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Modelling the Relationships Between the Use of STEM* Skills, Collaboration, R&D, and Innovation among Australian Businesses

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Abstract

This paper investigates the relationship between the use of STEM/Non-STEM skills, collaboration, R&D and innovation, including novelty of innovation, among Australian businesses. The analysis employs standard probit modelling using the 2010-11 and 2011-12 ABS Business Characteristics Survey data. Results show that the use of STEM skills and collaboration in R&D are very strongly associated with an increase in the likelihood of innovating. The combined impact of collaboration in R&D, expenditure in R&D, and the use of STEM skills on the probability of having a 'new to the world' type of innovation is also found to be strong.

Keywords: Skills, Collaboration, R&D, Innovation, Australia.

JEL Classification: O32, O31, J24, D29

1. Introduction

There is growing recognition of the importance of human capital in shaping Australia's future prosperity. A recent report for the Australian Council of Learned Academies argued that building capacity particularly in the fields of science, technology, engineering and mathematics (STEM) is pivotal to competitiveness in the global economy (Marginson, *et al*. 2013). Another study showed that an increase in the proportion of workers in skilled occupations is followed by an increase in labour

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productivity, and organisation of human capital was important in determining labour productivity (Connolly, *et al*. 2012).

A firm's competitiveness is attributed to R&D, innovation and collaborative efforts between firms. In Australia, however, not many studies have looked into the relationship between these and STEM employment. But in the U.S., Lieponen (2005) examined the complementarity between employees' skills and firms' innovation activities and found that high technical skills are complementary with R&D collaboration and product or process innovation and that human capital are seen as an enabling factor in profitable innovation. The study however did not specifically separate STEM skills.

The ABS has investigated several related topics in the past, such as skills shortages, information and communication technology (ICT), flexible working arrangements, government assistance, innovation and productivity, but none of these specifically looked at the effects of STEM skills and STEM employment (see, Wong, *et al*. 2007; Brunker and O-Fischer, 2008; ABS, 2008; Todhunter and Abello, 2011; Rotaru, Dzhumasheva and Soriano, 2013; and Rotaru, 2013).

This paper investigates the relationship between the use of STEM/Non-STEM skills, collaboration, R&D and innovation, including novelty of innovation, among Australian businesses. Specifically, it examines the association of the following factors: business size, industry, collaboration on R&D, foreign ownership, market competition, skills shortage, working arrangement, government assistance and ICT intensity, on the likelihood of the business innovating if it is using STEM or Non-STEM skills. The impact of having R&D and collaboration on the probability of achieving a specified highest degree of novelty between businesses using STEM or Non-STEM skills is also assessed.

Firm level data from the Australian Bureau of Statistics' annual Business Characteristics Survey (BCS) are used in the analysis. The study applies probit regression modelling on the 2010-11 to 2011-12 waves of the BCS.

Conceptual Framework and Definitions

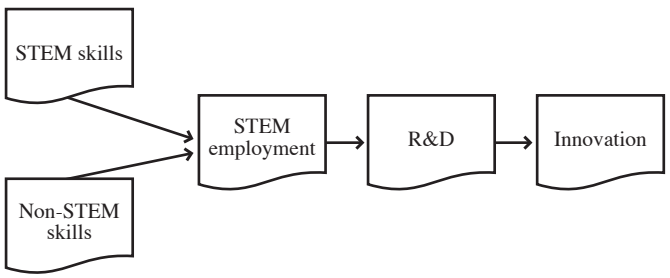
Innovation is a primary driver of a nation's economic growth. As Australia continues to compete in the global economy, Australian businesses need to be innovative to increase performance (DIISR, 2009). The association between innovation and economic growth is particularly important in an economy which is subject to binding constraints on the rate of growth of its primary inputs. In the current economic environment, Australia is experiencing an increasing incidence of such constraints particularly in relation to skilled labour markets (ABS, 2008).

An educated and skilled workforce is essential for successful innovation. Under normal circumstances, innovation increases productivity and creates prosperity. However, in reality in many cases, the link between innovation and productivity is convoluted and it may take many years for innovations to increase productivity. The relationship between skills and innovation in the long term, cycles. The skills of the workforce and management determine the innovation that takes place, which then help determine the demand for skills in a business, which then influence the innovation and so on (Tether, *et al*. 2005).

Research and experimental development work leads to innovation. Van Zon's (2001) model had demonstrated the link between skills and innovation through R&D. People with STEM capabilities (skills, knowledge and ways of thinking) are employed to drive R&D work. STEM capabilities come primarily from those with formal STEM qualifications, although some people employed in occupations requiring STEM skills may have non-STEM fields as their qualification. The literature review of Stanwick (2011) discussed the kind of skills which contribute to innovation. The latter also concluded that a good educational foundation is the key to promoting successful innovative practice.

Figure 1 below illustrates the relationships between the use of skilled workers, R&D and innovation.

Figure 1 - Conceptual framework for the analysis of STEM, R&D, and Innovation



Skills are typically acquired from formal education, general life experience and learning on the job. However, when policy makers talk about 'skills' they generally are referring to the skills obtained from formal education. Often qualifications and education levels are used as proxy for skills, for the simple reason that they can be quantified (Karmel, 2012).

STEM qualifications are defined according to the *Australian Standard Classification of Education, 2001*, as those of Postgraduate degree level, Master degree level, Graduate diploma and Graduate certificate level, Bachelor degree level, Advanced diploma level, and Certificates II and IV levels – in any of the fields below:

- Natural and Physical Sciences (NPS) (including Mathematical Sciences)
- Information Technology (IT)
- Engineering and Related Technologies (ERT)
- Agricultural, Environmental and Related Studies (AERS)

However, for this study, **STEM** skills variables have been constructed based on the type of skills used by a business as reported in the BCS. A business is considered to have used STEM skills if it reported using any of the following skills: Engineering, Scientific and Research, IT professionals, and IT support technicians. These are based on subjective responses by businesses to the BCS question about the types of skills used in undertaking core business activities.

Research and experimental development (R&D) comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of people, culture and society, and the use of this stock of knowledge to devise new applications. R&D contains an appreciable element of novelty and scientific or technological uncertainty, or risk, to overcome.

The R&D performed by business is investigative work that has actual or potential use in the development of new or enhanced materials, products, devices, processes, systems or services (see OECD, 2002, pp. 30-48 for the complete definition and convention of R&D).

In the current investigation, two R&D variables have been constructed and used in the modelling. The first one is business involvement in co-operative arrangements in joint research and development (i.e., collaboration in R&D). To collaborate is to participate in joint projects with other businesses or organisations (including wider parts of the business' enterprise group). The second R&D variable (i.e., expenditure on R&D) is used in the modelling of innovation novelty. This variable indicates whether or not innovating businesses have invested in research and experimental development.

The definition of **innovation** follows the Oslo Manual as '*…the implementation of a new and significantly improved product (good or service); or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations*.' (OECD, 2005, p.46)

A business is called 'innovation-active' if it engaged in any innovation activities that were implemented, ongoing or abandoned during a period. A business is called an 'innovator' if it successfully developed and implemented an innovation, which may have taken many years to complete. The current investigation is conducted for 'innovation-active' businesses.

Four types of innovation are covered in the analysis: product innovation, process innovation, organisational or managerial innovation, and marketing innovation (see OECD, 2005, pp. 48-53 for the full description of the different types of innovation). Note that a business could do more than one type of innovation.

It is important to note that many of the key variables used in this study are 'self-reported' rather than objectively measured. That is, a degree of subjective judgement on the part of the business respondent is inherent in the BCS data; for example, questions relating to the highest degree of innovation novelty (new to the world, new to Australia, new to the industry or new to the business). In such cases, the modelled outcomes should be properly interpreted as relating to the predicted likelihood of certain outcomes.

