Understanding Innovative Firms:
An Empirical Analysis of the GAPS*

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Abstract

This paper uses data from the Growth and Performance Survey of Australian firms to investigate the determinants of innovation. The measure of innovation is based on whether the firm introduced a new product or process in 1997. Various determinants are investigated including market structure, export status, the use of networks, and training. Regression analysis is conducted separately for manufacturing and non-manufacturing firms, and within each sector by firm size groups. Overall, the results show there is persistence in innovative activities (i.e. firms that innovated in 1995 are more likely to innovation in 1997); small manufacturing firms which use networks tend to be more innovative; and medium sized manufacturing firms that export are also more innovative. However, the main conclusion of the analysis is that many of the explanatory variables are not significant. Moreover, the results vary dramatically across firm size and sector, suggesting that the process of innovation is complex.

Key words: Innovation, networks.

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1. Introduction

Innovation is widely regarded as a key ingredient in business success. More broadly, an innovative economy is seen as vital to achieving economic and social prosperity. Firms spend considerable resources to foster an innovative culture and introduce innovations, with varying results.[1] Similarly, there have been a succession of policy initiatives, both in Australia and overseas, designed to promote innovation.[2] The demand for policies to encourage innovation raises the need for empirical analyses. While case studies of specific firms are of tremendous value in understanding innovation, there is a need to complement these with large sample empirical analysis which may provide 'representative' evidence for policy. This paper uses data on around 4,500 Australian firms for an empirical analysis of the determinants of innovation .

A number of specific hypotheses concerning innovation are investigated. First, how important are 'traditional' factors, such as market structure and firm size, in explaining innovative behaviour? Second, do the determinants of innovation vary substantially between manufacturing and non-manufacturing firms? Traditional analysis typically focuses on manufacturing firms and, given the increasing importance of the non-manufacturing economy, this is unsatisfactory. Third, what inferences can be drawn from this evidence about the role of inter-firm networks in the process of innovation? The issue of networks of innovators is thought to be especially important for SMEs, and the data here predominantly cover these firms. Fourth, do the determinants of innovation vary across firm size? This is an issue that is related to the role of networks, but may also have wider consequences.

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[1] In Australia, James Carlopio suggests that between 50% and 80% of firm's attempts to introduce innovative and technical changes fail (see http://www.agsm.edu.au/ob/jrc/start.htm).

[2] For example, among the most recent initiatives an 'Innovation Summit' was held in Australia in early 2000 (http://www.isr.gov.au/industry/summit/index.html). In the EU, a program called 'Promotion of Innovation and Encouragement of SME Particiaption' is in progress (http://www.cordis.lu/innovation-smes/src/projects.htm).

The structure of the paper is as follows. Section 2 contains a sketch of the innovation process and a brief review of previous empirical research. Section 3 discusses the data, and section 4 presents the analysis. Section 5 has some additional discussion of the results. Section 6 concludes.

2. A review of empirical research

This section is intended to summarise the empirical literature on firm-level innovation that is relevant for the empirical analysis below. Prior to this, however, it may be useful to provide a sketch of the innovation process.

An initial aspect of the innovation process is the ability of the firm to generate ‘new’ ideas, where ‘new’ means new to the firm, but not necessarily new to the wider economy. These may come from formal research, customer suggestions, observation of the world, the creativity of its employees, or other sources. Second, firms need to evaluate these ideas in a technological and economic sense. Third, ideas that seem economically and technologically sensible may need substantial additional investment in research, development and design before they can be integrated into the firm’s processes or, in the case of product innovations, launched as new products. In the case of the latter, a fourth stage is the marketing of the new product or service. Needless to say, these aspects should not be viewed as a linear process; there are important feedbacks between the different stages. All of these stages require some level of investment by the firm. Some investment decisions are largely unnoticed (e.g. an employee automatically has time to discuss ideas with a customer), others may be decided internally to the firm (e.g. the choice between two research projects), while others may involve agreements with banks or venture capitalists. The ability of the firm to make appropriate investment decisions of this kind will determine the innovativeness of the firm.

Although more could be said about the four steps and how investment decisions are made, this paper is not intended to contribute to this literature.[3] Instead, the above is used to motivate two following points. First, the innovation process is not solely an internal process. Firms need to be aware of customers, external ideas and research, and economic trends. Second, a firm requires a range of different, and often scarce, human capital skills. This implies that training and education, of both employees and managers, will be important in innovation. Equally, some skills may only be learnt by experience, suggesting the circular argument that 'firms learn how to be innovative by success in innovation'.

