Centre for Transformative Innovation

Global Prosperity Through Knowledge and Innovation


# What drives firm innovation? A review of the economics literature

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# What drives firm innovation?

## Introduction

Francis Bacon said, nearly half a millennium ago, that man (sic) does not create material things, he only creates ideas.[1] Knowledge is the only original factor of production that truly accumulates and is therefore the only factor that can cause a continual growth in output per worker. What economists call 'capital goods' – plant, equipment and infrastructure - are mere re-arrangements of natural resources. The amount of matter in the world is the same now as it always has been – it is just that we have moved and re-assembled some of it into manufactured items. If we think about the world being one large vertically integrated firm then plant, equipment and infrastructure are just intermediate inputs. Knowledge, combined with labour, must account for the difference between our lifestyle today and the lifestyles experienced at any point in the past.

Innovation represents the downstream embodiment of knowledge. It is the concrete application of knowledge to enhance our material well-being. However, knowledge and innovation are fuzzy, intangible concepts with ill-defined borders. We know that its quality matters but our difficulty in research is that we have yet to find an undisputed measure of knowledge that is cardinal, transitive and robust.

This paper aims to give the reader a sense of the stylised facts about what makes some firms attempt more changes compared with others. The report begins with a review of definitions of innovation; and why we care about innovation and its differential treatment in the economic and management literatures. It is relevant to mention, however, at this juncture that the definition of innovation used in this study embraces all attempts by the firm to change and improve its production and operation processes and menu of products – whether successful or not. We then proceed to draw out the main conclusions from the applied economics literature, first by looking at studies of new-to-the-world innovation and next considering new-to-the-firm innovation studies. Finally, we present results from our own interrogation of firm-level Australian databases. In our conclusion we discuss what these various empirical studies mean for policy. .

As with all reviews, we are selective in our coverage. We exclude, or note, studies which are not clear about how firm innovation is measured. In particular, we exclude studies lacking clarity about whether the innovation is new-to-the-firm or new-to-the-world, and where authors fail to distinguish between the act of undertaking innovation and being successful at innovation. Furthermore, we give little space to studies that

[1] 'Ad opera nil aliud potest homo quam ut corpora naturalia admoveat et amoveat, reliqua natura intus agit' Bacon (cited in Marshall 1920: 63). The original is from Novum Organum IV.

focus on what we believe are unfruitful lines of inquiry, either because their conclusions provide no guidance to public or corporate policy or because data issues render their findings too uncertain for both understanding and action. We give more space to studies which relate worker and manager skills and the institutions that support them to firm innovative activity. Finally, we try to comprehensively cover Australian studies.

The review only covers the economic literature. Almost all the economic papers are empirical and as such many have inbuilt biases arising from the particular measure of innovation used. Many studies rely on R&D data, but R&D activity is a subset of innovation activities. There is also a large body that uses patent data. These will be biased towards new-to-the-world product inventions.

## Background

### What is innovation?

The established (OECD) definition of innovation is:

> '…the implementation/commercialisation of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer... the implementation/adoption of new or significantly improved production or delivery methods... involv[ing] changes in equipment, human resources, working methods or a combination of these.' (Oslo Manual 2005).

Invention and innovation are not synonymous. Invention is the creation of a new idea, device, method, composition or process. Innovation is the application or use of inventions. Our definition encompasses both 'new to the firm' and 'new to the world' innovations.

New to the world innovation can involve systems of interrelated inventions that feedback and reinforce each other as exemplified by the introduction of the steam engine, electricity or computers.[2] The use of coking coal, for instance, reduced the costs of iron making, made precision parts for Watt's steam engine possible, which in turn created the engines to pump water from the coal mines and make cheaper coal mining possible. Electricity was just a hobby until the event of central power stations, transmission wires and metres. Bell Laboratories pioneering work on cellular telephony did not diffuse and develop until the Federal Government allocated an electromagnetic spectrum to carry wireless signals. These examples illustrate how collective action by public authorities is required to make revolutionary technologies ubiquitous. The most important type of new-to-the-world innovations are 'general purpose technologies', such as electricity, the internet and

[2] Rosenberg (1963; 1979) have several examples of the machine tool industry in the 19th and 20th centuries.

transistors, which open up new opportunities rather than offering complete, final solutions. These technologies have wide applicability to downstream sectors, where they can be applied in a variety of contexts and enable other technologies (Bresnahan and Trajtenberg, 1995).

New-to-the-world innovations can also be minor or incremental. Much learning-by-doing and learning-by-using generates cost and quality changes that are new to the world. Early stage technology is typically rudimentary with numerous glitches. In many cases, the original idea becomes a catalyst for improvements in complementary technologies which reinforce the efficacy of the initial invention. Inventions are typically far from their original incarnation by the time they acquire wide-spread use (Mowery and Rosenberg 1998). Examples are numerous but include the improvements to transistors, the petrol engine and electric generators *inter alia*. However, economic historians argue that the impact of minor improvements will dissipate without regular major inventions (Rosenberg 1982, Mokyr 1990).

New-to-the-firm innovations can also have wide or narrow impacts. These innovations can be dismissed as technology transfer, imitation, or copying. However, without the implied changes and adaptations to different contexts, new-to-the-world innovations will have almost no effect on productivity. The substitution of 'the new' for 'the old' is not a discrete step change. Rosenberg (1982) has found that firms continue with old technologies long after the introduction of a radical new invention either because of sustained improvements to the old technologies or because the new technology is insufficiently settled and reliable. The water wheel, for example, continued to develop and improve long after the steam engine was on the market, and wooden sailing ships were still built long after iron-hull ships were available. In some cases, the new technology only 'works' in a narrow range of uses because it does not fit into the existing architecture and organisation of firms. Floor space may need to be reconfigured, while workers with different skills need to be hired and new inputs sourced (Rosenberg 1982).

Much 20$^{th}$ century economic thought conceptualised technology and changes to the means of production as input-output 'manna from heaven'. Over time this understanding has changed and most analysts today would more usefully depicted innovation as part of the firm's investment strategy. Namely, that firms make deliberate decisions to incur costs today in order to benefit from higher sales and profits tomorrow.

## Why do we care about innovation?

Francis Bacon said, nearly half a millennium ago, that man (sic) does not create material things, he only creates ideas. Knowledge is the only original factor of production that truly accumulates and is therefore the only factor that can cause a continual growth in output per worker. What economists call 'capital goods' – plant, equipment and infrastructure – are mere re-arrangements of natural resources. The amount of matter in the world is the same now as it always has been – it is just that we have moved and re-assembled some of it into

manufactured items. If we think about the world being one large vertically integrated firm then plant, equipment and infrastructure are just intermediate inputs. Knowledge, combined with labour, must account for the difference between our lifestyle today and the lifestyles experienced at any point in the past.

So how does the economy organise this re-arrangement of matter to deliver material well-being for people? For production per capita to rise, people have to change or improve the way they work. The economy is a highly integrated and specialised system. For one part to fit seamlessly with another temporally and geographically distant part, we need a significant degree of stability and predictability. Large changes cause losses of material products and a misuse of skills, know-how and worker time. It is not clear what the optimal level of innovation and change is, but we do know that there are country-level correlations between hosting innovative firms and the level and rate of growth of national production.

There is debate over whether and how much government intervention is needed to optimise the level of change (i.e. innovation). Since Smith (1776), the dominant and unshaking intellectual thought is that vigorous competition, fuelled through free markets, is enough to force firms to compete. Many and possibly most economists, then and now, understand this to mean price competition. Since Schumpeter, however, a growing body of economists believe firms compete on process, organisation, market and product competition. Price is a secondary and minor consideration.

This shift in understanding the mode of competition has occasioned a re-think of government policy towards the behaviour of markets and firms. If competition mainly takes the form of price changes, it is difficult to see a role for government. However, if competition requires changes to very sophisticated production technologies, including long and complex production chains and the creation and generation of public goods, there can be major roles for large economy-wide institutions.

Which innovation definition and determinants are relevant in any discussion will depend on who wants to know. If governments want to know what drives firm innovation, the explanatory variables under scrutiny will be those which are subject to policy manipulation. Factors such as industry, age or ownership are, from this perspective, relatively empty. If businesses (or their associations) want to know, the model should include factors under the discretion of the manager – even if they are not truly causal. If academics want to know, or others merely seeking understanding, they will model determinants that are clearly exogenous. The academic literature does not tolerate proximate causes or correlations but seeks to identify the essential elements in the decision to innovate.

Studies that estimate the effect of innovation on productivity are sparse and considerably fewer than those that estimate the effect of R&D. Of these innovation studies, most rely on cross-sectional datasets that are

typically based on specially designed surveys of innovation activities. A good example here is Griffith, Huergo, Mairesse and Peters (2006) which uses a cross-section of Community Innovation Survey data from 1998 to 2000 for four countries, to find that product innovation is correlated with productivity in France, Spain and the United Kingdom (but not Germany). Hall et al (2009) find similar results for Italy and Halpern and Muraközy (2012) find that product innovation is correlated with productivity in Hungary.

Panel estimations have only recently appeared. In Australia, Palangkaraya, Spurling and Webster (2015) use a panel dataset of over 7000 SMEs and find innovation led (total factor) productivity to rise by 2.7 percentage points over the next year relative to other firms in their industry. Those firms that accompanied their innovations with an innovation-oriented collaboration raised their productivity by an additional 3.3 percentage points. Bartelsman, Dobbelaere and Peters (2013) show a positive effect of product innovation on labour productivity – an effect that is stronger for the most productive firms – using data from a sample of over 20 000 firms from Germany and the Netherlands between 2000 and 2008. They find no overall effect for process innovation and a negative effect of process innovation on the most productive firms. Bloom, Sadun and van Reenen (2012) find evidence consistent with the view that the productive use of IT depends on complementary management practices. Raymond, Mohnen, Palm, van der Loeff (2013) use two measures of innovation: a binary measure of whether an innovation has taken place and an intensity measure of the share of sales attributable to new products. Using a sample of about 3 000 firms from the Netherlands and France, they find clear results that innovation raises productivity. Furthermore, they observe a pattern in the data that suggests that in the short run, innovation reduces labour productivity as firms adjust to their new production routines. Bartel, Ichniowski and Shaw (2007) use data on 290 distinct valve products made during 1999 to 2003 and find a clear positive effect of IT innovation on productivity. Hubbard (2003) also finds a positive impact of IT use on productivity in the trucking industry. In sum, there is a clear evidence from panel data analysis that innovation, especially product innovation raises firm level productivity.

## How does the literature treat innovation?

Innovation typically involves making an outlay – expenditure – in the expectation of a future benefit – products – that are better, cheaper or both. As such innovation is an investment. Most economic theories of investment explicitly assume outlays are designed to expand productive capacity via more plant, equipment and infrastructure. But these theories and models can be generally applied to intangibles such as R&D, innovation, training, organisational change, marketing and distribution improvements.

The classic theoretical starting point for economic models of investment is the tautology that firms will invest in a scheme when the expected present value of its net benefits exceeds zero. A critical and contested element of this characterisation of investment decisions are assumptions concerning how expectations are formed;

how degrees of confidence about these expectations are treated; and how uncertainty and risk are built into the model. The most basic theories assume expected costs are determined by the tax regime, wages and the cost of capital goods, and the present value of benefits is determined by the rate of interest, depreciation, other technological changes and future market demand (Clark 1917; Jorgenson 1963; Haavelmo 1960). This generic theory is typically operationalised using a Cobb-Douglas production function, adjustment costs, distributed lag processes, options and dynamic processes governing the formation of expectations (Coen and Eisner 1986, Thomson 2008). Confidence and uncertainty – the hallmark of Keynes's general theory – is notably absent.

Economists interested in modelling innovation decisions have not extended these investment models into the intangible domain because of their mechanical nature. For this reason, and because of the limited availability of standardised innovation data, the economics of innovation literature has taken a more ad hoc approach to modelling the innovation decision. In many cases, the models amount to no more than multivariate correlations with ambiguous causation. However, they do reveal empirical regularities that lay foundations for more nuanced theories.

There is also an extensive literature within management and organisational studies investigating the determinants of firm-level innovation. In contrast to the economics literature, it typically defines innovation as the introduction of a *successful* new product, process, organisational or marketing method. As such, it conflates the decision to attempt to innovate and success at innovation into one variable. In this paper, we adopt the economic definition as conflation makes it hard to interpret the results. Although past successes may encourage further attempts to innovate, the question of why firms innovate and what makes the innovation successful are distinct.

There are two main types of decision rules used by managers contemplating an investment: organisational and economic. The former involve rules of thumb and managerial conventions whereas the latter relate to calculated cost-benefit ratios. Rules of thumb are typically used where the presence of uncertainty, long time horizons and bounded rationality prevent the reasonable calculation of future costs and benefits (Thompson 1999; Coad and Rao 2010). Clearly, however, a firm would become very inefficient and eventually lose market share if it sustained rules of thumb where the *ex ante* expectation of net benefits are continuously biased and not realised *ex post*. However, uncertainty about the future means basing the investment decision on cost-benefit calculations is problematic. Accordingly, it is reasonable to assume that rules of thumb prevail in the short term, but are likely to be adjusted gradually to realised costs and benefits. An exception would be where there was a large, abrupt change in circumstances wherein path dependent rules of thumb are inappropriate. An example might include the decision to establish a green fields site in a new location.

Innovation can be either new-to-the-firm or new-to-the-world. It is generally accepted that new-to-the-firm innovation, in aggregate, has the greatest direct impact on firm productivity. However, empirical studies are always constrained by the availability of standardised and broad-based data. The availability of R&D and patent data, as proxies for innovation, mean that a bias in this literature exists in favour of science-based new-to-the-world changes. Since the late 1990s, this bias has reduced with the proliferation of firm-level innovation surveys which seek to measure new-to-the-firm innovations, including managerial or organisational innovations, and the impact of such innovations on firm performance (e.g. Kleinknecht and Mohnen 2002).

