Centre for Transformative Innovation

Global Prosperity Through Knowledge and Innovation

Is there evidence that Australian businesses receive knowledge spillovers?

Paper for the Department of Industry and Science

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Executive Summary

This study uses a production function approach to test for (a) whether the introduction an innovation leads to higher firm productivity and (b) whether the magnitude of the effect depends on the source of ideas. In particular, we estimate whether innovations that are sourced from ideas external to the firm result in a greater rise in productivity than those that are sourced from within the firm. Not all externally sourced ideas, however, are knowledge spillovers. If the ideas are bought through the market they constitute a 'normal' good but we would expect that ideas which are drawn from informal contacts, casual suggestions, learning-by-watching, and attendance at networking events are in fact ex-market (i.e. spillovers).

Our estimations are based on a 7-year unbalanced panel dataset of nearly 9,000 Australian business units from 2005-06 to 2011-12.[2] To account for differences in prices and industry specific conditions, we normalised each firms' performance on the average for their 2-digit industry. When we did this, we found that introducing an innovation raised productivity (or TFP) by 5.4 percentage points over whatever the increase was for their non-innovating peers. This step change occurred over about 2 years so in annual terms the rise is about 2.7 percentage points. A rise of 2.7 percentage points (or 5.4 over the whole period) compares favourably with the average annual growth in output (value-added) of 2.2 per cent. With respect to sectors of the economy, we found that:

- Micro businesses (less than 10 employees) experienced a greater effect (8.4 percentage points) than medium and larger sized firms. However, this effect may be an artefact of the binary nature of the innovation measure.

- Young firms, those less than 5 years in operation, experienced the greatest effect at 8.4 percentage points.

- Firms that were not exporting exhibited greater effects than exporters (7.6 cf. 0 percentage points).

About 10 per cent of firms engaged in innovation that was substantially new to the world, Australia or the industry. Of these, few innovations were associated with higher productivity. Nonetheless, there were some sub-groups that appeared to be successful in new to the world, Australia or the industry innovation. These were older firms, those in operation over 10 years and exporters. The older firms achieved a productivity rise of 8.0 percentage points and exporters achieved a productivity rise of 8.6 percentage points as a result of prior innovations that were new to the world, Australia or the industry.

There are four broad sources of ideas for innovation: Own (and related) business; 'other businesses' (suppliers, customers, competitors and consultants); Public research organisations; and Networks (publications, web sites, conferences and industry associations). We found that:

[2] In the case of simple (SME) firms, there is one unit per business. However, large businesses may be comprised of several activity units.

- Networks had the largest impact on the production residual (6.0 percentage points) and their influence was largest for middle-aged firms (12.2 percentage points) and for firms with between 10 and 99 workers (6.5 percentage points).

- Innovation ideas sourced from other businesses had the lowest effects (4.3 percentage points). For both own and other business source of ideas, the resultant effects were largest for small firms (under 10 employees) and for firms operation for over 10 years.

- Public sector organisation ideas were only influential for middle-aged firms but this effect was very large (23.7 percentage points).

Overall, there was no productivity effect from collaborating with other organisations for the purpose of innovation. In particular, there was no effect on productivity of collaborating with a science-based organisation. Nonetheless:

- Firms that collaborated with other Australian organisations did experience a rise in their productivity residual (7.7 percentage points). The effect was greatest for old firms (8.9 percentage points) and non-exporters (7.2 percentage points).

- The only firms to benefit from collaboration with overseas organisations were the larger (more than 100 in employment) and older firms (over 10 years).

The evidence that networks, other businesses and public research organisations were significant sources of ideas for successful innovators is suggestive evidence that knowledge spillovers exist.

Introduction

Public support for Australian industry, either financial or in-kind, is predicated on the existence of unpaid and unrequited benefits flowing from one organisation to another. Organisations that are not renumerated for producing these third-party benefits (i.e. benefits that accrue to parties outside the market transaction) will not take their effects into account when making decisions. These organisations are therefore liable to under-produce benefits. Public support therefore corrects this underproduction by encouraging the beneficial activity (such as R&D). In the context of innovation and productivity, these third-party benefits are called knowledge spillovers.

Knowledge spillovers can be substantial. In fact, knowledge spillovers are thought to be the prime force behind the success of some industries, in some places, at some times. Marshall (1912) first identified how informal, uncodified sharing of ideas between related firms lead to the generation of new and better ideas. He classically described knowledge as being 'in the air' within regions. The dominance of nineteenth-century British industry was supported, he believed, by the presence of collective knowledge and ideas between firms in the same location. More recently, there has be a wave of studies which have documented the presence of spillovers and possible geographic limits to their reach [Hall (1996), Griliches (1998), Jaffe (1986), Mansfield et al. (1977), Bernstein and Nadiri (1989), Griffith, Redding and Van Reenen (2004, Boschma (2005), Goodridge et al. (2012), Trajtenberg (1990), Cook et al (2011)].

