# Networks, Firm Size and Innovation

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ABSTRACT. Using survey data on Australian firms this paper investigates the determinants of innovation. Various possible 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 categories. The results include evidence of persistence in innovative activities and that the use of networks is associated with innovation in some sector-firm size categories. Specifically, small manufacturing firms exhibit a positive association between networking and innovation. In contrast, for non-manufacturing firms this association is present for medium and large sized firms.

## 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, in explaining innovative behaviour? Second, do the determinants of innovation vary substantially between manufacturing and non-manufacturing firms? Traditionally, analysis has focused 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.

The structure of the paper is as follows. Section 2 contains a review of previous empirical research. Section 3 discusses the data, and Section 4 presents the main analysis. Section 5 contains 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 economi-

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cally 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.[4] 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.[5] 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.[6]

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 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.[7] This work, using panel data on innovations by U.K. 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 and, for manufacturing firms, a negative association between R&D intensity and effective rates of protection (a measure of total international protection of an industry) (Rogers, 1999b).

### 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).

- 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 (Cohen and Klepper, 1996).
- 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 U.K. and the U.S. suggest that smaller firms do have an advantage. Analysis on the SPRU major innovations data set for the U.K., and the Small Business Administration major innovations data set in the U.S., 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 U.S. data on innovations. Acs and Isberg (1991), using the same 1982 U.S. 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.[8] In particular, SMEs may 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 U.S. (Feldman, 1994). Almeida and Kogut (1997) find that small U.S. 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 U.K. manufacturing firms.[9] MacPherson (1997), in a study of U.S. scientific instrument companies in New York State, also finds support for external linkages raising innovation (the results also 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 U.K. 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 Australian Bureau of Statistics (ABS) Growth and Performance Survey (GAPS) which was conducted annually from 1994–1995 to 1996–1997.[10] 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 1994–1995 survey were identified as: innovative, had exported goods or services in 1993–1994 through 1994–1995, or firms that recorded an increase in sales or employment of 10% or over in 1993–1994 to 1994–1995.

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.[11]

## 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 whether the foreign ownership status of the firm is linked to innovation. The general model can be written

$$y = X\beta + \varepsilon \tag{1}$$

where $y$ is a measure of innovativeness, $X$ is the matrix of explanatory variables, $\beta$ are the coefficients of interest, and $\varepsilon$ is an error term ($\varepsilon_i$ ~ iid $N[0, \sigma^2]$). 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 $\beta$'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 for the probit analysis below is a binary (0, 1) variable defined on the basis of the 1997 answers to the questions in Table I. This measure of innovation has 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

TABLE I
Questions concerning innovation(s) introduced in growth and performance survey

| | Question<br>*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?<br>Did this business, in the last financial year, introduce any new or improved procedures for the supply of services?[12] |

subjective aspect to the issue of what is "new" or "substantially" changed.

The binary dependent variable suggests a probit model. This is based on equation (1), only now $y$ is not directly observed, instead we observe the outcome, $I$, which follows the rule:

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

The various explanatory variables are shown in Table II (summary statistics are shown in the Appendix). 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). In addition, all the regressions include industry dummies at the 2 digit level. The table shows that the explanatory variables come from both the 1995 and 1996 survey. There is often not a choice of which year to use since not all questions were asked in each year of the survey, this problem precludes a panel approach. Instead, the data are used to look at innovation in a single year (1997) using combined data from the previous two years to surveys to form a comprehensive set of explanatory variables.

### 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 III and Table IV.

Table III shows the results for manufacturing

TABLE II
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 (Catalogue No. 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 1994–1995 and 1995–1996). |
| Training intensity | Expenditure on formal training to employees to EFT (1994–1995). |
| Management training | Ratio of managerial staff who undertook training in business management in 1994–1995 to total management staff. |
| Foreign | Dummy variable for some level of foreign ownership in firm (= 1 if foreign) (1995). |
| 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 1994–1995 (= 1 if exporter). |
| R&D activity | Dummy variable for whether any expenditure on R&D occurred in 1994–1995 or 1995–1996 (= 1 if R&D done). |
| R&D intensity industry | 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). |

firms. The "all firms" or full sample regression results in the first column suggest that larger firms report more innovation, that innovation is persistence and that R&D activity has a positive association with innovative status – all results that we might expect. Perhaps of more interest is the fact that firms that use business comparisons or formal networking are also more innovative. Management training has a positive association but total training intensity does not. Lastly, for the full sample regression, foreign firms report less innovation while exporters report more. The subsequent 4 columns in Table III show regressions for different firm size sub-samples. What is of

