Determinants of Innovation

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ABSTRACT. The study examines how firm size, market structure, profitability and growth influence innovative activity in small to medium sized Australian manufacturing businesses, using the recently released Confidentialised Unit Record File drawn from the Business Longitudinal Survey of the Australian Bureau of Statistics. Regression analysis is conducted to determine the factors that effect subsequent innovative activity for the full sample of businesses, as well as for sub-samples of firms from high and low-technological opportunity industries. Most variables, including size, R&D intensity, market structure and trade shares are found to be conducive to further innovative activity for the full sample and for high-tech firms. For low-tech industries, fewer variables are significant.

1. Introduction

Since the seminal writing of Schumpeter (1950), the role of firm size in technical advance has preoccupied researchers in industrial organisation to conduct empirical studies for different countries with different data sources. With internationalisation of markets, the role of firm size and market characteristics in technological progress has emerged as one of the major concerns of policy-makers and industrialists.

In the case of Australia, the importance of innovation has been widely emphasised in recent years. According to the studies, which compare innovation of the different countries, Australia is well behind the United States and the Asia-Pacific region in terms of vision, attitude and strategic approach to innovation.[1] This is emphasised in the recent National Innovation Summit (February 2000), with its recommendations to improve the culture of innovation in this country.[2] Despite the importance of innovative activities and the attention given to the subject in popular press, very little empirical research has been conducted in the Australian industrial organisation literature (for exceptions, see McLean and Round, 1978 and Phillips, 1997).

This paper uses the recently released Confidentialised Unit Record File (hereafter, CURF) database from the Australian Bureau of Statistics, Business Longitudinal Survey (hereafter, ABS and BLS, respectively) for small to medium size businesses. First, we look at whether the "traditional" determinants such as firm size and market structure influence the innovative decisions of manufacturing firms.[3] Also, we investigate the effects of firm growth and profitability on subsequent innovative activity as suggested by Audretsch (1995). To examine the importance of technological opportunity, along with the full sample, we consider two sub-samples of firms, separating firms in high-technological-opportunity industries from those in low-technological-opportunity industries.

The remainder of the paper is organised as follows. Section II reviews the existing literature. The data, model and variables are specified in Section III. In Section IV we present the empirical findings and compare our results with overseas studies. The final section contains concluding comments, as well as suggestions for further research.

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2. A review of the literature

We briefly review here empirical literature on the Schumpetrian hypotheses relating innovation to firm size and innovation to market structure. More detailed discussions can be found in Baldwin and Scott (1987), Cohen and Levin (1989), Cohen (1995) and Kamien and Schwartz (1982).

2.1. *Firm size and innovation*

According to Schumpeter (1950), large firms have the wherewithal (large scale of production and capacity, infrastructure in marketing, finance and R&D) to exploit new technology. On the other hand, the argument in favour of small firms is that they have flexibility in adjusting employees in innovation related projects and less complex management structures in implementing new projects.

Most empirical studies test the Schumpeterian hypothesis about firm size on inventive/innovative activity (input or output) at the firm or industry level. Case studies are also used, with descriptive analysis of R&D and innovation data sets. In all Western economies, formalised R&D is dominated by large companies and is concentrated within a few industries.[4] Mostly, there is a threshold size of firms for any industry, below which formal R&D is hardly conducted. In the recent literature, it has been emphasised that the "unit" of analysis and "type" of industry are important in explaining size-R&D investment relationship (see Cohen et al., 1987).

2.2. *Market structure and innovation*

Schumpeter suggests that imperfect competition provides the best environment to internalise the benefits of R&D (see as well, Galbraith, 1952). Further, Levin and Reiss (1984) develop a formal model of non-cooperative oligopoly with free entry in explaining the relationship between market structure and R&D. Advertising is considered as a decision variable. The model, based on static industry equilibrium, establishes endogenous relationship between market structure and R&D.