2.1. Market structure and innovation

The traditional economic approach to understanding innovation suggests that market structure has an important role. This approach stresses the external, economic elements mentioned above.[4] In empirical studies, market structure is often proxied by (current) concentration ratios, market share ratios and measures of barriers to entry. These measures are intended to proxy the ability of a firm to appropriate the benefits from an innovation in a competitive situation. Comprehensive reviews of these issues can be found in Cohen (1989), Cohen (1995), and Symeonidis (1996). The empirical research into the impact of market structure on innovation, as summarised by these reviews, shows no clear consensus of results.[5]

One explanation for these mixed results is the difficulty in controlling for the complex, endogenous relationships between innovation and market structure in empirical studies. In other words, while it is likely that market structure affects

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[3] For a recent discussion on 'models' of innovation in this sense see Karlsson and Olsson (1998).

[4] This limited focus has attracted criticism. For example, Teece (1996, p.222) states "The framework developed [in this paper] is designed to shift the market structure-innovation debate in industrial organization beyond the domain where Schumpeter, Galbraith, Mansfield, Scherer and others have put it, and into a new domain where internal structure, interfirm agreements, and capital market structures attain new significance."

[5] Symeonidis (1996, p.16) states "The main characteristic of the empirical literature on the innovation-market structure hypothesis is its inconclusiveness".

innovation (i.e. high market share may boost incentives to innovate), it is also probable that innovation affects market structure (i.e. highly innovative firms come to dominate a market). In empirical analysis it is often difficult to control for these factors. Recent work by Blundell et al (1995, 1998) tries to control for these (and other) difficulties in such empirical work.[6] This work, using panel data on innovations by UK manufacturing companies, indicates that firms with high market share have higher rates of innovation, while higher industry concentration tends to reduce innovation.

There are a limited number of Australian studies relating to the issue of market structure. Empirical analysis on workplace data based on survey responses has shown no strong relationships between (self reported) measures of the intensity of competition and types of workplace change (see Rogers, 1999a, Nunes et al, 1993). An analysis of the R&D intensity of large and medium firms in Australia revealed a negative association between 4-firm concentration ratios and R&D intensity (Rogers, 1999b) and, for manufacturing firms a negative association between R&D intensity and effective rates of protection.

2.2. Firm size and innovation

A further aspect stressed by the traditional literature is the role of firm size, with large firms having an (alleged) advantage in innovation. This view is based on a number of subsidiary arguments, namely,

- Large firms have stronger cash flows to fund innovation. Equally, larger firms may have higher assets to use as collateral for loans. In each of these cases the assumption is that external capital markets may be unwilling to finance innovation (due to high level of risk or inability to understand technical details).

[6] The methods used by these papers involve dynamic count data models of the number of innovations, and a method of using pre-sample data on innovations to estimate a fixed effect for each firm. The 1998 paper also includes an analysis of share market value, using a Tobin q type approach.

- A larger volume of sales implies that the fixed costs of innovation can be spread over a larger sales base. This assumes that licensing methods are not available (or effective) and also applies more to process rather than product innovations.

- Large firms may have access to a wider range of knowledge and human capital skills than small firms, allowing higher rates of innovation.

There are, however, a number of factors that suggest small firms may have an advantage. Small firms may be faster at recognising opportunities. They may be more flexible with respect to adjusting research plans or in the implementation phase of innovations. Small firms may also find it easier to adjust employee incentives to provide optimal innovative effort, or allow less rigid management structures that allow key employees to devote time to innovation-related, not management-related, tasks. The findings from some data sets of innovations in the UK and the US suggest that smaller firms do have an advantage. Analysis on the SPRU major innovations data set for the UK, and the Small Business Administration major innovations data set in the US, show that small firms have higher innovations per employee. However, Tether (1998) points out that the number of innovations is not the same as measuring the value of innovations. Hence, small firms might have more innovations per employee but the average value of each of these innovations may be lower than the innovations in large firms. Using SPRU data, Tether finds this is in fact the case. More generally, it appears that the firm size-innovation relationship will vary according to the specific technological and market conditions. In empirical studies this suggests the need to control for variations in the relationship across industries and also over time within an industry (see Rothwell and Dodgson, 1994, for a review, and Arvanitis, 1997, for a recent study).

Although there appears to be no strong link between firm size and innovation per se, some empirical research has suggested that small and large firms have different determinants of innovation. Acs and Audretsch (1988) found empirical support for this using US data on innovations. Acs and Isberg (1991), using the same 1982 US data set of the number of innovations but concentrating on 384 high R&D intensity firms, found "that for large firms innovation tends to be more equity financed, while for small firms innovation appears to rely more heavily on debt". Dijk et al (1997) conduct an analysis of R&D activity of 1878 Dutch firms in the 1980s, finding that market concentration does not have a different effect on large and small firms (although is positive in both cases), while market growth does have a different effect (with the implied impact of market growth only being positive for large firms). A further issue, which is discussed below, is the extent to which small and large firms rely on external sources of knowledge. In summary, although a basic firm size-innovation link relationship is not apparent, it does appear that the determinants of innovation may vary between small and large firms.