Appendix A1 gives more definitions, including those of the variables used in the models.

2. Data

The analysis used data from the ABS Business Characteristics Survey which has detailed information on the types of skills used in the business, business demographics, innovation activity, ICT usage, R&D expenditure, innovation novelty, and many other variables relevant to the analysis. The study utilised firm level data for Australian businesses covered by the 2010-11 to 2011-12 waves of the BCS. The data is based

on the ANZSIC 2006 classification of industry. For each wave of the BCS, a unique sample was constructed from the responses of the small, medium-sized, large and complex businesses. (See ABS (2013b) for more information about the survey.)

3. Methodology

The analysis used standard probit modelling (see Wooldridge, 2010) to help answer the research questions above. A number of models have been estimated-three were binary probit models and three were ordered probit models. A model was run to establish the relationship between the use of STEM/Non-STEM skills, R&D and the degree of novelty of innovation among Australian innovating businesses. Weights were not used in the modelling as the variables used in the sample stratification design (i.e., industry and employment-based size) were already included as explanatory variables.

The study also examined the impact of the use of STEM/Non-STEM skills on business innovation and on the probability of achieving a specified highest degree of novelty. The marginal effects (or predicted probabilities) were also computed.

All modelling procedures were executed using SAS and STATA 12. Appendix A2 shows the details of the regression models.

4. Results

Cross-tabulations

The BCS covers four broad types of innovation (goods or services, operational processes, organisational/managerial processes, and marketing methods) across three innovation statuses (introduced, still in development, and abandoned). Businesses were asked to indicate if they had introduced any new or significantly improved type of innovation during the reference period (i.e., year ending 30 June 2011 for 2010-11 and year ending 30 June 2012 for 2011-12). Businesses could report multiple types of innovation and/or multiple innovation statuses. In the BCS, all businesses were also asked to report the types of skills used in undertaking their core business activities during the reference period. Again, businesses could report multiple types of skills used.

Table 1 presents the proportion of Australian businesses that engaged in any innovation activities by skills used in the two reference years. The table also shows the estimated proportion for innovation active businesses, i.e., those that undertook any innovative activity irrespective of whether the innovation was introduced, still in development or abandoned. Readers may again refer to appendix A1 for the full description of the five categories of skills used in the table.

Table 1 - Proportion of Innovating and Non-innovating Businesses using STEM and Other Skills, 2010-11 and 2011-12

Skills used	*Estimated number of businesses* (A) '000	*Businesses that introduced any new or significantly improved goods or services* (B) %	*Businesses that introduced any new or significantly improved operational processes* (C) %	*Businesses that introduced any new or significantly improved organisational/ managerial processes* (D) %	*Businesses that introduced any new or significantly improved marketing methods* (E) %	*Businesses with innovative activity which was abandoned or still in development* (F) %	*Businesses with any innovative activity (innovation–active businesses)* (G) %	*Businesses that did not have any-innovative activity (non innovation–active businesses)* (H) %
2011-12								
STEM and Non-STEM skills	224	29.1	31.9	37.4	31.8	44.9	66.7	33.3
STEM skills only	44	26.7	21.0	23.9	22.2	32.8	52.3	47.7
Other Non-STEM skills only	387	16.9	13.6	17.2	14.6	19.0	37.5	62.5
Trades and other Non-STEM skills	47	17.7	18.6	21.5	21.4	30.0	49.4	50.6
Trade skills only	74	10.6	8.5	10.9	9.4	12.1	28.3	71.7
TOTAL	776	20.4	19.1	23.0	19.9	27.3	46.6	53.4
2010-11								
STEM and Non-STEM skills	202	28.0	28.7	33.0	28.1	36.6	60.0	40.1
STEM skills only	50	23.4	19.2	20.0	15.8	24.9	45.5	54.5
Other Non-STEM skills only	397	12.9	11.0	12.5	12.6	15.6	29.8	70.2
Trades and other Non-STEM skills	50	11.1	13.1	17.3	12.2	23.6	35.8	64.2
Trade skills only	65	10.4	11.4	14.2	11.6	9.6	28.8	71.2
TOTAL	764	17.3	16.4	18.9	16.8	21.8	39.1	61.0

Note: Column A contains the estimated number of Australian businesses by skills used, and is the denominator used in calculating the proportions in columns B to H. Columns B to E contain the proportion of businesses that introduced a particular type of innovation by skills used. Column F contains the proportion of businesses with any innovative activity which was abandoned or still in development by skills used. Columns G and H contain the percentage frequency distributions for innovation-active and non-innovation-active businesses in each skills used category. Column G plus column H equals 100%.

Skills used and innovation-active businesses

From table 1, we observed that the proportion of businesses that were innovation-active in 2011-12 was 66.7 per cent, a significant increase of 6.7 percentage points from the previous year. For businesses that indicated using Trade skills only, and Other non-STEM skills only, the estimated proportion of non-innovation-active businesses was significantly higher than the proportion of innovation-active businesses (in both years).

Skills used and different types of innovation

Businesses that used a combination of STEM and Non-STEM skills were significantly more likely to engage in any one of the three broad types of innovation than other businesses. There was no significant difference between businesses using STEM skills only and STEM and Non-STEM skills in terms of the proportion engaged in goods and services innovation in 2011-12. In addition, businesses using the said skills categories were significantly more likely to engage in this type of innovation than other businesses. Businesses that reported using STEM and Non-STEM skills were significantly more likely than other businesses to have abandoned or still be in the development process of innovation activities.

Modelling and Impact Analysis

Below are the selected key findings coming from the different models. The regression modelling outputs are in appendix A3.

For the purpose of this paper, all calculated marginal effects are with reference to a firm that is small in size, has moderate ICT intensity, no skill shortage within business, no skill shortage within labour market, no effective competition, 100 per cent Australian owned, no flexible working arrangements, and received no government assistance.

STEM skills and innovation

The use of STEM skills is strongly associated with the likelihood of innovation. The predicted probability of being an innovator rises from 24.1 per cent for a non-STEM skills user to 38.3 per cent for a STEM skills user in 2011-12.

Other factors associated with innovating businesses

Also positively and significantly associated with innovation are higher ICT intensity, having minimal to strong degree of market competition, having flexible working arrangements, having >0 per cent to 50 per cent foreign ownership, lacking skilled staff, and receiving government financial assistance.

Cooperative arrangements or collaboration in R&D

Having cooperative arrangements or collaboration in R&D is also found to be strongly associated with innovation. The combined impact of collaboration in R&D and use of STEM skills on the likelihood of innovation is very strong. Collaborating businesses which use STEM skills have a 48.3 per cent (in 2010-11) and 53.0 per cent (in 2011-12) chances of innovating. A business which does not engage in any cooperative

arrangement in R&D as well as not using any STEM skills has lower chances of innovating (i.e., 19.2 per cent in 2010-11 and 22.9 per cent in 2011-12).

Business size

Where results are significant, business size is strongly associated with an increase in the predicted probability of innovation if the business uses STEM skills. In addition, generally for all business sizes, the model predicts that a reference firm in the Manufacturing industry that collaborates has more chances of innovating than a firm that does not engage in collaboration. Specifically, for 2011-12, the model predicts that a micro (1-4 employees) business has a 56.8 per cent chance of innovating if it uses STEM skills, compared with 60.5 per cent for small (5-19 employees), 57.9 per cent for medium (20-199 employees), and 52.7 for large (200+ employees) businesses.