The ultimate beneficiary of productivity improvements is the consumer who, with the diffusion of ideas and competition between firms, receives better products at lower cost. As such, good public policy demands that any publicly funded program which hastens the spread of good ideas between firms should be supported if the present value of (these perpetual) benefits exceed the one-off program costs.

Although there is considerable evidence that R&D spending by one firm has a positive effect on related firms, hard evidence for the effects of innovative activities is less common. This scarcity can be traced to the absence of accounting standards over innovation activities, compared with the more regular treatment of R&D spending (Hunter et al 2012). Innovation is in many respects a more relevant source of knowledge spillovers since it extends beyond R&D. It also includes knowledge acquisitions such as licences, technical services, acquisition of machinery and equipment (both incorporating new technology and for standard use when producing a new product), marketing and various other preparations for production and delivery such as tooling up, staff training.[3]

There is minimal Australian evidence on the spillover question (see Griffiths and Webster 2010, de Rassenfosse and Jensen 2013 for Australian examples using R&D data) and minimal evidence anywhere in the world on the presence of innovation spillovers. In this paper, we use a panel of approximately 9,000 Australian firms, over 2005-06 to 2011-12, to estimate first, the effect of introducing a new product, or new managerial, operational or marketing method into the workplace, on the firm's future productivity; and secondly, to identify whether the sources of these ideas have a differential impact on firm productivity.

[3] OECD and Eurostat (2005) 'Oslo Manual Guidelines For Collecting And Interpreting Innovation Data'. Third edition A joint publication of OECD and Eurostat. Paris.

We begin this paper with a review of the accepted stylised facts concerning firm-level knowledge spillovers. We then describe and estimate our model. We find that firms which introduced an innovation raised their productivity level on average (relative to their industry average) by 5.4 percentage points over the ensuing four years. This compares with an economy-wide annual growth in real output of 2.2 per cent.

The source of ideas has a significant effect on much effect the innovation has on productivity. Ideas from conferences, publications and industry associations contribute on average 6.0 percentage points to the rise in productivity compared with 5.5 percentage points for ideas from within the firm. Public sector organisations were only influential for middle-aged firms but in this case the effect was very large (23.7 percentage points). Although we cannot be certain that all these externally sourced ideas are true spillovers (i.e. not bought through the market), it is probable that most of the networking ideas are true spillovers.

Stylised facts

There is a clear deductive case that change, spearheaded by improved knowledge, is necessary to enhance economic well-being. If knowledge is static, marginal returns to investment into more of the same plant, equipment or worker skills will eventually diminish to zero. Unless new-to-the-world, and subsequently new-to-the-firm, products and methods of production are realised, firm-level productivity will plateau and our standard of living will stagnate. By contrast, the returns to accumulated knowledge is unbounded for it is difficult to imagine that there can be a limit to the advance in our stock of knowledge.

Although it is easy to deduce the importance of knowledge, it is far more difficult to trace how it wends its way through the economy and where its presence has been most felt or its need the greatest. Analysing the historic pattern of knowledge creation and transfer is classically an incomplete and biased undertaking as much of the transfer of knowledge is invisible and silent. Although some forms of knowledge can spread quickly and widely, many types resist transfer and many groups in society have difficulty incorporating new forms of knowledge into their behaviour. We know intuitively that the skill and capability of the receiver influences how knowledge is subsequently used, but our research in this area is still nascent and primitive. Knowledge is also extremely heterogeneous. Some ideas have lasting currency – the wheel still has wide and versatile use – whereas others are quickly superseded. There are few, if any, known measures of knowledge that capture these dimensions of knowledge and we must rely on known second-best forms of evidence.

Economic models constructed to reflect the effects of knowledge usually begin by estimating (firm, industry or national) productivity and then proceed to model the impact of their own stock of knowledge, and related firms' stock of knowledge on this productivity. In this paper, follow this approach. We combine qualitative survey data with accounting information to avoid the bias inherent in studies that rely exclusively on R&D and patent data. The sample of firms comprises a census of large firms (or more precisely 'type of activity unit') and a random sample of SMEs and should not be biased towards innovative firms. The measure of innovation and related activities has been generically worded to apply to all industries, technologies and firm sizes.

