Innovation and Performance: Benchmarking Australian Firms*

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Abstract

This paper empirically analyses the link between innovation and performance using a sample of large Australian firms, with a specific aim of developing benchmarking tools. Innovation is measured by firms' investment in R&D and applications for patents, trademarks and designs. An innovation index is constructed which incorporates a firm's innovative activities into a single figure after accounting for firm size. The index provides a ranking of the most innovative firms in Australia. Firms which have a higher (and lower) than expected performance outcome from their innovative activities are also identified.

Keywords: Benchmarking, innovation, R&D expenditure, intellectual property, firm performance

Contents

1. Introduction

Innovation can be defined as the application of new ideas to the products and processes of a firm's activities. Innovation is concerned with the process of commercialising or extracting value from ideas. This is in contrast with 'invention' which need not be directly associated with commercialisation. From this perspective, innovation would be expected to be closely linked to firm performance. Indeed there is widespread support for the assertion that firms must be innovative to survive and prosper in a competitive economy. This paper benchmarks performance given innovation. It uses quantitative data on R&D expenditure, patents, trade marks and designs to analyse the link between innovation and performance, with a specific aim of developing benchmarking tools.

Benchmarking is a method of comparing firms. Benchmarking provides a useful analytical tool for firms which allows them to compare their performance relative to an average or to other firms. This paper is concerned with comparing firms with respect to their innovative effort and the outcome of this effort.

The structure of the paper is as follows. Section 2 defines innovation and makes two important points. Firstly, that since innovative activities are diverse, benchmarking innovation must include as many elements of the innovation process as possible. Secondly, innovation is defined as something that 'adds value' to the firm. Section 3 defines benchmarking more closely. In this paper, we consider two distinct methods. The first uses data and regression results to construct an index of innovation. The components of the index include R&D expenditure and intellectual property activity. The relative importance of each element in the index is determined by regression analysis of the link between each element and the market value of the firm. This means that the index is based on the overall, or average, sample relationship between, say, R&D expenditure and market value. The second method of benchmarking innovation is to assess which firms appear to do better or worse that this overall, or average, performance.

Section 4 provides a description of the model used to analyses the link between innovation and performance. In short, there is a well established framework for this type of analysis which is followed, although prior studies have focused on R&D expenditure and patents only. Section 5 provides a brief overview of the data. Section 6 contains the analysis that allows an innovation index to be constructed. Section 7 outlines how the regression results can be used to assess over- and under- performing firms. Section 8 concludes.

2. The definition of innovation

Innovation is notoriously hard to define. There are various definitions of "innovation" that appear in the literature. Joseph Schumpter, writing in the 1930s, was one of the first economists to define innovation. He defined five possible types of innovation: (i) the introduction of a new product or a qualitative change in an existing product, (ii) process innovation new to an industry, (iii) the opening of a new market, (iv) development of new sources of supply for raw materials or other inputs, and (v) changes in industrial organisation (see OECD, 1997, p.28).

In Australian various definitions have been used. The Department of Industry Science and Resources (ISR)[1] use a relatively broad definition of innovation relating to new ideas. However, these new ideas do not necessarily have to add value:

> [I]nnovation, at the level of an individual firm, might be defined as the application of ideas that are new to the firm, whether the new ideas are embodied in products, processes, services, or in work organisation, management or marketing systems (DIST, 1996, p.2, and credited to Gibbons et al, 1994).

The Business Council of Australia's (BCA) definition highlights the link between innovation and performance ('adds value' in their terminology). Thus, the creation of abstract knowledge, or the invention of new products or processes, is not normally considered innovation until it has been productively incorporated into the enterprise's activities:

> In business, innovation is something that is new or significantly improved, done by an enterprise to create added value either directly for the enterprise or indirectly for it customers (Business Council of Australia 1993, p.3)

This means that innovative activity is not something that can occur separate from the firm's core activities, rather it must involve the coordination of various inventive, learning and

[1] Formerly the Department of Industry Science and Tourism (DIST)

implementation skills. This implies that measuring innovation activity is a near impossible task. Each firm's innovativeness will reflect a complex set of factors including investment in knowledge, skills of employees, management methods, culture and internal and external networks.