The most challenging empirical problem is that each innovative act is by definition different from the last act. It is therefore difficult to design measures that are beyond reproach in terms of being cardinal, transitive and meaningful. Nonetheless, three common measures of attempting to innovate exist, namely:

- Spending on R&D;
- Patent applications; and
- Binary survey questions; in which the classic question is '…did your firm introduce a new or significantly improved (or new) process or product in the last [defined] period'. More recent surveys clarify whether these improvements relate to new-to-the-firm or new-to-the-world changes but older surveys did not.

No author would pretend that these measures are unbiased and comprehensive measures of innovation. They represent the best analysis one can do with the available data. The binary survey measure of innovation, for example, only captures attempt to innovate at the extensive margin (how many firms innovate) since it does not tell the intensity of the attempt (how much firms innovate). For a fuller discussion about the innovation measurement biases, see Jensen and Webster (2009).

## Modelling the motive for innovation

Early empiricists modelled innovation as functions of:

- Skeletal firm characteristics such as its industry, size, market structure (the number and size distribution of firms in a given industry) and market share;
- Market demand which may be represented as a growth rate or share;
- Technological opportunity; or
- Managerial practices (supply chain management, worker training, quality management, and human resource management).

The findings from these early studies come in for a degree of criticism. Mowery and Rosenberg (1979) have pointed out that market demand can often be defined so broadly that it is meaningless. Moreover, the direction of causality between innovation and market demand is ambiguous. Many innovations, such as

computers and mobile phones, have to create their own market. Furthermore, endogenous dynamic cycles involving decreasing costs, increasing market demand, increasing profitability and a subsequent decrease in costs, might imply causality but may not be unidirectional. The question is: what initiates this cycle? History is replete with examples of unexploited opportunities which are never developed. The question is why do some opportunities proceed to the next step and others not? Discoveries can be made long after the essential pieces were present and known. Louis Pasteur, for example, discovered bacteria 200 years after the invention of the microscope. The essential scientific knowledge for the transistor existed 15 years before it was invented in Bell Labs (Nelson 1962). Breakthrough scientific discoveries are commonly accidents of applied research, technological inquiry or use.[3] There is evidence that resourcing is at the heart of what eventually succeeds (with the sovereign economic agents being the decider of what is invented[4]). Empirical associations between innovation and managerial practices tend to reveal activities that are complementary to innovation but not necessarily determinants. For example, we may find a statistical association between innovation in firms and the use managerial techniques such as virtual prototyping, product lifecycle management product line planning and portfolio management. However, this correlation cannot distinguish between practices which were introduced *because* managers decided to innovate, and those that *caused* managers to decide to innovate.

Overall, the conclusions from this literature are generally disappointing. Stable and robust 'determinants' tend to be either exogenous but empty, or endogenous and complementary. Nonetheless, we review the findings of the most pertinent early studies and new directions below.

Few studies organise themselves along the new-to-the-world and new-to-the-firm lines although for our purpose we will treat studies using R&D and patents as the dependent variable as those primarily associated with new-to-the-world innovation. Studies that did not clarify whether innovation was new-to-the-world or new-to-the-firm are not included in this review. But it is important to note that survey measures which embrace new-to-the-firm innovation include a probably small proportion of new-to-the-world innovations.

### a. New-to-the-world studies

The next section summarises the results from empirical studies over the last 15 years. Most of these papers estimate models using firm-level data sets, but a limited number use country-level data sets. Many studies

[3] Cohen (2010) gives a more complete discussion of evidence for the importance of scientific opportunity for innovation. He notes that Geroski suggests that technological opportunity is best treated as an unobservable variable given the difficulty of devising a measure of opportunity that spans industries (p174).
[4] See Cohen's (2010) comments on the role of government and military spending (pp. 179-80 and fn 63).

rely on a single cross-section of data, but for reasons we elaborate below, the time series dimension does not always allow us to infer causality.

*Firm size*

The prediction that innovation will be a function of firm size is the one of the oldest and most basic of 'hypotheses'. The common argument is that larger firms can amortise fixed costs over a broader base and will, therefore, be more innovative than smaller firms. But there are counter claims. It is also argued that smaller firms may be less bureaucratic, more flexible and therefore more efficient at innovation. Generally, studies find a positive, but not universal, association between size and measures of new-to-the-world innovation (see the reviews of Crepon, Duguet and Mairesse 1998; Becheikh 2006; Castellacci 2011; Le Basa and Scellato 2014 and Benevente 2006).

We say 'not universal' as the association depends heavily on the actual measure of innovation. First, any binary measure of innovation (e.g. 'Have you introduced a new product in the last year?') will inevitably yield a 'yes' response from large firms simply because their size means they do more activities of all types. More importantly, as mentioned earlier, all findings based on binary measures of innovation only reveal a partial picture. The relationship shown between the explanatory variable in question (in this case, firm size) and innovation measured by a binary variable is only at the extensive margin. It may suggest that larger firms are more likely to introduce a new product, but it does not necessarily imply that on average larger firms introduce more new products. Hence, we cannot directly infer from the finding that larger firms are more innovative without looking at the relationship at the intensive margin.

In fact, studies of the same relationship at the intensive margin based on measures of innovation input intensity, such as R&D spending per sales (Chang-Yang Lee 2009; Lööf and Heshmati 2006; Johansson and Lööf 2008) or innovation output intensity, such as share of sales from new to market products and services (Coad, Cowling, Nightingale, Pellegrino, Savona and Siepel 2014), will often draw negative or ambiguous associations between innovation and firm size.

Closely linked to the firm size question is the hypothesis that innovation will be a function of market share or market concentration. Here the findings are for a positive association between a high market share, concentration and a high innovation intensity (Crepon, Duguet and Mairesse 1998; Abdelmoula and Etienne 2010; Castellacci 2011).

Even if size, market share or concentration could be shown to have a clear link with innovation, it is hard to empirically identify causality. We know that these attributes are persistent, that is they change slowly. Hence, they are affected by innovation; it will be very difficult empirically to disentangle cause from effect. It is

possible, for example, that larger firms can pay the wages to employ the better managers who are also more innovative.

### *Age*

A review of the literature shows that the empirical results are mixed with a leaning towards a negative association between firm age and innovation (Abdelmoula and Etienne 2010; Becheikh 2006; Chang-Yang Lee 2009). To the extent, they do find a correlation between the age of the business and innovative activity, the former is probably a proxy for some other variable left out from the empirical analysis.

### *Persistence*

The degree of path dependence or persistence of new-to-the-world innovation has been extensively studied. We expect that if accumulating the complex capabilities required for new-to-the-world innovation is a slow and uncertain process that depends heavily on past experience and know-how, then persistence with innovation activity will be important for predicting innovation activity (Teece 2006). The plastic banknote developed by CSIRO and the Reserve Bank of Australia (RBA) is a good example of persistence both by the RBA in accumulating the complex capabilities required to produce the new note and by CSIRO in understanding the needs of the RBA (Solomon and Spurling 2014).

However, actual persistence in innovation is not widespread as theory suggests. Studies, and reviews of studies, by Amore (2015); Colombelli and Quatraro (2014); Antonelli, Crespi & Scellato (2013); Le Basa and Scellato (2013); Ganter (2013); Matvejeva (2014); Woerter (2014); Raymond et al (2010); Johansson and Lööf (2006), have all found that only a minority of firms, most particularly large firms and those in high-tech industries, are persistent innovators. The remaining firms are sporadically innovative or not innovative at all with the degree of persistence depending logically on the time horizon. Additionally, Hecker and Ganter (2014) have found that whereas product innovation tends to be path dependent (that is, related to what the firm did last period), being a process and organizational innovator is primarily shaped by time-invariant and unobserved firm characteristics such as the skill of the manager and senior staff. In the UK, Griffith et al (2006) argue that government support leads to more persistence, but it is not clear here which way the casualty runs. In Australia, Griffiths and Webster (2010) found that R&D activity is a highly path dependent process.

On a slightly different note, path dependence in general may inhibit the ability to innovate. The accumulation of core competencies over time may serve to lock in a particular pathway of development, from which a firm struggles to deviate. According to Garud, Tuertscher and Van de Ven (2013), the core competencies of Research-in-Motion, Kodak, Nokia and Polaroid became core rigidities and prevented the company from recognising when it needed to change. Firms can become unable to see that that the knowledge architecture

on which their information processing systems are based has shifted. Part of the problem lies in separating transient fashions from discontinuities.

More insightful variables, however, relate to the global connectedness of the firm; its immersion within networks and clusters and its use of government programs, especially high-risk procurement programs. These factors are overlapping.

### *Internationalisation*

The relationship between innovation and internationalisation of a firm's activity, measured by the propensity to export or foreign ownership, has attracted considerable attention in the innovation literature. The overwhelming evidence is that exporting firms do more new-to-the-world innovation (Palangkaraya et al 2010; Abdelmoula and Etienne 2010; Becheikh, Landry and Amara 2006; Castellacci 2011; Chang, Chen and McAleer 2013; Le Basa and Scellato 2013; Griffiths *et al* 2006; Mate-Sanchez-Val and Harris 2014; Siedschlag and Zhang 2015 but not Wu, Popp and Bretschneider 2007).

There is clear and consistent evidence that new-to-the-world innovation causes export (see Aw et al 2000, Chadha 2009, Wagner 2007; Kirbachs and Schmiedeberg 2008). However, the evidence is less clear on a number of important aspects of this relationship. First, prior research indicates that export activity may also predict innovation activity; that is, there are learning effects (Damijan, Kostevc and Polanec 2010, is the widely cited evidence for it). Second, the relationship between the type of innovation activity and the propensity to export is not clear from the available evidence. That is, do product or process innovations independently lead to a higher propensity to export, or are both important? The evidence on the relationship between foreign ownership and innovation activity is less clear. Un and Cuervo-Cazurra (2008) find that local subsidiaries of multi-national enterprises (MNEs) invest less in R&D than domestic firms, perhaps because they rely on their parents for new technologies. Similarly, Wang (2010) concluded from an analysis of 26 OECD countries that foreign imported technology, via MNE subsidiaries, does substitute for local R&D. By contrast, a review of 108 studies of the effects of foreign ownership on innovation by Becheikh, Landry and Amara (2006) found mixed results. Being an exporter, however, may be just a proxy for the number of competitors. Anwar and Sun (2014), for example, find that the entry of foreign firms into market has a positive effect on incumbent firm innovation.

### *Government programs*

Little so far has been said about whether government programs can affect the firm's decision to innovate. Much has been written on two types of policies: R&D tax concessions (or credits) and public procurement programs.

For most of the second half of the 20th century, the size and structure of government defence spending in the US, UK, Sweden, Israel and France has had a major impact on the innovative activities of their civilian firms (Mowery and Rosenberg 1998; Mowery 2012; Aschhoff and Sofka 2009; Audretsch, Leyden & Link 2012; Foray, Mowery and Nelson 2012)[5]. This largely occurred via public procurement programs by defence departments (i.e. DARPA[6]) but other major procurement programs in agriculture, space and health have also contributed. These government agencies typically had elaborate mechanisms and rules for selecting firms to undertake high-risk research for radical problems; staged processes for further development of nascent ideas; and enforced rules for idea exchange and technology transfer among client firms. These policies were designed to reduce investment uncertainty and reduce the need to re-invent what is already known. DARPA used a heavy hand in changing social networks to ensure the right people were brought together. In addition to procurement, its programs have been the well-spring of civilian spinoffs and support for general R&D infrastructure (including the jet engine, computer networking, radar, Microsoft windows, the Internet, computer memory technologies and other aircraft technologies, see Fuchs 2010, Mowery 2012). Wu, Popp and Bretschneider (2007) analysed data from the OECD countries and found that government R&D spending had a positive effect on firm R&D, but university R&D spending had a negative effect on firm R&D. Mowery and Rosenberg (1998) argue that the creation of the academic medical centre as an institution that linked academic scientists with practitioners was responsible for the rapid development of medical devices and pharmaceuticals in post-WWII America. This co-location and co-organisation arrangement allowed for rapid feedback between the inventors and users of ideas.

The most recent and nuanced study on the Australian R&D tax concession programs by Thomson and Skali (2015) found that firms which claim R&D tax subsidies invest around 50% more R&D than 'similar' firms which do not benefit from tax subsidies. The international evidence on the effect of R&D tax concessions implies that R&D increases by 60[c] for every dollar of tax revenue forgone, over the short run, and by $1.20 in the long run.

### *Intellectual property*

It is reasonably assumed, a priori, that the prospect of a return from innovation will increase the amount of innovations a firm will commit to. An intellectual property (IP) right is the privilege given to people or organisations to prevent others for using their idea, creation or invention for a defined period of time. Five forms of intellectual property exist in most countries: patents; designs; copyright; trade secrets and plant

[5] According to Mowery and Rosenberg (1998), in the US post-WWII period, the federal government funded between half and two thirds of total US R&D. However, most of this government funded R&D was performed by private industry.
[6] Defense Advanced Research Projects Agency.

breeders' rights. A sixth, trademarks, can be said to offer quasi-excludability (see Greenhalgh, Rogers, Schautschick and Sena 2011).

From a public policy point of view, IP rights operate most effectively when the cost of inventing and taking a commercial idea to market is expensive. There is considerable evidence that patents increase innovation on a partial equilibrium basis (i.e. from the perspective of the patentee) (Mansfield 1981; Webster and Jensen 2011). This effect is largest for pharmaceuticals, chemicals and instruments – that is where the boundaries between ideas are clear and the potential for expropriation is large (Mansfield 1986; Cohen, Nelson and Walsh 2000; Levin, Klevorick, Nelson, Winter, Gilbert and Griliches 1987).

