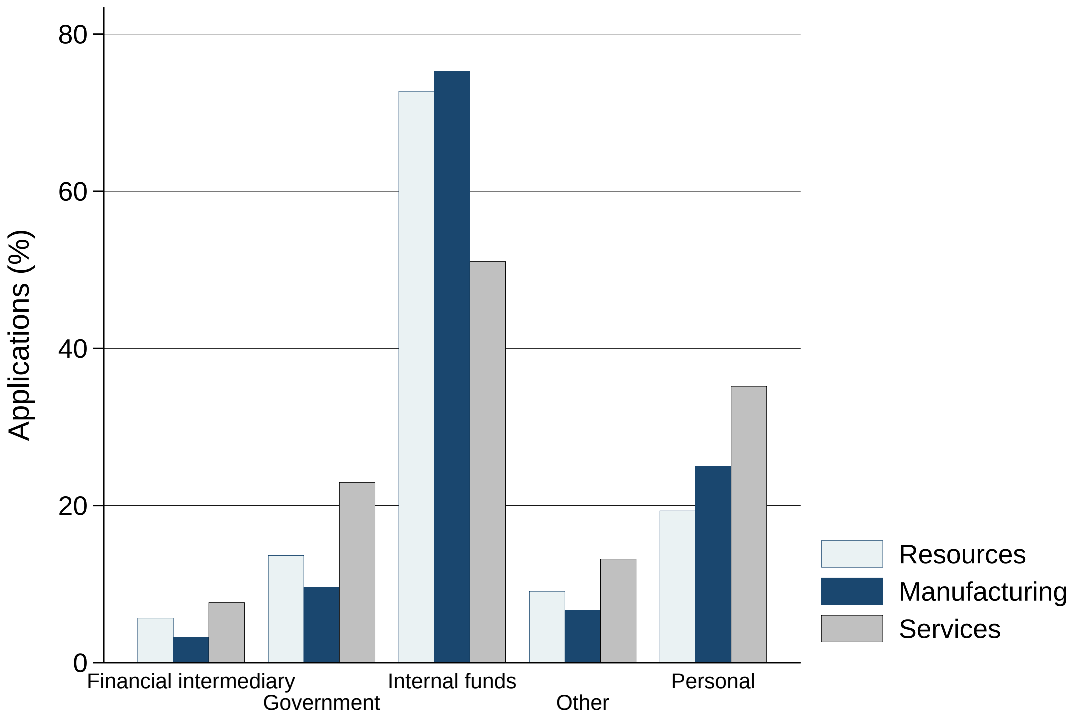
Figure 6.3: Infringement history (as at April 2007) of patent applications filed by organisations located in Australia by sector, 1986-2005



Source: Processed from Melbourne Institute's Australian Inventor Survey (see Appendix 4)

Figure 6.4 shows that most of the R&D funds used to produce the inventions in the Australian Inventor Survey were drawn from internal funds. While this is true for all sectors, it is most pertinent for Resources and Manufacturing. However, it is interesting to note that 9 per cent of manufacturing inventors nominated government funds as a major source of funding. Personal funds are also a significant source of funds in the service sector.

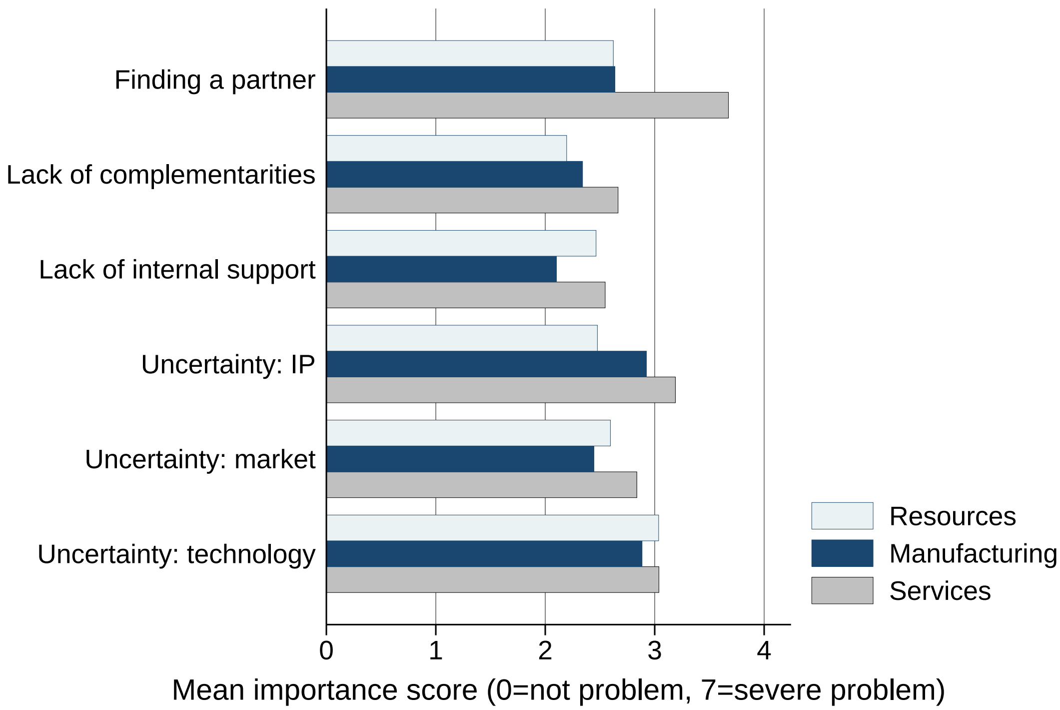
Figure 6.4: Source of research funds of patent applications filed by organisations located in Australia by sector, 1986-2005



Source: Processed from Melbourne Institute's Australian Inventor Survey (see Appendix 4)

Inventors were also asked to rate the relative importance of various barriers to commercialisation. Figure 6.5 reveals that 'finding a partner' was the most commonly-cited barrier for firms outside the Manufacturing industry, especially for Services sector firms. While Resources firms were more concerned about technological uncertainty, Manufacturing inventors were most likely to cite uncertainty over the ability of their IP to prevent infringement and uncertainty over the feasibility of the technology as the main barriers. This is consistent with Figure 6.4 which showed that manufacturing inventors were more likely to believe that another party had been copying their idea.

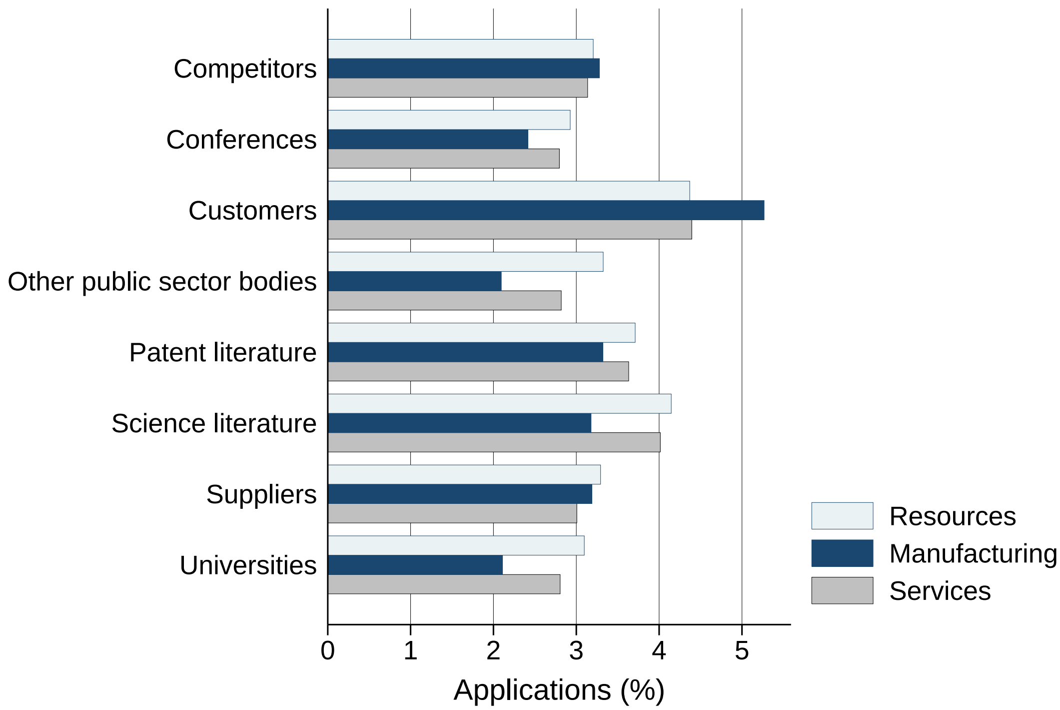
Figure 6.5: Importance of commercialisation barriers, patent applications filed by organisations located in Australia by sector, 1986-2005



Source: Processed from Melbourne Institute's Australian Inventor Survey (see Appendix 4)

According to Figure 6.6, customer product users are the most important source of ideas and knowledge for Manufacturing, and to a slightly lesser extent, Resources and Services inventors. Scientific literature is also very important for Resources and Services sector firms.