2.3. Networks and innovation

One area of considerable recent research is the role of networks in promoting firm innovation.[7] In particular, SMEs have been considered to rely more heavily on external knowledge networks as an input to innovation than do large firms. For example, Audretsch and Vivarelli (1994) consider the output of patents in 15 Italian regions. They find that patent output depends, as expected, on the level of R&D within the region, but also on the region's level of university research. Moreover, small firms – those with less than 100 employees – appeared to benefit more from external research than large firms. Similar results are found for the US (Feldman, 1994). Almeida and Kogut (1997) find that small US semiconductor firms are more closely linked to regional knowledge networks than large firms (as evidenced by patent citation data). Love and Roper (1999) find that 'network intensity' has a positive influence on the number of innovations in a sample of 576 UK manufacturing firms.[8] MacPherson (1997), in a study of US scientific instrument companies in New York State, also finds support for external linkages raising innovation (the results also

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[7] A network, in the context used here, can be considered as a web of relationships between organisations through which knowledge flows, either through formal or informal mechanisms. Freeman (1991) contains a discussion on networks and innovation. Interest in the networks-innovation link stretches across economics, geography, management and sociology (see, for example, Harrison et al, 1996, Sako, 1999, and Marceau, 1992). Australian Manufacturing Council (1994) and Phillips (1997) discuss some of these issues in relation to Australia.

[8] The measure of 'network intensity' is compiled from questions in the Product Development Survey conducted in 1995.

indicate that internal R&D effort combined with external linkages appear to yield the best results). In contrast, Karlsson and Olsson (1998), in a study of the adoption of new innovations by Swedish machinery, electrical and instrument industries, do not find that SMEs rely more on the regional environment than large firms.

2.4. Other factors

Previous research has investigated a large number of other potential determinants of innovation. Here, the focus is only on those relevant for the analysis below. One issue is the role of foreign ownership in innovation. Some arguments suggest a positive influence (foreign ownership may imply greater financial resources or access to knowledge and technology), whereas a product life cycle view implies R&D and innovative activities are conducted close to home markets. Bishop and Wiseman (1999) provide a summary of these issues. Some recent empirical analysis for the UK has suggested foreign ownership has a negative association with measures of innovation (Love and Roper, 1999, Bishop and Wiseman, 1999), although Love et al (1996) find a positive relationship for a sample of Scottish manufacturing plants. For Australia, Drago and Wooden (1994) find that foreign ownership reduces the likelihood of process change in workplaces, with Rogers (1999a) confirming this finding. Looking only at large firms in Australia, Rogers (1999b) finds a negative association of foreign ownership and R&D intensity.

Export performance and innovation are likely to be inter-related. In general, innovative firms may seek to exploit overseas markets, suggesting that the causality runs from innovation to exports. Empirical studies have shown that this appears to be the case (Lefebvre et al, 1998), although this work suggests a need to carefully control for both the nature of innovation and the type and destination of exports. However, it is also possible that firms that export also have access to improved knowledge flows and, possibly, higher incentives. Hobday (1995) suggests that the exporting activity of firms in SE Asia had a direct impact on their productivity and growth. He argues that knowledge of how to innovate was effectively passed to exporting firms from overseas markets. This is an issue we investigate here by using a lagged export status variable in the estimation equation.

The potential relationship between the extent and nature of training and innovation is another issue of importance. Some authors have suggested that a more highly trained workforce will have an advantage in developing, adopting and implementing new technologies (Gospel, 1991). The extent and nature of training is also an important issue for policy makers as there are potential market failures in its provision (Acemoglu, 1997).

Lastly, a number of other control variables are included in the analysis. Industry level variables for patent intensity (for manufacturing firms) and R&D intensity are included to attempt to control for technological opportunity. A dummy variable for whether the firm has any union present is also included. Drago and Wooden (1994) using Australian workplace data, suggest a small negative effect of unions, while Rogers (1999a) finds no impact of unions in process or product change in Australian workplaces.

3. Data

A major issue in any analysis concerning innovation is how to measure innovation itself. Previous literature has often focused on R&D (an input to the innovation process), patents (considered as both an output and input) as well as qualitative or subjective measures of innovation. All of these measures have various drawbacks (see Rogers, 1998, for a discussion). This paper uses a question from a survey of firms which asks whether new products, services or processes have been introduced over the last year. This question is used to classify firms into 'innovator' and 'non-innovator' categories. The aim of the analysis is to investigate factors which are associated with this innovative status.