TABLE III
Probit regressions, manufacturing firms

Dependent variable: Innovative status in 1997

| | All firms | 1–4 employees | 5–19 employees | 20–99 employees | 100+ employees |
|---|---|---|---|---|---|
| Log of employment | 0.0697# | 0.1913 | 0.0179 | 0.0838 | 0.0316 |
| | (0.037) | (0.276) | (0.189) | (0.142) | (0.133) |
| Innovator in 1995 | 0.4353* | 0.7248# | 0.2873 | 0.4271* | 0.6080* |
| | (0.111) | (0.385) | (0.215) | (0.168) | (0.251) |
| Age | 0.0012 | 0.0084 | –0.0071 | –0.0026 | 0.0080* |
| | (0.002) | (0.015) | (0.006) | (0.003) | (0.003) |
| Lagged profit margin | 0.0629 | –0.2085 | 0.1261 | 0.0579 | 0.0405 |
| | (0.058) | (0.239) | (0.125) | (0.297) | (1.020) |
| Training intensity | –0.0629 | –0.0243 | –0.1388 | –0.0652 | –0.1148 |
| | (0.048) | (0.059) | (0.100) | (0.065) | (0.160) |
| Management training | 0.2371* | –0.6931# | 0.4710* | 0.1161 | 0.4626 |
| | (0.117) | (0.395) | (0.230) | (0.173) | (0.302) |
| Foreign | –0.3362* | | –0.0538 | –0.3666* | –0.3227 |
| | (0.119) | | (0.410) | (0.169) | (0.224) |
| Union | –0.1088 | | –0.1374 | –0.1041 | 0.7701# |
| | (0.920) | | (0.182) | (0.117) | (0.464) |
| Business comparison | 0.1897* | 0.0578 | 0.2160 | 0.1988# | 0.1990 |
| | (0.082) | (0.246) | (0.161) | (0.120) | (0.227) |
| Network | 0.1762* | 1.0107* | 0.2871 | –0.0223 | 0.2529 |
| | (0.090) | (0.321) | (0.193) | (0.133) | (0.212) |
| Export activity | 0.4273* | 0.2671 | 0.5071* | 0.4685* | 0.4152 |
| | (0.085) | (0.286) | (0.167) | (0.123) | (0.268) |
| R&D activity | 0.4224* | 0.2842 | 0.5388* | 0.4150* | 0.5385# |
| | (0.114) | (0.382) | (0.221) | (0.171) | (0.294) |
| Market share | –0.0029 | –0.3081 | 0.0806* | –0.0647 | –0.0051 |
| | (0.005) | (0.322) | (0.025) | (0.039) | (0.007) |
| Patent intensity | 0.0004 | –0.0004 | 0.0155 | 0.0038 | –0.0046 |
| | (0.010) | (0.026) | (0.017) | (0.019) | (0.026) |
| 4-firm concentration ratio | –0.1200 | –0.6696 | 0.0086 | 0.0508 | –0.0582 |
| | (0.203) | (0.707) | (0.397) | (0.290) | (0.589) |
| Industry R&D intensity | 0.1214 | –0.2776 | 0.3556* | –0.0611 | 0.2988 |
| | (0.094) | (0.204) | (0.164) | (0.162) | (0.259) |
| % of innovators in sample | 22.4 | 15.1 | 18.1 | 26.6 | 33.6 |
| Observations | 1645 | 245 | 493 | 655 | 214 |
| Log likelihood | –730.7 | –76.2 | –188.8 | –328.0 | –105.5 |
| Psuedo $R^2$ | 0.16 | 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. Note that the 1–4 firm size sample regression drops 38 observations since the data in these perfectly predicts innovative status.