Empirical framework

In the first part of the model we estimate the productivity of each firm, while making sure that there is no reverse causality (feedback from productivity to firm's decision on whether or not to innovate). We follow our approach previously used in Palangkaraya et al (2015). For our purposes we want to measure the part of production that is not explained by counts of workers and other purchased factors of production. The most flexible way to do this, with the readily available data, is to specify the output (sales less materials) of each firm i in year t (Y_{it}) as a function of K_{it}, the accounting value of the tangible capital stock, and L_{it}, the level of employment. Using the Cobb-Douglas production function this can be depicted as:

$$Y_{it} \equiv J_{it} K_{it}^{\alpha_k} L_{it}^{\alpha_l} \quad (1)$$

where J_{it} denotes the production residual (or intangible capital stock).[4] We do not need a coefficient for J_{it} as it is not defined in natural units such as dollars or people. Using the corresponding lower case letters to denote the logarithmic values of the inputs and output above, equation (1) can be re-written as:

$$y_{it} \equiv j_{it} + \alpha_k k_{it} + \alpha_l l_{it} \quad (2)$$

In the above specification, we assume that the log of current production residual (j_{it}) is determined by the firm's measured ability (A_{it}) such that:

$$j_{it} = \beta A_{it} + \theta_i + u_{it} \quad (3)$$

where θ_i and u_{it} denote unobserved time-invariant firm-specific and random effects, respectively. We would expect that θ_i includes the slow changing managerial and worker-based skills referred to above.

Substituting (3) into (2) yields our augmented Cobb-Douglas function to be estimated as follows:

$$y_{it} = \beta A_{it} + \alpha_k k_{it} + \alpha_l l_{it} + \theta_i + u_{it} \quad (4)$$

The problem with directly estimating (4 is that analysts rarely have reliable measures of the level of A. Very occasionally we might have a monetary measure of the investment laid out on these stocks of intangibles,[5] but almost inevitably we do not have a measure of how much was spent or when the changes were effective.[6] In contrast, datasets derived from survey questions typically provide measures of attempts to change A (that is, innovation which we denote below with N)

A further complication in the estimation process is knowing the appropriate interval between the introduction of a change and its ensuing effect on intangible capital stock. These time lags could vary by type, the magnitude of the change, the industry or the technology. In the immediate investment

[4] An intangible asset is a non-monetary asset without physical substance.

[5] For a discussion of how this problem relates to the accounting system, see Hunter, Webster and Wyatt (2012).

[6] To the extent intangible investments are time-invariant (at least over certain period), their effects will be conflated with the firm-specific fixed effects. There are often data limitations, as in this study, in terms of the length of the period covered or missing responses in some of the years which make it difficult to estimate equation (4) directly using a dynamic panel model such as those proposed by Arellano and Bond (1991), Olley and Pakes (1996), or Blundell and Bond (2000).

phase of an innovation, the effect on the stock of usable intangible capital could well be negative. Therefore, when we calculate the year-by-year effects, we may be averaging the effects over different phases of different life cycles (i.e. a negative, neutral and positive phase).[7] So we need to re-cast (3) and write as the effect of current innovation N on the production residual with a lag of length *n*:[8]

$$\overline{J_{it+n}} - j_{it} = \beta N_{it} + \varepsilon_{it} \quad (5)$$

where $\overline{J_{it+n}}$ is the average production residual over n forward years.

With substitution from (2), the LHS of (5) is:

$$\overline{J_{it+n}} - j_{it} \equiv (\overline{y_{it+n}} - \alpha_k \overline{k_{it+n}} - \alpha_l \overline{l_{it+n}}) - (y_{it} - \alpha_k k_{it} - \alpha_l l_{it}) \quad (6)$$

Our aim is to estimate the βs in (5), we first need to estimate the change in the production residual from (6). Then we regress the estimate $\overline{J_{it+n}} - j_{it}$ on its determinants (5). By construction we expect no feedback effect from net output (estimated using later period data) on N (measured from earlier period data). However, this proposition is testable.

We can expand (5) by disaggregating N into firm level changes in: the a range of products (P_{it}); managerial processes (M_{it}); operational procedures (O_{it}); and marketing methods (D_{it}), such that:

$$\overline{J_{it+n}} - j_{it} = \beta_p P_{it} + \beta_m M_{it} + \beta_o O_{it} + \beta_d D_{it} + \varepsilon_{it} \quad (5a)$$

Furthermore, we can include the effect of prior collaborations on changes to intangible capital stock by including a prior collaboration variable (C_{it}) in the estimation.

$$\overline{J_{it+n}} - j_{it} = \beta_p N_{it} + \beta_c C_{it} + \varepsilon_{it} \quad (5b)$$

Equations (5), (5a) and (5b) are our estimating equations.

The ABS data

Our empirical analysis uses data from the Australian Bureau of Statistics covering over 8,989 Australian firms for the period 2005-06 to 2011-12. The data includes information collected by the Business Characteristics Survey linked to the corresponding Business Income Taxation and Business Activity Statement taxation data. The response rate for the survey was approximately 95 per cent in all years.[9]

Each survey year has between 27,000 and 34,000 observations, yielding about 241,206 year-firm observations. After deleting observations without a year, an ABN or taxation data we are left with

[7] To illustrate this, we have estimated a Cobb-Douglas production function augmented with different measures of innovation. The results which are presented in Appendix, Table A1 show that when modelled in this way, these innovation variables are not significant. The insignificance of these results is consistently found whether or not we use lagged explanatory variables, adjust nominal values, and measure innovation in different ways.