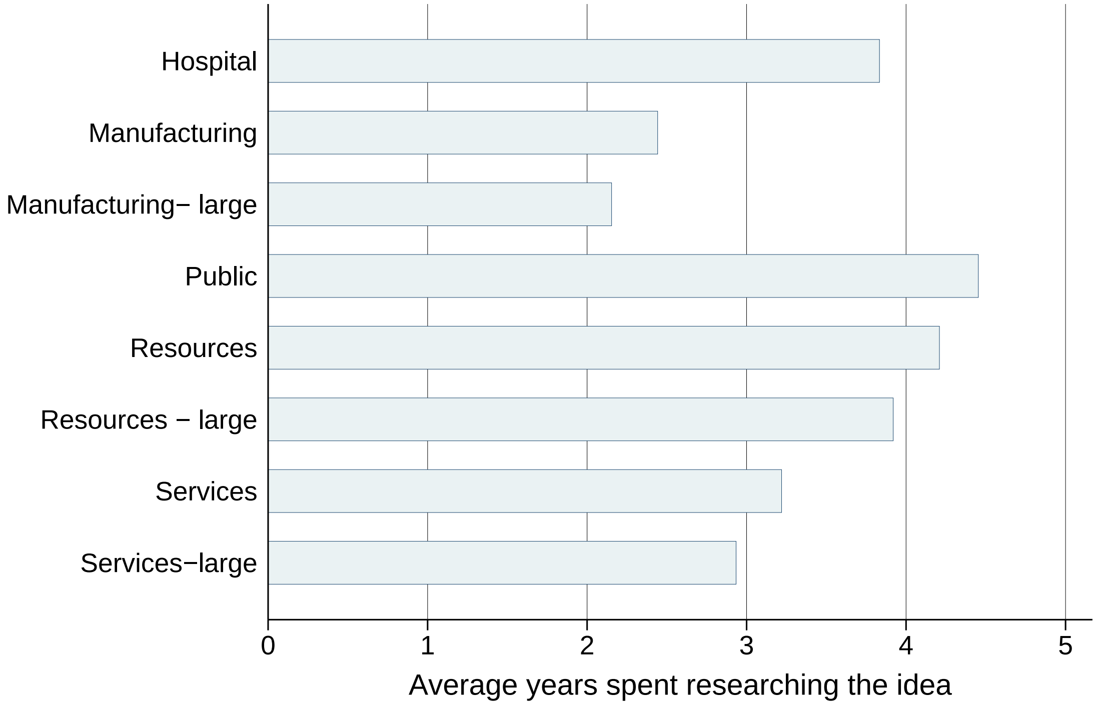
Figure 6.6: Importance of knowledge sources, patent applications filed by organisations located in Australia by sector, 1986-2005



Source: Processed from Melbourne Institute's Australian Inventor Survey (see Appendix 4)

Finally, Figure 6.7 reveals that compared with other firms, Manufacturing firms, especially large ones, spend a smaller amount of time researching the ideas behind their inventions. Public sector organisations (which are not classified into sectors) spend the most amount of time researching the idea behind the patent. All in all, SMEs appear to spend more time on research than large firms, which may reflect greater overall caution by SMEs when it comes to patenting compared to large firms.

Figure 6.8: Average years spent researching the invention, patent applications filed by organisations located in Australia, 1986 to 2005



Source: Processed from Melbourne Institute's Australian Inventor Survey (see Appendix 4)

7. Determinants and Impacts of Innovation

This chapter discusses some preliminary findings from a multivariate analysis of the determinants of innovative activities and their outcomes by small and medium sized Australian enterprises and the impacts of innovation on enterprise performance. As reviewed in Chapter 2, theories and evidence from existing studies show that firms' decisions about whether or not to undertake innovation activities, the outcomes of these activities and the resulting economic performance of the enterprise are systematically related. To a limited extent, the descriptive analyses in Chapters 4–6 seem to support the notion that there is a systematic link between R&D, innovation and performance for Australian enterprises, and show that factors such as firm size and access to finance are important. The multivariate analysis discussed in this chapter aims to sharpen the preceding analyses by controlling for the influence of all other factors when examining these relationships.

7.1 Empirical framework

Our multivariate analysis is based on a structural model developed by Crépon *et al.* (1998). The basic intuition of the model can be described as follows. First, firms decide whether or not to engage in innovative activities by investing in R&D. Then, given their investment in innovative activities, along with other relevant inputs, firms produce new knowledge as measured by their innovative outputs. Finally, they incorporate their new knowledge into their production activities, the effect of which is captured by their productivity or profitability. In this way, the interdependence of the components of the system is appropriately accounted for, such that the estimates obtained are less prone to simultaneity bias and more reliable to interpret. This approach has been applied to a number of studies based on matched, firm-level production and innovation data from various countries including France (Crépon *et al.* 1998), the Netherlands (van Leeuwen and Klomp 2006, and Klomp and van Leeuwen 2001), Chile (Benavente 2006), Sweden (Lööf and Heshmati, 2006), China (Jefferson *et al*., 2006), Argentina (Chudnovsky *et al.* 2008), Estonia (Masso and Vahther 2008), and Australia (Wong et al. 2007).

Due to data limitations, the approach used in this chapter is a simplified version of the original CDM model as applied by Griffith *et al.* (2006)[22] which assumes a recursive structure where no feedback effect is allowed and consists of the following estimating equations:

R&D:

$$r_i^* = x_{0i}b_0 + u_{0i} \tag{7.1}$$

where r_i^* is a latent variable denoting the expected present value of profit from doing R&D, x_{0i} is a vector of explanatory variables and u_{0i} is an error term.

Innovation output:

$$prod_i^* = E\left[prod_i \middle| r_i^*, x_{2i}, u_{2i}; \alpha_{r1}, b_2\right] \tag{7.2.a}$$

$$proc_i^* = E\left[proc_i \middle| r_i^*, x_{3i}, u_{3i}; \alpha_{r2}, b_3\right] \tag{7.2.b}$$

where $prod_i^*$ and $proc_i^*$ are binary variables which measure the firm product and process innovative outputs, respectively. Thus, the conditional average of innovative outputs is specified to depend on whether or not the firm engages in R&D activities (r_i^*) and other exogenous explanatory variables.

Productivity:

$$q_i = \alpha_{prod}\, prod_i^* + \alpha_{proc}\, proc_i^* + x_{5i}b_5 + u_{5i} \tag{7.3}$$

where q_i represents firm *i*'s labour productivity (in log form), x_{5i} is a vector of explanatory variables, and u_{5i} is the disturbance term.

Because of the recursive structure, equations (7.1) – (7.3) can be estimated in three stages sequentially by using the predicted values of the preceding dependent variables as instruments. Equation (7.1) is usually appended with another equation which controls for the intensity of R&D expenditure and it is the intensity of R&D which enters equation (7.2). For example, Wong *et al*. (2007) used the collected information on innovation

[22] See also Wong et al. (2007).

expenditure available in the 2003 Australian Innovation Survey Data (ABS, 2006) to estimate a separate R&D intensity equation, in addition to the discrete dependent variable equation, propensity to do R&D. However, because the level of R&D expenditure is not available in the BLD data that we use in this report, we only specify R&D propensity in the innovation output equations.

7.2 Implementation

We estimate equations (7.1)–(7.3) using the 2004–05 and 2005–06 BLD data used for the descriptive analyses in Chapter 4. Thus, the analysis is restricted to small and medium enterprises with fewer than 200 employees, and restricted to the level of detail provided by the CURF version of the database. For example, we do not observe the actual number of employees in each enterprise; therefore, our proxies for labour productivity (sales per employee or value added per employee) are crude and as such our findings should be treated with caution.