The evidence that IP encourages invention, creation or innovation for non-patent forms in IP is scarcer. However, there is solid evidence that non-IP ways to preserve innovation profits, such as secrecy, lead time and production complexity, are effective (Jensen and Webster 2009; Harabi 1995; Arundel 2001; Moser 2012). If the patent system was abolished, innovation would probably shift towards areas where non-patent forms of appropriation are effective (see the conclusions of Moser 2005).

However, from a general equilibrium perspective, many authors argue that patents stifle innovation because the benefits to the patentee are outweighed by the costs to third parties (Moser 2016, Lerner 2000). Patents can hinder follow-on idea development and impose financial costs and legal uncertainty on people working in patent-intensive domains. Indeed, there is good evidence that firms file for a patent to stop other people conducting R&D in their area. Wang (2010) examines data from the OECD countries and finds that 'strength' of national patent rights are only a fragile determinant of R&D. Barbosa and Faria (2011) find that strengthening IP rights in EU does not stimulate innovation. Branstetter and Sakakibara (1988) analyse a natural experiment in the Japanese patent system and find only a modest effect of strengthening patents on R&D. Moser (2012) examined world new product trade fairs in the 19$^{th}$ century. Switzerland and the Netherlands had considerably higher per capita exhibitions and prize-winning entries than countries with patent systems. As evidence of the power of patents to block follow-on innovation, Moser (2013) reports her own study that found a 20 per cent increase in domestic patenting (i.e. innovation) following the compulsory licensing of foreign patents (i.e. increase in freedom-to-operate) during WWI.

### *External networks*

Networks, social capital, clusters and localised groups of supporting industries represent overlapping theories of what drives innovation. Their role derives from the notion that individuals and single firms have a limited basis on which to collate and judge the meaning of fast moving and complicated information. As knowledge becomes more complex and dispersed, it is not possible for a single firm to keep up with and exploit all relevant knowledge (Lane and Lubatkin 1998). Trusted outsiders, colleagues and friends can reduce uncertainty and

the anxiety associated with costly decisions through the provision of nuanced information and know-how. Close interactions between corporate and communal judgment becomes highly indispensable (Alnuaimi, Opsahl and George 2012; Baba and Walsh 2010;[7] Della Malva 2013; Dedrick 2015; Johansson and Lööf 2006). Firms need to be connected in appropriate ways to be alert to opportunity. Networks reduce the perceived cost of making a decision to innovate or not. They reduce procrastination arising from uncertainty.

The local industry environment, or cluster, becomes the organ that absorbs external information; slices the knowledge, re-interprets it and then supports the actions of its members by providing specialised intermediate services.[8] Firms interact with suppliers, partners and customers to keep up, or hire people from competitors or acquire suppliers or competitors outright.[9] These industry clusters, or innovation eco-systems, include lead firms, suppliers, customers and providers of complementary technologies (Sturgeon, 2002). Essentially, networks between firms and clusters de-risk the innovation decision and give the business confidence to invest. In Australia, Thomson and Webster (2013) found that firms outsource the development of inventions to share risk. In addition, Palangkaraya et al (2010) found an association between the propensity for Australian firms to do R&D and participation in a formal network.

Rosenberg (1982) argues that a distinguishing feature of the last two centuries is the growth of these specialist capital producing firms. Silicon Valley is the leading contemporary example of a cluster, but competitor clusters exist in Korea, Taiwan, and Southeast Asia.

Finding an average association between firms' decisions to innovate and membership of a cluster is almost true by definition (Harris and Trainor 2011; Yang, Motohashi and Chen 2009; Abdelmoula and Etienne 2010). Even without problems of defining what is and is not a cluster, there is clearly going to be an endogenous element to the relationship as firms wanting to make a step-change in their innovation activities will chose to locate in a cluster that offers appropriate and effective support. Regardless of the ultimate determinant of the decision to innovate, the fact that firms choose to locate in certain clusters is prima facie evidence that clusters provide an advantage.

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[7] Baba and Walsh (2010) describe how Merck, the first body to commercialised statins (a Japanese discovery), used its strategic position at the centre of an open network to collate information about substitute drugs, sophisticated know-how, regulations that allowed them to make correct but new-to-the-world intuitive decisions.

[8] Shearmur and Doloreux (2013) argue that knowledge-based business services – specialist IT, knowledge systems, marketing and managerial services) are the antidote to the emergence of more open and flexible production wrought through global production chains.

[9] Miguélez and Moreno (2015) find that the networks and the mobility of inventors within these networks are associated with more innovative firms.

Most empirical research seeks to identify which firms within a cluster are most affected by being located there rather than whether the cluster induced innovation per se. Lee (2009), for example, found that other things being equal firms that locate in homogeneous clusters are less willing to invest in exploiting non-proprietary R&D opportunities. Oakey and Cooper (1989), Shaver and Flyer (2000a and 2000b) and Iammarino and McCann (2006), have pointed out that differences in technological competence matter. Firms with low technological competence may benefit more from being located in a cluster, while firms with high technological competence may face the risk of detrimental outward knowledge spillovers. Interestingly, Battisti, Hollenstein, Stoneman and Woerter (2014) found that the availability of external sources of knowledge had no effect on whether the firm innovated, which suggests that it is the context and how ideas are delivered that matters.

### *Frontier science*

Historical studies consistently throw up examples of how new technologies emerge from established not new science (Kline and Rosenberg 1986).[10] Innovation uses knowledge with which people are familiar and comfortable. In fact, Rosenberg (1982) argues that the normal course of events is to discover what works (i.e. new technology) before we understand why it works (i.e. new science). Recently, Schoenmakers and Duysters (2010) analysed 157 patents and found that radical inventions actually depend more on existing science than incremental inventions. Mansfield (1991) has qualified this 'stylised fact' by arguing that new science is more relevant for drugs, medical, bio-tech (and other high R&D industries). Della Malva and Carree (2013) investigated 86 European regions in seven countries. They found that the mere presence of university researchers had no significant impact on the innovativeness of nearby firms. Others argue that the advance of technology in some fields has been very slow because of the limited guidance from science.

This is not the same as saying that frontier scientists are not major contributors to innovation. There is evidence that regions hosting leading-edge research departments produce significantly more inventions and more innovations. Mowery and Ziedonis (2015) analysed data from nearly 1000 invention disclosures in the US. They found proximity matters for formal contracts between universities and firms possibly because the incompleteness of contracts means that firms know they should be near inventors for the know-how to transfer. Proximity was less important for knowledge spillovers. Aschhoff and Sofka (2009) and Brehm and Lundin (2012) both found positive effects of the presence of universities on firm innovation but note that it depends on firms' absorptive capacities. Koch and Strotmann (2008) report that German companies that

[10] Rosenberg (1982) defines science as '…systematized knowledge within a consistently integrated theoretical framework…' (p13). He notes that the role of such knowledge before the 20th century was small.

access knowledge from universities and other public institutions were more likely to engage in radical innovation. However, it is possible that the knowledge accessed from universities is established not frontier science. The real questions here are: Are firms which fail to absorb new science overlooking lucrative opportunities? And what are the features of firms who do exploit new science?

### *Customer and supplier interaction*

A consistent stylised fact found in both overseas and Australian surveys is that more innovative firms claim to have more interaction with customers and suppliers (see Becheikh, Landry and Amara 2006). Firm surveys about collaboration consistently find that interaction with universities and public research organisations are not rated highly.

### *Entrepreneurs and managers*

In search of the ultimate source of a firm's innovative drive, some authors are turning to the characteristics of the founder or entrepreneur. There is a vast management literature in this area, and we confine ourselves to selected studies from the economics literature.

Audretsch, Leyden and Link (2012) reveal that founders with academic backgrounds are more innovative while Goel and Grimpe (2012) have shown that academics who spend more time consulting and participating in conferences are more likely to be entrepreneurs. Matvejeva (2014) argues that the personal qualities of the innovation champion matter. In her eye surgery case study, what mattered were the relational skills of the leader and persistent search for unconventional solutions for existing problems. In a review of 108 studies, Becheikh, Landry and Amara (2006) concluded that a CEO who sets challenging goals for employees, who is ambitious, and who embodies transformational leadership will create a more innovative firm. Consistent with this is Driver (2012) who found that more internal firm governance rules tend to depress R&D. Crossan and Apaydin (2010) cite over a dozen studies which correlate leaders' characteristics with their ability and motivation to innovate. These comprise the tolerance of ambiguity; self-confidence; openness to experience; unconventionality; originality; rule governess; authoritarianism; independence; proactivity; intrinsic (versus extrinsic) attribution bias; determination to succeed, personal initiative and tolerance of change.

Griffiths and Webster (2010) also found evidence that R&D activity in Australian firms is associated with more aggressive and intuitive managers and the extensive use of incentive schemes for employees. However, economists have not, generally speaking, delved in this area and we do not present a comprehensive summary of these factors.

*Managerial practices*

Different measures of managerial skill and processes are regularly associated with the innovative functions of firms. Criscuolo, Haskel and Slaughter (2004) report that process innovation is associated with quality circles and that product innovation is associated with automatically linked IT systems. Hong, Oxley and McCann (2010) report that more innovative firms have more well-defined communications strategies. In the main, however, it would be difficult to use this evidence to conclude that these managerial functions cause the firm to be innovative. It could also be plausibly argued that when a company decides to undertake a product or process innovation, they introduce changes to the organisation or managerial practices. The same qualifier applies to appropriability conditions such as intellectual property protection. Barge-Gil and López (2014) and Becheikh, Landry and Amara (2006) propose that internal protection strategies are always present, but this does not imply causality. Without panel firm-level datasets, it is very difficult to identify whether certain managerial practices cause or complement innovation.

Milgrom and Roberts (1995) argue that for change to be successful, all the complementary structures and processes within the firm need to change simultaneously. As an example of this, Harris and Trainor (2011) found that doing R&D successfully required relevant capabilities, a high level of absorptive capacity, and many external linkages for sourcing technology. Scott and Bruce (1994) discovered that where subordinates are allowed greater autonomy and decision latitude by their supervisor, there is more individual innovative behaviour. Ar and Baki (2011) examined 270 Turkish firms and found that top managerial support is positively related to product innovation but has no effect on process innovation. On the other hand, process innovation was influenced by organisational learning capability and organisational collaboration.

## New-to-the-firm innovation

Most empirical studies of new-to-the-firm innovation depend on survey information, with the binary question '…introduced a new or improved product or process…' being the dominant measure. As such, it is not usually possible to assess whether the density of new-to-the-firm innovations are related to firm size. The studies, which are fewer in number than the new-to-the-world studies, are dominated by the European Community Innovation Surveys and their equivalents in other countries. In Australia, the largest dataset used is the Expanded Analytical Business Longitudinal Database (EABLD).

*Conduit technologies*

The drive to undertake new-to-the-firm innovation springs from recognition of the need to change accepted ways of doing things and the cost of making these changes. Much change is spearheaded by the adoption of new off-the-shelf ICT systems or new capital equipment. The role these conduit technologies have played in general change is aptly illustrated by Rosenberg (1963). He describes how the machine tool industry during

the latter part of the 19th century became the main transmission centre for the transfer of new skills throughout manufacturing. It is possible that today, the presence of skilled ICT workers and the establishment of automated and integrated IT systems, is a catalyst for other new-to-the-firm innovations. As with the new-to-the-world examples above, many of the explanatory factors given below are not truly causal, but represent part of the decision making process.

### *Conduit technologies - ICT*

Adopting new ICT systems is a process of innovation in itself but also an enabler of further innovations. Both Battisti et al. (2007) and Moshiri and Simpson (2011) have found evidence that ICT adoption is often accompanied by new organisational practices, and is more common in larger firms and those with higher levels of human capital. Engelstätter (2012) has examined the effects of ICT on innovation. Firms with supply chain management systems in place are more likely to introduce other innovations.

### *Conduit technologies - machines*

Many new technologies are embodied in machines. Heidenreich (2009) examined low and medium technology industries, especially those with weak internal innovation capabilities. New-to-the-firm innovation was dependent on the external provision of machines, equipment and software. For these firms, suppliers are an important source of information and knowledge. Using data on Australian firms, both Webster (2004) and Palangkaraya et al. (2010) have found a clear positive association between new-to-the-firm innovation and investment in new physical capital. According to Saxonhouse (as cited in Rosenberg 1982), the rapid transmission of best-practice techniques in the Japanese textile industry owe much to the actions of business associations and common capital goods supplies which made the cost of acquiring information cheap.

### *Age, ownership and market characteristics*

There is limited evidence on the association with conventional factors such as age, ownership and market characteristics. Skuras, Tsegenidi and Tsekouras (2008) found that the probability that a firm has carried out product innovation reduces with the firm's age. In Australia, Webster (2004) found that locally-owned companies were found to be more innovative, *ceteris paribus*; and Bhattacharya and Bloch (2004) found that market concentration was associated with greater new-to-the-firm innovation in high-tech industries. Webster (2004) found that large Australian firms operating in more volatile product markets adopted more innovation. However, in contrast to above firms in less contestable (i.e. less ease of entry and concentration), markets were more innovative. Finally, export (and import) status have a positive association with new-to-the-firm innovation (Bhattacharya and Bloch 2004; Schneider, Günther and Brandenburg 2010; Smolny 2003; Palangkaraya 2012; Lin and Lo 2015).