The hypothesis that there is a positive relationship between research input and concentration has been tested in the literature with varying findings. A common finding is that R&D intensity and innovative performance first increase then decrease with a rise in concentration. For example, Scherer (1970) and Kelly (1970) find that maximum research intensity occurs at the 50 to 60 percent level of concentration ratio. This is replicated using Federal Trade Commission data in Scott (1984) and Levin et al. (1985). However, they find the concentration-innovation relationship is sensitive to industry conditions. Scott finds that the line of business concentration and its square can only explain 1.5 percent variance in R&D intensity in 3388 businesses, while in Levin et al. (1985), these two variables explain only 4 percent of the variance in R&D intensity across 127 lines of business.

2.3. *Measurement issues*

There is no consensus in measuring firms' inventive and innovative efforts. Expenditures on research and development, the number of personnel engaged in formal R&D activities, a count of invention patents received, a count of significant innovation pioneered and estimates of sales associated with new products are used for this purpose.[5] R&D expenditures are considered as input and patent counts as output in the innovative process.[6]

Aside from these difficulties, Fisher and Temin (1973) and Kohn and Scott (1982) show that even an elasticity of R&D inputs with respect to firm size exceeding unity does not necessarily imply that scale economies exist for R&D in producing innovative output. Further, Acs and Audretsch (1987, 1988 and 1990) show that in some industries small firms are as innovative as their larger counterparts.[7] Recent studies emphasise determinants that vary across industries, for example, demand, technological opportunity and appropriability conditions. In summary, the empirical findings based on the Schumpeterian hypotheses are inconclusive and in many cases the results are muddied with methodological difficulties.

3. Data, model, specification of variables and estimation technique

3.1. *Data*

Our analysis is based on data taken from the BLS. The survey was designed to provide information on growth and performance of employing businesses and to identify selected economic and structural characteristics of these businesses. The response rate over the period was 75 percent. Data were collected on size of business unit, R&D expenditure, innovations, profits and growth. Data from the survey is provided in a CURF database for small to medium size businesses (see ABS, 1999).[8] Our sample includes 1213 business units covering 1728 manufacturing business locations.

3.2. *Model*

Knowledge is a decisive input into innovation and technological progress. R&D is a major source of knowledge. The effectiveness of R&D in generating innovation varies across industries, as well as across firms. According to Scherer (1965, 1991), differences in the "technological-opportunity environment" are important in determining the relationship between R&D and innovation activity. For empirical purposes the following model is considered:

$$INNOV = \beta_0 + \beta_1 SIZE + \beta_2 SIZESQ + \beta_3 PROFIT + \beta_4 GROWTH + \beta_5 RRD + \beta_6 CONC + \beta_7 EXP + \beta_8 IMP. \qquad (1)$$

In the following paragraphs, we discuss the variables of (1) in detail.

The dependent variable
In the absence of any other measure of innovation (e.g., number of patents) we consider a dummy variable INNOV as a proxy for innovative activity. INNOV equals one if the business developed or introduced new or substantially changed products or services. Otherwise, it is zero. The value of INNOV in 1997–1998 is the dependent variable in our regression analysis.

Independent variables
Business size (SIZE) is measured by sales (in thousands of dollar). Following Schumpeter, the relationship of size with INNOV is expected to be positive. However, as discussed above the literature is not unambiguous in this respect. A squared term is also taken into account, following Acs and Audretsch (1991) and Doi (1994, 1996), to check the non-linearity of the relationship.

As innovative activity is one of the important strategic instruments of businesses, high profit may induce subsequent innovations. Branch (1974) and Grabowski (1986) are among the few studies that consider the effect of profitability on subsequent technological change, but their studies rely on R&D input rather than output. Audretsch (1995) uses a direct measure of innovative activity and finds a significant positive influence of profitability on innovative activity only in high-tech industries. A positive sign is expected for the PROFIT coefficient in at least some industries.

According to Mueller (1967, p. 73), "The faster a firm's sales are increasing, the more confidence it will have about its ability to secure the benefits from uncertain R&D projects, and the more patience it can afford to show in waiting for these benefits". Therefore, growth is conducive to innovative activity, however the strength of this relationship may vary between high and low-tech industries. In particular, Audretsch (1995) finds a positive influence only in some low-tech industries. A positive sign is expected for the GROWTH coefficient in at least some industries.

The technology variable, RRD, is R&D intensity measured by R&D expenditure on sales. This is expected to increase subsequent innovation if firms make rational decisions on the level of R&D expenditure. Therefore, a positive sign is expected for the RRD coefficient.