For analytical work on a large sample of firms, in–depth knowledge of each firm's characteristics is not practical. Hence in this paper various proxies for innovative effort are used. Innovative activities can be measured using 'inputs' which relate to the process of discovering new products and processes and 'outputs' which relate to the outcomes of these 'inputs'. This paper uses both measures, namely, research and development expenditure (R&D) as an 'input', and patent applications, trade mark applications and design applications as 'outputs'. Although this is a broad range of measures compared to similar work, which often use R&D expenditure and patents only, it still cannot capture all aspects of innovation. For this reason the analysis must consider firm performance and construct models that offer further insight into innovativeness.

3. Benchmarking

Benchmarking refers to the method of comparing a firm's performance to a set of comparable firms. Benchmarking is therefore an analytical tool that can help understand the complex nature of firm performance. The set of such firms can be defined in a number of ways although, ultimately, the definition used depends on the usefulness of the benchmarking results to the organisation concerned.

Benchmarking innovation, therefore, involves the process of comparing firms with respect to their innovative effort and the outcome of this effort. As an example, consider two firms, the first spends £1 million on R&D and has 2 patent applications in a single year. The second spends £5 million on R&D and has 1 patent application. Which is more innovative? They are various possible answers to the question. For example, we could say the £5 million on R&D, being five times as great outweighs the 2:1 ratio in patents. This would implicitly value a patent at less than £4 million-worth of R&D.[2] Alternatively, we might also be interested in the relative sizes of the two firms. If the first firm has revenue only 1/20th of the second, our

[2] As an equation, the constraint is $5 + V > 1 + 2V$, where V is value of patent.

view may be changed. Lastly, it might also be of interest to assess which firm has a higher performance outcome after controlling for the average impact of R&D expenditure and patents on performance.

It is not possible to benchmark innovation against an optimal standard. The relationship between innovation and performance is non-monotonic. Innovation is a risky activity and an optimal firm does not want to maximise innovative activities. This paper is concerned with comparing firms with respect to their innovative effort and the outcome of this effort. Firms can be compared to each other and to the average of this relationship.

The analysis initially focuses on constructing an index that allows different measures of innovative activity to be combined and which also controls for firm size. The creation of an index requires some method of 'adding' R&D (R), patents (P), trade marks (T) and designs (D) together to form an innovation metric. In other words we need to form an index (I) from a weighted sum of the various components,

$$I = \alpha R + \beta P + \chi T + \delta D \ . \tag{1}$$

Firms which do not undertake any innovative activities will record a zero for each component and will not appear in the index. The next section discusses empirical methods of obtaining the parameters, or weights, from regression analysis. In particular, it is arguable that the weights should be derived from a regression that links performance to the innovative activities. Assuming weights can be found from large sample analysis, these will reflect an 'average' impact of innovation on performance.

A further possible method of benchmarking innovation is to analyse which firms appear to do better or worse than others also involved in innovative activities. Thus, the issue here is assessing which firms have a *higher than expected* performance outcome from their innovative activities. This can also be investigated using regression analysis. An important difference is that this type of analysis can only be done for firms in the regression sample, whereas the previous method can be used for all firms. This is an important distinction since the regression sample only contains firms quoted on the stock market.