The survey data used in this paper come from the ABS's Growth and Performance Survey (also called Business Longitudinal Survey) which was conducted annually from 1994-95 to 1996-97.[9] In the initial year, 8,911 firms were surveyed on the basis of a stratified (by firm size and industry) random sample of the population. The population frame was based on the ABS Business Register. The selection of firms for inclusion in the second year of the survey was more complex. First, all firms that satisfied the following criteria were included

- those firms that in the 1994-95 survey were identified as: innovative, had exported goods or services in 1993-94 through 1994-95, or firms that recorded an increase in sales or employment of 10% or over in 1993-94 to 1994-95

This sample of firms provided around 3,400 firms. In addition to surveying these firms in year two, a random sample of the other firms in the first year survey was also taken. These other firms – which might be termed 'normal performers' – were randomly sampled on the basis of between 1 in 2 and 1 in 3 and those selected were surveyed in year two. The third year of the survey continued to follow the firms selected in year two.[10]

4. Analysis

4.1. Introduction

This complex nature of the survey design means that care must be taken in conducting statistical analysis. If population estimates of means or proportions are required it is important to use the weights provided by the ABS. In more advanced econometric analysis (as is undertaken here) the issue is less straightforward. In particular, there is a debate over whether to use OLS (ordinary least squares) methods or WLS (weighted least squares) methods. Econometric analysis is ultimately concerned with uncovering associations or relationships within the data. For example, we might be interested in

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[9] The survey requests information on firms' activities in the financial year to June.

[10] The survey also included some totally new firms in each year, since the ABS is interested in population estimates for some characteristics. Since we restrict our analysis to those firms in the data for all three years, this aspect of the survey design is not of relevance here.

whether the foreign ownership status of the firm is linked to innovation (since we might suggest that foreign firms are better financed, or that foreign firms have access to overseas knowledge, etc). The general model can be written

$$y = X\beta + \varepsilon \qquad [1]$$

where y is a measure of innovativeness, X is the matrix of explanatory variables, β are the coefficients of interest, and ε is an error term (ε_i ~ iid N[0, σ^2]). As long as the errors are independent of X there is no problem with using OLS (see Deaton, 1997, Chapter 2, or DuMouchel and Duncan, 1983). However, a potentially more important issue is whether the β's are constant across all firms in the population. If the answer is "no" then the implication is that regressions should be run on sub-samples of the population (or survey), since there is no justification for pooling firms together. Note that this issue is due to the coefficient heterogeneity in the population not some artifact of the survey design. However, since the strata are, in fact, based on industry and firm size, which are likely 'candidates' for coefficient heterogeneity in the population, the issues are associated to some degree.

Given these points, and the issues discussed in section 2, the focus in this paper is on sub-sample regressions. For example, regressions are run on manufacturing firms and non-manufacturing firms separately. Equally, within each sector regressions are run on sub-samples by firm size, as we expect that some of the relationships will vary according to the size of the firm.

The dependent variable in our analysis is a binary (0,1) variable defined on the basis of the answers to the questions in Table 1. This measure of innovation has potential drawbacks. First, there is no distinction between the quantity or quality (value) of the innovation. A firm which released a series of highly valuable new products will be labeled innovative, as would a firm that released a single improvement in one product or service. Second, there is an obvious subjective aspect to the issue of what is 'new' or 'substantially' changed.

Table 1 Questions concerning innovation(s) introduced in GAPS

	Question *YES / NO response required*
Question to manufacturing firms	Did this business, in the last financial year, develop any new products or substantially changed products or introduce any new or substantially changed processes
Questions to non-manufacturing firms	Did this business, in the last financial year, offer any new or improved products (goods or services) to its clients?
	Did this business, in the last financial year, introduce and new or improved procedures for the supply of services?[11]

Use of the binary dependent variable means that a probit model is used for analysis. The probit model is based on equation [1] above, only now *y* is not directly observed, instead we observe the outcome, *I*, which follows the rule:

$$\begin{array}{ll} I = 1 & \text{if} \quad y > 0 \\ I = 0 & \text{otherwise} \end{array} .$$

The various explanatory variables are shown in Table 2. Note that a dummy variable for whether the firm was an innovator in 1995 is included. This investigates the issue of persistence in innovative activities, but also provides some adjustment for the survey design (i.e. since the data in 1997 are over represented with 'innovators' on the basis of 1995 responses).[12] In addition, the regressions include industry dummies at the 2 digit level.

[11] In this paper we have combined the responses to the two non-manufacturing questions so that a 'yes' answer to either question means the service firm is an 'innovator'.

[12] Regressions were also run including dummies for employment growth and sales growth (since, again, the survey design over samples these types of firms). The main problem with this approach is that, at time of writing, the ABS cannot supply the exact criteria used for such growth (e.g. exactly what % figure for growth was used). Regressions were run using a dummy variable based on a 10% growth figure for 1993-4 to 1994-5, and omitting missing values for growth rates from the sample; none of the coefficients on the dummy variables were significant.