We also consider three industry variables, along with the above independent variables. CONC is a four-firm concentration ratio, an index of market structure. Concentrated industries are expected to have more innovative activity. A positive sign is expected for the CONC coefficient.

To incorporate the effects of international competition we add EXP (exports/total sales) and IMP (imports/total sales) into the model. Export promotion and import competition may force firms to increase innovation. A positive sign is expected in each case.

Except for the last three industry variables (CONC, EXP and IMP), all variables are taken from the CURF data set. Data on industry characteristics are drawn from other sources of the ABS.[9] The dependent dummy variable, INNOV, is measured in 1997–1998, so for most of the independent variables (except CONC, EXP and IMP) we consider 1994/1995 data. This is the maximum time lag we could consider given the restriction on the availability of data.[10]

Table I presents the descriptive statistics of the independent variables for the full sample and for separate sub-samples of firms in high-tech and low-tech industries, using the Australia New Zealand Standard Industrial Classification (ANZSIC) industry classification. Food, beverage and tobacco (ANZSIC21), textile clothing footwear and leather (ANZSIC22), wood and paper product and printing (ANZSIC23) and publishing and recorded media (ANZSIC24) are low-tech industries. Petroleum, coal, chemical and associated product (ANZSIC25), non-metallic mineral (ANZSIC26), metal product (ANZSIC27) and machinery and equipment (ANZSIC28) are high-tech industries.

It is noticeable that the R&D intensity and R&D expenditure are four times higher in the high-tech group compared to the low-tech group. However, the average value of sales is close to one and half times higher in low-tech group than in the high-tech one. Also the average growth of low-tech firms is double that of the high-tech firms.

3.3. *The estimation technique*

As the dependent variable is a dichotomous dummy, we estimate equation (1) using the PROBIT regression technique. It is not possible to identify whether R&D expenditure with a “zero” entry signifies non-reported items or the absence of R&D spending. To deal this “zero” problem, we also provide results using the TOBIT regression technique.[11]

TABLE I
Descriptive statistics of the variables for full sample, high and low technological opportunity firms

Variables	Full sample Mean (Std. dev)	High-tech Mean (Std. dev)	Low-tech Mean (Std. dev)
SIZE (thousand dollars)	5612.4 (11046)	3784.2 (6509.0)	5204.7 (9380.7)
PROFIT	0.0657 (0.214)	0.0641 (0.262)	0.065 (0.145)
GROWTH	9.598 (282.05)	1.189 (14.215)	2.234 (24.795)
R&D expenditure	37.265 (131.28)	43.555 (142.08)	12.313 (57.449)
RRD	0.0122 (0.053)	0.0182 (0.069)	0.0041 (0.017)
CONC	0.482 (0.097)	0.507 (0.088)	0.490 (0.104)
EXP	0.119 (0.045)	0.113 (0.027)	0.104 (0.052)
IMP	0.274 (0.107)	0.310 (0.088)	0.177 (0.090)

4. Empirical findings

Tables II and III present the findings for the full sample, high-technology industries and low-technology industries using PROBIT and TOBIT regression techniques, respectively. In addition to each regression coefficient and corresponding *t*-ratio, we report the number of firms in the estimation sample and the log-likelihood statistic for each regression.

4.1. *Full sample*

Findings from the PROBIT and TOBIT regressions are very similar. Innovative activity increases significantly with firm size, but at a decreasing rate.[12] Lagged profitability does not significantly increase innovative activity, providing no evidence that availability of internal finance encourages innovative activity. Also, firm growth is insignificant in inducing subsequent innovation. R&D intensity is significantly positive in influencing successive innovation, as expected if R&D expenditures are rationally determined. The three industry variables, concentration, export and import shares each have a significant positive influence on subsequent innovations. The coefficients of concentration and import share are significant at the ten percent level for both PROBIT and TOBIT regressions, while the coefficient of export share is significant at the one percent level for the TOBIT regression and ten percent level for the PROBIT.