[8] To derive (5) from (3), for example, consider the case of if n=1. From (2), $\overline{J_{it+n}} - j_{it} = \overline{J_{it+1}} - j_{it} = j_{it+1} - j_{it} = \beta(A_{it+1} - A_{it}) + (u_{it+1} - u_{it}) = \beta N_{it} + \varepsilon_{it}$ where N_{it} is innovation introduced by the firm in period t. Note that in estimation, we use $N_{it} = A_{it} - A_{it-1}$ to reduce the extent of endogeneity (feedback effect) from the dependent variable $(\overline{J_{it+n}} - j_{it})$ to N_{it}.

[9] Firms can be directed by the Australian Government to complete the survey.

91,581 observations and 22,850 distinct firms. We subsequently excluded firms from Agriculture, Forestry and Fishing (7210 observations) due to the inclusion of large values of land in the assets data (84,371 observations and 21,023 distinct firms). For the analysis of this data, the data extraction and execution of our programs was undertaken by officers of the ABS who confidentialised the outputs before release.

The advantage of this dataset is twofold: size and diversity. With the exception of R&D studies, most existing studies use datasets that are either cross-sectional, small or unrepresentative. Although suggestive, one cannot draw strong causality conclusions from these studies – a casual analysis should, as a minimum, include both cross-sectional and time-series dimensions. Second, the explanatory and dependent variables in the ABS dataset are drawn from separate sources. It is too easy to find correlations in data reported by the same respondent and the more diverse the data sources, the greater is our confidence in the results. It is much harder to find patterns in data drawn from independent sources.

We define our time of analysis to be the survey sequence year, not calendar year due to the cohort rotation. This means we model the effect of a change in N in year 0 on output over the subsequent one to five years (bearing in mind we are using an unbalanced panel of up to 6 years).

Table A1 in the appendix compares our sample with the estimate population of business counts. It shows an over-representation of mining, manufacturing, wholesale trade and information media and telecommunications; and an under-representation in construction, retail trade, professional, scientific and technical series and health care and social assistance firms. Aside from these differences, the sample is broadly representative.

A full description of the variables used in the estimations is presented in the appendix Table A2, but briefly: the value of output is total sales less material inputs; the value of tangible capital stock is non-current assets; and employment is the number of persons working in the firm during the last pay period. To control for cross-industry effects in the productivity estimates, we normalise each variable in the production function with respect to industry average for each year. For variables denoted in current prices, such as output and tangible capital, the normalisation also substitutes for the need for industry-specific price deflators (Klette 1999).[10] Flow variables refer to activity up until year end 30 June and stock variables are as of 30 June. The first stage, equation (2), only includes (normalised) output, capital stock and employment.

In the second stage, equations (5) (5a) and (5b), we regress $\overline{j_{it+n}} - j_{it}$ against prior measures of innovative activities. The innovation status explanatory variables are alternatively (a) a binary variable for whether or not the business introduced any new or significantly improved goods and services, operational processes, organizational and managerial processes or marketing methods; (b) four binary variables for the source of ideas for the innovation, (c) two binary variables to denote innovations that are new-to-the-firm versus new-to-the-world, Australia or industry and (d) binary variables for the four types of business innovation listed above.[11] All innovation variables relate to

[10] The alternative is using either a combination of broader GDP or sector price deflators or nominal values. Our estimates are robust to whether or not we use nominal values.

[11] Separately identified innovations comprised new or significantly improved: goods; services; methods of manufacturing or producing goods or services; logistics, delivery or distribution methods for goods and

the firms activity in the year to June 30. Selected variables, that are more stable over time, were only asked every second year (as indicated in Table A2). In this case, we interpolated missing variables from the year after, or if that were missing the year before. All other missing variables were recoded to zero.

In equation (5a), we disaggregate innovative activity into the four main types listed above. In equation (5b) we test for the effect of prior collaboration in two possible ways. First, whether the firm was involved in a collaborative arrangement for any purpose such as marketing, joint buying, manufacturing, supply chain access or R&D. Second, whether the business collaborated specifically for the purposes of innovation (given the firm had introduced an innovation). We are able to disaggregate the second measure according to whether the partners were in Australia or overseas; or were from a research-orientated organisation (science-based collaboration) or not. All collaboration variables relate to the firms activity in the year to June 30.

Table 1 presents the mean value for each characteristic for each firm for the first and last years of the dataset used in our estimations. It reveals that the mean value of sales was $224 and $227 million in nominal prices. Tangible capital stock was $468 million and $464 million and employment was 551.0 and 510.5.