TABLE IV
Probit regressions, non-manufacturing firms

Dependent variable: Innovative status in 1997

| | All firms | 1–4 employees | 5–19 employees | 20–99 employees | 100+ employees |
|---|---|---|---|---|---|
| Log of employment | 0.0958* | 0.3425* | 0.1094 | 0.1116 | –0.0998 |
| | (0.024) | (0.134) | (0.135) | (0.118) | (0.118) |
| Innovator in 1995 | 0.4557* | 0.4435* | 0.4592* | 0.4322* | 0.4632* |
| | (0.068) | (0.168) | (0.123) | (0.111) | (0.208) |
| Age | 0.0008 | –0.0183* | 0.0043 | 0.0006 | 0.0033 |
| | (0.002) | (0.008) | (0.004) | (0.002) | (0.003) |
| Lagged profit margin | 0.0005 | 0.0769 | –0.0906 | –0.1487 | 0.0003* |
| | (0.000) | (0.060) | (0.214) | (0.123) | (0.000) |
| Training intensity | –0.0376 | –0.0323 | –0.0097 | –0.0730 | –0.1204# |
| | (0.026) | (0.051) | (0.053) | (0.067) | (0.071) |
| Management training | 0.1520# | 0.2645 | 0.2370 | 0.0179 | 0.2899 |
| (0.086) | (0.195) | (0.154) | (0.155) | (0.272) | |
| Foreign | 0.1282 | 0.3328 | –0.3670 | 0.3306* | 0.3003 |
| | (0.963) | (0.454) | (0.301) | (0.140) | (0.208) |
| Union | –0.1205 | 0.0108 | –0.2859# | –0.0276 | –0.0259 |
| | (0.077) | (0.259) | (0.157) | (0.111) | (0.228) |
| Business comparison | 0.1708* | 0.3525* | 0.1189 | 0.0864 | 0.1614 |
| | (0.063) | (0.144) | (0.116) | (0.106) | (0.196) |
| Network | 0.1880* | –0.0003 | 0.3043* | 0.0727 | 0.5378* |
| | (0.066) | (0.177) | (0.121) | (0.104) | (0.192) |
| Export activity | 0.1145 | 0.0729 | –0.0931 | 0.1581 | 0.2326 |
| | (0.085) | (0.250) | (0.182) | (0.130) | (0.205) |
| R&D activity | 0.2944* | 0.6731* | 0.4252# | 0.2893 | 0.0660 |
| | (0.118) | (0.319) | (0.257) | (0.184) | (0.265) |
| Market share | –0.0002 | –0.5740 | 0.0241 | 0.0181 | 0.0096 |
| | (0.006) | (0.779) | (0.040) | (0.025) | (0.010) |
| 4-firm concentration ratio | 0.0320 | –0.3990 | –0.4129 | 0.4940 | 0.5046 |
| | (0.188) | (0.497) | (0.330) | (0.333) | (0.618) |
| Industry R&D intensity | 0.0105 | 0.0443* | 0.0333 | 0.0102 | –0.1053* |
| | (0.013) | (0.019) | (0.025) | (0.021) | (0.051) |
| % of innovators in sample | 22.3 | 11.5 | 24.7 | 29.2 | 34.2 |
| Observations | 2669 | 833 | 770 | 746 | 257 |
| Log Likelihood | –1285.6 | –263.3 | –393.1 | –425.4 | –141.2 |
| Psuedo $R^2$ | 0.09 | 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. Note some observations are dropped from sub-sample regressions due to perfect prediction, hence the sum of observations in sub samples is only 2606.

interest here is how often the full sample regression results are not reflected in the sub-sample regressions. The following bullet points highlight some of the differences.

- The dummy variable for management training is negative and significant for the smallest firm size category, but positive and significant for the 5–19 employee firm size category.
- In the sub-sample regressions the dummy variable for foreign ownership always has a negative sign, although it is only significant in the 20–99 firm size category (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, although yielding an insignificant coefficient

for the full sample, has a positive and significant coefficient 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.

Turning to the results for the non-manufacturing firms in Table IV. The "all firms" regression shows some similarity with the results in Table III: large firms report more innovation, there is innovation persistence, management training appears a positive influence, and business comparison and networking are positively associated with innovation. In contrast to manufacturing firms, the results in Table IV for all firms suggest there is no apparent role for foreign ownership status or export status.

Again, however, the sub-sample regressions for different firm size groups suggest that these results do not apply universally. Specifically,

- Foreign owned firms in the medium-large firm size group 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 5–19 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.

Table III and Table IV suggest that the market share and concentration measures show almost no significant association with innovation (the exception is a positive coefficient for market share in the 5–19 employee manufacturing sub-sample). From these results, therefore, the traditional market structure variables appear to play almost no role. A difference between Table III and Table IV is the higher pseudo $R^2$ for the manufacturing firms. This could be due to the higher sample sizes in Table IV, or the lack of explanatory power of export status, or the possibility that the survey question for non-manufacturing firms provides a less clear distinction between innovators and non-innovators that the (simpler) question to manufacturing firms (see Table I).[13]