The explanatory variables in each equation are selected based on the insights learned from earlier studies, most of which were discussed in the literature review chapter. The choice of the variables was also made in order to facilitate direct comparisons of the findings with other international studies such as those summarised in Griffith *et al.* (2006). In contrast to the Wong *et al*. (2007), the set of explanatory variables we use are more compact and focused on providing more intuitive interpretations of the findings found by of the descriptive analysis in the preceding chapters.

For the R&D propensity estimation specified in equation (7.1), four main determinants of R&D activities appear on the right hand side of the equation: international competition (proxied by whether or not the business had any export income and the degree of foreign ownership); appropriability conditions (proxied by whether or not the business was engaged in a formal networking with other businesses, and by franchise agreements); public funding (proxied by whether or not the business received any financial assistance from the Australian Government); and private funding (proxied by whether or not the business had available debt financing and whether or not they were able to raise equity financing when required). In addition, control variables such as size of employment and industry, and a sampling indicator variable of whether or not the business was part of the food industry (which was over-sampled),, also appear on the right hand side.

The inclusion of exposure to international competition as a determinant of R&D follows earlier studies such as Griffith *et al.* (2006), which recognised the higher barrier and pressure for businesses to enter and compete in the international market. In addition, participation in the export market may also improve a firm's ability to tap into new knowledge developed overseas, the absorption of which may require specific capacity developed through its own R&D. Thus we expect that, all else equal, businesses exposed to the international market are more likely to conduct R&D.[23]

The second determinant, appropriability conditions, is important in the sense that it measures how effectively innovators can capture the returns to their R&D investment. If effective appropriability is low, then the incentive for businesses to conduct R&D activities is also low. Ideally we would measure appropriability conditions using a direct measure such as the possible strength of intellectual property rights protection that each business can have. However, we must rely on proxies for appropriability conditions which assume that businesses are less likely to engage in formal networking or franchise agreements if appropriating the returns from these activities is more difficult.

The third and fourth determinants of R&D are related to financing. Public funding can provide further incentives for businesses to undertake knowledge production activities because of the 'public good' nature of the outputs. Furthermore, risk aversion combined with the uncertain nature of such activities mean only those businesses which have access to financing are in the position to invest in R&D activities.

For the innovation equation, knowledge production is modelled separately for product innovation and process innovation. The same set of determinants of each type of output is used except in the case of process innovation, where we include investment intensity as another factor to capture the possible complementary effects of investment in operational process-enhancing capital on innovation (Griffith *et al.* 2006). Controls for variation in

[23] The implicit assumption here is that export decisions come after innovation instead of before or at the same time.

appropriability conditions are also included in the second set of determinants. To this group we add an indicator variable of whether or not the business was engaged in joint R&D, which we exclude from the R&D regression because (by definition) those who responded with a “yes” would respond “yes” to the R&D status question.

Another important group of determinants on the right-hand side of the innovation equation are demand-pull factors. The stronger are these factors, the higher is the incentive for businesses to innovate. For example, businesses were asked whether or not environmental factors significantly hampered their business activities. We assume that those which responded positively refer to the barriers from a stricter environmental regime such as the requirements, costs and implications of conducting environmental impact assessments before any project. Thus, we assume that a stricter environmental regime would provide an increased incentive to a firm which responds positively to the questionnaire to innovate (by inventing or implementing a better, more environmentally friendly technology) than a more relaxed regime would, at least in the long run.[24] The other two proxies for demand-pull factors are market-demand uncertainty, where we expect higher uncertainty to be negatively correlated with the incentive to innovate, and government regulations, where we expect that a more restrictive regime would lead to lower incentives to innovate.[25]

For the productivity equation, we use both sales per employee and value added per employee as the dependent variable (proxying for labour productivity). The first proxy is used to allow for direct comparisons with the findings of existing studies. The second proxy is used because it is a more refined measure of productivity since it controls for the variation in other (non-labour) inputs used for production. Unfortunately, due to lack of capital stock information, we are not able to use multifactor productivity in this

[24] It is possible, however, for conforming to stricter environmental factors could actually hinder innovation even if just temporarily that in balance the sign of this demand shifter may be either positive or negative.
[25] It is possible that the restrictiveness of regulations may work in the similar way as the environmental regime discussed earlier. However, this is probably less likely due to the more general nature of government regulations being asked. Nevertheless, the expected sign of the determinant might be ambiguous.

estimation. However, we do include investment intensity as a proxy for capital in the estimating equation.[26]

The most interesting explanatory variables in the productivity equation for our purpose are the propensities to introduce product or process innovations. The main hypothesis is that innovations are important drivers of firm performance. On average, we expect that more innovative firms have higher performance as measured by productivity. To account for the influence of market structure and firm heterogeneity, we include market structure measures (whether or not the firm has a captive market and market shares), age of firm (5–10 years, 10–20 years, 20 years) and industry dummy variables, as used in all other equations. The employment size of the firm is included to account for the fact that we have binary dependent variables and large firms generally conduct more of all types of activities than smaller firms by virtue of their size.

7.3 Data

The data we use to estimate equations (7.1) – (7.3) are cross-sectional data from the first two panels of the BLD, covering Australian businesses with 1–200 employees between 2004–05 and 2006–07 financial years. The period of the sample used in the estimation is limited to 2004–05, because the information about whether or not the businesses undertook R&D was collected for the whole sample only in that period.[27] Overall, there were 1,824 businesses with at least one employee in 2004–05, with non-missing responses to the question of whether or not they carried out R&D in that year.

Table 7.1 provides a descriptive summary of the relevant variables for these firms.[28] From the table, it is apparent that 13 per cent of the sample carried out R&D in 2004–05. Around 17 per cent of the sampled businesses had a product innovation and 15 per cent had a process innovation.[29] Furthermore, 14.5 per cent of the businesses participated in

[26] As noted by ABS (2007b), the BLD only provides weak proxies of productivity and one needs to be cautious in interpreting it. For lack of other data, we assume that these proxies still correlate with the underlying productivity so that at least the estimated signs of the relationships in question are not spurious.
[27] A similar question is asked in the 2006-07 period, but it was only asked to innovating businesses.
[28] The number of valid responses varied across the variables with investment intensity having the most missing observations (1109 valid observations).
[29] Thus, it appears that not all of the innovative firms in that year performed R&D. This is possible because in addition to doing it through R&D, businesses may innovate through technology adoption, outsourcing,

the export market and 5 per cent were owned/partially owned by foreign entities. Finally, in terms of collaboration, only 3 per cent of the sample was involved in any joint R&D, a relatively small number given that close to 18 per cent of the businesses had formal networking arrangements with other businesses.

Table 7.1: Descriptive Statistics

Variable	Description	N	Mean	Std. Deviation
Dependent variables				
rd*	=1 if carried out any R&D in 2004-05	1824	0.130	0.336
prodinnov*	=1 if had goods/service innovation in 2004-05	1824	0.167	0.373
procinnov*	=1 if had operational process innovation in 2004-05	1824	0.150	0.357
llabprod§	= log of sales per employee[30] in 2004-05	1780	11.176	1.339
llabprodva§	= log of value added (sales less non-capital purchases) per employee in 2004-05	1592	10.255	1.355
Independent variables				
Exposure to international competition				
expincome*	=1 if received any income from export in 2004-05	1824	0.145	0.352
foreign*	=1 if had any degree of foreign ownership in 2004-05	1824	0.051	0.220
Appropriability conditions				
network*	=1 if had formal networking with other business in 2004-05	1824	0.177	0.382
franchise*	=1 if involved in any franchising agreement in 2004-05	1824	0.058	0.234
rdcollab*	=1 if involved in any joint R&D	1481	0.034	0.182
Public support				
pubfund*	=1 if received any financial assistance from the government in 2004-05	1824	0.157	0.364
Private financing/costs				
debtfin*	=1 if sought and found debt financing in 2004-05	1824	0.371	0.483
eqfind*	=1 if sought and raised equity finance in 2004-05	1824	0.069	0.254
Demand pull				
envfactors*	=1 if reported environmental factors a significant factor	1610	0.201	0.401

and others, or simply because there is lag in knowledge production processes. See, for example, Arundel *et al.* (2008) for further discussion.