The portion of firms which had introduced an innovation (either new-to-the-firm or new-to-the-world) in the last 12 months was 0.616 in 2005-06 and 0.545 in 2011-12. In 2011-12, a quarter of firms introduced a new good or service; one third of firms introduced new operational processes; one third introduced organisational and managerial processes and a quarter introduced a new marketing method. In each year, about one in four firms had participated at least once in a collaboration and one in seven had participated in an innovation-specific collaboration. Most collaboration were with Australian-based organisations. Overall, only about 2 per cent of firms had collaborated with a science-based organisation.

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services; supporting activities for business operations; other operational processes; knowledge management processes; the organisation of work; business practices for organising procedures; methods of organising work responsibilities and decision making; significant changes in relations with others; methods of organising external relations with other businesses or institutions; other organisational/managerial processes; the design or packaging of a good or service; media or techniques for product promotion; sales or distribution methods/methods of product placement or sales channels; methods of pricing goods or services; and other market innovation.

Table 1: Characteristics of firms in estimation sample, 2005-06 and 2011-12.

Characteristic	2005-06		2011-12	
	Mean	No.	Mean	No.
Sales (A$m)	227	3035	224	3944
Materials (A$m)	156	3035	157	3944
Production (A$m)	71.1	3035	66.9	3944
Tangible capital (A$m)	468	3035	464	3944
Employment	551.0	3035	510.5	3944
Introduced an innovation	0.616	3035	0.545	3915
New-to-the-firm	0.331	3035	0.484	3915
New-to-the-world, Australia, industry	0.099	3035	0.117	3915
Source of innovation ideas				
Own or related business	0.330	3035	0.459	3915
Other businesses	0.305	3035	0.426	3915
Public research organisation	0.033	3035	0.043	3915
Networks	0.147	3035	0.231	3915
Research	0.044	3035	0.053	3915
Collaborated for any purpose	0.225	3035	0.259	3944
Collaborated for innovation	0.146	3035	0.143	3944
Collaborated with Australian org.	0.102	3035	0.149	3944
Collaborated with overseas org.	0.047	3035	0.054	3944
Collaborated with science-based org.	0.017	3035	0.021	3944
Type of innovation				
New good or service	0.322	3035	0.269	3915
Operational processes	0.406	3035	0.303	3915
Organisational/management processes	0.381	3035	0.351	3915
Marketing method	0.255	3035	0.262	3915
R&D expenditure (yes=1)	0.146	3035	0.105	3915
Age (years in operation)	29.2	2768	27.6	3928
Export status (yes=1)	0.310	3035	0.221	3907

Key points

Table 2-10 present the results from estimating equations (5), (5a) and 5(b). Results from estimating equation (6), the change in the productivity residual, is found in Appendix Table A3. We define productivity to be the production residual from the cobb-douglas production equation (6) and use data which has been normalised by industry so each firm's productivity is a relative measure.

Table 2 shows that innovating raised productivity, from one to 6 years later, by an average of 5.4 percentage points. This implies that innovators experience a 5.4 percentage increment in their productivity relative to non-innovators *in their industry*. We might think of this as approximately 2.7 percentage points a year. This 2.7 (or 5.4) percentage points compares with an average annual rate of growth in (real) production of 2.2 per cent over the years 2005-06 to 2011-12.

With respect to sub-populations, we found that:

- Small businesses (less than 10 employees) experienced a greater effect (8.4 percentage points) than medium and large sized firms.

- Young firms, those less than 5 years in operation, experienced the greatest effect at 8.2 percentage points.

- Firms that were not exporting exhibited greater effects than exporters (7.6 cf. -4.7 percentage points but the latter was not statistically significant).

According to Table 3 few of the firms that engaged in substantially new to the world, Australia or the industry innovations reported higher productivity. As a group, the most successful firms were older firms, those in operation over 10 years, and exporters. The older firms achieved a productivity rise of 8.0 percentage points and exporters achieved a productivity rise of 8.6 percentage points.

There are five sources of ideas for innovation: own (and related) business; 'other businesses' (suppliers, customers, competitors and consultants); public research organisations; and networks (publications, web sites, conferences and industry associations). As reported in Tables 4 to 7:

- Networks had the largest impact on the production residual (6.0 percentage points) and their influence was largest for middle-aged firms (12.2 percentage points) and for firms with between 10 and 99 workers (6.5 percentage points).

- Own business and 'other businesses' had lower effects (5.5 and 4.3 percentage points respectively). The both sources were largest for small firms (under 10 employees) and the oldest firms (operating for over 10 years).

- Public sector organisations were only influential for middle-aged firms and the effect was very large (23.7 percentage points).

Tables 8 to 10 provide estimates of the effects of collaborating with other organisations for the purpose of innovation

- According to Table 8, collaborating with a science-based organisation had no effect on productivity.