Table 2 Explanatory variables

Variable	Description
Log of employment	Log of effective full time (EFT) employees (1995). EFT is calculated as sum of working proprietors, managers, full timers and 0.426 times part timers (fraction based on the average hours worked by part timers and full time employees ABS (6306.0, May 1995)).
Innovator in 1995	Dummy variable for whether the firm was an innovator in 1995.
Age of firm	Age of firm (years) in 1995.
Lagged profit margin	Net profit before tax and extraordinary items to total sales (averaged for 1994-95 and 1995-96)
Training intensity	Expenditure on formal training to employees to EFT (1994-95)
Management training	Ratio of managerial staff who undertook training in business management in 1994-95 to total management staff
Foreign	Dummy variable for some level of foreign ownership in firm (=1 if foreign)
Union	Dummy variable for whether any employees were members of union(s) (1995) (=1 if unions present)
Business comparison	Dummy variable for whether the business 'compared its performance with other businesses' (1995) (=1 if comparison made)
Network	Dummy variable for whether the business uses 'formal networking with other businesses' (1996) (=1 if networking used)
Export activity	Dummy variable for whether the business exported in 1994-95? (=1 if exporter)
R&D activity	Dummy variable for whether any expenditure on R&D occurred in 1994-95 or 1995-96 (=1 if R&D done)
R&D intensity industry[13]	R&D divided by total income (as %) defined at the 4 digit ANZSIC level (source: ATO tax return data, average 1994 to 1997).
Patent intensity industry	Number of patent applications per billion dollars revenue defined at 4 digit level (source: IBIS-Innovation Scoreboard data base, which contains data on large and medium Australian based firms, average 1995-1997)
Market Share	Share of market (%) of firm at the four digit ANZSIC level (source: ATO tax return data, average 1994 to 1997)
4-firm concentration ratio	Share of total income accounted for by largest entities in industry, defined as the 4 digit ANZSIC level (source: ATO tax return data, average 1994 to 1997)

[13] Some analysis was undertaken using R&D intensity rather than a dummy variable. This showed no clear results, an issue possibly related to the presence of very high (outlier) values for R&D intensity. Investigation of such outliers is hindered by the confidential nature of the data.

4.2. Regression results

Probit regressions were run on the manufacturing firms and non-manufacturing firms separately. In addition, within each sector four separate regressions were run based on firm size. The firm size groups are based on the number of effective full time employees with small (1-4), medium-small (5-19), medium-large (20-99), and large (100+). The results of these regressions are shown in Table 3 and Table 4.

Looking first at manufacturing firms in Table 3, the results can be summarised as follows:

- Overall, the majority of the coefficients are not significantly different from zero. There appears no association between firm size (measured by log of employment) and innovation, the lagged profit margin has no apparent role, the coefficient on training intensity is never significant, and the industry based variables of patent intensity and concentration are never significant. In addition, the coefficient for market share, management training and firm age are, generally, not significant.

- There does appear to be some persistence in innovative activity. The coefficient on ‘innovator in 1995’ is positive and significant in the small, medium-large and large firm size regressions.

- The dummy variable for foreign ownership always has a negative sign, although it is only significant in the 20-100 firm size regression (note that this variable is omitted from the small group due to no foreign owned firms being in this group).

- The dummy variable for union presence is only significant in the regression for the largest firms. The positive coefficient implies firms with unions have a higher probability of reporting being innovative. This is a surprising result given the previous empirical results.

- Although the coefficients on ‘business comparisons’ and ‘formal networking’ dummies are generally positive, they are usually not significantly different from zero. The exceptions are for small firms, where use of networks raises the probability of innovation, and in the medium-large category, where use of business comparison raises the probability of being innovative.

- Export activity (in 1995) always shows a positive association, although the coefficient is only significant for the medium firm size groups.

- As expected, the dummy variable for whether the firm undertook R&D in the two previous years always has a positive coefficient. However, in the small firm size group the coefficient is not significant.

Table 3 Probit regressions, manufacturing firms

Dependent variable: Innovative status in 1997

	1-4 employees	5-20 employees	20-100 employees	100+ employees
Log of employment	0.1913	0.0179	0.0838	0.0316
	(0.276)	(0.189)	(0.142)	(0.133)
Innovator in 1995	0.7248#	0.2873	0.4271*	0.6080*
	(0.385)	(0.215)	(0.168)	(0.251)
Age	0.0084	-0.0071	-0.0026	0.0080*
	(0.015)	(0.006)	(0.003)	(0.003)
Lagged profit margin	-0.2085	0.1261	0.0579	0.0405
	(0.239)	(0.125)	(0.297)	(1.020)
Training intensity	-0.0243	-0.1388	-0.0652	-0.1148
	(0.059)	(0.100)	(0.065)	(0.160)
Management training	-0.6931#	0.4710*	0.1161	0.4626
	(0.395)	(0.230)	(0.173)	(0.302)
Foreign		-0.0538	-0.3666*	-0.3227
		(0.410)	(0.169)	(0.224)
Union		-0.1374	-0.1041	0.7701#
		(0.182)	(0.117)	(0.464)
Business comparison	0.0578	0.2160	0.1988#	0.1990
	(0.246)	(0.161)	(0.120)	(0.227)
Network	1.0107*	0.2871	-0.0223	0.2529
	(0.321)	(0.193)	(0.133)	(0.212)
Export activity	0.2671	0.5071*	0.4685*	0.4152
	(0.286)	(0.167)	(0.123)	(0.268)
R&D activity	0.2842	0.5388*	0.4150*	0.5385#
	(0.382)	(0.221)	(0.171)	(0.294)
Market Share	-0.3081	0.0806*	-0.0647	-0.0051
	(0.322)	(0.025)	(0.039)	(0.007)
Patent intensity	-0.0004	0.0155	0.0038	-0.0046
	(0.026)	(0.017)	(0.019)	(0.026)
4-firm concentration ratio	-0.6696	0.0086	0.0508	-0.0582
	(0.707)	(0.397)	(0.290)	(0.589)
Industry R&D intensity	-0.2776	0.3556*	-0.0611	0.2988
	(0.204)	(0.164)	(0.162)	(0.259)
% of innovators in sample	15.1	18.1	26.6	33.6
Observations	245	493	655	214
Log Likelihood	-76.2	-188.8	-328.0	-105.5
Psuedo R^2	0.27	0.19	0.13	0.23