[30] The version of BLD data used in this report only provides the number of employees in terms of intervals: 1-4, 5-19, 20-200. We use the midpoints of these intervals to proxy the unobserved number of employees. Given that the number of intervals provided is probably too small to ensure that the midpoints represent the underlying values well (see, for example, Fryer and Pethybridge 1972), tackling this limitation with a more complete (unpublished) version of the BLD data would greatly improve our analysis.

	which hampered business activities in 2005-06			
demanduncert*	=1 if reported demand uncertainty as a significant factor which hampered innovation in 2005-06	1587	0.092	0.289
regulation*	=1 if reported government regulation as a significant factor which hampered innovation in 2005-06	1610	0.149	0.356
Market competition				
captive*	=1 if had a captive market or no effective competitor in 2004-05[31]	1824	0.299	0.458
mktshr1050*	=1 if market share is between 10 and 50% in 2005-06	1556	0.314	0.464
mktshr50*	=1 if market share is more than 50% in 2005-06	1556	0.108	0.310
Other characteristics				
linvint§	= log of capital purchase per employee in 2004-05	1109	7.873	2.141
age510*	=1 if had been operating for 5-10 years in 2004-05	1792	0.193	0.394
age1020*	=1 if had been operating for 10-20 years in 2004-05	1792	0.283	0.451
age20*	=1 if had been operating for 20+ years in 2004-05	1792	0.325	0.468
size519*	=1 if had 5-19 employees in 2004-05	1824	0.355	0.479
size20*	=1 if had 20-200 employees in 2004-05	1824	0.228	0.419
resource	=1 if industry division is Agriculture, Forestry and Fishing or Mining	1824	0.273	0.446
mfg	=1 if industry division is manufacturing	1824	0.157	0.364
FIS	=1 if a Food Industry Sample	1824	0.319	0.466

*Discrete variables with 0/1 value.
§The number of employees is the mid-point of the available employment intervals as follows (2 for 0-4 interval, 12 for 5-19 interval, 110 for 20-200 interval).

7.4 Results

Table 7.2 summarises the estimated marginal effects of international competition, appropriability conditions, public and private funding, size, and industry on the probability of carrying out R&D in 2004–05, based on a probit estimation of equation (7.1).[32] As shown in the table, at least one proxy variable for each of these determinants except size is statistically significant, and of the expected sign. International competition, for example, is associated with a 12 percentage point higher probability of carrying out R&D. In addition, those firms engaged in formal networks are on average 13 percentage

[31] Captive and mktshr variables are based on two different questions. In theory, captive should be equivalent to 100% or close to it. If mktshr50=1 then captive=1, but not the reverse.
[32] The marginal effects are evaluated at the mean.

points more likely to carry out R&D. Financing is also statistically significant, with marginal effects of around 4–11 percentage points in terms of the probability of conducting R&D.

Table 7.2: Propensity to Conduct R&D

	Marginal effects at the mean		Std. Errors
International competition			
had export income	0.122	***	0.028
foreign ownership	-0.012		0.029
Appropriability conditions			
in a formal network	0.129	***	0.025
franchise agreement	-0.019		0.030
Public funding			
had govt financial assist.	0.046	**	0.023
Private funding			
had access to debt finance	0.038	**	0.016
can raise equity finance	0.107	***	0.037
Size			
5-19 employees	0.014		0.018
20-200 employees	0.014		0.022
Industry			
resources	0.086	***	0.025
manufacturing	0.159	***	0.034
Sample size	1824		
log-likelihood	-623.7		
Pr[y=1]	0.107		

Note: *,**,***: statistically significant at 10%, 5%, and 1% , respectively.

Whether or not a business received any financial assistance from an Australian government organisation is associated with around a 5 percentage point increase in the probability of conducting R&D. The ability to raise equity finance or to have access to debt finance are also positively correlated with the propensity to conduct R&D. Finally, the estimates in Table 7.2 show that manufacturing businesses are the most likely to conduct R&D, followed by businesses in the resource sector, confirming the earlier finding shown by Figure 4.6.

Table 7.3 presents the estimated marginal effects of R&D investment, capital purchase intensity, appropriability conditions, and demand-pull factors on the propensity to produce product innovation and process innovation. These estimates were obtained from instrumental variable probit regressions of equations 7.2.a and 7.2.b using the predicted probability of R&D estimated earlier (equation 7.1) as the instrument for R&D investment.[33] Apart from the dependent variable, equations 7.2.a and 7.2.b differ in that the second equation includes investment intensity as one of the regressors on the assumption that capital purchases might be complementary to the introduction of operational process innovation, but not to product innovation (Griffith *et al.* 2006).

From Table 7.3, R&D investment is the most important factor (statistically and economically) for innovation. Businesses with any R&D are associated with more than a 50 percentage point higher probability of introducing either type of innovation. As hypothesised, capital purchases are positively correlated with the likelihood of introducing process innovations. Finally, joint R&D appears to be an important determinant of process innovation, much more important than all other factors beside R&D.[34]

Finally, Table 7.4 provides the regression estimates of the effects of innovation on business performance (equation 7.3) using the predicted probabilities to introduce product or process innovation as the instruments for innovation outputs. Overall, the expected positive correlation between innovation and performance (as proxied by sales per employee or value added per employee) is weak statistically. Only product innovation is statistically significant at the 10 per cent significance level—businesses with product innovation are almost twice as productive.[35] One possible reason for the imprecise effects of innovation is that performance measures are based on aggregated categories of employment (1–4, 5–19, 20–200) as opposed to the actual level of employment. The most

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[33] Other studies usually used R&D intensity instead of R&D propensity. Unfortunately, R&D intensity is not available in the BLD data.

[34] The strong relationship between joint R&D and the probability to innovate appears to be case for product innovation as well. However, the estimate for production innovation is too imprecise to draw any statistically meaningful conclusion.

[35] As noted earlier, the estimated magnitude needs to be interpreted with caution given the quality of the data and the fact that the simple labour productivity is defined in terms of sales (that is, more of a measure of revenue productivity as opposed to output productivity).

significant factors determining performance appear to be firm size and age, indicating the importance of firm heterogeneity factors that would be more appropriately addressed in a longitudinal analysis once the data are available.

Table 7.3: Propensity to Introduce Product or Process Innovation

	Product Innovation			Process Innovation		
	Marginal effects at the mean		Std. Error	Marginal effects at the mean		Std. Error
Propensity to do R&D	0.512	***	0.126	0.513	***	0.164
Investment intensity				0.014	***	0.006
Appropriability conditions						
in a formal network	-0.008		0.030	-0.008		0.040
franchise agreement	0.064		0.049	-0.053		0.047
joint R&D	0.095		0.064	0.216	**	0.088
Demand pull						
environmental barriers	0.022		0.028	0.046		0.034
uncertain demand	0.002		0.033	0.066		0.050
regulation barriers	-0.004		0.027	0.015		0.034
Size						
5-19 employees	0.044	*	0.025	0.050		0.034
20-200 employees	0.062	**	0.030	0.080	*	0.042
Industry						
resources	-0.065	**	0.027	-0.040		0.037
manufacturing	-0.042		0.034	-0.022		0.050
Sample size	1415			893		
log-likelihood	-610.8			-393.1		
Pr[y=1]	0.158			0.166		

Note: *,**,***: statistically significant at 10%, 5%, and 1% , respectively.

Table 7.4: Productivity Equation

	Sales per employee			Value added per employee		
	Coefficient		Std. Error	Coefficient		Std. Error
Investment intensity	0.234	***	0.026	0.226	***	0.029
Innovation						
process innovation	0.106		0.882	0.521		0.978
product innovation	1.903	*	1.143	0.413		1.301
Market structure						
captive market[36]	-0.359	***	0.131	-0.073		0.148
market share 10-50%	0.093		0.092	0.090		0.100
market share 50% or more	0.055		0.134	0.244	**	0.119
Age						
5-10 years	0.493	***	0.155	0.669	***	0.189
10-20 years	0.669	***	0.136	0.677	***	0.171
20 years	0.723	***	0.131	0.730	***	0.163
Size						
5-19 employees	-0.303	***	0.115	-0.265	**	0.128
20-200 employees	-0.849	***	0.132	-0.731	***	0.142
Industry						
Resources	-0.533	***	0.122	-0.464	***	0.148
Manufacturing	-0.007		0.141	0.134		0.133
Sample size	767			701		
R-squared	0.254			0.239		
E[y]	11.3			10.3		

Note: *,**,***: statistically significant at 10%, 5%, and 1% , respectively.