Interestingly, the Australian study by Palangkaraya (2013) found that innovation leads (i.e. causes) export, but the reverse direction was weak. He noted that it was only in the service sector that there was evidence that export led to process innovation. Hence there is reason to suspect that the correlations between exports and innovation do not mean exports cause innovation, on average. Ganter and Hecker (2013) report German evidence that the speed of technological change and to a lesser extent brevity of product life cycle appear to foster organizational innovation.

### *Persistence*

There is consistent but qualified evidence of persistence among new-to-the-firm innovators. Tavassolia and Karlsson (2015) found evidence of state dependence for product, process and organisational innovation but not marketing innovation. The strongest persistency was found for product innovators. Triguero and Córcoles (2013) report clear evidence of persistence especially for large firms and those in dynamic markets. Triguero, Córcoles and Cuerva (2014) found that plentiful technological opportunities, cumulativeness of learning and the use of generic knowledge provided by universities enhance persistence in innovative activity.

On the other hand, Ganter and Hecker (2013) do not find persistence for new-to-the-firm innovative activity at all. According to Palangkaraya et al (2010), more than half of innovating Australian firms in the services industry are 'one-time' innovators, whereas about 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.

### *Managerial practices*

The effects on productivity of managerial behaviours are relatively well studied. However, the effect on the decision to innovate is less well considered. Bloom and Van Reenen (2010) argue that 'good management' should include practices around (a) monitoring what goes on inside their firms and using this for continuous improvement; (b) setting targets, track the right outcomes, and taking appropriate action if the two are inconsistent; and (c) promoting and rewarding employees based on performance, and hiring and keeping the best employees. In their study of managerial practices, Bloom and Van Reenen (2010) found that imperfectly competitive markets, family ownership, regulations restricting management practices, and informational barriers allow poor management practices to persist.

Skuras, Tsegenidi and Tsekouras (2008) also found that the probability that a firm has shown innovative activity is positively affected by regular and formal contact with clients. Griffiths and Webster (2010) analysed Australian firms and found organisational goals and managerial strategies and dimensions are key to stimulating innovation. Webster (2004) also note that more flexible styles of management and more

aggressive managerial approaches were significantly associated with more innovative modes of production. According to Hult, Hurley and Knight (2004), the firm's innovativeness hinges on the extent to which managers acquire and have the capabilities to act on market intelligence. Collecting information is not enough.

### *Managers' character and education*

More highly educated managers, those with tertiary education or an MBA, tend to adopt good management practices and/or be innovative (Khan and Manopichetwattana 1989; Souitaris 2002; Skuras, Tsegenidi and Tsekouras 2008; Bloom and Van Reenen 2010).

There is a sparse literature on the effect of the CEO's or entrepreneur's character. Khan and Manopichetwattana (1989) and Souitaris (2002) found that young owner-CEOs are more enthusiastic about innovation. Zhao and Seibert (2006), examined the relationship between personality and entrepreneurial status, and found that compared with managers, entrepreneurs are more conscientious and open to experience and less neurotic and agreeable. Furthermore, entrepreneurs with a creative cognitive style had lower levels of thoroughness and were moderately more aversive, extrovert and emotionally stable.

### *Workers' education and skill*

We would expect that the level of workers' education will influence how easy it is for managers to affect change within a firm. Implementing new practices may be easier with a more educated workforce that is familiar with budgeting, data analysis and standard human resources practices. Evangelista and Mastrostefano (2006) found that some obstacles to innovation are firm-specific and arise from lack of qualified personnel. Dostie (2014) has demonstrated that more training leads to more product and process innovation, with on-the-job training playing a role that is as important as classroom training; Gonzàlez, Miles-Touya and Pazò (2012) estimate that the average proportion of employees who undertook on-the-job training in workplaces that innovated with new products was 42%, compared to 24% in workplaces that did not.

In addition, Østergaard, Timmermans and Kristinsson (2011) have found a positive relation between diversity in education and gender on the likelihood of introducing an innovation. McGuirk, Lenihan and Hart (2015) found employee education and training was positively associated with innovation in small firms. However, Schneider, Günther and Brandenburg (2010) found that a large share of highly skilled employees does not substantially increase the probability of a firm being innovative.

Formal education and training, however, represents only one avenue for acquiring skills. It is well accepted that many skills are tacit in nature and can only be gained via experience or working alongside a 'master'. We expect that the extent to which this matters varies according to tacit-codified content of the knowledge base. It is this theory that underlies the rational for foreign direct investment, wherein the foreign parent company

transplants whole teams of people. A classic example of the difficulties of transferring technology without the benefit of people-to-people contact is the Haber-Bosch process for nitrogen fixation. Mowery and Rosenberg (1998) describe how when the supplies of nitrogen from Germany to the US were cut off during WWI, the US was unable to competently copy the process despite its advanced technological capabilities.

### *Organisational flexibility*

Related to the above are organisational rigidities, Evangelista and Mastrostefano (2006) found that some specific obstacles to innovation relate to the presence of organizational rigidities. Foss, Lyngsie and Zahra (2013) revealed that the use of external knowledge sources is positively associated with opportunity exploitation, but the strength of this association is influenced by organizational designs around accessing external knowledge.

Grolleau, Mzoughi and Pekovic (2013) estimate that good work culture – as reported by employees – is associated with greater engagement in innovation activities. Hempell and Zwick (2008) found that employee participation is strongly positively associated with product and process innovations. McGuirk, Lenihan and Hart (2015) found that better education, training, willingness to change and job satisfaction, leads to more innovation in firms with less than 50 employees.

### *Government programs*

There are very few evaluations of government programs to either improve managerial practices or encourage new-to-the-firm innovation. Quantitative evaluations of government's business support programs using a control group matched on pre-program characteristics are a relatively recent phenomenon around the world. It is still common practice for governments to evaluate business programs though case studies, or at best surveys of participants, often without the benefit of pre-program performance data or baseline data.[11] In cases

[11] Despite the difficulty of accessing data of many government programs and their evaluations, a number of published articles have summarised their evaluation methods. Edler et al (2012) read 171 business program evaluations in the EU and found that only 20 per cent used a control group; 76 per cent were simple descriptive analyses and 67 per cent were qualitative. Gok and Elder (2012) summarised 216 papers on behavioural additionality and claim that 39 per cent do not even address the question of additionality (less use a control group). Gu, Karoly and Zissimopoulos (2008), reviewed 22 US studies on SME programs, and found one (in the early 1990s) that used a randomised control trial method and only two with a matched control group. The remainder only compared post-program outcomes with a post-program matched comparison group. Fayl et al (1998), studied over 100 EU business evaluations on research and technology programs, and reported that they were all qualitative assessments by expert panels. Roessner and Coward (1999)[11] reviewed 50 studies of US university-industry programs and reported that few were formal data based evaluations, with most being surveys, case studies and personal interviews. This includes evaluations of well-known programs such as EUREKA, SEMATECH, ATP and the SBIR. Lerner (1996) used a control group for his evaluation of the SBIR program but the match was only made on industry and employment level. The much cited Wallsten (2000) study used 90 unsuccessful SBIR applicants as his control group and found the SBIR program merely replaced the firm's own R&D spending. Roessner (1989) reported that an unpublished National Science Foundation evaluation on the SBIR program with a 'well crafted' control group exists

where a comparison group is present, it is often based (or 'matched') on post-program characteristics and does not account for selection into the program. Most evaluations to date have been (unpublished) public sector reports, possibly because they were only intended for internal consumption. We have uncovered only 13 published academic studies which had quantitatively evaluated business support programs (other than R&D subsidy programs).

Palangkaraya and Webster (2015), who provide a summary of these evaluations, show that after taking selection into account, all programs had a clear and positive effect on firm performance. We cannot glean from these studies, however, how long the benefits last as most evaluations can only measure benefits for a few years post-program. Randomised control trial evaluations of business programs are very rare. But recently, Bakhshi et al (2015) have conducted a trial to evaluate an innovation voucher program (a program which gives firms credit for spending on university services). The authors found that receipt of a voucher increased innovation by 84% in first year, but had little to no effect after 12 months.

### *Financial constraints*

Finally, financial constraints, as reflected in low gross profit margin ratio or large banking debt, significantly reduce the likelihood that firms have innovative activities (Savignac 2008; Smolny 2003).

## New Australian findings – the EABLD

We now turn to the analysis of the business surveys within the ABS which provide information on new-to-the-firm innovation. Our empirical analysis uses an unpublished, confidential Australian Bureau of Statistics (ABS) dataset of 2,765 Australian large and SME businesses for the period 2005/06 to 2011/12. This dataset is called the Extended Analytic Business Longitudinal Dataset (EABLD). It has been created by linking the Business Characteristics Survey data to the corresponding Business Income Taxation and Business Activity Taxation data. The unit of analysis is the Type of Activity Unit (TAU). To contain respondent burden, SMEs are rotated out of the survey after five years and replaced by a new cohort. Large firms are included in each wave. The response rate for the survey was approximately 95 per cent in all years.[12] After we exclude firms from agriculture, forestry and fishing, we are left with 5630 TAU-year observations. For the analysis of these data, the data extraction and execution of our programs was undertaken by officers of the ABS who removed all identifiers from the outputs before release.

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however he does not report the findings. Some SBIR evaluations merely compare types of SBIR programs in place of using a control group that has not undertaken any SBIR program (Toole 2008 for example). These studies reflect the extreme difficulty of finding an equivalent control business for SBIR winners.

12 Firms are directed by the Australian Government to complete the survey and the response rate is very high.

The ABS survey questions follow the definition of innovation promulgated by the OECD Oslo Manual for measuring innovation. These data differentiate between four main types: product, process, organisational and marketing innovation. Since all of these innovation measures are binary variables, the relationships they reveal when regressed on any explanatory variable are only partial at the extensive margin. Formally, the variables are defined as:

| Variable | Survey question |
|---|---|
| Introduced innovation – product | = 1 if business introduced any new or significantly improved Goods; Services in the last 12 months; =0 if otherwise. |
| Introduced innovation – process | = 1 if business introduced any new operational processes - Methods of manufacturing or producing goods or services; Logistics, delivery or distribution methods for goods and services; Supporting activities for business operations; Other operational processes in the last 12 months; = 0 if otherwise. |
| Introduced innovation – organisational | = 1 if business introduced any new organisational/managerial processes - Knowledge management processes; Major change to the organisation of work; New business practices for organising procedures; New methods of organising work responsibilities and decision making; Significant changes in relations with others; Other organisational/managerial processes in the last 12 months; = 0 if otherwise. |
| Introduced innovation – marketing | = 1 if business introduced any new Changes to the design or packaging of a good or service; New media or techniques for product promotion; Sales or distribution methods/new methods of product placement or sales channels; New methods of pricing goods or services; Other marketing method in the last 12 months; = 0 if otherwise. |

Tables 1 to 3 present results from a regression of whether or not the firm innovated against a series of one-year lagged explanatory variables. We have lagged the variables to reduce endogeneity between the right-hand side variables and the measure of innovation, but there is no suggestion that this would remove all reverse causation or other associated correlations. Given the persistence over time of all the variables, it will always be difficult to unambiguously detect causation in observational data.

The main right-hand side variables comprise measures of different forms of flexible working arrangement, foreign ownership, government financial assistance, market competition, ICT integration, collaboration, finance refusal, and the type of core skills used by the firm. Appendix B gives the definition of the measures used. Two measures are binary (captive market and collaborative research) and the remaining variables are bound between 0 and 1 or 0 and 3. Noting the caveat about causation, the data reveal some interesting correlations (see also Soriano and Abello 2015).

Table 1 presents the results from a cross-sectional regression. Firms that are innovative in all four dimensions have a greater number of flexible work arrangements; have more ICT systems automatically linked and are more likely to engage in collaborative research.

As most variables are measured on the 0-1 scale, the size of the coefficients indicate the relative importance of the explanatory variable. Furthermore, to account for the non-linearity of the model, we translated the coefficients of certain explanatory variables of interests into the associated change in the probability of each specific innovation. Table 1 shows that the extent of automatically linked ICT systems has significant (statistically and in magnitude) positive association with having introduced each type of innovation. For example, the coefficient of 0.438 in the probability of undertaking any innovation model implies 9.3 percentage points higher probability of introducing any innovation if the firm had all 7 automatically linked IT systems[13], compared with no automatically linked IT systems.[14] The effects are even stronger when we considered specific innovation. The increase in probability in introducing product, process, organisational, and marketing innovation is 17.9, 15.8, 16.5 and 18.0 percentage points, respectively. As the introduction of automatically linked ICT systems would constitute a process or organisational innovation itself, we are not surprised that there was a high rate of correlation for these types of innovation (see Battisti et al. 2007 and Moshiri and Simpson 2011). However, as with Engelstätter (2012), the presence of automatically linked ICT systems was also related to product innovation.

The second largest relationship was with working arrangements and financial assistance from government. A firm with all 7 flexible working arrangements was 6.9 percentage points more likely to engage in one or more innovation.[15] Flexible working arrangements were significantly associated with all types of innovation, but the effect was especially large (coefficient estimate of 0.429 or marginal effect on probability of approximately 16.2 percentage points) for organisational innovation. The third largest effect was being part of a collaboration. Engaging in collaborative research raised the probability of undertaking any innovation by 4.4 percentage points (corresponding to coefficient estimate of 0.179). Collaboration was important for all forms of innovative activity except for marketing innovation.

Firm size appeared to be positively associated with the introduction of innovation, particularly process and organisation innovation, but the magnitude of the effect is small. A one per cent increase in the number of employees is associated 2.6 and 2.1 percentage points higher probability of introducing process and organisation innovation respectively. As noted earlier, since all the results presented in Tables 1–3 are estimated effects at the extensive margins, this finding does not necessarily mean that larger firms are more innovation intensive.