Note: All regressions contain a set of 2 digit industry dummies. Standard errors are based on White's robust method. A * means the coefficient in significant at the 5% level, a # the 10% level.

Turning to the results for the non- manufacturing firms, again the overall impression is that most of the explanatory variables do not have significant coefficients. The coefficients on the management training dummy variables, although positive, are never significant. Similarly, and in contrast to manufacturing, there is no apparent role for export status. The industry based variables for R&D intensity and concentration are also not significant. Other results can be summarised as follows:

- Again, there is evidence of persistence in innovation, with all the coefficients on the 'innovator in 1995' dummy being significantly different from zero.

- Foreign owned firms do not generally appear to have a higher or lower probability of innovating. The exception is the medium-large firm size group, where foreign firms are more likely to report an innovation. Note that this is the opposite result to the manufacturing firm results.

- The presence of unions only appears to have a link to innovation for the 5-20 firm size group. Here, the negative coefficient implies the presence of unions reduces the probability of the firm being innovative.

- The dummy variables for 'business comparisons' and 'formal networking' nearly always have positive coefficients, although in only three cases are they significant. Use of 'business comparisons' appears to boost the chances of innovation in the small firm size category, while use of networks does the same for the medium-small and large firm size groups.

- R&D activity has a significant association with innovation for only the two smallest firm size groups.

Table 4 Probit regressions, non-manufacturing firms

Dependent variable: Innovative status in 1997

	1-4 employees	5-20 employees	20-100 employees	100+ employees
Log of employment	0.3425*	0.1094	0.1116	-0.0998
	(0.134)	(0.135)	(0.118)	(0.118)
Innovator in 1995	0.4435*	0.4592*	0.4322*	0.4632*
	(0.168)	(0.123)	(0.111)	(0.208)
Age	-0.0183*	0.0043	0.0006	0.0033
	(0.008)	(0.004)	(0.002)	(0.003)
Lagged profit margin	0.0769	-0.0906	-0.1487	0.0003*
	(0.060)	(0.214)	(0.123)	(0.000)
Training intensity	-0.0323	-0.0097	-0.0730	-0.1204#
	(0.051)	(0.053)	(0.067)	(0.071)
Management training	0.2645	0.2370	0.0179	0.2899
	(0.195)	(0.154)	(0.155)	(0.272)
Foreign	0.3328	-0.3670	0.3306*	0.3003
	(0.454)	(0.301)	(0.140)	(0.208)
Union	0.0108	-0.2859#	-0.0276	-0.0259
	(0.259)	(0.157)	(0.111)	(0.228)
Business comparison	0.3525*	0.1189	0.0864	0.1614
	(0.144)	(0.116)	(0.106)	(0.196)
Network	-0.0003	0.3043*	0.0727	0.5378*
	(0.177)	(0.121)	(0.104)	(0.192)
Export activity	0.0729	-0.0931	0.1581	0.2326
	(0.250)	(0.182)	(0.130)	(0.205)
R&D activity	0.6731*	0.4252#	0.2893	0.0660
	(0.319)	(0.257)	(0.184)	(0.265)
Market Share	-0.5740	0.0241	0.0181	0.0096
	(0.779)	(0.040)	(0.025)	(0.010)
4-firm concentration ratio	-0.3990	-0.4129	0.4940	0.5046
	(0.497)	(0.330)	(0.333)	(0.618)
Industry R&D intensity	0.0443*	0.0333	0.0102	-0.1053*
	(0.019)	(0.025)	(0.021)	(0.051)
% of innovators in sample	11.5	24.7	29.2	34.2
Observations	833	770	746	257
Log Likelihood	-263.3	-393.1	-425.4	-141.2
Psuedo R^2	0.12	0.09	0.06	0.15

Note: All regressions contain a set of 2 digit industry dummies. Standard errors are based on White's robust method. A * means the coefficient in significant at the 5% level, a # the 10% level.