- Only those firms that collaborated with other Australian organisations experienced rise in their productivity residual. This effect was large over all (7.7 percentage points) greatest for old firms (8.9 percentage points) and non-exporters (7.2 percentage points).

- The only firms to benefit from collaboration with overseas organisations where the large firms (more than 100 people in employment) and older firms (over 10 years).

The evidence that networks, other businesses and public research organisations were significant sources of ideas for some successful innovators is evidence that knowledge spillovers exist.

Table A4 in the appendix presents a summary of the innovation equation by industry. It reveals that when we disaggregate the data, very few of the estimated coefficients are statistically significant. We attribute this to the small sample sizes.

Table 2: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All			Employment size			Years in operation			Export status	
				1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced	0.054***	0.053***	0.048***	0.084***	0.026	0.044	0.082*	0.056	0.045**	0.076***	-0.047
	(0.017)	(0.017)	(0.017)	(0.032)	(0.026)	(0.035)	(0.048)	(0.048)	(0.020)	(0.019)	(0.043)
Any form of collaboration (cooperation)		0.010									
		(0.021)									
Collaborated for innovation			0.042	0.018	0.075*	0.032	0.079	0.132*	0.021	0.035	0.063
			(0.026)	(0.052)	(0.038)	(0.041)	(0.073)	(0.072)	(0.029)	(0.030)	(0.048)
Observations	8,989	8,989	8,989	3,590	3,206	2,184	1,546	1,152	6,291	7,198	1,755
R-squared	0.001	0.001	0.001	0.002	0.002	0.001	0.003	0.005	0.001	0.003	0.001

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 3: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All		Employment size			Years in operation			Export status	
			1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced – new-to-the-world, Australian or industry	0.044	0.033	0.051	0.009	0.065	-0.113	0.068	0.080**	0.034	0.086*
	(0.031)	(0.032)	(0.078)	(0.051)	(0.043)	(0.099)	(0.097)	(0.034)	(0.041)	(0.050)
Collaborated for innovation		0.053**								
		(0.025)								
Observations	8,989	8,989	3,590	3,206	2,184	1,546	1,152	6,291	7,198	1,755
R-squared	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.002

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 4: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All		Employment size			Years in operation			Export status	
			1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced – source networks	0.060***	0.053**	0.057	0.065**	0.064*	0.066	0.122**	0.054**	0.069***	0.039
	(0.022)	(0.023)	(0.047)	(0.032)	(0.037)	(0.064)	(0.061)	(0.025)	(0.026)	(0.045)
Collaborated for innovation		0.048*								
		(0.025)								
Observations	8,989	8,989	3,590	3,206	2,184	1,546	1,152	6,291	7,198	1,755
R-squared	0.001	0.001	0.000	0.001	0.001	0.001	0.004	0.001	0.001	0.000

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 5: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All		Employment size			Years in operation			Export status	
			1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced – source own business	0.055***	0.050***	0.074*	0.053**	0.066**	0.006	0.069	0.075***	0.054***	0.087**
	(0.018)	(0.018)	(0.040)	(0.027)	(0.032)	(0.052)	(0.051)	(0.020)	(0.021)	(0.038)
Collaborated for innovation		0.046*								
		(0.025)								
Observations	8,989	8,989	3,590	3,206	2,184	1,546	1,152	6,291	7,198	1,755
R-squared	0.001	0.001	0.001	0.001	0.002	0.000	0.002	0.002	0.001	0.003

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 6: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All		Employment size			Years in operation			Export status	
			1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced – source other businesses	0.043**	0.036*	0.068*	0.032	0.048	0.023	0.042	0.057***	0.044**	0.064*
	(0.018)	(0.019)	(0.038)	(0.027)	(0.032)	(0.052)	(0.051)	(0.021)	(0.021)	(0.038)
Collaborated for innovation		0.048*								
		(0.025)								
Observations	8,989	8,989	3,590	3,206	2,184	1,546	1,152	6,291	7,198	1,755
R-squared	0.001	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.002

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 7: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All		Employment size			Years in operation			Export status	
			1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced – source public research organisations	0.036	0.027	0.100	0.038	0.006	0.196	0.237*	-0.005	0.095	-0.051
	(0.050)	(0.050)	(0.119)	(0.080)	(0.067)	(0.168)	(0.138)	(0.055)	(0.063)	(0.082)
Collaborated for innovation		0.056**								
		(0.025)								
Observations	8,989	8,989	3,590	3,206	2,184	1,546	1,152	6,291	7,198	1,755
R-squared	0.000	0.001	0.000	0.000	0.000	0.001	0.003	0.000	0.000	0.000