TABLE II

Results of the PROBIT regression analysis for the full sample, high-technological-opportunity and low technological-opportunity firms

Independent variables	Full sample	High-tech	Low-tech
SIZE (thousand dollars)	$0.520 \times 10^{-4\,a}$	$0.757 \times 10^{-4\,a}$	$0.423 \times 10^{-4\,a}$
	(5.365)	(3.607)	(2.327)
SIZESQ	$-0.725 \times 10^{-9\,a}$	-0.167×10^{-8a}	$-0.515 \times 10^{-9\,c}$
	(4.117)	(2.484)	(1.726)
PROFIT	0.131	0.061	0.942[c]
	(0.655)	(0.291)	(1.410)
GROWTH	-0.269×10^{-2}	-0.269×10^{-2}	-0.609×10^{-1}
	(1.103)	(0.609)	(1.0009)
RRD	2.282[a]	1.937[a]	–0.336
	(3.642)	(2.990)	(0.062)
CONC	0.831[c]	3.450[a]	–0.832
	(1.569)	(2.586)	(0.324)
EXP	1.580[c]	12.163[a]	4.811
	(1.440)	(3.056)	(0.945)
IMP	0.754[c]	1.191[c]	2.188[c]
	(1.443)	(1.349)	(1.395)
Constant	–1.866	–4.48	–0.947
Log-likelihood	–593.71	–336.62	–146.35
N	1213	670	358

The dependent variable is a dichotomous dummy representing innovative activity for 1997/1998. The value given in parentheses is the *t*-ratio statistic for the coefficient above.

[a] Indicates coefficient is significant at the 0.01 level of significance using one-tailed *t*-test.

[b] Indicates coefficient is significant at the 0.05 level of significance using one-tailed *t*-test.

[c] Indicates coefficient is significant at the 0.10 level of significance using one-tailed *t*-test.

TABLE III

Results of the TOBIT regression analysis for the full sample, high-technological-opportunity and low technological-opportunity firms

Independent variables	Full sample	High-tech	Low-tech
SIZE (thousand dollars)	0.487×10^{-4} [a]	0.707×10^{-4} [a]	0.406×10^{-4} [a]
	(5.384)	(3.609)	(2.360)
SIZESQ	-0.680×10^{-9} [a]	-0.157×10^{-8} [a]	-0.492×10^{-9} [b]
	(4.116)	(2.493)	(1.769)
PROFIT	0.124	0.052	0.987[c]
	(0.649)	(0.261)	(1.456)
GROWTH	-0.423×10^{-2}	-0.250×10^{-2}	-0.617×10^{-1}
	(0.951)	(0.590)	(0.989)
RRD	2.244[a]	1.926[a]	–0.362
	(3.704)	(3.073)	(0.069)
CONC	0.824[c]	3.322[a]	–0.794
	(1.638)	(2.647)	(0.324)
EXP	1.564[a]	11.602[a]	4.606
	(3.100)	(3.100)	(0.948)
IMP	0.724[c]	1.151[c]	2.069[c]
	(1.504)	(1.380)	(1.383)
Constant	–1.787	–4.276	–0.919
Log-likelihood	–805.51	–461.63	–194.79
N	1213	670	358

The dependent variable is a dichotomous dummy representing innovative activity for 1997/1998. The value given in parentheses is the *t*-ratio statistic for the coefficient above.

[a] Indicates coefficient is significant at the 0.01 level of significance using one-tailed *t*-test.

[b] Indicates coefficient is significant at the 0.05 level of significance using one-tailed *t*-test.

[c] Indicates coefficient is significant at the 0.10 level of significance using one-tailed *t*-test.

4.2. *High technology industries*

For high-tech industries innovative activity increases significantly with firm size, but at a decreasing rate. Lagged profitability and firm growth have no significant influence in successive innovative activity. R&D intensity is again significantly positive in influencing successive innovation. For this group of industries, concentration and export share variables have strong significant positive influence on subsequent innovations for both regression techniques. This indicates in high-tech firms, a concentrated market and export orientation are highly desirable for successive innovation. Imports have a weak influence in promoting further innovative activity in both PROBIT and TOBIT regression techniques in case of high-tech industries, perhaps indicating a positive reaction to the presence of foreign competition.