7.5 Comparison with other countries

Table 7.5 compares the estimated productivity-innovation elasticity of Australian SMEs with those in other countries. Note that because of variation in data definitions and model specifications, this comparison should be interpreted as indicative of similarities in the direction (sign) of the correlation rather than similarities (or differences) in the magnitudes. For example, Crépon *et al.* (1998) and Janz *et al.* (2003) used an analytical framework which allows for feedbacks from productivity into the innovation equations

[36] captive market = 1 if the firm answered ‘Captive market/no effective competition’ to the question “How many competitors did this business have during the year.”

and/or controls for firm heterogeneity via fixed effects panel estimation (such as Chudnovsky *et al.* 2006).

It is clear from Table 7.5 that the relationship between innovation and performance varies according to study, which may reflect the specific country, industry or time effects across countries, across industries and within industry but across time, even when the data and the model used to estimate the relationship is almost identical (such as Griffith *et al.* 2006). As in other countries, the link between product innovation and productivity is more important in Australia than that between process innovation and productivity. In terms of magnitude, the extremely high elasticity estimated for Australia reflects a number of potential sources of bias. First, unlike most of the other studies, we do not use R&D intensity as an input measure in the innovation equation. Therefore, the estimated elasticity may capture firm-level variation. Second, our measure of productivity is very noisy due to the use of grouped employment data. The noise is reflected in the standard errors of the estimates. Finally, we do not control for firm fixed-effects or any feedback effects. Thus, because of the cross-section nature of our estimation and the omissions of the feedback effects, the results are merely correlation rather than causation and should be interpreted accordingly.[37]

Table 7.5: Innovation Elasticity of Firm Productivity Across Countries

Country	Study	Size	Productivity measures	Elasticity	
				Product Innov.	Process Innov.
Australia	(This report)	SMEs	Sales per employee	190.3%	ns
			Value added per employee	ns	ns
Argentina	Chudnovsky et al. (2006)[38]	Mfg. firms.	Sales per employee	ns	17.7%

[37] This limitation is not unique to this report. Most of the studies summarised in Table 7.5 use the same recursive structure or cross-sectional setup. One way to pin down the direction of causality is to estimate the systems presented in equations 7.1–7.3 simultaneously, with appropriate lag structures and feedback effects being included. To do this requires a complete longitudinal database with all of the relevant variables present in the data. In Table 7.5, the studies which adopted such approach include Crépon et al. (1998), Janz et al. (2003), and Chudnovsky et al. (2006).

[38] In this study, three types or innovation dummy variables are used: process only, product only, and process and product. The results compared are those of process or product only. The overall innovation elasticity is 13%.

Chille	Benavente (2006)[39]	Mfg. firms	Value added per employee	17.9%	-
China	Jefferson et al. (2006)	Medium & large firms	TFP[40]	3.5%	-
France	Crépon et al. (1998)	Mfg firms	Value added per employee	6.5%	-
France	Griffith et al. (2006)	All	Sales per employee	6.0%	6.9%
France	Mairesse & Robin (2009)[41]	Mfg CIS3	Sales per employee	57.0%	112.0%
France	Mairesse & Robin (2009)	Mfg CIS4	Sales per employee	109.0%	ns
France	Mairesse & Robin (2009)	Service CIS4	Sales per employee	375.0%	144.0%
Germany	Janz et al. (2003)	Knowledge intensive mfg firms[42]	Sales per employee	26.9%	-
Germany	Griffith et al. (2006)	All	Sales per employee	ns	ns
Italy	Parisi et al. (2006)[43]	Large	TFP Growth	ns	ns
Spain	Griffith et al. (2006)	All	Sales per employee	17.6%	ns
Sweden	Lööf and Heshmati (2002)	All	Value added per employee	12.8%	-
Sweden	Janz et al. (2003)	Knowledge intensive mfg firms[44]	Sales per employee	29.0%	-
UK	Griffith et al. (2006)	All	Sales per employee	5.5%	ns

Note: ns = not statistically significant

[39] The estimated elasticity corresponds to percentage change in productivity per one percent change in innovation intensity (number of sales-weighted innovations).
[40] Total factor productivity.
[41] This study compares different waves of the Community Innovation Survey (CIS) data for France. In the analysis, product and process innovation is an additional innovation variable included in the productivity equation.
[42] These are firms in the chemistry and pharmaceuticals, machinery and equipment, office machinery and computers, electrical and communication equipment, medical, precision and optical instruments as well as transport equipment industries.
[43] The elasticities are statistically significant (particularly process innovation) if each type of innovation enters the regression separately.
[44] These are firms in the chemistry and pharmaceuticals, machinery and equipment, office machinery and computers, electrical and communication equipment, medical, precision and optical instruments as well as transport equipment industries.

8. Concluding Remarks and Policy Implications

Given the importance of innovation as a determinant of aggregate productivity growth, it is surprising that Australia is a long way behind Europe and America in terms of analysing the causes and effects of innovation. Part of the reason for this has been the lack of available data on firm-level innovative activity in Australia. Governments can affect this process of change via rigorous, evidence-based industry policy. This report aims to undertake a systematic analysis of the characteristics of innovative firms in Australia, with a special focus on the manufacturing industry. To achieve this, we have used data from the Business Longitudinal Database (and the BLS 1994-97), IBISWorld, the Australian Inventor Survey, and the IPRIA R&D Scoreboard. Although we have made a small step forward in this direction, there are still some obvious data limitations which hinder a comprehensive analysis of the effects of innovation on productivity at the firm level.

With this important caveat in mind, we nonetheless find some interesting results which should provide a good basis for developing the evidence base required for sound innovation policy. In particular, we note that one of the hallmarks of sound innovation policy is that it identifies the ‘best’ firms which to assist. This is not simply a question of indemnifying those firms that are in financial distress. It involves understanding the conditions under which government assistance can aid the development and commercialisation of new technologies; how informal networks and collaboration can nurture the environment in which Australian firms conduct their innovative activities; and the barriers posed by the inability of firms to finance their innovative activities. These are the issues which form the heart of the analysis presented in this report.

One of the most important findings we make in this report relates to the persistence of innovation. More than half of innovating firms in the services industry group are ‘one-time’ innovators, while around half of innovators in the resources industry group are ‘sporadic’ innovators. In contrast, there is a much higher proportion of ‘persistent’ innovation in the Manufacturing industry group. Over and above this, we find that innovation is very concentrated in that ‘persistent’ innovators account for the bulk of innovative activity in each industry. Given that there is strong evidence suggesting that persistence of innovation is an important characteristic of successful firms, this suggests that the causes of persistence in innovation in Manufacturing (and the lack of it in the services and resources industries) is worthy of further investigation.

Another consideration of increasing policy importance relates to the creation of conditions conducive to nurturing collaboration between innovative firms (or between buyers and sellers of technology). Much of the recent evidence in the international literature suggests that informal networks are an important determinant of successful commercialisation. In our analysis we find that 'finding a partner' was a commonly-cited barrier to commercialising Australian inventions. The exception to this was in the manufacturing industry group where uncertainty over the ability of their IP to prevent infringement and the feasibility of the technology were the most commonly-cited problems.

Although much of the analysis undertaken in this report is simple, descriptive analysis, we also undertook some more sophisticated econometric analysis using simultaneous equations. In estimating this model, we attempt to understand the relationships between R&D, innovation and productivity in three stages. Drawing conclusions from this part of the report must be undertaken caution due to the absence of R&D information for all three years of the study, making a proper longitudinal analysis unfeasible. Nevertheless, some important tentative observations can be made. First, we find that whether or not a business received any financial assistance from the Australian Government is associated with around a 5 percentage point increase in the probability of conducting R&D. This suggests that government financial assistance can play a role in stimulating R&D activity. Although it is unclear what form this government assistance takes (R&D grants or simply assistance for firms in distress), this is important information. Second, we find that the correlation between innovation and productivity is weak: at the 10 per cent significance level, we find that businesses with a product innovation are almost twice as productive. However, this issue can only be fully investigated with more comprehensive panel data, and this cannot be attained without the incorporation of additional R&D information into the BLD; linking available firm level R&D data to productivity data for all years in the BLD thus becomes an urgent issue.