## 5. Additional analysis and discussion

A number of additional regressions were run to investigate various issues in the data. One issue highlighted by a referee is that the inclusion of a prior innovative status dummy (to allow for persistence) may reduce the significance of other explanatory variables. To assess this all the regressions were re-run excluding this variable. The results were, generally, very similar to those in Tables III and IV. For manufacturing the main differences were for the 100+ employee sub-sample where both lagged profit margin and export activity now showed a positive association with innovation. For non-manufacturing, the main differences were that the coefficient on the lagged profit margin was now significant and positive in the full sample and 1–4 sub-samples, and that management training appeared to have a positive influence on innovation in the 1–4 and 5–19 sub-samples. The inclusion of the R&D activity dummy variable in Tables III and IV might also change the results on other coefficients. Again, regressions were re-run excluding both the R&D activity and prior innovative status dummies. The results were little changed from the regressions which only excluded the innovative status dummy.

Another issue concerns the presence of outlier observations. 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 show the level of past profitability has little association with innovation. 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). To test the robustness of this result, additional regressions were run excluding extreme values of the profit margin present in the data; the results confirmed no significant role for past profitability. To the extent that past profit margins indicate profits available for discretionary investment, the evidence suggests, therefore, that firms do not have an external capital constraint on investment in innovation. However, it should be stated that profit margins are a ratio and are not the same as absolute funds available, indeed accounting profits may over- or under-state the true cash available for investment.

Regressions were also run including dummies for employment growth and sales growth (since the survey design over samples these types of firms). Regressions were run using a dummy variable based on a 10% growth figure for 1993–1994 to 1994–1995 (and omitting any observations with missing values for this growth rate from the sample); none of the coefficients on the dummy variables were significant. Lastly, 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.

## 6. Conclusions

This paper uses data from a survey of Australian firms to assess the potential determinants of innovative activity. A probit regression framework is used, with innovative status in 1997 as the dependent variable. The explanatory variables include a wide range of firm and industry characteristics that have been linked to innovation. The analysis is conducted separately for manufacturing and non-manufacturing firms, and within these sectors by firm size categories.

The results of the analysis show 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 the full sample of manufacturing firms, the analysis indicates innovation may be higher in exporting firms, firms with higher management training, firms that network, firms that conduct comparisons with other businesses, 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 example, the networking effect appears only to be strong in the smallest firm size group (1–4 employees), while any positive link between business comparison and innovation appears only to occur in the 20–99 employee firm size group. These results prompt the thought that the process and determinants of innovation may vary across firm size.

For non-manufacturing firms the analysis again suggested persistence in innovation, a positive influence of management training, networking and business comparisons, although no role for export activity or foreign ownership was detected. The results from the regressions on different firm size sub-samples again showed instability in coefficients. For example, for non-manufacturing firms the role of networks appeared strongest in the medium (5–19) and largest (100+) employee firm size groups.

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 varies 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.

## Appendix: Summary statistics for regression samples

| Manufacturing firms (Table 3) | All firms | | 1–4 employees | | 5–20 employees | | 20–100 employees | | 100+ employees | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean | s.d. |
| Log of employment | 0.22 | 0.42 | 0.15 | 0.36 | 0.18 | 0.39 | 0.26 | 0.44 | 0.34 | 0.47 |
| Innovator in 1995 | 3.07 | 1.53 | 0.95 | 0.40 | 2.26 | 0.40 | 3.72 | 0.45 | 5.75 | 0.94 |
| Age | 0.42 | 0.49 | 0.33 | 0.47 | 0.34 | 0.47 | 0.50 | 0.50 | 0.56 | 0.50 |
| Lagged profit margin | 16.38 | 18.43 | 8.18 | 7.33 | 12.10 | 12.27 | 19.05 | 18.89 | 28.61 | 28.36 |
| Training intensity | –0.69 | –29.94 | 0.11 | –0.31 | 0.02 | –0.82 | 0.04 | –0.19 | 5.60 | –82.99 |
| Management training | 0.44 | 1.46 | 0.40 | 3.29 | 0.35 | 0.80 | 0.50 | 0.84 | 0.59 | 0.67 |
| Foreign | 0.22 | 0.33 | 0.10 | 0.26 | 0.15 | 0.30 | 0.29 | 0.34 | 0.36 | 0.35 |
| Union | 0.12 | 0.33 | 0.00 | 0.00 | 0.03 | 0.17 | 0.16 | 0.37 | 0.38 | 0.49 |
| Business comparison | 0.43 | 0.50 | 0.00 | 0.00 | 0.23 | 0.42 | 0.58 | 0.49 | 0.92 | 0.27 |
| Network | 0.30 | 0.46 | 0.19 | 0.39 | 0.24 | 0.42 | 0.30 | 0.46 | 0.59 | 0.49 |
| Export activity | 0.22 | 0.41 | 0.11 | 0.31 | 0.15 | 0.36 | 0.25 | 0.43 | 0.45 | 0.50 |
| R&D activity | 0.43 | 0.50 | 0.19 | 0.39 | 0.29 | 0.45 | 0.55 | 0.50 | 0.72 | 0.45 |
| Market Share | 0.43 | 0.50 | 0.32 | 0.47 | 0.31 | 0.46 | 0.50 | 0.50 | 0.66 | 0.47 |
| Patent intensity | 2.30 | 7.80 | 0.06 | 0.29 | 0.30 | 1.90 | 1.40 | 3.20 | 12.64 | 17.43 |
| 4-firm concentration ratio | 1.23 | 3.77 | 1.53 | 4.59 | 1.52 | 4.13 | 0.91 | 3.13 | 1.22 | 3.72 |
| Industry R&D intensity | 0.46 | 0.23 | 0.43 | 0.24 | 0.43 | 0.22 | 0.47 | 0.23 | 0.55 | 0.22 |