5. Discussion and modifications

A number of additional regressions were run to investigate various issues in the data. First, the training intensity variable contains some high, and possibly erroneous, values (for example, a number of firms report training per (effective) employee of $100,000 or more in a given year). To investigate this a dummy variable was created for firms that have a training intensity above the 95th percentile for the full sample (i.e. high values equal to 1, all other values 0). This was interacted with the actual training intensity and entered as a regressor. However, even with this modification the coefficient on the existing training intensity variables was almost never significant. Why should the extent of training show no link with innovation? Part of the reason may be that the training variable is not proxying the actual human capital present in the workforce. Obviously, a single observation of training intensity is likely to be a poor proxy for the stock of human capital. In addition, high training expenses could be caused by high labour turnover, or rapid employment growth, or the introduction of new equipment or systems that require training. In these cases high training intensity reflects the particular circumstances of the firm and is not an indicator of the quality of human capital.

The results above showed little role for the level of past profitability. The inclusion of this variable is intended to proxy the ability of the firm to self finance innovation, which is only an issue if there are capital market imperfections (i.e. that prevent the firm from obtaining external finance). Regressions were also run that allowed for the fact that some profit ratios are high values and that this may bias the results. In general, the results showed no significant role for past profitability. While this might be taken as evidence that firms do not have an external capital constraint on investment in innovation, it should be noted that a preferred variable would be (past) cash flow (a variable that is not available in the GAPS data).

Although firms that used ‘business comparisons’ and ‘formal networks’ appeared to have a higher probability of innovating, this association was often not significant. One possibility for this is that the two variables are correlated. In the full GAPS sample used here around 32% of firms use ‘business comparisons’, while 26% use ‘formal networks’. A Chi-squared test of the association between these two binary variables is highly significant (χ^2=173, prob =0.00), suggesting some firms tend to use both methods. This may be a reason for lack of significance of the coefficients.

6. Conclusions

The analysis has shown that there is some degree of persistence in innovative activities with innovative status in 1995 having a positive association with innovative status in 1997. For manufacturing firms, the analysis indicates innovation may be higher in exporting firms, firms that network, and firms that do R&D; in contrast, foreign ownership may lower innovation. These results, however, are not consistent across all firm size groups. For non-manufacturing firms, the analysis shows fewer variables have significant associations with innovation. Medium and large firms that networked appear to have higher innovation rates, while foreign ownership is positively associated with innovation in firms with 20-100 employees.

Overall, however, the results give the impression of a general failure of the innovation models discussed. There appears very little role for traditional factors such as market share, industry concentration, or technological opportunity factors (proxied by industry R&D and patent intensity). The impact of other variables seem to vary dramatically across firm size groups and between sectors. There are two broad explanations for these results. First, the ‘models’ used are too simplistic and fail to do justice to the complex nature of innovation. Second, that the problems of measuring innovation, and the explanatory variables, introduce too much ‘noise’ into the regressions.[14] An optimistic view would be that many of the coefficients are insignificant for this reason.

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[14] Rob Phillips, a referee on an earlier draft of this paper, highlighted this issue and suggested various ways of exploring the measurement of innovation. These included: using the 1996-97 GAPS question on total innovation expenditure (see Phillips, 1997) and forming a variable categorizing frequent,

These issues can be highlighted with respect to the results on networks. In summary, the dummy variable for whether a firm uses ‘formal networks’ is included in eight separate regressions. In six cases the coefficient on this dummy is positive, but only three coefficients are statistically different from zero (at the 5% level). This might indicate that the dummy variable is too ‘blunt’ to capture use of networks (i.e. a measure of the intensity of networking activity is required). Perhaps a better measure of networks would show stronger results. Alternatively, the international evidence on the positive role of networks may not be appropriate for Australia. Australian firms may, for whatever reason fail to use networks, or if they do, they may fail to generate benefits from them. Assessing whether network usage is different or underdeveloped in Australia would obviously be helpful for policy, but further analysis is necessary before such conclusions can be drawn.

periodic and infrequent innovators (see Rogers, 1999a, for an example of such a classification using AWIRS data).

Bibliography

Acemoglu, D. (1997). “Training and Innovation in an Imperfect Labour Market”. *Review of Economic Studies*, 64, 445-464.

Acs, Z. and S. C. Isberg (1991). “Innovation , Firm Size and Corporate Finance”. *Economic Letters*, 35, 323-326.

Acs, Z. J. and D. B. Audretsch (1988). “Innovation in Large and Small Firms”. *American Economic Review*, 78, 678-690.

Almeida, P. and B. Kogut (1997). “The Exploration of Technological Diversity and the Geographical Localization of Innovation”. *Small Business Economics,* 9, 21-31.

Arvanitis, S. (1997). “The Impact of Firm Size on Innovative Activity - an Empirical Analysis Based on Swiss Firm Data”. *Small Business Economics*, 9, 473-490.

Audretsch, D. and M. Vivarelli (1994). “Small firms and R&D Spillovers: Evidence from Italy”. CEPR Discussion Paper 927.

Australia Manufacturing Council (1994). *The Wealth of Ideas: How Linkages Help Sustain Innovation and Growth*. Australian Manufacturing Council.