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 8: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All	Employment size			Years in operation			Export status	
		1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced	0.054***	0.087***	0.037	0.046	0.097**	0.076	0.048**	0.080***	-0.035
	(0.017)	(0.031)	(0.026)	(0.035)	(0.046)	(0.046)	(0.020)	(0.019)	(0.043)
Collaborated with science-based org	-0.056	-0.052	-0.071	-0.042	-0.290	0.063	-0.015	0.028	-0.107
	(0.077)	(0.227)	(0.144)	(0.090)	(0.237)	(0.298)	(0.083)	(0.108)	(0.110)
Observations	8,983	3,590	3,206	2,178	1,545	1,151	6,287	7,192	1,755
R-squared	0.001	0.002	0.001	0.001	0.004	0.002	0.001	0.002	0.001

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 9: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All	Employment size			Years in operation			Export status	
		1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced	0.044**	0.077**	0.027	0.036	0.091*	0.068	0.036*	0.071***	-0.047
	(0.017)	(0.032)	(0.026)	(0.035)	(0.048)	(0.047)	(0.020)	(0.019)	(0.043)
Collaborated with Australian org.	0.077***	0.102	0.082*	0.074*	0.028	0.089	0.089***	0.072**	0.087
	(0.029)	(0.071)	(0.045)	(0.041)	(0.085)	(0.092)	(0.032)	(0.035)	(0.053)
Observations	8,983	3,590	3,206	2,178	1,545	1,151	6,287	7,192	1,755
R-squared	0.002	0.003	0.002	0.002	0.003	0.003	0.002	0.003	0.002

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 10: Dep var: Percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All	Employment size			Years in operation			Export status	
		1-9	10-99	>100	Under 5 years	6-10 years	Over 10	Not export	Export
Innovation introduced	0.052***	0.089***	0.038	0.038	0.099**	0.081*	0.042**	0.077***	-0.040
	(0.017)	(0.031)	(0.026)	(0.035)	(0.047)	(0.047)	(0.020)	(0.019)	(0.043)
Collaborated with overseas org.	0.048	-0.131	-0.048	0.120**	-0.165	-0.094	0.109**	0.119	0.042
	(0.049)	(0.170)	(0.096)	(0.056)	(0.185)	(0.151)	(0.053)	(0.078)	(0.065)
Observations	8,983	3,590	3,206	2,178	1,545	1,151	6,287	7,192	1,755
R-squared	0.001	0.002	0.001	0.003	0.003	0.003	0.002	0.003	0.001

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table 11: Effect of innovation on percentage change in production residual between year 0 and the average of years 1-6, OLS estimation

Explanatory variables (reported in year 0)	All	Expenditure on R&D ?	
		Yes	No
Innovation introduced	0.054***	-0.015	0.060***
Collaborated for innovation	0.058**	-0.008	0.075***
Innovation introduced – new-to-the-world, Australian or industry	0.025	0.024	0.029
Innovation introduced – source networks	0.056***	0.058	0.058***
Innovation introduced – source other businesses	0.043**	0.067	0.044**
Innovation introduced – source public research organisations	0.030	-0.07	0.080
Observations	9963	1022	8941

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Appendix

Table A1: Counts of business units‡. ABS population count and ABS EABLD sample count†

Industry (ANZSIC06)	ABS population count June 2012	%	ABS EABLD Year 0	%
Mining	4,908	0.5	956	2.7
Manufacturing	60,869	6.4	7084	19.8
Electricity, Gas, Water And Waste Services	3,412	0.4	546	1.5
Construction	204,165	17.6	2667	7.5
Wholesale Trade	49,293	5.4	3596	10.1
Retail Trade	83,236	10.4	2626	7.3
Accommodation And Food Services	42,059	7.6	2336	6.5
Transport, Postal And Warehousing	77,596	5.2	2729	7.6
Information Media And Telecommunications	10,295	0.9	1540	4.3
Financial And Insurance Services	93,760	4.3	1153	3.2
Rental, Hiring And Real Estate Services	153,359	4.2	1548	4.3
Professional, Scientific And Technical Services	144,874	14.5	2648	7.4
Administrative And Support Services	42,087	4.7	2205	6.2
Public Administration And Safety	4,034	0.5	13	0.0
Education And Training	14,767	1.5	56	0.2
Health Care And Social Assistance	66,875	6.5	932	2.6
Arts And Recreation Services	15,831	1.2	1225	3.4
Other Services	52,831	6.3	1919	5.4
Not known	9,175	1.9	5	0.0
Total	1,280,201	100	35,784	100.0

Notes: Excludes Agriculture, Forestry and Fishing; † BCS= Business Characteristics Survey; BAS = Business Activity Statement; BIT = Business Income Tax.

Source: 81650 Counts of Australian Businesses, including Entries and Exits, Jun 2008 to Jun 2012; ABS BCS-BAS-BIT linked dataset 2005-06 to 2011-12.