Appendix 1: Data Notes

This report utilises firm level data obtained from the following five sources:

1. ABS Business Longitudinal Databases (BLD) confidentialised unit record file (CURF) of two firm panels, annually from 2004–05 to 2006–07.
2. IPRIA R&D and IP Scoreboard, annually from 1998 to 2007.
3. Melbourne Institute Australian Inventor Survey Database, 2007.
4. European Commission (EC)'s EU Industrial R&D Investment Scoreboard, annually from 2004 to 2008.
5. United Kingdom (UK) R&D Scoreboard, annually from 2004 to 2008.

Each of these data sources is explained in further detail in the subsequent appendices. In this appendix, we highlight some important factors for consideration in order to ensure that correct interpretations are drawn from the comparative descriptions within this report.

Sample coverage

Large firms

As explained in Chapter 5, we use IPRIA Scoreboard data to provide descriptive analyses of large Australian firms. These large firms are defined as firms with annual total revenues of at least $50 million. While some of them may have less than 200 employees, we think it would be inappropriate to classify them as SMEs. More importantly, we note that while in the charts for large enterprises in Chapter 4 we have a <200 employee classification, one should not compare this group directly to the SME group constructed using the BLD data, even though the BLD sample consists of only businesses with less than 200 employees.

As detailed in Appendix 3, the data source of large firms reported in the IPRIA Scoreboard and used in this report, IBISWorld enterprise database, includes all large Australian enterprises, profit and not-for-profit, in all sectors including Education, and Government services. However, in this report, we exclude sectors such as Education and Government services when we make comparisons with small and medium firms based on the BLD data, or large, top-R&D performing firms based on the EC or UK Scoreboard data, because these sectors are excluded from those comparison databases.

Small and medium firms

As detailed in Appendix 2, the BLD data specifically exclude large (200+ employees) and/or complex enterprises and not-for-profit entities. In addition, BLD does not cover government enterprises, educational institutions and many sectors (such as Finance and Insurance) which are excluded because of the size and/or complexity restrictions. Consequently, we use the BLD data to provide descriptive analysis of small and medium sized enterprises (SMEs). In theory, we should be able to identify the overlapping firms between the IPRIA Scoreboard data and BLD data, namely those BLD firms which have more than $50 million in annual revenues, and then combine them with the IPRIA Scoreboard data for inclusion in the analysis of large enterprises. However, ABS CURF data access restrictions prohibit us from doing this.

Top R&D performers

There are other sample coverage issues arising from the use of data from multiple sources which may affect the findings from our comparative analyses of innovative activities by Australian, European (EU), and UK enterprises. In particular, unlike the IPRIA Scoreboard data which can be treated as containing the whole population of large Australian enterprises, by design the EC and UK Scoreboards contain only the top R&D performing European and UK enterprises. Thus, if we compare level variables, such as the average amount of R&D expenditures, we would expect that Australian firms would rank poorly. To a lesser extent, intensity variables such as R&D per sales may also be affected.

However, although the IPRIA Scoreboard data contain the whole population of large Australian enterprises, R&D reporting is not mandatory and only around 10 per cent of the enterprises have non-missing observations on R&D expenditures. If we assume that firms with larger R&D expenditures are more likely to ‘voluntarily’ report these expenditures in their annual reports, then arguably the IPRIA Scoreboard data can be treated as containing only the top Australian R&D performers. Thus, one can interpret the findings from the comparative analysis as indicative of the top R&D performers in each region.

Industry

The BLD data provide only a single digit industry classification. This forces us to conduct our analysis in terms of three primary industry groupings: Resources, Manufacturing and Services, even when more detailed classification is available for the large firms. Under resources are A (Agriculture, forestry and fishing) and B (Mining); whereas manufacturing includes those firms with C (Manufacturing) as the reported industry division in the BLD data. Finally, services include E (Construction), F (Wholesale trade), G (Retail trade), H (Accommodation, cafes and restaurants), I (Transport and storage), J (Communication services), L (Property and business services), P (Cultural and recreational services), and Q (Personal and other services).

However, for large enterprise analyses based on IPRIA, EC and UK Scoreboard data services also include Financial services which are not covered by the BLD, but exclude Government organisations, such as CSIRO, since the EC and UK Scoreboards exclude such organisation. This is done because we believe the value of more complete comparisons with EU and UK firms for the service industry is more important than ensuring as similar industry coverage as possible with the BLD data. In fact, in the case of large enterprises, it is not possible to follow BLD's exclusion of complex businesses.

Type of information and Definition

Another important data issue arises from the variation in the types information recorded and how they are defined. One of the most important restrictions in the BLD data includes the lack of information on the amount of R&D expenditures. Second, the BLD data define innovation rather loosely as the introduction of new goods, processes, or organisation where 'new' can be either new-to-the-firm or new-to-the-world. In contrast, the innovation measure we use for large firms is based on the IPRIA Scoreboard's IP rights applications (patent/design, and trade marks) data which are more consistent with the new to the world interpretation. As a result, it is relatively 'harder' for the large firms to be classified as innovators, and one needs to be cautious in making direct comparisons of innovation activities between the SMEs (based on BLD) and the large enterprises (based on IPRIA's Scoreboard).

With respect to the EU and UK Scoreboard data, there are two main concerns arising from differences in the way industries are classified and how financial information is recorded, particularly with respect to R&D expenditure. In terms of industry classification and the definition of R&D expenditures, the EU and UK Scoreboards are relatively consistent with each other. However, industry classification in the IPRIA Scoreboard data is not as detailed as in the other two Scoreboards, and it is unclear what constitutes R&D expenditures as reported in the IBISWorld entrerprise finance database on which the IPRIA Scoreboard was based. Therefore, one needs to take these considerations into account when making direct comparisons of innovative performance by Australian large enterprises and EU and UK enterprises.

Appendix 2: ABS Business Longitudinal Database (BLD)

The BLD database we use is from the first CURF edition which contains two panels of around 3,000 small and medium businesses (ABS 2007a and 2007b). The first panel provides annual information for 2004–05, 2005–06 and 2006–07 financial years, while the second panel provides annual information for 2005–06 and 2006–07 financial years. The BLD database provide a range of information, including business characteristics (e.g. business structure, markets and competition, financing arrangements, innovation, barriers to business activity, IT use) and a set of financial information (sourced from the Business Activity Statements and Business Income Tax reported to the ATO).

One main restriction of the BLD data is that it is limited to simple businesses with less than 200 employees (including non-employers). In other words, the BLD does not include complex businesses and large Australian businesses, which suggests that a large proportion of the innovation puzzle is missing from the BLD. Moreover, the BLD only covers a limited set of industries; many important industries—including Government administration, Education, Health, Utilities—are excluded from the data.

The other important restriction of the BLD data is that while the same businesses in each panel are observed in more than one period, because of omissions of relevant questions over time, often it is not possible to conduct proper longitudinal analyses. For example, for the 2004–05 financial year, businesses were asked whether or not they carried out any research and experimental development. However, the exact same question was not asked in the two following financial years: 2005–06 and 2006–07. For 2006–07, a similar question (whether or not the business had any research and experimental expenditure *for innovation*) was asked, however it was asked only to businesses which has responded positively to the innovation status questions. Given the nature of R&D expenditure, which may fluctuate from year to year, and the propensity for innovators to do R&D expenditure, the R&D information in one year, or of the innovating firms, is not sufficient to allow extrapolation to other years, or to non-innovating firms. Effectively, this limitation renders any longitudinal analysis of R&D activities as impossible, even when the underlying sample is of a longitudinal nature.

In terms of size of employment, the BLD data cover employer and non-employer businesses. In this report, we exclude all non-employer businesses. Furthermore, the database provides information on the number of employees only in three categories: 0–4 persons, 5–19 persons, and 20 or more persons. Because of this limitation, we construct a proxy variable for the size of employment as the mid-point of each corresponding interval. Furthermore, we exclude observation where a missing value in the employment category is reported.

Finally, in terms of the definition of innovator and non-innovator, the BLD database actually provides relatively more detailed information on innovation based on the introduction of new product or process. However, because of the lack of information regarding the ‘newness’ of the innovation, the BLD database only allows for a relatively ‘loose’ definition of innovation which may include imitation (introduction of product or process which is new-to-the-firm or new to Australia only). On the contrary, the IPRIA Scoreboard’s innovation indicator is based solely on whether or not a firm made either a patent or design application. Therefore, the IPRIA Scoreboard’s definition of innovator is more strict in the sense that it only includes firms with innovation which can be considered as new-to-the-world, whereas, under the BLD’s definition, there is no such restriction. In addition, the IPRIA Scoreboard’s definition of innovator is relatively more restricted, because patent and design application are more likely to be used by product innovation than in process innovation.