Use of STEM skills across industries

The probability of innovation is relatively higher for a business that uses STEM skills compared with a business that does not use STEM skills, in all of the industries. Relative to the manufacturing industry, financial and insurance services (in 2010-11 only), businesses in retail trade and wholesale trade industries have relatively higher likelihood of innovation.

Types of innovation

The use of STEM skills and collaboration in R&D are strongly associated with higher likelihood of innovating in all types of innovation. In 2011-12, for goods and services innovation, collaborating businesses which use STEM skills have 32.1 per cent probability of innovating compared with 22.3 per cent for businesses that do not use STEM skills. For operational processes innovation, collaborating businesses which use STEM skills have 25.9 per cent likelihood of innovating compared with 15.8 per cent for businesses that do not use STEM skills. For organisational/managerial processes innovation, collaborating businesses that use STEM skills have 31.8 per cent likelihood of innovation compared with 20.4 per cent for businesses not using STEM skills. For marketing methods innovation, collaborating businesses that use STEM skills have a 15.6 per cent likelihood of innovation compared with 9.5 per cent for businesses not using STEM skills. The results were similar for 2010-11.

Degree of novelty in innovation

Innovating businesses that use STEM skills are significantly more likely to achieve a higher degree of novelty of innovation than innovating businesses that do not use STEM skills. On average, a small non-collaborating Australian-owned innovating business in manufacturing that is not engaged in R&D, but is using STEM skills, is 63.6 per cent more likely to achieve a highest degree of novelty of 'new to the world' than a firm not using STEM skills; or 39.5 per cent more likely to achieve a highest degree of novelty of 'new to Australia' than a firm not using STEM skills.

Having expenditure in R&D is significantly associated with an increase in the predicted probability of achieving a 'new to the world' innovation. The model

predicts that a small non-collaborating Australian owned innovating business in the Manufacturing industry that is investing in R&D has an 11.2 per cent probability of having a 'new to the world' innovation, compared with 3.6 per cent for a similar business that is not engaged in R&D.

Having cooperative arrangements in R&D is associated with statistically significant but relatively modest increases in the probability of higher degrees of innovation novelty among innovating businesses. This probability is higher if the business uses STEM skills. Innovating businesses having collaboration in R&D, expenditure in R&D, and using STEM skills are 15 per cent more likely to achieve 'new to the world' innovation, compared with 10.7 per cent for similar businesses that do not use STEM skills.

5. Conclusion

This paper investigated the relationship between the use of STEM/Non-STEM skills, collaboration, R&D and innovation among Australian businesses. It explored the association between use of skills and innovation for each type of innovation (i.e., goods and services, operational processes, organisational/managerial processes, marketing methods). It also examined the relationship between the degree of novelty of innovation achieved by innovating Australian businesses, whether they are using STEM skills or not. Other relevant business characteristics such as business size, industry of operation, skill shortages, degree of market competition, degree of foreign ownership, ICT intensity, flexible working arrangements, and government financial assistance were also taken into account alongside collaboration and R&D.

The data available from the ABS BCS have proven to be adequate to model the above relationships using standard probit modelling procedures.

The probit regression models found that the use of STEM skills and collaboration in R&D are very strongly associated with an increase in the likelihood of being an innovating business. In most cases, the following variables: ICT intensity, market competition, lacking skilled staff, flexible working arrangements and government financial assistance are found to be significantly associated with a higher likelihood of being an innovator. The predicted probability for achieving a highest degree of innovation novelty is higher for an innovating business which is using STEM skills and has invested in R&D than for an innovating business not using STEM skills and has not invested in R&D.

Possible future work that would further enhance the current investigation is to consider labour productivity and link it with innovation and use of STEM/Non-STEM skills. The Australian Bureau of Statistics is currently in the process of creating an 'Expanded Analytical Business Longitudinal Database (EABLD)' that could provide a rich data source for micro level labour productivity analysis and panel data modelling.

Appendices

A1 Definitions of Variables

This section describes the compilation of the variables used in the analysis.

Innovation

The scope of innovative activity, as measured by the BCS, follows the Oslo Manual (OECD, 2005) and covers four broad types of innovation:

- *Goods or services* – Any good or service or combination of these which is new to a business (or significantly improved). Its characteristics or intended uses differ significantly from those previously produced/offered.
- *Operational processes* – New or significantly improved methods of producing or delivering goods or services of a business (including significant change in techniques, equipment and/or software).
- *Organisational/managerial processes* – New or significantly improved strategies, structures or routines of a business which aim to improve performance.
- *Marketing methods* – New or significantly improved design, packaging or sales methods aimed to increase the appeal of goods or services of a business or to enter new markets.

There are three statuses of innovation, namely:

- *Introduced or implemented* – the business successfully introduced or implemented an innovation during the reference period (although the innovation does not need to have been commercially successful);
- *Still in development* – the business was in the process of developing, introducing or implementing an innovation during the reference period but work on the innovation was still in progress at the end of the period; and,
- *Abandoned* – the business abandoned the development and/or introduction of an innovation during the reference period (i.e., work on the innovation ceased without full introduction occurring).

A business is called 'innovation-active' if it engaged in any innovation activities that were implemented, still in development or abandoned during the period. Note that in the BCS, businesses could report more than one type of innovation.

The BCS also asked the degree of novelty of innovation achieved by innovating Australian businesses. The degree of novelty are categorised as:

- Innovation is new to the world;
- Innovation is new to Australia but not new to the world;
- Innovation is new to the industry within Australia but not new to the world or Australia; and,
- Innovation is new to the business only. The table below describes the different innovation (dependent) variables used for modelling.

Description	*Range of Values*
Innovation (binary) Firm engaged/not engaged in any types of innovation (i.e., overall measure of innovation)	0/1 dummy
Innovation (binary) – for particular type of innovation Firm engaged/not engaged in this type of innovation, say • Goods and services • Operational processes • Organisational/Managerial processes • Marketing methods	0/1 dummy
Innovation Diversity (categorical) • No innovation activity at all • Exactly 1 type of innovation • Exactly 2 types of innovation • Exactly 3 types of innovation • Exactly 4 types of innovation	0 to 4
Innovation Novelty (categorical) • Innovation is new to the world • Innovation is new to Australia but not new to the world • Innovation is new to the industry within Australia but not new to the world or Australia • Innovation is new to the business only	3 to 0

STEM Skills

Two forms of STEM/Non-STEM skills variables have been constructed, a binary and a categorical. The categorical variable was designed to refine and capture the association of the use the different types of skills (e.g., STEM; Non-STEM; Trade; and Other Non-STEM) on business innovation.

Description	*Range of Values*
STEM Skills (binary) Firm used/not used any of the following types of STEM skills • Engineering • Scientific and Research • IT professionals • IT support technicians	0/1 dummy
STEM/Non-STEM Skills (categorical) • Firm did use any STEM skills and Non-STEM skills (i.e., Trade or Other Non-STEM – Transport, plant and machinery operation; Marketing; Project management; Business management; and Financial) • Firm did use STEM skills only • Firm did use Trade skills only • Firm did use Trade and Other Non-STEM skills only • Firm did use Other Non-STEM skills only	0/1 dummy (each category)

Collaboration and R&D

The following collaboration and R&D indicators were also compiled.

Description	*Range of Values*
Collaboration in R&D (binary) Business was involved in co-operative arrangement for joint research and development (R&D)	0/1 dummy
Expenditure on R&D (binary) Business reported having expenditure on research and experimental development either acquired from other firms or performed by the businesses itself, for innovation	0/1 dummy

Selected key business characteristics

The other key business characteristics employed in the modelling are described below. The selection of the key business characteristics has been mainly based on the two recent research publications of ABS on innovation. See Rotaru (2013); and Rotaru, *et al*. (2013) for more information about the justification for their selection. Skill shortage indicators have been added following the ABS (2008) paper submission to the Innovation Review.