[13] Linked to Suppliers' business systems; Customers' business systems; Own systems - Reordering replacement supplies; Own systems - Invoicing and payment; Own systems - Production or service operations; Own systems - Logistics, including electronic delivery; Own systems - Marketing operations; and Other

[14] The baseline group's probability of introducing any innovation is 82 per cent.

[15] The corresponding coefficient estimate displayed Table 1 is 0.304.

There does not appear to be any relationship between the number of years the business had been in operation and innovation. The negative coefficient for organisational innovation was statistically significant, but the magnitude in terms of probability change is close to zero. This contrasts with Skuras, Tsegenidi and Tsekouras (2008) which found that the probability that a firm has carried out *product* innovation reduces with the firm's age.

Selling into a captive market (that is having market power) reduced the likelihood of being a product, organisational and marketing innovator (thus supporting earlier Australian studies by Bhattacharya and Bloch 2004 but not Webster 2004). Table 1 shows that the probability that businesses had introduced an innovation was about 2.5 percentage points[16] lower if they claimed they had no effective competition. The negative effect of being in a captive market was the strongest on the probability of marketing innovation at about 8.1 percentage points lower (with a baseline probability of 34 per cent).

We included being in receipt of government assistance in the model, but we do not want to overplay this result as it is likely to be endogenous. Receiving government assistance was associated with being more innovative on all dimensions – especially product and process innovation (the coefficients being 0.813 and 0.786 respectively; which imply about 31.6 and 30.1 percentage points probability change[17]). This can mean that firms that plan to innovate, are very adept at obtaining some form of assistance such as R&D tax concessions.

To test whether these associations are related to time-invariant unobservable firm characteristics, we repeated the model in Table 1 using a panel data estimation. This analysis is presented in Table 2. The results are essentially the same. After we exclude the time-invariant features of the firm (both the variables listed and unobserved characteristics such as the calibre of the manager and workers), the significant variables in Table 1 remain significant. This supports the view that there is a real association (which does not necessarily imply causation) between the above significant results and innovation. It is notable that the importance of government financial assistance rises, the importance of automatically linked IT systems falls and the importance of collaborative research rises. These changes speak more to the marginal change in the right-hand side variables rather than their overall importance.

The statistic rho, reported in Table 2, is fraction of the variation in the innovation variable due to the time-invariant firm characteristics. It is our measure of persistence. At 0.367, it implied that about a third of the

[16] The coefficients estimate was -0.235 and the baseline probability was 82 per cent.
[17] With baseline probabilities of 35 and 28 per cent respectively.

factors that drive a firm to innovate are constant over the 6-year estimation period, which is in contrast to Ganter and Hecker (2013) but consistent with Palangkaraya et al (2010).

In Table 3, we expand the set of explanatory variables to include the types of skills the firm considers 'core' to its business. Unfortunately, there are no other comparable studies on this issue. The previous variables – systems linked automatically, collaborative research, and working arrangements – are still large in effect and statistically significant. In addition, the results show that science and research core skills had the most consistent positive association with all types of innovation except marketing innovation. The coefficient on these variables were 0.236 for any innovation; and 0.275, 0.194 and 0.163 for product process and organisational innovation, respectively. In terms of probability change, these correspond to about 6.0, 10.4, 6.8, 5.8 and 3.2 percentage points higher probability, respectively.[18] Interestingly, engineering core skills only had a statistically significant positive impact on process innovation (0.072 coefficient or about 2.5 percentage points higher probability). Professional IT skills were the second most important core skill group – it had a positive and significant effect on both product and process innovation (0.134 and 0.088 coefficients or about 5.0 and 3.0 percentage points respectively). Of the business skills, marketing only affected marketing innovation but business management skills affected both process and organisational innovation. Financial skills were not related to any form of innovation.

We also include a variable to indicate that the firm had sought, but was refused debt or equity finance. Both were insignificant. This result contrasts with Savignac (2008) and Smolny (2003) who found that financial barriers, as reflected in a low gross profit margin ratio, or large banking debt, significantly reduce the likelihood of innovation.

Tables 1 to 3 are part of a larger set of results which have been estimated to serve as robustness checks. These tables, which show similar results, are included in Appendix C.

[18] The baseline groups' probabilities were 80, 33, 28, 30 and 30 per cent, respectively.

**Table 1 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation, 2005-06 to 2011-12**

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Ln(employment)† | 0.049*** | -0.001 | 0.075*** | 0.059*** | 0.008 |
| | (0.012) | (0.010) | (0.010) | (0.010) | (0.010) |
| Years in operation | -0.001 | -0.001 | 0.001 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.304*** | 0.263*** | 0.205*** | 0.429*** | 0.266*** |
| | (0.078) | (0.069) | (0.069) | (0.069) | (0.069) |
| Foreign ownership (0-3) | 0.009 | 0.072*** | 0.004 | -0.006 | -0.009 |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) |
| Financial assistance from governments – types (0-1) | 0.293 | 0.813*** | 0.786*** | 0.456** | 0.360* |
| | (0.232) | (0.197) | (0.199) | (0.199) | (0.196) |
| Financial assistance from governments – levels (0-1) | 0.090 | 0.018 | -0.101 | 0.143 | 0.005 |
| | (0.118) | (0.093) | (0.093) | (0.094) | (0.093) |
| Captive market (0/1) | -0.105* | -0.098* | -0.074 | -0.111** | -0.235*** |
| | (0.060) | (0.056) | (0.056) | (0.056) | (0.057) |
| Systems link automatically (0-1) | 0.438*** | 0.459*** | 0.425*** | 0.435*** | 0.463*** |
| | (0.115) | (0.097) | (0.097) | (0.098) | (0.096) |
| Collaborative research (0/1) | 0.179*** | 0.251*** | 0.155*** | 0.178*** | 0.043 |
| | (0.062) | (0.052) | (0.052) | (0.053) | (0.052) |
| Intercept | 0.905*** | -0.400*** | -0.573*** | -0.516*** | -0.427*** |
| | (0.256) | (0.042) | (0.042) | (0.042) | (0.042) |
| Observations | 5,635 | 5,635 | 5,635 | 5,634 | 5,635 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; † Control variable only because the dependent variable is binary. This does not mean large firms are more innovation intensive.
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

**Table 2 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit random effects estimation, 2005-06 to 2011-12**

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Ln(employment)† | 0.062*** | 0.009 | 0.121*** | 0.084*** | 0.026 |
| | (0.015) | (0.017) | (0.017) | (0.016) | (0.016) |
| Working arrangements (0-1) | 0.307*** | 0.271** | 0.107 | 0.460*** | 0.263** |
| | (0.101) | (0.112) | (0.108) | (0.106) | (0.107) |
| Foreign ownership (0-3) | 0.011 | 0.081*** | 0.024 | 0.006 | -0.024 |
| | (0.026) | (0.030) | (0.029) | (0.029) | (0.029) |
| Financial assistance from governments – types (0-1) | 0.351 | 0.911*** | 0.954*** | 0.780** | 0.707** |
| | (0.308) | (0.329) | (0.319) | (0.313) | (0.308) |
| Financial assistance from governments – levels (0-1) | 0.102 | 0.098 | -0.032 | 0.186 | -0.083 |
| | (0.144) | (0.159) | (0.153) | (0.150) | (0.150) |
| Captive market (0/1) | -0.102 | -0.053 | -0.081 | -0.096 | -0.247*** |
| | (0.077) | (0.086) | (0.083) | (0.081) | (0.082) |
| Systems link automatically (0-1) | 0.551*** | 0.671*** | 0.742*** | 0.650*** | 0.581*** |
| | (0.154) | (0.167) | (0.162) | (0.157) | (0.155) |
| Collaborative research (0/1) | 0.202** | 0.247*** | 0.170** | 0.164** | 0.029 |
| | (0.080) | (0.084) | (0.082) | (0.079) | (0.080) |
| Intercept | 0.366*** | -0.649*** | -0.821*** | -0.774*** | -0.638*** |
| | (0.060) | (0.075) | (0.072) | (0.071) | (0.070) |
| Observations | 5,638 | 5,638 | 5,638 | 5,636 | 5,637 |
| Number of units | 2,765 | 2,765 | 2,765 | 2,765 | 2,765 |
| Rho | 0.367 | | | | |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; † Control variable only because the dependent variable is binary. This does not mean large firms are more innovation intensive.
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

**Table 3 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation, 2005-06 to 2011-12**

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Ln(employment)† | 0.044*** | -0.006 | 0.061*** | 0.044*** | 0.002 |
| | (0.012) | (0.011) | (0.011) | (0.011) | (0.011) |
| Years in operation | -0.001 | -0.001* | 0.000 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.281*** | 0.236*** | 0.165** | 0.377*** | 0.219*** |
| | (0.080) | (0.070) | (0.070) | (0.070) | (0.071) |
| Foreign ownership (0-3) | 0.005 | 0.061*** | -0.009 | -0.013 | -0.011 |
| | (0.019) | (0.017) | (0.017) | (0.017) | (0.017) |
| Financial assistance from governments – types (0-1) | 0.235 | 0.736*** | 0.654*** | 0.351* | 0.394** |
| | (0.234) | (0.199) | (0.200) | (0.200) | (0.199) |
| Financial assistance from governments – levels (0-1) | 0.072 | 0.001 | -0.141 | 0.117 | 0.034 |
| | (0.118) | (0.094) | (0.094) | (0.094) | (0.094) |
| Captive market (1/0) | -0.108* | -0.094* | -0.074 | -0.112** | -0.225*** |
| | (0.061) | (0.056) | (0.056) | (0.056) | (0.058) |
| Systems link automatically (0-1) | 0.415*** | 0.430*** | 0.404*** | 0.391*** | 0.401*** |
| | (0.117) | (0.098) | (0.098) | (0.099) | (0.098) |
| Collaborative research (0/1) | 0.131** | 0.164*** | 0.076 | 0.126** | 0.043 |
| | (0.065) | (0.054) | (0.055) | (0.055) | (0.055) |
| Debt finance refused (0/1) | -0.048 | 0.124 | 0.007 | 0.061 | -0.016 |
| | (0.175) | (0.160) | (0.162) | (0.163) | (0.164) |
| Equity finance refused (0/1) | 0.050 | 0.118 | 0.144 | 0.085 | 0.118 |
| | (0.108) | (0.094) | (0.094) | (0.094) | (0.094) |
| Core skills – Engineering (0/1) | -0.095* | 0.020 | 0.072* | -0.055 | -0.247*** |
| | (0.051) | (0.042) | (0.042) | (0.042) | (0.043) |
| Core skills – Scientific and research (0/1) | 0.236*** | 0.275*** | 0.194*** | 0.163*** | 0.089 |
| | (0.066) | (0.055) | (0.055) | (0.055) | (0.055) |
| Core skills – IT professionals (0/1) | 0.081* | 0.134*** | 0.088** | 0.040 | 0.037 |
| | (0.048) | (0.044) | (0.043) | (0.043) | (0.044) |
| Core skills – IT support technicians (0/1) | -0.008 | -0.063 | -0.067 | 0.009 | -0.008 |
| | (0.048) | (0.044) | (0.044) | (0.043) | (0.044) |
| Core skills – Marketing (0/1) | 0.114** | 0.197*** | -0.024 | -0.023 | 0.462*** |
| | (0.046) | (0.042) | (0.041) | (0.041) | (0.042) |
| Core skills – Project management (0/1) | -0.058 | -0.056 | 0.048 | 0.064 | -0.100** |
| | (0.050) | (0.045) | (0.045) | (0.045) | (0.045) |
| Core skills – Business management (0/1) | 0.091* | -0.002 | 0.110** | 0.124*** | 0.021 |
| | (0.050) | (0.046) | (0.046) | (0.046) | (0.046) |
| Core skills – Financial (0/1) | -0.092* | -0.103** | 0.022 | 0.045 | -0.074 |
| | (0.052) | (0.048) | (0.048) | (0.048) | (0.049) |
| Intercept | 0.839*** | -0.448*** | -0.595*** | -0.540*** | -0.531*** |
| | (0.263) | (0.044) | (0.045) | (0.045) | (0.045) |
| Observations | 5,630 | 5,630 | 5,630 | 5,629 | 5,630 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; † Control variable only because the dependent variable is binary. This does not mean large firms are more innovation intensive.
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

## Conclusions

There exists four (overlapping) cohorts of studies on the determinants of the firm's decision to innovate. The first group, which was largely inspired by Schumpeter, tested measures such as size, market share, competition, export and foreign ownership and age. The results from these studies are largely ambiguous, with the exception of competition. The single clear result is that innovation appears to be more prevalent in markets subject to more vigorous competition.

The second cohort of analyses tested for less superficial factors such as market demand and technological opportunity. However, as pointed out by Mowery and Rosenberg (1979), it is difficult to identify these drivers without being so broad that the measure is meaningless or circular. The results showed that market demand is important but neither a necessary nor sufficient condition for innovation to occur. These empirical studies should be noted, but not uncritically accepted.

The third cohort focused upon a group of measured factors such as proximity to a cluster or research precinct, collaborative status and presence of skilled ICT, science and research workers. The underlying mechanism by which these workers might stimulate innovation is not clearly articulated. Perhaps these workers are hired, and collaborations are made, after the decision has been made to innovate. Alternatively, we suggest that the common element in these factors is that they incidentally de-risk the business environment by giving firms, or would be firms, triangulated information about new relevant technologies; market trends; changes to government regulation; tacit information from suppliers and clients; and political events that could have major implications for markets. ICT, science and research staff may behave as a conduit technology for the firm. Casual contact with peers, competitors, suppliers, clients and research organisations can provide the uncodified, frontier bits of knowledge that enable firms to piece together a scenario with confidence. As we discussed, trusted outsiders, colleagues and friends can reduce uncertainty and the anxiety associated with costly decisions through the provision of nuanced information and know-how. A reduction in the uncertainty premia could have a massive impact on the present value of the innovation investment. We have no direct evidence on this information triangulation theory as it is the subject of current, incomplete investigation at the Swinburne University of Technology.