4.3. *Low technology industries*

As is the case with the results above, innovative activity increases significantly with firm size. The effect of size on innovation is only some sixty percent of that for firms in the high-tech group. Also the size effect on innovation decreases at a slower rate than in the high-tech group and the coefficient of squared size is significant now only at the five and ten percent levels in Tables II and III, respectively, rather than at one percent for the high-tech group.

Profitability has a weak positive effect on subsequent innovative activity in the low technology group. This suggests that low-tech firms undertake innovation only when they have access to internal finance from retained profit. This is in stark contrast to the findings by Audretsch (1995). Using innovation rate as a measure of innovative activity for the U.S., he shows that the availability of funds (indicated by company profitability) is more conducive to subsequent innovation only in high-tech industries.

It is noticeable that in the low technology group, R&D intensity is no longer positive and significant in influencing innovation. However, this is based on a minute level of R&D intensity, so the result is likely to be unreliable. Firm growth, concentration and export shares are insignificant influences on subsequent innovations for this group. As in the full sample and high-tech industry sample, import share has a weak positive influence in promoting further innovative activity.

5. Summary and conclusions

We examine the role of firm profitability, growth and R&D opportunity along with other variables in determining subsequent innovative activity. Consistent with the Schumpeterian view, results for the full sample and both sub-samples support a positive relationship between size and innovation.

We find significant positive influences on subsequent innovation for the firm's R&D intensity, and for industry characteristics of concentration, export and import intensity in our full sample of firms. However, the pattern of these influences varies with the "technological environment". In particular, R&D intensity, market concentration and export intensity significantly increase subsequent innovation only for firms in high-tech industries, while profitability in contrast has a significant positive influence on subsequent innovation only for firms in low-tech industries.

An implication of our findings is that small to medium size Australian manufacturing firms react positively to market opportunities, at least in the high-tech industries. High market concentration provides an opportunity for smaller firms gain a share of potential market power through innovation. Likewise, openness in the form of either high import or export intensity encourages innovation, possibly through the opportunity to penetrate foreign markets or compete effectively with imports at home. These positive reactions offer some hope that Australia will be able to meet the challenge of a shift from domestic to global competition through the innovative activity of its small to medium enterprises.

Notes

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1 Worldwide Study on Innovation Management-Australian edition: Barriers to Success Factors of Innovation, Droege and Comp 1999. Also see the Report of the Business Taskforce on Leadership and Management Skills, April 1995, p. 111.

2 The details can be found on http://www.isr.gov.au/industry/summit/index.html.

3 Most of the overseas literature is based on manufacturing businesses, a focus on manufacturing makes for easier comparisons of our findings with other studies.

4 Examples of high R&D activity industries are aircraft, pharmaceuticals, electronics, instrument engineering and chemicals.

5 R&D employment and expenditure are subject to substantial reporting error. Differences between process and product innovation or basic and applied research are not considered in many empirical models. For detail discussion see Cohen and Levin (1989, pp. 1065–1066).

6 The OECD (1996) provides a conceptual understanding of the structure and characteristics of the innovation in details. In case of Australia, data for R&D in manufacturing were only available at aggregated industry level. The new series of BLS data covers most manufacturing firms.

7 R&D productivity diminishes with firm size. This is confirmed in Acs and Audretsch (1991).

8 These small to medium sized businesses employ less than two hundred employees.

9 Data for concentration are from the Australian Bureau of Statistics (ABS), "*Integrated Economic Censuses, Enterprise Statistics Data on Magnetic Tape, Australia*", Catalogue Number 8113.0, averaged over 1989/1990 and 1992/1993. Data for exports and imports for 1989/1990 and 1992/1993 are unpublished and supplied by the ABS.

10 Scherer (1965) assumes a two-year time lag between the implementation of a firm's strategy such as R&D expenditure and subsequent innovation for the U.S. industries.

11 For detail, see Johnston and Dinardo (1997, pp. 436–441). Acs and Audretsch (1991) estimate innovation with the help of OLS and TOBIT regression techniques. They find nearly identical results using both techniques.

12 In results not reported in which R&D expenditure is used as the dependent variable measuring innovative activity, we find size has significant positive effect on R&D expenditure but at a decreasing rate.

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