Description	*Range of Values*
Number of employees (business size) • 1-4 Employees • 5-19 Employees • 20-199 Employees • 200+ Employees	0/1 dummy (each category)
Degree of competition in the market • No effective competition (0 competitor) • Minimal (1-2 competitors) • Moderate to strong (3 or more competitors)	0/1 dummy (each category)
Degree of foreign ownership • 100 per cent Australian owned • > 0 per cent to 50 per cent foreign owned • > 50 per cent foreign owned	0/1 dummy (each category)
Industry division *(ANZSIC2006)* • Agriculture, Forestry and Fishing • Mining • Manufacturing • Electricity, water, gas and waste services • Construction • Wholesale • Retail Trade • Accommodation and food service • Transport, postal and warehousing • Information, media and telecommunications • Financial and insurance services • Rental, hiring and real estate services • Professional, scientific and technical services • Administrative and support services	0/1 dummy (each category)

Description	*Range of Values*
• Health care and social assistance • Arts and recreation services • Other services	
ICT intensity • Most intense *Business had broadband connection, web presence, and places or receives orders via the internet or web* • High *Business had broadband connection, web presence, but does not receive orders via the internet or web* • Moderate *Business had broadband connection, but has no web presence* • Low *Business does not use broadband connection*	0/1 dummy (each category)
Flexible Working Arrangement (binary) Firm offered the following working arrangements to their employees: • Flexible working hours • Flexible leave • Job sharing • Working from home	0/1 dummy
Government financial assistance (binary) Firm received/not received any form of assistance (i.e., grants, on-going funding; tax concession; subsidies; rebates; and other government financial assistance)	0/1 dummy
Skills shortage (binary) • Firm reported that lack of skilled persons within the business significantly hampers their innovation • Firm reported that lack of skilled persons within the labour market significantly hampers their innovation	0/1 dummy (each)

A2 Methodology

The following methodological approaches have been used to answer the research questions.

Probit regression

To address the research question:

- *What is the relationship between the use of STEM/Non-STEM skills, collaboration in R&D and innovation among Australian businesses?*

Five models (i.e., Models 1-5) have been specified and estimated using the standard probit modelling procedure.

Model 1. Binary probit with binary STEM skill

The first model is given by

Innovation = Binary Probit (*STEM skills*, X_2)

where:

Innovation – Binary variable taking the value 1 if the business was innovative and 0 otherwise

STEM skills – Binary

X_2 stands for the vector of other variables included in the model. These variables included the following:

- Business size
- Industry of operation
- Cooperative R&D
- Market Competition
- Foreign Ownership
- Flexible Working Arrangement
- Government Financial Assistance
- ICT intensity
- Skill shortage.

Note that in order to specify the binary probit model we can follow the traditional approach of using the latent variable y_i^* to determine the binary variable, y_i, a binary variable indicating whether a firm innovated (i.e., $y_i = 1$) or not (i.e., $y_i = 0$) the latent variable is given by

$$y_i^* = X_{1,i}\ \beta + \varepsilon_i\ \forall\, i = 1,\ldots,N$$

where ε_i is the random error term (which is assumed to have a standard normal distribution), N stands for total number of businesses, $X_{1,i}$ is a ($1\ x\ k$) vector of conditioning variables for business i (i.e. X_2 including the STEM skills), and β is a vector of parameters corresponding to the k conditioning variables. However, as y_i^* is unobserved in practice, we used the observed dichotomous variable y_i which indicates the sign of the latent variable, y_i^*. Note that y_i is given by

$$y_i = \begin{cases} 1, & if\ y_i^* > 0 \\ 0, & otherwise. \end{cases}$$

Following this approach, the binary probit model is specified by

$$P(y_i = 1|X_1) = P(y_i^* > 0|X_1) = \Phi(X_1\beta)$$

where $\Phi(.)$ is the standard normal cumulative distribution function. Note that the values of the parameter vector β were estimated using maximum likelihood estimation (MLE).

Model 2. Binary probit with categorical STEM/Non-STEM skills

The second model is the same as the first model but with categorical skills variable. The categorical variable is designed to capture the association of the use the other types of skills (i.e. Trade and Non-STEM) on innovation. The skills variable is defined as follows:

- Firm did use any STEM skills and Non-STEM skills (i.e., Trade or Other Non-STEM – Transport, plant and machinery operation; Marketing; Project management; Business management; and Financial)
- Firm did use STEM skills only
- Firm did use Trade skill only
- Firm did use Other Non-STEM skills only
- Firm did use Trade and Other Non-STEM skills only

Model 3. Binary probit for a particular type of innovation

The third model is a variation of models 1 and 2 with the dependent variable (i.e., innovation) taking a value of 1 if the firm performed a particular type of innovation (e.g., goods and services) and 0 otherwise. This model is run for each of the four types of innovation with either a binary STEM skills or categorical skills variables.

Model 4. Ordered probit with binary STEM skills

The fourth model is an ordered probit given by:

Innovation = Ordered Probit (*STEM skills,* X_2).

In this case, all covariates are the same as in Model 1 but Innovation is categorical (or polychotomous) having the following subcategories: no innovation, exactly 1 type of innovation, exactly 2 types of innovation, exactly 3 types of innovation, and exactly four types of innovation.

The derivation of this model is not too different from the previous binary probit model derivation. The difference now consists in the fact that the innovation variable y_i has five values, 0 if there is no innovation, 1 if the business engaged in exactly one type of innovation, 2 if the business engaged in exactly two types of innovation, 3 if the business engaged in exactly three types of innovation, and 4 if the business engaged in exactly four types of innovation.

By considering the latent variable y_i^* and the threshold parameters ($\gamma_1, \gamma_2, \ldots, \gamma_4$), y_i can be determined as

$$y_i = \begin{cases} 0, \text{ if } y_i^* \le \gamma_1 \\ 1, \text{ if } \gamma_1 < y_i^* \le \gamma_2 \\ 2, \text{ if } \gamma_2 < y_i^* \le \gamma_3 \\ 3, \text{ if } \gamma_3 < y_i^* \le \gamma_4 \\ 4, \text{ if } y_i^* > \gamma_4 \end{cases}$$

The model is then specified by:

$$P(y_i = 0|X_1) = P(y_i^* \le \gamma_4|X_1) = 1 - \Phi(X_{1,i}\beta - \gamma_1)$$
$$P(y_i = 1|X_1) = P(\gamma_1 < y_i^* \le \gamma_2|X_1) = \Phi(X_{1,i}\beta - \gamma_1) - \Phi(X_{1,i}\beta - \gamma_2)$$
$$P(y_i = 2|X_1) = P(\gamma_2 < y_i^* \le \gamma_3|X_1) = \Phi(X_{1,i}\beta - \gamma_2) - \Phi(X_{1,i}\beta - \gamma_3)$$
$$P(y_i = 3|X_1) = P(\gamma_3 < y_i^* \le \gamma_4|X_1) = \Phi(X_{1,i}\beta - \gamma_3) - \Phi(X_{1,i}\beta - \gamma_4)$$
$$P(y_i = 4|X_1) = P(y_i^* > \gamma_4|X_1) = \Phi(X_{1,i}\beta - \gamma_4)$$

where, as before, Φ(.)stands for the standard normal cumulative distribution function. Once again the parameters were estimated using MLE.

Model 5. Ordered probit with categorical STEM/Non-STEM skills

The fifth innovation model is the same as the fourth model but with a categorical skills variable. In this case, all covariates are the same as in Model 2. To address the research question:

- *What is the relationship between the use of STEM/Non-STEM skills, collaboration inR&D, R&D expenditure and the degree of novelty of innovation among Australian innovating businesses?*

another model has been specified and estimated again using the standard probit modelling procedure. The model is run for a sample of innovating firms only.