Appendix 3: IPRIA R&D and IP Scoreboard Data

The IPRIA R&D Scoreboard is arguably one of the most comprehensive sources for data on innovative activities of large Australian enterprises. As a Scoreboard, it provides an invaluable information source for benchmarking and competitor analysis in terms of R&D and innovation. The innovative activities covered by the Scoreboard include up-to-date information on the level of R&D and applications for intellectual property (patents, trade marks and designs). It also includes: an innovation index, ranking Australia's most innovative firms; R&D expenditure and intensity rankings for parent companies; the level and intensity of intellectual property applications (patents, trade marks and designs) for parent companies; and industry listings (all measures combined).

The Scoreboard is constructed based on data sourced from IP Australia and IBISWorld Pty Ltd. The first data source provides data on patent, trade mark, and design application filed in Australia in a calendar year. The second data source provides financial data on approximately 3,000 companies operating in Australia, including public, private, foreign-owned and government organisations. Most of the financial and non-financial information is sourced by IBISWorld Pty Ltd from Annual Reports issued by the companies. IPRIA researchers then match these two data sources using company names listed in the two databases as the matching key. Because of the possibility for IP right applicants to file their applications under their own name when they are subsidiaries of other companies, during the matching process all IP applications by subsidiaries are attributed to the parent companies. This is done because the IBISWorld database only provides the financial information of the parent companies, so that the unit of analysis is the parent company. The overall results of the data matching process for the year 2000 is summarised in Table A3.1. Note that since the bulk of IP rights applications filed at IP Australia come from overseas, the overall match rate to companies operating in Australia is low.

At present, the IPRIA R&D Scoreboard data are publicly available in annual format from 1998 to 2007. These data provide us with detailed financial information for 1996-97 to

2006-07 financial years and detailed IP rights applications (patent, design, and trade marks) in 1998–2008 calendar years. As discussed earlier, for the comparative analysis presented in this report, we define innovation as an application of either a patent or design. This definition is more conservative and consistent with the idea of introducing new product and processes to the world used by other relevant studies.

Table A3.1 Number of IP Applicants by Category, 2000

Type of entity	Number of applicants	Percentage (of applicants)	Number matched to IBISWorld database	Match rate (%)
Foreign[(a)]	79588	95.5	6002	7.5
Individual	1598	1.9	-	-
Private company [(b)]	1547	1.9	294	19.0
Statute[(c)]	209	0.3	177	84.7
Residual[(d)]	405	0.5	202	49.9
Total	83347	100	6675	8.0

Source: IPRIA (2006).

Notes:

(a) Based on the applicant's address. Most of the IBISWorld matches represent applications filed by Australian subsidiaries of foreign companies.

(b) Consists mostly of applicant with "Proprietary in its name.

(c) Any applicant with the words "association", "commonwealth", "university" or "institute" in the company name.

(d) Predominantly are publicly listed Australian companies.

One of the most important pieces of financial information available in the IBISWorld database is the amount of R&D expenditure. Bosworth and Rogers (1998) compared the IBISWorld R&D data with the ABS data and found that the former can be considered as realtively comprehensive in capturing overall R&D activity in Australia. Approximately 70 per cent of R&D expenditure by firms with more than 1,000 employees reported by ABS data is accounted for by around 3,000 companies listed in the IBISWorld database. In terms of industry, the IBISWorld coverage of R&D activity is particularly good for mining and manufacturing, and less so for service industries.

Appendix 4: Australian Inventor Survey

The Australian Inventor Survey was mailed out in three mail outs between July and December 2007 by the Melbourne Institute of Applied Economic and Social Research at the University of Melbourne. The recipients of the survey constituted the population of Australian inventors who filed a patent application at the Australian Patent office – IP Australia – during the period 1986-2005. The survey recipients were identified by the country of applicant (Australia) and their postal address.

The inventor-invention relationship is a many-to-many relationship. That is, one inventor can have many patent applications, and one patent application can have many inventors. In total, there were 43,200 inventor-application pairs in the population with a complete inventor name and Australian address.[45] Of the 31,313 applications, 76.2 percent had only one inventor and almost all (99.3 per cent) had five or less inventors (see Table A4.1). Of the 31,947 inventors, the vast majority (82.5 per cent) had only filed one application between 1986 and 2005 (see Table A4.2). To limit the administrative burden, inventors were asked about each invention, up to a maximum of five patent applications.

Table A4.1: Number inventors per application, 1986 to 2005

Inventors per application	Number of applications	%
1	23,866	76.2
2-5	7,225	23.1
6-10	218	0.7
>10	4	0.0
Total applications	31,313	100.0

[45] 8413 applications did not have an inventor name and 37 did not have an address.

Table A4.2: Number of applications per inventor, 1986 to 2005

Applications per inventor	Number of inventors	%
1	26,360	82.5
2-10	5,506	17.2
11-20	66	0.2
>20	15	0.0
Total inventors	31,947	100.0

There was no initial screening of survey recipients, and 47.0 per cent of surveys were returned to us (as "return to sender") unopened, presumably because the address was no longer valid. To estimate the number of non-responses which also had invalid addresses, we selected a random sample of 600 non-respondents (both those from the "return to sender" and "no response" groups) and manually looked up the applicant by name and address in both the telephone book and internet. People with a valid telephone number were then called to confirm that they were the correct person. This search revealed that only 11.7 percent of the sample of non-respondents had a complete address and/or were still at the listed address (some had moved while others had apparently disappeared). Assuming that this is representative of all non-respondents, we can infer that we had a valid inventor address for 5,446 of our original population of inventions. We received completed questionnaires for 3,736 inventions.

The following four tables show the pattern of survey response by year of application across various characteristics. According to Table A4.3, there is a clearly defined rise in the percentage of completions over time. Response rates also varied according to whether the inventor was employed by a large company (63.6 percent), SME (64.6 percent), PRO (70.6 percent), or filed as an individual (73.4 percent), as demonstrated in Table A4.4.

Table A4.3: Number of patent applications with a complete survey response by year, 1986-2005

Year	Number of patent applications			
	Complete	Est. address valid[a] & not complete	Est. address not valid	Total
1986-1990	254	245	3,705	4,204
1991-1995	553	385	5,832	6,770
1996-2000	1,124	541	8,187	9,852
2001-2005	1,805	538	8,144	10,487
Total	3,736	1,710	25,867	31,313

Note: a Excludes surveys that were returned as 'return to sender' and the estimated 88.3% of non-responses which we estimated, through a post-enumeration survey, to have had an invalid address.

The grant rate (as of April 2007) for the entire population of applications lodged at the Australian Patent Office between 1989 and 2005 was 68.6 per cent.[46] In Table A4.5, a simple comparison of the patent application outcomes for survey respondents and non-respondents is presented. This shows that inventors whose applications were still pending were more likely to respond, followed by inventors whose applications were granted, rejected and withdrawn respectively.[47] Finally, Table A4.4Table A4.6 presents the distribution of responses by technology area. It shows that there is a modest level of variation in the response rate across technology groups: there was a slightly lower response rate from the electricity and electronics area and 'other'.

Table A4.4: Number of patent applications with a complete survey response by organization type, 1986-2005

Organization	Number of patent applications			
	Complete (response %)	Est. address valid[a] & not complete	Est. address not valid	Total
Large company[b]	588 (63.6%)	337	5,097	6,022
SME[b]	1,175 (64.6%)	643	9,727	11,545
Public sector research	269 (70.6%)	112	1,697	2,078
Individual	1,704 (73.4%)	618	9,346	11,668
Total	3,736 (68.6%)	1,710	25,867	31,313

Notes: a Excludes surveys that were returned as 'return to sender' and the estimated 88.3% of non-responses which we estimated, though a post-enumeration survey to have had an invalid address. b A company is 'Large' where it, or its highest Australian-located parent company, has a turnover greater than A$50m per annum. Otherwise the company is defined as an SME.

[46] We exclude applications lodged between 1986 and 1988 as the high percentage of grants suggests that some non-granted applications are missing from the database.

[47] However, this is partly due to the fact that recent applications have not yet been examined. For applications lodged between 1989 and 2000, the response rate is 12.6 percent for non-grants and 18.6 percent for granted applications.