| Non-manufacturing firms (Table 4) | All firms | | 1–4 employees | | 5–20 employees | | 20–100 employees | | 100+ employees | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean | s.d. | Mean | s.d. |
| Log of employment | 0.22 | 0.42 | 0.12 | 0.32 | 0.25 | 0.43 | 0.29 | 0.46 | 0.34 | 0.48 |
| Innovator in 1995 | 2.58 | 1.63 | 0.88 | 0.46 | 2.24 | 0.42 | 3.74 | 0.45 | 5.76 | 0.97 |
| Age | 0.20 | 0.40 | 0.12 | 0.32 | 0.21 | 0.41 | 0.28 | 0.45 | 0.23 | 0.42 |
| Lagged profit margin | 14.33 | 18.23 | 9.73 | 11.43 | 12.20 | 11.62 | 19.21 | 23.02 | 21.91 | 29.17 |
| Training intensity | 2.15 | 118.59 | 0.19 | –1.76 | 0.07 | –0.20 | 0.24 | –4.17 | 23.61 | 381.98 |
| Management training | 0.47 | 2.43 | 0.42 | 4.09 | 0.38 | 1.11 | 0.55 | 0.78 | 0.71 | 1.19 |
| Foreign | 0.25 | 0.35 | 0.14 | 0.32 | 0.23 | 0.35 | 0.35 | 0.34 | 0.35 | 0.33 |
| Union | 0.11 | 0.31 | 0.02 | 0.12 | 0.04 | 0.19 | 0.17 | 0.37 | 0.42 | 0.49 |
| Business comparison | 0.25 | 0.44 | 0.08 | 0.27 | 0.17 | 0.38 | 0.39 | 0.49 | 0.65 | 0.48 |
| Network | 0.34 | 0.47 | 0.17 | 0.38 | 0.31 | 0.46 | 0.47 | 0.50 | 0.61 | 0.49 |
| Export activity | 0.28 | 0.45 | 0.13 | 0.34 | 0.24 | 0.42 | 0.41 | 0.49 | 0.52 | 0.50 |
| R&D activity | 0.15 | 0.36 | 0.04 | 0.20 | 0.11 | 0.32 | 0.26 | 0.44 | 0.28 | 0.45 |
| Market Share | 0.06 | 0.23 | 0.02 | 0.14 | 0.04 | 0.19 | 0.08 | 0.28 | 0.16 | 0.37 |
| 4-firm concentration ratio | 0.97 | 4.60 | 0.04 | 0.26 | 0.21 | 1.41 | 0.79 | 2.24 | 6.30 | 11.77 |
| Industry R&D intensity | 0.27 | 0.18 | 0.22 | 0.15 | 0.26 | 0.17 | 0.28 | 0.20 | 0.33 | 0.19 |

## Notes

[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 Participation" is in progress (http://www.cordis.lu/innovation-smes/src/projects.htm).

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

[4] In fact, these two points are linked. Cohen and Levinthal (1989) use the idea of "absorptive capability" in modeling a firm's R&D investments which stresses the fact that the presence of external knowledge may encourage firms to invest more in R&D, and internal human capital more generally, to be able to benefit from external knowledge.

[5] 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."

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

[7] 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.

[8] 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.

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

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

[11] 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.

[12] 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".

[13] This latter point is due to an anonymous referee.

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