Model 6. Ordered probit on innovation novelty with binary collaboration

The sixth innovation model is an ordered probit given by:

Degree of Innovation Novelty = Ordered Probit (*Skills, Collaboration in R&D, Expenditure on R&D,* X_3).

where:

Degree of Innovation Novelty is categorical (or polychotomous) having the following subcategories:

- Innovation is new to the business only
- Innovation is new to the industry within Australia but not new to the world or Australia
- Innovation is new to Australia but not new to the world
- Innovation is new to the world

Skills – Either a binary STEM skills or categorical skills variables

X_3 stands for the vector of other covariates included in the model. These are:

- Business size
- Industry of operation
- Foreign Ownership.

The estimation procedure for the above model follows that of Model 4.

Impact Analysis

The modelling conducted here are all cross-sectional in nature and as such it is not possible to establish the existence or direction of 'causality' between the various conditioning (business characteristics) variables and innovation. While there may be broadly or particularly prior views in relation to causality, the current analysis can establish only statistical association between the conditioning variables and innovation.

However, the impact of using STEM/Non-STEM skills on the likelihood of business innovating can be investigated. Also, the impact of using STEM/Non-STEM skills on the probability of engaging in a particular type of innovation can also be measured. Hence, to complement the interpretation of the regression results, the all-else-equal incremental impacts of selected conditioning variables are also calculated. These are referred to as 'marginal' effects even though the conditioning variables were in almost all cases discrete. For binary variables (e.g., use of STEM skill vs. not use of STEM skill), the 'marginal' effect was the increment to the probability arising

from varying the variable from 0 to 1. While for categorical variables, the effect was the increment to the probability from moving from the reference value to the value in question.

The DITR (2006, pp. 32-34; and 2007, p. 40-41) studies provide an illustration of the methodology behind the estimation of this 'marginal' effect (i.e. impact on probability).

A3 Selected Regression Results

Table A1 - Results of the Probit (binary) Model for Innovation with STEM Skills as Binary

Variable	*2010-11*	*2011-12*
Intercept	-0.548 ***	-0.081
STEM skills		
Not used STEM skills		
Used STEM skills	0.440 ***	0.405 ***
Skills shortage within business hampering innovation		
No skills shortage		
Have skills shortage	0.316 ***	0.368 ***
Skills shortage within labour market hampering innovation		
No skills shortage		
Have skills shortage	0.147 ***	0.296 ***
ICT Intensity		
ICT_intensity=1 (Most intense)		
ICT_intensity=2 (High)	-0.318 ***	-0.372 ***
ICT_intensity=3 (Moderate)	-0.666 ***	-0.741 ***
ICT_intensity=4 (Low)	-0.824 ***	-1.055 ***
Number of employees		
1-4 employees	-0.101 **	-0.095
5-19 employees		
20-199 employees	-0.010	-0.067
200+ employees	-0.122 **	-0.197 ***
Market competition		
No effective competition		
Minimal	0.333 ***	0.310 ***
Moderate to strong	0.367 ***	0.281 ***
Foreign ownership		
100% Australian owned		
Foreign ownership > 0% to 50%	0.226 **	0.236 **
Foreign ownership > 50%	0.056	0.047
Collaboration in R&D		
Joint R&D (co-operative) agreement	0.387 ***	0.413 ***
No joint R&D (co-operative) agreement		
Flexible Working Arrangement		
Have flexible working arrangements	0.378 ***	0.296 ***
No flexible working arrangement		
Government financial assistance		
Received government assistance	0.152 ***	0.189 ***
Not received government assistance		
Industry		
Manufacturing		
Accomodation and food services	-0.067	-0.205 **
Administrative and support services	-0.105	-0.103
Agriculture, forestry and fishing	-0.048	-0.212 *

Table A1 - Results of the Probit (binary) Model for Innovation with STEM Skills as Binary (continued)

Variable	*2010-11*	*2011-12*
Arts and recreation services	-0.042	-0.020
Construction	-0.181 **	-0.267 ***
Electricity, water, gas and waste services	0.051	-0.152
Financial and insurance services	0.167 *	-0.140
Health care and social assistance	-0.023	-0.079
Information, media and telecommunications	0.035	-0.079
Mining	-0.471 ***	-0.408 ***
Other services	0.028	-0.141
Professional, scientific and technical services	-0.087	-0.234 ***
Rental, hiring and real estate services	-0.183 **	-0.185
Retail Trade	0.192 **	0.062
Transport, postal and warehousing	-0.229 ***	-0.216 **
Wholesale trade	0.106	0.010
Number of observations (n)	7548	5554
AIC	8765.5	6219.3
Log Likelihood	-4349.7	-3076.6

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table A2 - Results of the Probit (binary) Model for Innovation with STEM/ Non-STEM Skills as Categorical

Variable	*2010-11*	*2011-12*
Intercept	-0.558 ***	-0.074
STEM skills		
Other Non-STEM skills only		
STEM and Non-STEM skills	0.470 ***	0.430 ***
STEM skills only	0.354 ***	0.229 **
Trade skills only	0.030	-0.123
Trade and other Non-STEM skills only	0.105	0.129
Skills shortage within business hampering innovation		
No skills shortage		
Have skills shortage	0.314 ***	0.366 ***
Skills shortage within labour market hampering innovation		
No skills shortage		
Have skills shortage	0.141 ***	0.293 ***
ICT Intensity		
ICT_intensity=1 (Most intense)		
ICT_intensity=2 (High)	-0.316 ***	-0.367 ***
ICT_intensity=3 (Moderate)	-0.666 ***	-0.733 ***
ICT_intensity=4 (Low)	-0.822 ***	-1.051 ***
Number of employees		
1-4 employees	-0.099 **	-0.095
5-19 employees		
20-199 employees	-0.013	-0.073
200+ employees	-0.131 **	-0.212 ***
Market competition		
No effective competition		
Minimal	0.331 ***	0.304 ***
Moderate to strong	0.363 ***	0.276 ***

Table A2 - Results of the Probit (binary) Model for Innovation with STEM/ Non-STEM Skills as Categorical (continued)

Variable	*2010-11*	*2011-12*
Foreign ownership		
100% Australian owned		
Foreign ownership > 0% to 50%	0.227 **	0.238 **
Foreign ownership > 50%	0.058	0.045
Collaboration in R&D		
Joint R&D (co-operative) agreement	0.385 ***	0.409 ***
No joint R&D (co-operative) agreement		
Flexible Working Arrangement		
Have flexible working arrangements	0.373 ***	0.292 ***
No flexible working arrangement		
Government financial assistance		
Received government assistance	0.147 ***	0.186 ***
Not received government assistance		
Industry		
Manufacturing		
Accomodation and food services	-0.062	-0.205 **
Administrative and support services	-0.095	-0.099
Agriculture, forestry and fishing	-0.050	-0.230 *
Arts and recreation services	-0.033	-0.023
Construction	-0.191 **	-0.265 ***
Electricity, water, gas and waste services	0.049	-0.159
Financial and insurance services	0.173 *	-0.143
Health care and social assistance	-0.006	-0.072
Information, media and telecommunications	0.048	-0.062
Mining	-0.472 ***	-0.414 ***
Other services	0.026	-0.127
Professional, scientific and technical services	-0.072	-0.221 **
Rental, hiring and real estate services	-0.177 **	-0.189
Retail Trade	0.199 **	0.058
Transport, postal and warehousing	-0.227 ***	-0.224 **
Wholesale trade	0.112	0.007
Number of observations (n)	7548	5554
AIC	8767.1	6216.8
Log Likelihood	-4347.6	-3072.4