Table A4.5: Number of patent applications with a complete survey response by patent application outcome, 1986-2005

Patent grant status	**Number of patent applications**			
	Complete	Est. address valid[a] & not complete	Est. address not valid	Total
Withdrawn	572	331	5,006	5909
Pending	731	167	2,535	3433
Rejected	382	232	3,512	4126
Granted	2,051	979	14,815	17,845
Total	3,736	1,710	25,867	31,313

Note: a Excludes surveys that were returned as 'return to sender' and the estimated 88.3% of non-responses which we estimated, though a post-enumeration survey to have had an invalid address.

Table A4.6: Number of patent applications with a complete survey response by technology area, 1986-2005

OST technology area[b]	**Number of patent applications**			
	Complete	Est. address valid[a] & not complete	Est. address not valid	Total
I Electricity and electronics	329	181	2,739	3,249
II Instruments	440	175	2,654	3,269
III Chemicals, pharmaceuticals	410	166	2,516	3,092
IV Process engineering	447	187	2,825	3,459
V Mechanical engineering	1,061	476	7,204	8,741
VI Other	1,048	524	7,927	9,499
Total	3,736	1,710	25,867	31,313

Notes: a Excludes surveys that were returned as 'return to sender' and the estimated 88.3% of non-responses which we estimated, though a post-enumeration survey to have had an invalid address. b OST refers to the Office of Science and Technology classification which is based on the International Patent Classification system which is based on the International Patent Classification system

Table A4.7: Characteristics of respondents

Characteristic of invention	Freq.	Percent
Relative to state of art at time of application, the invention was…		
Incremental improvement	1158	31.3
Radical improvement	2240	60.5
Unsure	307	8.3
Did the invention underlying the patent relate to a new or improved...		
Good or product	2189	59.1
Way of manufacture	1016	27.4
Both	499	13.5
PCT status		
Paris Convention (non-PCT)	2306	61.7
Patent Cooperation Treaty (PCT)	1430	38.3
Number of other patents also used to develop product		
None	2476	66.8
1 to 5	1101	29.7
6 to 10	86	2.3
11 to 20	22	0.6
20+	23	0.6
Number of prior patent applications by organisation since 1986		
None	1688	45.5
More than none to 10	1349	36.4
More than 10 to 50	344	9.3
More than 50 to 100	68	1.8
More than 100	259	7.0
Total	3736	100.0

Note: the sum of each section may not add to 3,736 if some observations are missing a reported characteristic. The main complicating factor in collating the information for this report is estimating the industry classification. This has been done by matching the name of the patent applicant across to business directories for each year. Not all names could be matched, especially for SMEs where the match rate was about 40 per cent. By contract, a higher match rate is achievable for large firms, public research organisations and hospitals. To account for this, all estimates have been weighted up by the inverse of the match rate for their organisational type.

Appendix 5: European Commission's EU Industrial R&D Investment Scoreboard

Since 2004, the Joint Research Centre of the European Commission has published an annual series which benchmarks European enterprises in terms of R&D investment activities. Titled *EU Industrial R&D investment Scoreboard*, the 2009 edition of the annual report provides data on R&D expenditures as well as other financial information such as sales, employment and profits of the top 1000 European-based enterprises in terms of R&D expenditures. The complete series of the report are available online (http://iri.jrc.ec.europa.eu/reports.htm) from 2004 to 2009, covering the 2003–04 to 2008–09 financial years, with the latest version of the Scoreboard providing comparisons of the top 1,000 European firms against the top 1,000 non-European firms. Table A5.1 provides a summary of the sample EU and non-EU companies in the 2009 edition of the Scoreboard.

Table A5.1 Sample companies in EU 2009 Scoreboard

EU Companies	
Number of companies by country	UK 247; DE 209; FR 125; SE 70; FI 58; IT 57; NL 53; DK 47; BE 39; etc.
Top 10 sectors	Pharmaceuticals & Biotechnology 127; Software & Computer Services 108; Industrial Engineering 96; Electronic & Electrical Equipment 67; Technology Hardware & Equipment 57; Automobiles & Parts 47 (45); Chemicals 47; Food producers 35; Support services 31 (33); Health care Equip. & Services 30.
Non-EU Companies	
Number of companies by country	US 531; Japan 256; Taiwan 41; Switzerland 38; South Korea 22; Canada 18; India 15; etc.
Top 10 sectors	Technology Hardware & Equipment 195; Pharmaceuticals & Biotechnology 133; Electronic & Electrical Equipment 87; Software & Computer Services 89; Chemicals 72; Automobiles & Parts 61; Industrial Engineering 53; Health Care Equip. & Services 45; Leisure goods 28; General Industrials 27.

Source: EC (2009, Table 1, p. 13)

As with the company information collected in the IBISWorld database used in the construction of IPRIA Scoreboard, the company information used for the EU Scoreboard is also sourced from published companies' annual reports and accounts provided by an independent data provider (EC, 2009).[48] In the same way, companies which are subsidiaries of other companies are not listed separately, except when the account of the ultimate parent company is not available. Unlike the IPRIA Scoreboard, however, the EU Scoreboard and the UK Scoreboard described in the next appendix do not provide any information about IP rights application or any other 'output' measure of innovation activities.

For R&D expenditures, only cash expenditures funded by the companies themselves are included. Excluded R&D expenditures are those undertaken under contract for other organisations and under joint venture (when disclosed). As with the IBISWorld data, there is a possibility that undisclosed R&D expenditures are not covered by the EU Scoreboard. However because the European Union has required all EU companies to follow the IFRS (International Financial Reporting Standards) with regards to R&D expenditure disclosure since 2005, the EU Scoreboard has thus undertaken steps to minimise the impact of transition to IFRS.[49]

Finally, because the country of each company is determined by the address of the their registered office, which may be different from the address of the operational or R&D headquarters, it is possible that the reported R&D expenditure is independent of the location of the R&D activity. In fact, as noted on page 47 of EC (2009),

> "The data used for the Scoreboard are different from data provided by statistical offices, e.g. BERD data. The Scoreboard refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed. BERD refers to all R&D activities performed by businesses within a particular sector and territory, regardless of the location of the business's headquarters, and regardless of the sources of finance."

[48] For the 2009 Scoreboard, as many as 8437 EU and 2398 non-EU companies were considered before the top 1000 in R&D from each group were selected for the Scoreboard.
[49] At the moment, it is not clear to us if IBISWorld companies have followed IFRS standard in their financial statements.

Thus, the EU Scoreboard differs from the IPRIA Scoreboard, to the extent that the R&D data used in the latter has a much closer link to the R&D activities within the country, as reported by ABS BERD data.

Another important difference between the EU and IPRIA Scoreboard's company data is in terms of timing. In the EU Scoreboard, the company information is intended to capture the latest published accounts of that company. For example, the 2008 EU Scoreboard would refer to company accounts in the fiscal year of 2008 such that "the current year set of the 2008 Scoreboard can include accounts ending on a range of dates from late 2007 to early 2009" (EC, 2009, p. 49). By contrast, in order to ensure data completeness and consistent comparisons across time, the 'current year' IPRIA Scoreboard always refers to company accounts of the previous fiscal year. For example, the 2006 IPRIA Scoreboard would contain R&D expenditures spent in the 2004–05 financial year.

Appendix 6: United Kingdom R&D Scoreboard

The UK Scoreboard series published by the Department for Business Innovation & Skills (BIS) provide data on R&D investment and other financial information such as sales, employment and profits of top UK-based enterprises in terms of R&D expenditures. As with the EU Scoreboard, the latest edition of the UK Scoreboard compares the top 1,000 UK and 1,000 global companies according to R&D Investment (BIS, 2009). Likewise, unlike the IPRIA Scoreboard, the UK Scoreboard does not provide any information on IP rights applications or other measures of innovation output. Complete historical data are available online from 1991 to 2009 covering the 1990-91 to 2008-09 financial years (http://www.innovation.gov.uk/rd_Scoreboard/?p=46).

In terms of the sample coverage, type of information and data definitions, the UK Scoreboard is quite similar to the EU Scoreboard, making direct comparisons of the two publications relatively straight forward. In other words, the differences between the IPRIA Scoreboard and the EU Scoreboard data noted earlier are more or less the same and should be taken into account when interpreting the results summarised in Chapter 5 of this report.

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