Bishop, P. and N. Wiseman (1999). “External Ownership and Innovation in the United Kingdom”. *Applied Economics*, 31, 443-450.

Blundell, R., R. Griffith and J. Van Reenen (1995). “Dynamic Count Data Models of Technological Innovation”. *Economic Journal,* 105, 333-344.

Blundell, R., R. Griffith and J. Van Reenen (1998). “Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms”. mimeo, UCL and IFS.

Cohen, W. (1995). “Empirical Studies of Innovative Activity”, in (eds) P. Stoneman, *Handbook of the Economics of Innovation and Technological Change*. Oxford, Oxford University Press.

Cohen, W. M. and R. C. Levin (1989). “Empirical Studies of Innovation and Market Structure”, in (eds) R. Schmalensee and R. D. Willig, *Handbook of Industrial Organisation*. Amsterdam, Elsevier.

Deaton, A. (1997). *The Analysis of Household Surveys*. Washington, World Bank.

Dijk, B., R. Hertog, B. Menkveld and R. Thurik (1997). “Some New Evidence on the Determinants of Large- and Small-Firm Innovation”. *Small Business Economics,* 9, 335-343.

Drago, R. and M. Wooden (1994). “Unions, Innovation and Investment: Australian Evidence”. *Applied Economics,* 26, 609-615.

DuMouchel, W. H. and G. J. Duncan (1983). “Using Sample Survey Weights in Multiple Regression Analyses of Stratified Samples". *Journal of the American Statistical Assocation*, 78, 535-543.

Feldman, M. P. (1994). "Knowledge Complementarity and Innovation". *Small Business Economics,* 6, 363-372.

Freeman, C. (1991). "Networks of Innovators: A Synthesis of Research Issues". *Research Policy*, 20, 499-514.

Gospel, H. (1991). "Industrial Training and Technological Innovation: an Introduction", in (eds) H. Gospel*, Industrial Training and Technological Innovation.* London, Routledge.

Harrison, B., M. Kelley and J. Gant (1996). "Innovative Firm Behaviour and Local Milieu: Exploring the Intersection of Agglomeration, Firm Effects, and Technological Change". *Economic Geography,* 72, 3, 233-258.

Hobday, M. (1995)*. Innovation in East Asia*. Aldershot, UK, Edward Elgar.

Karlsson, C. and O. Olsson (1998). "Product Innovation in Small and Large Enterprises". *Small Business Eocnomics*, 10, 31-46.

Lefebvre, E., L. Lefebvre and M. Bourgault (1998). "R&D-Related Capabilities as Determinants of Export Performance". *Small Business Economics*, 10, 365-377.

Love, J. and S. Roper (1999). "The Determinants of Innovation: R&D, Technology Transfer and Networking Effects". *Review of Industrial Organisation,* 15, 43-64.

Love, J., B. Ashcroft and S. Dunlop (1996). "Corporate Structure, Ownership and the Likelihood of Innovation". *Applied Economics,* 28, 737-746.

MacPherson, A. D. (1997). "A Comparison of Within-Firm and External Sources of Product Innovation". *Growth and Change*, 28, 289-308.

Marceau, J. (1992)*. Reworking the World: Organisations, Technologies, and Cultures in Comparative Perspective*. Berlin, Walter de Gruyter.

Nunes, N., G. Crockett and P. Dawkins (1993). "The Impact of Competition and Trade Unions on Workplace reform and Organisational and Technological Change". *Australian Economic Review,* 71-88.

Phillips, R. (1997). "Innovation and Firm Performance in Australian Manufacturing." Industry Commission, Staff Research Paper (Canberra).

Rogers, M. (1998). "The Definition and Measurement of Innovation". Melbourne Institute Working Paper 10/98.

Rogers, M. (1999a). "Innovation in Australian Workplaces: An Empirical Analysis using AWIRS 1990 and 1995". Melbourne Institute Working Paper 3/99.

Rogers, M. (1999b). "The Influence of Diversification and Market Structure on the R&D intensity of large Australian firms”. Paper presented at Industry Economics conference, Melbourne, July.

Rothwell, R. and M. Dodgson (1994). “Innovation and Size of Firm”, in (eds) M. Dodgson and R. Rothwell, *The Handbook of Industrial Innovation*. Cheltenham, UK, Edward Elgar.

Sako, M. (1999). “From Individual Skills to Organizational Capability in Japan”. *Oxford Review of Economic Policy*, 15, 114-126.

Symeonidis, G. (1996). “Innovation, Firm Size and Market Structure: Schumpeterian Hypotheses and Some New Themes”. OECD Economics Dept. Working Paper 161.

Teece, D. J. (1996). “Firm Organisation, Industrial Structure, and Technological Innovation”. *Journal of Economic Behavior and Organization*, 31, 192-224.

Tether, B. S. (1998). “Small and Large Firms: Sources of Unequal Innovations?”. *Research Policy*, 27, 725-745.