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table A3 - Results of the Probit (binary) Model for the Different Types of Innovation with STEM Skills as Binary

	Goods and Services		*Operational Processes*		*Organisational/Managerial*		*Marketing Methods*	
Variable	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*
Intercept	-0.976 ***	-0.714 ***	-1.008 ***	-0.571 ***	-1.210 ***	-0.816 ***	-1.325 ***	-0.923 ***
STEM skills								
Not used STEM skills								
Used STEM skills	0.379 ***	0.296 ***	0.383 ***	0.355 ***	0.361 ***	0.354 ***	0.295 ***	0.298 ***
Skills shortage within business hampering innovation								
No skills shortage								
Have skills shortage	0.202 ***	0.307 ***	0.285 ***	0.300 ***	0.349 ***	0.394 ***	0.287 ***	0.237 ***
Skills shortage within labour market hampering innovation								
No skills shortage								
Have skills shortage	0.132 ***	0.146 **	0.149 ***	0.239 ***	0.202 ***	0.220 ***	0.140 ***	0.160 **
ICT Intensity								
ICT_intensity=1 (Most intense)								
ICT_intensity=2 (High)	-0.257 ***	-0.253 ***	-0.272 ***	-0.324 ***	-0.211 ***	-0.247 ***	-0.199 ***	-0.356 ***
ICT_intensity=3 (Moderate)	-0.465 ***	-0.540 ***	-0.475 ***	-0.536 ***	-0.431 ***	-0.510 ***	-0.766 ***	-0.843 ***
ICT_intensity=4 (Low)	-0.456 ***	-0.640 ***	-0.634 ***	-0.965 ***	-0.678 ***	-0.874 ***	-0.852 ***	-1.033 ***
Number of employees								
1-4 employees	-0.032	0.055	-0.080	-0.187 ***	-0.135 ***	-0.220 ***	0.095 *	0.027
5-19 employees								
20-199 employees	-0.133 **	-0.142 *	0.115 **	-0.040	0.101 **	-0.044	-0.059	-0.214 ***
200+ employees	-0.232 ***	-0.249 ***	0.123 **	0.073	0.041	-0.017	-0.293 ***	-0.345 ***
Market competition								
No effective competition								
Minimal	0.342 ***	0.503 ***	0.182 **	0.169 **	0.176 **	0.184 **	0.403 ***	0.229 **
Moderate to strong	0.309 ***	0.422 ***	0.187 ***	0.159 **	0.220 ***	0.177 ***	0.470 ***	0.391 ***
Foreign ownership								
100% Australian owned								
Foreign ownership > 0% to 50%	0.244 ***	0.117	0.102	0.079	0.110	0.241 ***	0.167 *	0.173 *
Foreign ownership > 50%	0.142 **	0.193 ***	0.059	-0.027	0.097 *	0.011	-0.005	-0.002

Table A3 - Results of the Probit (binary) Model for the Different Types of Innovation with STEM Skills as Binary (continued)

	Goods and Services		*Operational Processes*		*Organisational/Managerial*		*Marketing Methods*	
Variable	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*
Collaboration in R&D								
Joint R&D (co-operative) agreement	0.401 ***	0.330 ***	0.354 ***	0.329 ***	0.387 ***	0.399 ***	0.259 ***	0.245 ***
No joint R&D (co-operative) agreement								
Flexible Working Arrangement								
Have flexible working arrangements	0.299 ***	0.187 ***	0.303 ***	0.246 ***	0.370 ***	0.370 ***	0.323 ***	0.224 ***
No flexible working arrangement								
Government financial assistance								
Received government assistance	0.146 ***	0.118 ***	0.140 ***	0.111 **	0.165 ***	0.128 ***	0.159 ***	0.072
Not received government assistance								
Industry								
Manufacturing								
Accomodation and food services	-0.171 **	-0.249 ***	-0.219 ***	-0.455 ***	-0.005	-0.272 ***	0.290 ***	0.305 ***
Administrative and support services	-0.368 ***	-0.424 ***	-0.082	-0.265 **	0.110	0.045	0.105	0.158 *
Agriculture, forestry and fishing	-0.430 ***	-0.831 ***	0.017	-0.144	-0.034	0.039	0.011	-0.029
Arts and recreation services	-0.208 ***	-0.322 ***	-0.189 **	-0.311 ***	0.009	-0.268 **	0.316 ***	0.414 ***
Construction	-0.560 ***	-0.723 ***	-0.195 **	-0.275 ***	0.089	0.037	-0.302 ***	-0.179 **
Electricity, water, gas and waste services	-0.475 ***	-0.718 ***	0.143	-0.092	0.106	-0.121	-0.144	-0.173
Financial and insurance services	-0.080	-0.305 **	0.273 ***	-0.079	0.279 ***	0.057 *	0.245 **	0.099
Health care and social assistance	-0.274 ***	-0.319 ***	-0.112	-0.240 ***	0.085	0.137 *	0.024	0.167 **
Information, media and telecommunications	0.142 *	-0.065	-0.058	-0.249 **	-0.097	-0.161	0.183 **	0.098
Mining	-0.903 ***	-1.088 ***	-0.272 ***	-0.349 ***	-0.231 ***	-0.228 **	-0.793 ***	-0.738 ***
Other services	-0.204 **	-0.368 ***	-0.125	-0.361 ***	-0.023	0.041	0.241 ***	-0.020
Professional, scientific and technical services	-0.281 ***	-0.399 ***	-0.118	-0.332 ***	0.099	-0.060	-0.010	-0.075
Rental, hiring and real estate services	-0.416 ***	-0.579 ***	-0.141	-0.225 *	0.124	0.108	0.108	0.235 **
Retail Trade	0.083	-0.087	-0.036	-0.208 **	0.125	-0.133	0.387 ***	0.398 ***
Transport, postal and warehousing	-0.540 ***	-0.513 ***	0.006	-0.098	0.087	-0.071	-0.235 ***	-0.113
Wholesale trade	0.120	-0.071	-0.009	-0.123	0.112	-0.024	0.247 ***	0.280 ***
Number of observations (n)	7548	5554	7548	5554	7548	5554	7548	5554
AIC	7989.8	6240.7	8490.3	6438.4	8486.9	6483.7	7946.7	6220.6
Log Likelihood	-3961.9	-3087.3	-4212.2	-3186.2	-4210.4	-3208.9	-3940.3	-3077.3

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table A4 - Results of the Probit (binary) Model for the Different Types of Innovation with STEM/Non-STEM Skills as Categorical