Our new Australian findings from the EABLD support the international studies which have found that more innovative firms are also more collaborative and operate in more competitive product markets. In contrast with these studies however, we do not find that firms which have previously been refused debt or equity finance are less likely to innovate that other firms. Finally, we reveal that innovators are more likely to offer flexible work arrangements to their staff, and consider their research, IT and science based staff as core skills than non-innovators.

## Appendix A - The ABS Data

Our empirical analysis uses an unpublished, confidential Australian Bureau of Statistics (ABS) dataset of 2,765 Australian large and SME businesses for the period 2005/06 to 2011/12. This dataset is called the Extended Analytic Business Longitudinal Dataset (EABLD). It has been created by linking the Business Characteristics Survey data to the corresponding Business Income Taxation and Business Activity Taxation data. The unit of analysis is the Type of Activity Unit (TAU). To contain respondent burden, SMEs are rotated out of the survey after five years and replaced by a new cohort. Large firms are included in each wave. The response rate for the survey was approximately 95 per cent in all years.[19] After we exclude firms from agriculture, forestry and fishing, we are left with 5630 TAU-year observations. For the analysis of these data, the data extraction and execution of our programs was undertaken by officers of the ABS who removed all identifiers from the outputs before release.

19 Firms are directed by the Australian Government to complete the survey and the response rate is very high.

## Appendix B - – Definition of variables

| Variable | Survey question |
|---|---|
| Introduced innovation – product | = 1 if business introduced any new or significantly improved Goods; Services in the last 12 months; =0 if otherwise. |
| Introduced innovation – process | = 1 if business introduced any new operational processes - Methods of manufacturing or producing goods or services; Logistics, delivery or distribution methods for goods and services; Supporting activities for business operations; Other operational processes in the last 12 months; = 0 if otherwise. |
| Introduced innovation – organisational | = 1 if business introduced any new organisational/managerial processes - Knowledge management processes; Major change to the organisation of work; New business practices for organising procedures; New methods of organising work responsibilities and decision making; Significant changes in relations with others; Other organisational/managerial processes in the last 12 months; = 0 if otherwise. |
| Introduced innovation – marketing | = 1 if business introduced any new Changes to the design or packaging of a good or service; New media or techniques for product promotion; Sales or distribution methods/new methods of product placement or sales channels; New methods of pricing goods or services; Other marketing method in the last 12 months; = 0 if otherwise. |
| Introduced innovation – any | = 1 if Introduced innovation – product, process, organisation and marketing; = 0 if otherwise. |
| Captive market (0/1) | = 1 if Captive market/no effective competition; =0, otherwise |
| Years in operation | Years of operation - Regardless of changes in ownership. |
| Working arrangements (0-1) | The average of 7 binary items measuring the presence of Flexible work hours; Ability to buy or cash out extra leave, or take LWOP; Selection of own roster or shifts; Job sharing; Ability for staff to work from home; Paid parental leave; Flexible use of personal sick, unpaid or compassionate leave. |
| Foreign ownership (0-3) | Percentage of foreign ownership - 0 = 0%; 1 = GT 0% and LT 10%; 2 = GE 10% and LE 50%; 3 = GT 50%. |
| Financial assistance from governments – types (0-1) | The average of 7 binary items measuring whether the business received any financial assistance from Australian government organisations – Grants; Ongoing funding; Subsidies; Tax concessions; Rebates; Other. |
| Financial assistance from governments – levels (0-1) | The average of 2 binary items measuring the whether the business received government financial assistance received from Federal government; State/territory or local government. |
| Systems link automatically (0-1) | The average of 7 binary items measuring the whether the business had systems that linked automatically with Suppliers' business systems; Customers' business systems; Own systems - Reordering replacement supplies; Own systems - Invoicing and payment; Own systems - Production or service operations; Own systems - Logistics, including electronic delivery; Own systems - Marketing operations; Other. |
| Collaborative research (0/1) | = 1 if Business collaborated for innovation; = 0 if otherwise |
| Debt finance refused (0/1) | = 1 if sought but not obtained debt finance; =0 otherwise |
| Equity finance refused (0/1) | = 1 if sought but not obtained equity finance; =0 otherwise |
| Core skills – Engineering (0/1) | = 1 if Skills used in undertaking core business activities – Engineering; = 0 if otherwise. |
| Core skills – Scientific and research (0/1) | = 1 if Skills used in undertaking core business activities – Scientific and research; = 0 if otherwise |
| Core skills – IT professionals (0/1) | = 1 if Skills used in undertaking core business activities – IT professionals; = 0 if otherwise |
| Core skills – IT support technicians (0/1) | = 1 if Skills used in undertaking core business activities – IT support technicians; = 0 if otherwise |

| | |
|---|---|
| Core skills – Marketing (0/1) | = 1 if Skills used in undertaking core business activities – Marketing; = 0 if otherwise |
| Core skills – Project management (0/1) | = 1 if Skills used in undertaking core business activities – Project management; = 0 if otherwise |
| Core skills – Business management (0/1) | = 1 if Skills used in undertaking core business activities – Business management; = 0 if otherwise |
| Core skills – Financial (0/1) | = 1 if Skills used in undertaking core business activities – Financial; = 0 if otherwise |
| Ln (employment) | Log of employment number |

## Appendix C – Additional tables from the EABLD

This appendix presents the full list of tables that the ACOLA SAF10 working party requested for this review. The probit estimations used the pooled cross-section time series dataset, whereas the random effects probit utilises the panel dimension of the data.

Model 1 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.002*** | -0.000 | -0.001 | -0.003*** | -0.001 |
| | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| Working arrangements (0-1) | 0.353*** | 0.305*** | 0.304*** | 0.432*** | 0.291*** |
| | (0.051) | (0.047) | (0.046) | (0.046) | (0.047) |
| Foreign ownership (0-3) | 0.029** | 0.074*** | 0.034*** | -0.009 | -0.011 |
| | (0.013) | (0.012) | (0.012) | (0.012) | (0.012) |
| Financial assistance from governments – types (0-1) | 0.200 | 0.946*** | 0.596*** | 0.222 | 0.288** |
| | (0.152) | (0.135) | (0.135) | (0.136) | (0.137) |
| Financial assistance from governments – levels (0-1) | 0.194*** | -0.038 | 0.039 | 0.225*** | 0.012 |
| | (0.074) | (0.062) | (0.061) | (0.061) | (0.062) |
| Captive market (1/0) | -0.141*** | -0.154*** | -0.112*** | -0.107*** | -0.278*** |
| | (0.036) | (0.036) | (0.035) | (0.035) | (0.037) |
| Observations | 12,490 | 12,493 | 12,493 | 12,492 | 12,493 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 2 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.001 | -0.001 | 0.001 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.304*** | 0.263*** | 0.205*** | 0.429*** | 0.266*** |
| | (0.078) | (0.069) | (0.069) | (0.069) | (0.069) |
| Foreign ownership (0-3) | 0.009 | 0.072*** | 0.004 | -0.006 | -0.009 |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) |
| Financial assistance from governments – types (0-1) | 0.293 | 0.813*** | 0.786*** | 0.456** | 0.360* |
| | (0.232) | (0.197) | (0.199) | (0.199) | (0.196) |
| Financial assistance from governments – levels (0-1) | 0.090 | 0.018 | -0.101 | 0.143 | 0.005 |
| | (0.118) | (0.093) | (0.093) | (0.094) | (0.093) |
| Captive market (0/1) | -0.105* | -0.098* | -0.074 | -0.111** | -0.235*** |
| | (0.060) | (0.056) | (0.056) | (0.056) | (0.057) |
| Systems link automatically (0-1) | 0.438*** | 0.459*** | 0.425*** | 0.435*** | 0.463*** |
| | (0.115) | (0.097) | (0.097) | (0.098) | (0.096) |
| Collaborative research (0/1) | 0.179*** | 0.251*** | 0.155*** | 0.178*** | 0.043 |
| | (0.062) | (0.052) | (0.052) | (0.053) | (0.052) |
| Observations | 5,635 | 5,635 | 5,635 | 5,634 | 5,635 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 3 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.001 | -0.001 | 0.001 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.304*** | 0.260*** | 0.201*** | 0.427*** | 0.264*** |
| | (0.078) | (0.069) | (0.069) | (0.069) | (0.069) |
| Foreign ownership (0-3) | 0.010 | 0.073*** | 0.004 | -0.006 | -0.009 |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) |
| Financial assistance from governments – types (0-1) | 0.292 | 0.814*** | 0.784*** | 0.456** | 0.358* |
| | (0.232) | (0.197) | (0.199) | (0.199) | (0.196) |
| Financial assistance from governments – levels (0-1) | 0.088 | 0.019 | -0.102 | 0.143 | 0.005 |
| | (0.118) | (0.093) | (0.093) | (0.094) | (0.093) |
| Captive market (1/0) | -0.105* | -0.096* | -0.073 | -0.110** | -0.234*** |
| | (0.060) | (0.056) | (0.056) | (0.056) | (0.057) |
| Systems link automatically (0-1) | 0.438*** | 0.456*** | 0.423*** | 0.433*** | 0.461*** |
| | (0.115) | (0.097) | (0.097) | (0.098) | (0.096) |
| Collaborative research (0/1) | 0.179*** | 0.250*** | 0.153*** | 0.177*** | 0.042 |
| | (0.062) | (0.052) | (0.052) | (0.053) | (0.052) |
| Debt finance refused (0/1) | -0.035 | 0.131 | 0.009 | 0.059 | 0.006 |
| | (0.174) | (0.160) | (0.162) | (0.162) | (0.162) |
| Equity finance refused (0/1) | 0.040 | 0.110 | 0.152 | 0.094 | 0.101 |
| | (0.107) | (0.093) | (0.094) | (0.094) | (0.092) |
| Observations | 5,635 | 5,635 | 5,635 | 5,634 | 5,635 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 4 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.001 | -0.001* | 0.000 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.281*** | 0.236*** | 0.165** | 0.377*** | 0.219*** |
| | (0.080) | (0.070) | (0.070) | (0.070) | (0.071) |
| Foreign ownership (0-3) | 0.005 | 0.061*** | -0.009 | -0.013 | -0.011 |
| | (0.019) | (0.017) | (0.017) | (0.017) | (0.017) |
| Financial assistance from governments – types (0-1) | 0.235 | 0.736*** | 0.654*** | 0.351* | 0.394** |
| | (0.234) | (0.199) | (0.200) | (0.200) | (0.199) |
| Financial assistance from governments – levels (0-1) | 0.072 | 0.001 | -0.141 | 0.117 | 0.034 |
| | (0.118) | (0.094) | (0.094) | (0.094) | (0.094) |
| Captive market (1/0) | -0.108* | -0.094* | -0.074 | -0.112** | -0.225*** |
| | (0.061) | (0.056) | (0.056) | (0.056) | (0.058) |
| Systems link automatically (0-1) | 0.415*** | 0.430*** | 0.404*** | 0.391*** | 0.401*** |
| | (0.117) | (0.098) | (0.098) | (0.099) | (0.098) |
| Collaborative research (0/1) | 0.131** | 0.164*** | 0.076 | 0.126** | 0.043 |
| | (0.065) | (0.054) | (0.055) | (0.055) | (0.055) |
| Debt finance refused (0/1) | -0.048 | 0.124 | 0.007 | 0.061 | -0.016 |
| | (0.175) | (0.160) | (0.162) | (0.163) | (0.164) |
| Equity finance refused (0/1) | 0.050 | 0.118 | 0.144 | 0.085 | 0.118 |
| | (0.108) | (0.094) | (0.094) | (0.094) | (0.094) |
| Core skills – Engineering (0/1) | -0.095* | 0.020 | 0.072* | -0.055 | -0.247*** |
| | (0.051) | (0.042) | (0.042) | (0.042) | (0.043) |
| Core skills – Scientific and research (0/1) | 0.236*** | 0.275*** | 0.194*** | 0.163*** | 0.089 |
| | (0.066) | (0.055) | (0.055) | (0.055) | (0.055) |
| Core skills – IT professionals (0/1) | 0.081* | 0.134*** | 0.088** | 0.040 | 0.037 |
| | (0.048) | (0.044) | (0.043) | (0.043) | (0.044) |
| Core skills – IT support technicians (0/1) | -0.008 | -0.063 | -0.067 | 0.009 | -0.008 |
| | (0.048) | (0.044) | (0.044) | (0.043) | (0.044) |
| Core skills – Marketing (0/1) | 0.114** | 0.197*** | -0.024 | -0.023 | 0.462*** |
| | (0.046) | (0.042) | (0.041) | (0.041) | (0.042) |
| Core skills – Project management (0/1) | -0.058 | -0.056 | 0.048 | 0.064 | -0.100** |
| | (0.050) | (0.045) | (0.045) | (0.045) | (0.045) |
| Core skills – Business management (0/1) | 0.091* | -0.002 | 0.110** | 0.124*** | 0.021 |
| | (0.050) | (0.046) | (0.046) | (0.046) | (0.046) |
| Core skills – Financial (0/1) | -0.092* | -0.103** | 0.022 | 0.045 | -0.074 |