Table A2: Variable definition – ABS EABLD

Variable	Source	Definition	Scale
Sales (A$m)	BAS	Total sales	0-22,700
Materials (A$m)	BIT	Cost of sales for tax purposes.	0-15,700
Tangible capital (A$m)	BIT	Non-current (derived) assets . Non-current assets includes assets that the company holds for at least one year, eg cars, land, buildings, office equipment, computers, bonds, stocks, notes, .patents, trademarks, and goodwill.	0-11,700
Employment	BCS	Number of persons working for this business during last pay period	0- 86,843
Innovation introduced	BCS*	Business introduced any new or significantly improved good or service; Operational processes; Organisational/managerial processes; Marketing methods.	0/1
New good or service	BCS	Introduced a new or significantly improved: goods; services.	0/1
Operational processes	BCS	Introduced a new or significantly improved: 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;	0/1
Organisational/management processes	BCS	Introduced a new or significantly improved: knowledge management processes; the organisation of work; business practices for organising procedures; methods of organising work responsibilities and decision making; significant changes in relations with others; methods of organising external relations with other businesses or institutions; other organisational/managerial processes;	0/1
Marketing method	BCS	Introduced a new or significantly improved: the design or packaging of a good or service; media or techniques for product promotion; sales or distribution methods/methods of product placement or sales channels; methods of pricing goods or services; and other market innovation	0/1
New-to-the-firm innovation		Introduced an innovation which was only new-to-the-firm	0/1
New-to-the-world, Australia or industry innovation		Introduced an innovation which was either new-to-the-world, Australia or industry	0/1
Source of ideas: Own business or related business		Introduced an innovation & sources of ideas/ information was own business or related company	0/1
Source of ideas: Other businesses		Introduced an innovation & sources of ideas/ information was clients, customers or buyers; suppliers; competitors and other businesses from the same industry; consultants	0/1
Source of ideas: Public sector research organisations		Introduced an innovation & sources of ideas/ information was universities or other higher education institutions; government agencies; private non-profit research institutions	0/1
Source of ideas: Networks		Introduced an innovation & sources of ideas/ information was commercial laboratories/r&d enterprises; websites, journals, research papers, publications; professional conferences, seminars, meetings, trade shows; industry associations; and other	0/1
Collaborated for any purpose	BCS	Has a cooperative ("collaborative" from 2007-08 onwards) arrangement (any type) for marketing, production, supply chain, innovation	0/1
Collaborated for innovation	BCS	Collaborated for innovation	0/1

Collaborated with Australian org.	BCS*	Collaborated with an Australian organisation for innovation purposes	0/1
Collaborated with overseas org.	BCS*	Collaborated with an overseas organisation for innovation purposes	0/1
Collaborated with science-based org.	BCS	Collaborated with an science-based organisation for innovation purposes (as defined above) for innovation	0/1
Exports	BCS*	Has income from exporting goods or services	0/1
Age	BCS	Business years of operation	0-100

Note: * These BCS items are derivation of directly collected data items. All variables relate to the firms activity in the year to June 30.

Table A3: Dep var: Value of output†, fixed-effects estimation, years 1 to 6

Explanatory variables	Excl. firms in not-for profit industries[a]
Log(Value of non-current assets)†	0.050***
	(0.007)
Log(Level of employment)†	0.248***
	(0.014)
Observations	18,728
Units	8,989
R^2-within	0.039
Rho	0.931

Notes: † Variables have been normalised with respect to the corresponding 2-digit ANZSIC average in each year. Standard errors are in parentheses. The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included. [a] Not for profit industries comprises Administrative and support services; Public administration and safety and Education and training. [b] Any firm with an annual change in the value of output, value of non-current assets or employment in the top of bottom 5% of observations is called an outlier.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

Table A4: Effect of innovation on percentage change in production residual between year 0 and the average of years 1-6, OLS estimation, by industry

Industry (1-digit)		Est. coefficient
A	Agriculture, forestry and fishing	na
B	Mining	0.201
C	Manufacturing	0.001
D	Electricity, gas, water and waste services	na
E	Construction	-0.036
F	Wholesale trade	0.022
G	Retail trade	0.161**
H	Accommodation and food services	0.068
I	Transport, postal and warehousing	0.075
J	Information media and telecommunications	0.100
K	Financial and insurance services	-0.045
L	Rental, hiring and real estate services	0.088
M	Professional, scientific and technical services	0.060 .
N	Administrative and support services	na
O	Public administration and safety	na
P	Education and training	0.198
Q	Health care and social assistance	Na
R	Arts and recreation services	0.057
S	Other services	0.026

Notes: The notations *; ** ; *** indicate that the coefficient estimates are statistically significant at the 10%, 5% and 1% level respectively. Constant included.

Source: ABS Business *Characteristics Survey and Business Longitudinal Database and ATO Business Activity Statement data.*

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