	Goods and Services		*Operational Processes*		*Organisational/Managerial*		*Marketing Methods*	
Variable	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*
Intercept	-0.959 ***	-0.687 ***	-1.010 ***	-0.542 ***	-1.227 ***	-0.799 ***	-1.345 ***	-0.923 ***
STEM skills								
Other Non-STEM skills only								
STEM and Non-STEM skills	0.390 ***	0.281 ***	0.411 ***	0.361 ***	0.419 ***	0.366 ***	0.353 ***	0.322 ***
STEM skills only	0.278 ***	0.216 **	0.250 ***	0.121	0.121	0.145	0.056	0.173 *
Trade skills only	-0.184 *	-0.252 **	-0.044	-0.257 **	0.050	-0.166	0.079	-0.108
Trade and other Non-STEM skills only	0.104	-0.018	0.104	0.031	0.155 *	0.045	0.135	0.160
Skills shortage within business hampering innovation								
No skills shortage								
Have skills shortage	0.202 ***	0.306 ***	0.284 ***	0.297 ***	0.346 ***	0.392 ***	0.283 ***	0.235 ***
Skills shortage within labour market hampering innovation								
No skills shortage								
Have skills shortage	0.131 ***	0.150 **	0.146 ***	0.243 ***	0.194 ***	0.222 ***	0.132 ***	0.158 ***
ICT Intensity								
ICT_intensity=1 (Most intense)								
ICT_intensity=2 (High)	-0.254 ***	-0.250 ***	-0.269 ***	-0.318 ***	-0.206 ***	-0.242 ***	-0.196 ***	-0.353 ***
ICT_intensity=3 (Moderate)	-0.462 ***	-0.535 ***	-0.472 ***	-0.528 ***	-0.428 ***	-0.503 ***	-0.765 ***	-0.837 ***
ICT_intensity=4 (Low)	-0.456 ***	-0.635 ***	-0.634 ***	-0.964 ***	-0.678 ***	-0.868 ***	-0.851 ***	-1.029 ***
Number of employees								
1-4 employees	-0.031	0.055	-0.078 *	-0.187 **	-0.132 ***	-0.220 ***	0.100 *	0.027
5-19 employees								
20-199 employees	-0.139 ***	-0.145 *	0.111 **	-0.049	0.095 *	-0.052	-0.064	-0.218 ***
200+ employees	-0.244 ***	-0.255 ***	0.112 **	0.056	0.023	-0.033	-0.311 ***	-0.355 ***
Market competition								
No effective competition								
Minimal	0.341 ***	0.502 ***	0.180 **	0.165 **	0.173 **	0.181 **	0.401 ***	0.226 **
Moderate to strong	0.308 ***	0.423 ***	0.184 ***	0.157 **	0.215 ***	0.174 ***	0.467 ***	0.387 ***
Foreign ownership								
100% Australian owned								
Foreign ownership > 0% to 50%	0.241 ***	0.116	0.100	0.079	0.106	0.241 ***	0.161 *	0.174 *
Foreign ownership > 50%	0.140 **	0.188 ***	0.060	-0.031	0.099 *	0.008	-0.004	-0.003

Table A4 - Results of the Probit (binary) Model for the Different Types of Innovation with STEM/Non-STEM Skills as Categorical (continued)

	Goods and Services		*Operational Processes*		*Organisational/Managerial*		*Marketing Methods*	
Variable	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*	*2010-11*	*2011-12*
Collaboration in R&D								
Joint R&D (co-operative) agreement	0.398 ***	0.331 ***	0.350 ***	0.327 ***	0.381 ***	0.396 ***	0.252 ***	0.242 ***
No joint R&D (co-operative) agreement								
Flexible Working Arrangement								
Have flexible working arrangements	0.295 ***	0.184 ***	0.299 ***	0.241 ***	0.366 ***	0.367 ***	0.318 ***	0.219 ***
No flexible working arrangement								
Government financial assistance								
Received government assistance	0.145 ***	0.120 ***	0.135 ***	0.111 **	0.154 ***	0.127 ***	0.148 ***	0.069
Not received government assistance								
Industry								
Manufacturing								
Accomodation and food services	-0.178 **	-0.260 ***	-0.217 ***	-0.462 ***	0.005	-0.276 ***	0.299 ***	0.307 ***
Administrative and support services	-0.373 ***	-0.429 ***	-0.075	-0.264 ***	0.131 *	0.048	0.125	0.162 *
Agriculture, forestry and fishing	-0.447 ***	-0.847 ***	0.009	-0.166	-0.038	0.023	0.009	-0.042
Arts and recreation services	-0.220 **	-0.334 ***	-0.188 **	-0.323 ***	0.021	-0.276 **	0.330 ***	0.412 ***
Construction	-0.564 ***	-0.700 ***	-0.201 **	-0.260 ***	0.074	0.047	-0.318 ***	-0.182 **
Electricity, water, gas and waste services	-0.492 ***	-0.726 ***	0.134	-0.101	0.100	-0.127	-0.150	-0.177
Financial and insurance services	-0.088	-0.317 ***	0.274 ***	-0.089	0.289 ***	0.052	0.255 ***	0.100 *
Health care and social assistance	-0.276 ***	-0.329 ***	-0.100	-0.242 ***	0.116	0.140 *	0.054	0.175 **
Information, media and telecommunications	0.140	-0.068	-0.049	-0.233 **	-0.073	-0.142	0.208 **	0.114
Mining	-0.917 ***	-1.093 ***	-0.278 ***	-0.356 ***	-0.234 ***	-0.232 **	-0.794 ***	-0.745 ***
Other services	-0.192 **	-0.335 ***	-0.121	-0.336 ***	-0.025	0.062	0.238 **	-0.013
Professional, scientific and technical services	-0.280 ***	-0.401 ***	-0.103	-0.319 ***	0.131 *	-0.044	0.021	-0.063
Rental, hiring and real estate services	-0.427 ***	-0.590 ***	-0.142	-0.235 **	0.134	0.101	0.119	0.234 **
Retail Trade	0.078	-0.096	-0.032	-0.215 **	0.138 *	-0.136	0.401 ***	0.397 ***
Transport, postal and warehousing	-0.553 ***	-0.525 ***	0.002	-0.113	0.089	-0.079	-0.231 **	-0.116
Wholesale trade	0.112	-0.073	-0.007	-0.124	0.123	-0.024	0.258 ***	0.280 ***
Number of observations (n)	7548	5554	7548	5554	7548	5554	7548	5554
AIC	7987.8	6241.1	8489.7	6432.3	8473.8	6481.3	7935.5	6220.4
Log Likelihood	-3957.9	-3084.6	-4208.9	-3180.1	-4200.9	-3204.6	-3931.7	-3074.2

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table A5 - Results of the Ordered Probit Model for Innovation with STEM Skills as Binary

Variable	*2010-11*	*2011-12*
Intercept		
1 type of innovation	-0.533 ***	-0.050
2 types of innovation	-0.997 ***	-0.587 ***
3 types of innovation	-1.508 ***	-1.129 ***
4 types of innovation	-2.056 ***	-1.694 ***
STEM skills		
Not used STEM skills		
Used STEM skills	0.414 ***	0.382 ***
Skills shortage within business hampering innovation		
No skills shortage		
Have skills shortage	0.312 ***	0.350 ***
Skills shortage within labour market hampering innovation		
No skills shortage		
Have skills shortage	0.174 ***	0.214 ***
ICT Intensity		
ICT_intensity=1 (Most intense)		
ICT_intensity=2 (High)	-0.274 ***	-0.345 ***
ICT_intensity=3 (Moderate)	-0.619 ***	-0.708 ***
ICT_intensity=4 (Low)	-0.762 ***	-1.019 ***
Number of employees		
1-4 employees	-0.064	-0.103 **
5-19 employees		
20-199 employees	0.006	-0.118 *
200+ employees	-0.107 **	-0.163 ***
Market competition		
No effective competition		
Minimal	0.304 ***	0.298 ***
Moderate to strong	0.329 ***	0.317 ***
Foreign ownership		
100% Australian owned		
Foreign ownership > 0% to 50%	0.177 **	0.176 **
Foreign ownership > 50%	0.075 *	0.054
Collaboration in R&D		
Joint R&D (co-operative) agreement	0.380 ***	0.366 ***
No joint R&D (co-operative) agreement		
Flexible Working Arrangement		
Have flexible working arrangements	0.369 ***	0.290 ***
No flexible working arrangement		
Government financial assistance		
Received government assistance	0.165 ***	0.137 ***
Not received government assistance		
Industry		
Manufacturing		
Accomodation and food services	-0.038	-0.188 **
Administrative and support services	-0.083	-0.134 *
Agriculture, forestry and fishing	-0.112	-0.273 ***
Arts and recreation services	-0.022	-0.115
Construction	-0.251 ***	-0.321 ***
Electricity, water, gas and waste services	-0.075	-0.288 ***
Financial and insurance services	0.188 **	-0.071
Health care and social assistance	-0.075	-0.068
Information, media and telecommunications	0.047	-0.104
Mining	-0.564 ***	-0.603 ***