| | | | | | |
|---|---|---|---|---|---|
| | (0.052) | (0.048) | (0.048) | (0.048) | (0.049) |
| Observations | 5,630 | 5,630 | 5,630 | 5,629 | 5,630 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 5 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.001 | -0.001 | 0.000 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.277*** | 0.226*** | 0.154** | 0.379*** | 0.222*** |
| | (0.079) | (0.070) | (0.070) | (0.070) | (0.070) |
| Foreign ownership (0-3) | 0.005 | 0.066*** | -0.006 | -0.014 | -0.013 |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) |
| Financial assistance from governments – types (0-1) | 0.256 | 0.750*** | 0.705*** | 0.384* | 0.326* |
| | (0.232) | (0.198) | (0.200) | (0.199) | (0.197) |
| Financial assistance from governments – levels (0-1) | 0.063 | -0.003 | -0.126 | 0.123 | -0.005 |
| | (0.118) | (0.093) | (0.093) | (0.094) | (0.093) |
| Captive market (1/0) | -0.102* | -0.098* | -0.072 | -0.106* | -0.228*** |
| | (0.061) | (0.056) | (0.056) | (0.056) | (0.057) |
| Systems link automatically (0-1) | 0.415*** | 0.426*** | 0.385*** | 0.389*** | 0.431*** |
| | (0.116) | (0.097) | (0.098) | (0.098) | (0.097) |
| Collaborative research (0/1) | 0.163*** | 0.207*** | 0.110** | 0.149*** | 0.053 |
| | (0.063) | (0.053) | (0.053) | (0.054) | (0.053) |
| Debt finance refused (0/1) | -0.036 | 0.135 | 0.012 | 0.062 | 0.000 |
| | (0.174) | (0.160) | (0.162) | (0.162) | (0.162) |
| Equity finance refused (0/1) | 0.035 | 0.102 | 0.140 | 0.084 | 0.096 |
| | (0.107) | (0.093) | (0.094) | (0.094) | (0.092) |
| Core skills – STEM (0-1) | 0.114 | 0.271*** | 0.234*** | 0.104 | -0.213*** |
| | (0.083) | (0.071) | (0.071) | (0.071) | (0.072) |
| Core skills – Business (0-1) | 0.090 | 0.034 | 0.137** | 0.223*** | 0.379*** |
| | (0.066) | (0.059) | (0.059) | (0.059) | (0.059) |
| Observations | 5,630 | 5,630 | 5,630 | 5,629 | 5,630 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 6 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.001 | -0.001 | 0.000 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.276*** | 0.225*** | 0.153** | 0.378*** | 0.220*** |
| | (0.079) | (0.070) | (0.070) | (0.070) | (0.070) |
| Foreign ownership (0-3) | 0.006 | 0.066*** | -0.005 | -0.014 | -0.013 |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) |
| Financial assistance from governments – types (0-1) | 0.263 | 0.752*** | 0.709*** | 0.387* | 0.335* |
| | (0.232) | (0.198) | (0.200) | (0.200) | (0.197) |
| Financial assistance from governments – levels (0-1) | 0.067 | -0.002 | -0.123 | 0.124 | -0.001 |
| | (0.118) | (0.093) | (0.093) | (0.094) | (0.093) |
| Captive market (1/0) | -0.103* | -0.098* | -0.073 | -0.106* | -0.228*** |
| | (0.061) | (0.056) | (0.056) | (0.056) | (0.057) |
| Systems link automatically (0-1) | 0.419*** | 0.427*** | 0.386*** | 0.390*** | 0.435*** |
| | (0.116) | (0.097) | (0.098) | (0.098) | (0.097) |
| Collaborative research (0/1) | 0.170*** | 0.208*** | 0.112** | 0.151*** | 0.058 |
| | (0.064) | (0.053) | (0.054) | (0.054) | (0.053) |
| Debt finance refused (0/1) | -0.031 | 0.136 | 0.015 | 0.064 | 0.005 |
| | (0.174) | (0.160) | (0.162) | (0.162) | (0.162) |
| Equity finance refused (0/1) | 0.034 | 0.101 | 0.140 | 0.084 | 0.094 |
| | (0.107) | (0.093) | (0.094) | (0.094) | (0.092) |
| Core skills – STEM (0-1) | 0.252* | 0.292** | 0.297** | 0.146 | -0.083 |
| | (0.134) | (0.121) | (0.122) | (0.122) | (0.123) |
| Core skills – Business (0-1) | 0.167* | 0.045 | 0.171** | 0.246*** | 0.447*** |
| | (0.088) | (0.080) | (0.079) | (0.079) | (0.079) |
| Core skills – Business*STEM (0-1) | -0.243 | -0.035 | -0.105 | -0.071 | -0.213 |
| | (0.186) | (0.164) | (0.165) | (0.165) | (0.165) |
| Observations | 5,630 | 5,630 | 5,630 | 5,629 | 5,630 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 7 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.001 | -0.001 | 0.000 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.279*** | 0.228*** | 0.165** | 0.388*** | 0.230*** |
| | (0.079) | (0.070) | (0.070) | (0.070) | (0.070) |
| Foreign ownership (0-3) | 0.008 | 0.070*** | 0.001 | -0.009 | -0.012 |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) |
| Financial assistance from governments – types (0-1) | 0.279 | 0.795*** | 0.764*** | 0.429** | 0.337* |
| | (0.232) | (0.197) | (0.199) | (0.199) | (0.196) |
| Financial assistance from governments – levels (0-1) | 0.073 | 0.012 | -0.109 | 0.134 | -0.004 |
| | (0.118) | (0.093) | (0.093) | (0.094) | (0.093) |
| Captive market (1/0) | -0.104* | -0.096* | -0.074 | -0.109* | -0.233*** |
| | (0.061) | (0.056) | (0.056) | (0.056) | (0.057) |
| Systems link automatically (0-1) | 0.423*** | 0.435*** | 0.399*** | 0.407*** | 0.441*** |
| | (0.116) | (0.097) | (0.098) | (0.098) | (0.096) |
| Collaborative research (0/1) | 0.172*** | 0.239*** | 0.140*** | 0.167*** | 0.035 |
| | (0.063) | (0.052) | (0.052) | (0.053) | (0.052) |
| Debt finance refused (0/1) | -0.035 | 0.133 | 0.012 | 0.062 | 0.006 |
| | (0.174) | (0.160) | (0.162) | (0.162) | (0.162) |
| Equity finance refused (0/1) | 0.033 | 0.099 | 0.139 | 0.081 | 0.092 |
| | (0.107) | (0.093) | (0.094) | (0.094) | (0.092) |
| Core skills – STEM (0/1) | 0.065 | 0.102** | 0.128*** | 0.058 | 0.016 |
| | (0.048) | (0.045) | (0.045) | (0.044) | (0.045) |
| Core skills – Business (0/1) | 0.086* | 0.098** | 0.094** | 0.193*** | 0.194*** |
| | (0.050) | (0.047) | (0.047) | (0.047) | (0.047) |
| Observations | 5,635 | 5,635 | 5,635 | 5,634 | 5,635 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 8 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Years in operation | -0.001 | -0.001 | 0.000 | -0.002*** | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Working arrangements (0-1) | 0.279*** | 0.227*** | 0.165** | 0.388*** | 0.230*** |
| | (0.079) | (0.070) | (0.070) | (0.070) | (0.070) |
| Foreign ownership (0-3) | 0.008 | 0.070*** | 0.001 | -0.009 | -0.012 |
| | (0.019) | (0.016) | (0.016) | (0.016) | (0.016) |
| Financial assistance from governments – types (0-1) | 0.279 | 0.795*** | 0.764*** | 0.429** | 0.338* |
| | (0.232) | (0.197) | (0.199) | (0.199) | (0.196) |
| Financial assistance from governments – levels (0-1) | 0.074 | 0.010 | -0.111 | 0.136 | -0.007 |
| | (0.118) | (0.093) | (0.093) | (0.094) | (0.093) |
| Captive market (1/0) | -0.104* | -0.096* | -0.074 | -0.109* | -0.234*** |
| | (0.061) | (0.056) | (0.056) | (0.056) | (0.057) |
| Systems link automatically (0-1) | 0.423*** | 0.435*** | 0.399*** | 0.407*** | 0.440*** |
| | (0.116) | (0.097) | (0.098) | (0.098) | (0.096) |
| Collaborative research (0/1) | 0.171*** | 0.239*** | 0.140*** | 0.166*** | 0.036 |
| | (0.063) | (0.052) | (0.052) | (0.053) | (0.052) |
| Debt finance refused (0/1) | -0.035 | 0.132 | 0.011 | 0.063 | 0.005 |
| | (0.174) | (0.160) | (0.162) | (0.162) | (0.162) |
| Equity finance refused (0/1) | 0.033 | 0.098 | 0.138 | 0.082 | 0.091 |
| | (0.107) | (0.093) | (0.094) | (0.094) | (0.092) |
| Core skills – STEM (0/1) | 0.093 | 0.073 | 0.080 | 0.096 | -0.054 |
| | (0.080) | (0.076) | (0.076) | (0.076) | (0.077) |
| Core skills – Business (0/1) | 0.108 | 0.075 | 0.056 | 0.222*** | 0.141** |
| | (0.070) | (0.067) | (0.067) | (0.067) | (0.067) |
| Core skills – Business*STEM (0/1) | -0.044 | 0.044 | 0.073 | -0.056 | 0.105 |
| | (0.099) | (0.093) | (0.093) | (0.093) | (0.094) |
| Observations | 5,635 | 5,635 | 5,635 | 5,634 | 5,635 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 1 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.390*** | 0.344*** | 0.292*** | 0.478*** | 0.295*** |
| | (0.064) | (0.076) | (0.070) | (0.070) | (0.073) |
| Foreign ownership (0-3) | 0.040** | 0.087*** | 0.050** | -0.008 | -0.027 |
| | (0.018) | (0.022) | (0.020) | (0.020) | (0.021) |
| Financial assistance from governments – types (0-1) | 0.232 | 1.261*** | 0.831*** | 0.404* | 0.507** |
| | (0.201) | (0.230) | (0.215) | (0.214) | (0.217) |
| Financial assistance from governments – levels (0-1) | 0.160* | -0.007 | 0.065 | 0.198** | -0.049 |
| | (0.090) | (0.106) | (0.097) | (0.097) | (0.100) |
| Captive market (1/0) | -0.150*** | -0.147*** | -0.133*** | -0.107** | -0.305*** |
| | (0.045) | (0.055) | (0.051) | (0.050) | (0.053) |
| Observations | 12,500 | 12,500 | 12,500 | 12,498 | 12,499 |
| Number of unitid | 6,497 | 6,497 | 6,497 | 6,497 | 6,497 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 2 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.307*** | 0.271** | 0.107 | 0.460*** | 0.263** |
| | (0.101) | (0.112) | (0.108) | (0.106) | (0.107) |
| Foreign ownership (0-3) | 0.011 | 0.081*** | 0.024 | 0.006 | -0.024 |
| | (0.026) | (0.030) | (0.029) | (0.029) | (0.029) |
| Financial assistance from governments – types (0-1) | 0.351 | 0.911*** | 0.954*** | 0.780** | 0.707** |
| | (0.308) | (0.329) | (0.319) | (0.313) | (0.308) |
| Financial assistance from governments – levels (0-1) | 0.102 | 0.098 | -0.032 | 0.186 | -0.083 |
| | (0.144) | (0.159) | (0.153) | (0.150) | (0.150) |
| Captive market (1/0) | -0.102 | -0.053 | -0.081 | -0.096 | -0.247*** |
| | (0.077) | (0.086) | (0.083) | (0.081) | (0.082) |
| Systems link automatically (0-1) | 0.551*** | 0.671*** | 0.742*** | 0.650*** | 0.581*** |
| | (0.154) | (0.167) | (0.162) | (0.157) | (0.155) |
| Collaborative research (0/1) | 0.202** | 0.247*** | 0.170** | 0.164** | 0.029 |
| | (0.080) | (0.084) | (0.082) | (0.079) | (0.080) |
| Observations | 5,638 | 5,638 | 5,638 | 5,636 | 5,637 |
| Number of units | 2,765 | 2,765 | 2,765 | 2,765 | 2,765 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 3 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.307*** | 0.272** | 0.106 | 0.460*** | 0.261** |
| | (0.101) | (0.112) | (0.108) | (0.106) | (0.107) |
| Foreign ownership (0-3) | 0.011 | 0.081*** | 0.024 | 0.006 | -0.024 |
| | (0.026) | (0.030) | (0.029) | (0.029) | (0.029) |
| Financial assistance from governments – types (0-1) | 0.351 | 0.916*** | 0.955*** | 0.780** | 0.704** |
| | (0.308) | (0.329) | (0.319) | (0.313) | (0.308) |
| Financial assistance from governments – levels (0-1) | 0.102 | 0.102 | -0.031 | 0.187 | -0.084 |
| | (0.144) | (0.159) | (0.153) | (0.150) | (0.150) |
| Captive market (1/0) | -0.102 | -0.052 | -0.080 | -0.095 | -0.245*** |
| | (0.077) | (0.086) | (0.083) | (0.081) | (0.082) |
| Systems link automatically (0-1) | 0.551*** | 0.669*** | 0.739*** | 0.646*** | 0.576*** |
| | (0.154) | (0.167) | (0.162) | (0.157) | (0.155) |
| Collaborative research (0/1) | 0.202** | 0.245*** | 0.168** | 0.162** | 0.027 |
| | (0.080) | (0.084) | (0.082) | (0.080) | (0.080) |
| Debt finance refused (0/1) | -0.019 | 0.250 | 0.124 | 0.166 | 0.037 |
| | (0.215) | (0.233) | (0.226) | (0.225) | (0.224) |
| Equity finance refused (0/1) | -0.007 | 0.002 | 0.066 | 0.086 | 0.133 |
| | (0.134) | (0.144) | (0.137) | (0.136) | (0.135) |
| Observations | 5,638 | 5,638 | 5,638 | 5,636 | 5,637 |
| Number of unitid | 2,765 | 2,765 | 2,765 | 2,765 | 2,765 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. . Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 4 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.284*** | 0.266** | 0.080 | 0.405*** | 0.213** |
| | (0.101) | (0.113) | (0.109) | (0.107) | (0.105) |
| Foreign ownership (0-3) | 0.005 | 0.074** | 0.006 | -0.000 | -0.023 |
| | (0.026) | (0.031) | (0.029) | (0.029) | (0.028) |
| Financial assistance from governments – types (0-1) | 0.277 | 0.826** | 0.811** | 0.696** | 0.678** |
| | (0.307) | (0.328) | (0.318) | (0.313) | (0.302) |
| Financial assistance from governments – levels (0-1) | 0.088 | 0.074 | -0.099 | 0.156 | -0.058 |
| | (0.143) | (0.159) | (0.153) | (0.150) | (0.146) |
| Captive market (1/0) | -0.103 | -0.052 | -0.078 | -0.094 | -0.245*** |
| | (0.076) | (0.086) | (0.082) | (0.081) | (0.081) |
| Systems link automatically (0-1) | 0.526*** | 0.661*** | 0.722*** | 0.596*** | 0.512*** |
| | (0.154) | (0.167) | (0.162) | (0.157) | (0.151) |
| Collaborative research (0/1) | 0.140* | 0.169** | 0.090 | 0.120 | 0.021 |
| | (0.082) | (0.085) | (0.083) | (0.081) | (0.080) |
| Debt finance refused (0/1) | -0.030 | 0.236 | 0.113 | 0.160 | 0.027 |
| | (0.214) | (0.232) | (0.225) | (0.225) | (0.220) |
| Equity finance refused (0/1) | 0.004 | 0.009 | 0.061 | 0.074 | 0.138 |
| | (0.134) | (0.145) | (0.137) | (0.136) | (0.133) |
| Core skills – Engineering (0/1) | -0.111* | 0.039 | 0.108 | -0.107 | -0.334*** |
| | (0.061) | (0.069) | (0.067) | (0.066) | (0.065) |
| Core skills – Scientific and research (0/1) | 0.317*** | 0.356*** | 0.265*** | 0.168** | 0.161* |
| | (0.085) | (0.088) | (0.086) | (0.084) | (0.082) |
| Core skills – IT professionals (0/1) | 0.088 | 0.099 | 0.066 | 0.038 | 0.035 |
| | (0.060) | (0.065) | (0.063) | (0.062) | (0.061) |
| Core skills – IT support technicians (0/1) | -0.016 | -0.099 | -0.106* | 0.001 | 0.017 |
| | (0.059) | (0.064) | (0.063) | (0.061) | (0.061) |
| Core skills – Marketing (0/1) | 0.130** | 0.193*** | -0.033 | 0.010 | 0.431*** |
| | (0.057) | (0.062) | (0.061) | (0.060) | (0.059) |
| Core skills – Project management (0/1) | -0.080 | -0.088 | 0.058 | 0.068 | -0.117* |
| | (0.063) | (0.068) | (0.066) | (0.065) | (0.064) |
| Core skills – Business management (0/1) | 0.104* | 0.033 | 0.161** | 0.160** | 0.099 |
| | (0.062) | (0.068) | (0.066) | (0.065) | (0.065) |
| Core skills – Financial (0/1) | -0.104 | -0.169** | 0.030 | 0.048 | -0.112* |
| | (0.065) | (0.071) | (0.069) | (0.068) | (0.067) |
| Observations | 5,633 | 5,633 | 5,633 | 5,631 | 5,632 |

| | | | | | |
|---|---|---|---|---|---|
| Number of unitid | 2,764 | 2,764 | 2,764 | 2,764 | 2,764 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 5 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.277*** | 0.250** | 0.060 | 0.407*** | 0.226** |
| | (0.101) | (0.113) | (0.109) | (0.106) | (0.107) |
| Foreign ownership (0-3) | 0.004 | 0.080*** | 0.012 | -0.003 | -0.030 |
| | (0.026) | (0.031) | (0.029) | (0.029) | (0.029) |
| Financial assistance from governments – types (0-1) | 0.300 | 0.866*** | 0.871*** | 0.718** | 0.659** |
| | (0.307) | (0.329) | (0.317) | (0.313) | (0.306) |
| Financial assistance from governments – levels (0-1) | 0.085 | 0.084 | -0.069 | 0.159 | -0.099 |
| | (0.143) | (0.159) | (0.152) | (0.150) | (0.149) |
| Captive market (1/0) | -0.100 | -0.052 | -0.076 | -0.089 | -0.241*** |
| | (0.077) | (0.086) | (0.082) | (0.081) | (0.082) |
| Systems link automatically (0-1) | 0.524*** | 0.654*** | 0.691*** | 0.597*** | 0.545*** |
| | (0.154) | (0.167) | (0.161) | (0.157) | (0.154) |
| Collaborative research (0/1) | 0.180** | 0.219*** | 0.131 | 0.140* | 0.035 |
| | (0.081) | (0.085) | (0.082) | (0.080) | (0.080) |
| Debt finance refused (0/1) | -0.017 | 0.248 | 0.125 | 0.165 | 0.036 |
| | (0.214) | (0.232) | (0.225) | (0.225) | (0.222) |
| Equity finance refused (0/1) | -0.016 | -0.006 | 0.053 | 0.074 | 0.124 |
| | (0.134) | (0.144) | (0.136) | (0.136) | (0.134) |
| Core skills – STEM (0-1) | 0.135 | 0.230** | 0.213** | 0.040 | -0.209* |
| | (0.102) | (0.113) | (0.108) | (0.107) | (0.107) |
| Core skills – Business (0-1) | 0.092 | -0.036 | 0.195** | 0.309*** | 0.386*** |
| | (0.082) | (0.091) | (0.088) | (0.086) | (0.086) |
| Observations | 5,633 | 5,633 | 5,633 | 5,631 | 5,632 |
| Number of unitid | 2,764 | 2,764 | 2,764 | 2,764 | 2,764 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 6 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.274*** | 0.249** | 0.060 | 0.407*** | 0.224** |
| | (0.101) | (0.113) | (0.109) | (0.106) | (0.107) |
| Foreign ownership (0-3) | 0.005 | 0.080*** | 0.012 | -0.003 | -0.029 |
| | (0.026) | (0.031) | (0.029) | (0.029) | (0.029) |
| Financial assistance from governments – types (0-1) | 0.315 | 0.867*** | 0.871*** | 0.718** | 0.663** |
| | (0.307) | (0.329) | (0.317) | (0.313) | (0.306) |
| Financial assistance from governments – levels (0-1) | 0.092 | 0.085 | -0.069 | 0.159 | -0.094 |
| | (0.143) | (0.159) | (0.152) | (0.150) | (0.149) |
| Captive market (1/0) | -0.101 | -0.052 | -0.076 | -0.089 | -0.241*** |
| | (0.076) | (0.086) | (0.082) | (0.081) | (0.082) |
| Systems link automatically (0-1) | 0.527*** | 0.654*** | 0.691*** | 0.597*** | 0.547*** |
| | (0.154) | (0.167) | (0.161) | (0.157) | (0.154) |
| Collaborative research (0/1) | 0.189** | 0.220*** | 0.131 | 0.141* | 0.038 |
| | (0.081) | (0.085) | (0.082) | (0.081) | (0.080) |
| Debt finance refused (0/1) | -0.011 | 0.249 | 0.125 | 0.166 | 0.038 |
| | (0.214) | (0.233) | (0.225) | (0.225) | (0.222) |
| Equity finance refused (0/1) | -0.017 | -0.006 | 0.053 | 0.074 | 0.123 |
| | (0.134) | (0.144) | (0.136) | (0.136) | (0.134) |
| Core skills – STEM (0-1) | 0.345** | 0.259 | 0.213 | 0.047 | -0.108 |
| | (0.169) | (0.186) | (0.180) | (0.178) | (0.178) |
| Core skills – Business (0-1) | 0.206* | -0.020 | 0.195* | 0.312*** | 0.441*** |
| | (0.110) | (0.123) | (0.118) | (0.116) | (0.115) |
| Core skills – Business*STEM (0-1) | -0.370 | -0.049 | 0.000 | -0.011 | -0.173 |
| | (0.235) | (0.257) | (0.248) | (0.244) | (0.243) |
| Observations | 5,633 | 5,633 | 5,633 | 5,631 | 5,632 |
| Number of unitid | 2,764 | 2,764 | 2,764 | 2,764 | 2,764 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment)
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 7 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.276*** | 0.248** | 0.071 | 0.417*** | 0.230** |
| | (0.101) | (0.113) | (0.109) | (0.106) | (0.107) |
| Foreign ownership (0-3) | 0.007 | 0.079*** | 0.019 | 0.001 | -0.028 |
| | (0.026) | (0.030) | (0.029) | (0.029) | (0.029) |
| Financial assistance from governments – types (0-1) | 0.330 | 0.903*** | 0.932*** | 0.753** | 0.685** |
| | (0.307) | (0.328) | (0.318) | (0.312) | (0.306) |
| Financial assistance from governments – levels (0-1) | 0.093 | 0.091 | -0.045 | 0.167 | -0.099 |
| | (0.143) | (0.159) | (0.152) | (0.150) | (0.149) |
| Captive market (1/0) | -0.102 | -0.052 | -0.079 | -0.094 | -0.243*** |
| | (0.077) | (0.086) | (0.082) | (0.081) | (0.082) |
| Systems link automatically (0-1) | 0.531*** | 0.652*** | 0.713*** | 0.615*** | 0.554*** |
| | (0.154) | (0.166) | (0.162) | (0.157) | (0.155) |
| Collaborative research (0/1) | 0.191** | 0.239*** | 0.155* | 0.151* | 0.021 |
| | (0.080) | (0.084) | (0.081) | (0.080) | (0.079) |
| Debt finance refused (0/1) | -0.017 | 0.249 | 0.125 | 0.169 | 0.040 |
| | (0.214) | (0.233) | (0.226) | (0.225) | (0.223) |
| Equity finance refused (0/1) | -0.018 | -0.006 | 0.052 | 0.071 | 0.122 |
| | (0.134) | (0.144) | (0.137) | (0.136) | (0.134) |
| Core skills – STEM (0/1) | 0.084 | 0.057 | 0.128** | 0.061 | 0.035 |
| | (0.059) | (0.067) | (0.064) | (0.063) | (0.064) |
| Core skills – Business (0/1) | 0.096 | 0.088 | 0.106 | 0.236*** | 0.181*** |
| | (0.062) | (0.070) | (0.067) | (0.066) | (0.066) |
| Observations | 5,638 | 5,638 | 5,638 | 5,636 | 5,637 |
| Number of unitid | 2,765 | 2,765 | 2,765 | 2,765 | 2,765 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment).
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

Model 8 – Dependent variable = Introduced an innovation during last 12 months=1, otherwise=0; random effects probit estimation

| | Introduced innovation | | | | |
|---|---|---|---|---|---|
| **Explanatory variables (one year lag)** | **Any** | **Product** | **Process** | **Organisational** | **Marketing** |
| Working arrangements (0-1) | 0.277*** | 0.249** | 0.069 | 0.417*** | 0.229** |
| | (0.101) | (0.113) | (0.109) | (0.106) | (0.107) |
| Foreign ownership (0-3) | 0.007 | 0.079*** | 0.020 | 0.001 | -0.028 |
| | (0.026) | (0.030) | (0.029) | (0.029) | (0.029) |
| Financial assistance from governments – types (0-1) | 0.329 | 0.903*** | 0.937*** | 0.753** | 0.688** |
| | (0.307) | (0.328) | (0.318) | (0.312) | (0.306) |
| Financial assistance from governments – levels (0-1) | 0.094 | 0.093 | -0.050 | 0.167 | -0.102 |
| | (0.143) | (0.159) | (0.153) | (0.150) | (0.149) |
| Captive market (1/0) | -0.102 | -0.052 | -0.079 | -0.094 | -0.243*** |
| | (0.077) | (0.086) | (0.082) | (0.081) | (0.082) |
| Systems link automatically (0-1) | 0.530*** | 0.652*** | 0.714*** | 0.615*** | 0.555*** |
| | (0.154) | (0.166) | (0.162) | (0.157) | (0.155) |
| Collaborative research (0/1) | 0.191** | 0.239*** | 0.156* | 0.151* | 0.021 |
| | (0.080) | (0.084) | (0.082) | (0.080) | (0.079) |
| Debt finance refused (0/1) | -0.017 | 0.248 | 0.128 | 0.169 | 0.040 |
| | (0.214) | (0.233) | (0.226) | (0.225) | (0.223) |
| Equity finance refused (0/1) | -0.017 | -0.006 | 0.050 | 0.071 | 0.120 |
| | (0.134) | (0.144) | (0.137) | (0.136) | (0.134) |
| Core skills – STEM (0/1) | 0.119 | 0.077 | 0.005 | 0.071 | -0.045 |
| | (0.099) | (0.113) | (0.109) | (0.107) | (0.108) |
| Core skills – Business (0/1) | 0.122 | 0.103 | 0.013 | 0.244*** | 0.122 |
| | (0.086) | (0.098) | (0.095) | (0.093) | (0.093) |
| Core skills – Business*STEM (0/1) | -0.054 | -0.031 | 0.185 | -0.016 | 0.118 |
| | (0.122) | (0.137) | (0.132) | (0.130) | (0.131) |
| Observations | 5,638 | 5,638 | 5,638 | 5,636 | 5,637 |
| Number of unitid | 2,765 | 2,765 | 2,765 | 2,765 | 2,765 |

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Includes a constant; ln(employment).
Source: Authors' estimation based on the ABS Business Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data, 2005-06 to 2011-12.

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