Table A5 - Results of the Ordered Probit Model for Innovation with STEM Skills as Binary (continued)

Variable	*2010-11*	*2011-12*
Other services	-0.020	-0.191 *
Professional, scientific and technical services	-0.095	-0.250 ***
Rental, hiring and real estate services	-0.113	-0.146
Retail Trade	0.160 **	0.000
Transport, postal and warehousing	-0.199 ***	-0.226 ***
Wholesale trade	0.141 **	0.019
Number of observations (n)	7548	5554
AIC	19589.8	15250.6
Log Likelihood	-9758.9	-7589.3

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table A6 - Results of the Ordered Probit Model for Innovation with STEM/ Non-STEM Skills as Categorical

Variable	*2010-11*	*2011-12*
Intercept		
1 type of innovation	-0.540 ***	-0.035
2 types of innovation	-1.005 ***	-0.572 ***
3 types of innovation	-1.517 ***	-1.115 ***
4 types of innovation	-2.067 ***	-1.680 ***
STEM skills		
Other Non-STEM skills only		
STEM and Non-STEM skills	0.457 ***	0.396 ***
STEM skills only	0.245 ***	0.194 **
Trade skills only	-0.007	-0.197 **
Trade and other Non-STEM skills only	0.143 **	0.094
Skills shortage within business hampering innovation		
No skills shortage		
Have skills shortage	0.310 ***	0.348 ***
Skills shortage within labour market hampering innovation		
No skills shortage		
Have skills shortage	0.169 ***	0.216 ***
ICT Intensity		
ICT_intensity=1 (Most intense)		
ICT_intensity=2 (High)	-0.271 ***	-0.340 ***
ICT_intensity=3 (Moderate)	-0.617 ***	-0.700 ***
ICT_intensity=4 (Low)	-0.760 ***	-1.014 ***
Number of employees		
1-4 employees	-0.062	-0.103 **
5-19 employees		
20-199 employees	0.0005	-0.125 **
200+ employees	-0.122 ***	-0.177 ***
Market competition		
No effective competition		
Minimal	0.301 ***	0.294 ***
Moderate to strong	0.325 ***	0.314 ***
Foreign ownership		
100% Australian owned		
Foreign ownership > 0% to 50%	0.175 **	0.177 **
Foreign ownership > 50%	0.077 *	0.051

Table A6 - Results of the Ordered Probit Model for Innovation with STEM/ Non-STEM Skills as Categorical (continued)

Variable	*2010-11*	*2011-12*
Collaboration in R&D		
Joint R&D (co-operative) agreement	0.376 ***	0.365 ***
No joint R&D (co-operative) agreement		
Flexible Working Arrangement		
Have flexible working arrangements	0.363 ***	0.286 ***
No flexible working arrangement		
Government financial assistance		
Received government assistance	0.158 ***	0.135 ***
Not received government assistance		
Industry		
Manufacturing		
Accomodation and food services	-0.032	-0.192 **
Administrative and support services	-0.071	-0.132 *
Agriculture, forestry and fishing	-0.117	-0.291 ***
Arts and recreation services	-0.015	-0.121
Construction	-0.262 ***	-0.309 ***
Electricity, water, gas and waste services	-0.083	-0.295 ***
Financial and insurance services	0.193 **	-0.077
Health care and social assistance	-0.055	-0.065
Information, media and telecommunications	0.064	-0.087
Mining	-0.570 ***	-0.610 ***
Other services	-0.017	-0.168 *
Professional, scientific and technical services	-0.074	-0.237 ***
Rental, hiring and real estate services	-0.108	-0.152 *
Retail Trade	0.168 **	-0.005
Transport, postal and warehousing	-0.200 ***	-0.235 ***
Wholesale trade	0.147 **	0.020
Number of observations (n)	7548	5554
AIC	19579.9	15242.5
Log Likelihood	-9750.9	-7582.2

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table A7 - Results of the Ordered Probit Model for Innovation Novelty with STEM Skills as Binary, 2010-11

Variable	*2010-11*
Intercept	
New to the industry	-1.107 ***
New to Australia	-1.495 ***
New to the world	-1.991 ***
STEM skills	
Not used STEM skills	
Used STEM skills	0.208 ***
Number of employees	
1-4 employees	0.018
5-19 employees	
20-199 employees	-0.100
200+ employees	-0.170 **
Foreign ownership	
100% Australian owned	
Foreign ownership > 0% to 50%	0.133
Foreign ownership > 50%	0.310 ***
Collaboration in R&D	
Joint R&D (co-operative) agreement	0.181 ***
No joint R&D (co-operative) agreement	
Expenditure on R&D	
Have expenditure on R&D	0.586 ***
No expenditure on R&D	
Industry	
Manufacturing	
Accomodation and food services	-0.356 ***
Administrative and support services	-0.411 ***
Agriculture, forestry and fishing	-0.337 **
Arts and recreation services	-0.152
Construction	-0.459 ***
Electricity, water, gas and waste services	-0.254
Financial and insurance services	-0.287 **
Health care and social assistance	-0.280 **
Information, media and telecommunications	0.078
Mining	-0.679 ***
Other services	-0.264 *
Professional, scientific and technical services	-0.174
Rental, hiring and real estate services	-0.240
Retail Trade	-0.151
Transport, postal and warehousing	-0.266 **
Wholesale trade	-0.006
Number of observations (n)	3554
AIC	4189.5
Log Likelihood	-2067.7

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table A8 - Results of the Ordered Probit Model for Innovation Novelty with STEM/Non-STEM Skills as Categorical, 2010-11

Variable	*2010-11*
Intercept	
New to the industry	-1.048 ***
New to Australia	-1.437 ***
New to the world	-1.934 ***
STEM skills	
Other Non-STEM skills only	
STEM and Non-STEM skills	0.168 **
STEM skills only	0.204 *
Trade skills only	-0.584 **
Trade and other Non-STEM skills only	0.007
Number of employees	
1-4 employees	0.013
5-19 employees	
20-199 employees	-0.105
200+ employees	-0.173 **
Foreign ownership	
100% Australian owned	
Foreign ownership > 0% to 50%	0.134
Foreign ownership > 50%	0.305 ***
Collaboration in R&D	
Joint R&D (co-operative) agreement	0.179 ***
No joint R&D (co-operative) agreement	
Expenditure on R&D	
Have expenditure on R&D	0.583 ***
No expenditure on R&D	
Industry	
Manufacturing	
Accomodation and food services	-0.373 ***
Administrative and support services	-0.434 ***
Agriculture, forestry and fishing	-0.358 **
Arts and recreation services	-0.179
Construction	-0.450 ***
Electricity, water, gas and waste services	-0.275
Financial and insurance services	-0.308 **
Health care and social assistance	-0.302 **
Information, media and telecommunications	0.054
Mining	-0.699 ***
Other services	-0.235
Professional, scientific and technical services	-0.193 *
Rental, hiring and real estate services	-0.267 *
Retail Trade	-0.172
Transport, postal and warehousing	-0.288 **
Wholesale trade	-0.024
Number of observations (n)	3554
AIC	4188.258
Log Likelihood	-2064.1289

Note: *** ,** and * denote significance at the 1%, 5% and 10% levels, respectively.

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