4. The Model

This paper compares the performance of firms relative to their innovative effort. Following previous studies, the performance of firms is measured by market value. The theoretical framework used to link market value and innovation is based on the Tobin Q approach. Essentially the approach assumes that the market value of the firm is related to the value of tangible and intangible assets. Most applied studies follow Griliches (1981) in assuming that the market value (*V*) of the firm is given by

$$V = q(A + \gamma K)^{\sigma} \qquad [2]$$

where *A* is the stock of tangible assets of the firm, *K* is the stock of intangible assets, *q* is the 'current market valuation coefficient' of the firm's assets, σ allows for the possibility of non constant returns to scale, and γ is the shadow value of intangible assets to tangible assets (i.e. $\frac{\partial V}{\partial K} \Big/ \frac{\partial V}{\partial A}$).[3] In general, *q* may vary across firms and time

$$q_{it} = \exp(m_i + d_t + u_{it}) \ , \qquad [3]$$

where m_i is a permanent firm effect, d_t is the market effect at time *t*, and u_{it} is an independently distributed error term. Hence the term *q* allows for the fact that the market valuation may vary across firms and time, and that there may also be "noise" in such valuations.

In this paper, *K* is proxied by the book value of intangible assets (*B*), R&D expenditure (*R*), patent (*P*), trade mark (*T*) and design (*D*) activity. Commonly, R&D expenditure is used as a proxy for all innovative investment, primarily since other data are not available, and productivity, profitability and market value are used as performance measures. R&D expenditure and productivity studies are not of direct concern here, since there are no productivity measures in the data used in this investigation (see Griliches, 1995).

Equations [2] and [3] can be rearranged to yield the empirical specification (using the approximation $\log(1+\varepsilon) \approx \varepsilon$)

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[3] It might appear that equation [2] is an identity. This would be the case if *A* and *K* were measured by their true value – in which case the parameters *q*, χ and σ would be one. However, the magnitudes of *A* and *K* are based on accounting methods which do not necessarily correspond to economic value.

$$\log V_{it} = m_i + d_t + \sigma \log A_{it} + \sigma \left[\gamma_1 \frac{B_{it}}{A_{it}} + \gamma_2 \frac{R_{it}}{A_{it}} + \gamma_3 \frac{P_{it}}{A_{it}} + \gamma_4 \frac{T_{it}}{A_{it}} + \gamma_5 \frac{D_{it}}{A_{it}} \right] + \beta X + u_{it} \quad [4]$$

where X is any additional explanatory variables. The existing literature has investigated various different variables for X (for example, growth of sales, Hall, 1993, technological appropriability, Cockburn and Griliches, 1988, and diversification, Lang and Stultz, 1994).

Hall (1988) reviews the empirical analysis on innovation and market value, although "innovation" refers solely to R&D expenditure and patents. Hall concludes that the majority of studies find that R&D investment and patent activity are positively linked to market value. Market value is defined as the sum of the value of shares issued plus debt (i.e. the theoretical amount required to own the firm outright). In theory, the market value reflects the discounted, expected stream of future profits for the firm. This approach assumes that stock markets correctly value firms, especially with respect to their innovative investments[4].

5. Data

Firm level data came from the IBIS Enterprise Database. The IBIS database contains annual information on the financial activities of large firms in Australia from 1979 to the present. Accounting data are available through the inclusion of each firm's profit and loss statement and balance sheet in the database. All firm reporting R&D expenditure are included in the subsequent analysis.

Patent, trade mark and design application data come from IP Australia's *Annual Record of Proceedings*. The *Proceedings* lists all applications for patents, trademarks and designs for a calendar year. These data were matched to firms appearing in the IBIS database. The name of each parent firm, as well as each of its subsidiaries, was checked against the list of intellectual property applicants in the *Proceedings*.

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[4] Some studies also consider R&D expenditure and profitability, for example, Lev and Sougiannis (1996) find, for US manufacturing firms 1975-91, that R&D expenditure and profits are positively linked. Moreover, they also find that the stock market's valuation of manufacturing firms appeared too low, casting some doubt on the market value based empirical research. However, using profitability requires a long time series since past lags of R&D expenditure need to be included (Lev and Sougiannis analyse the impact of up to 7 years of past R&D on current profits). Given that the IBIS data available only covers four years, this paper uses the market value methodology.

Market value is defined as the sum of the total value of ordinary shares issued and long term liabilities.[5] Data on market value were made available by the Securities Industry Research Centre of Asia-Pacific (SIRCA), University of Sydney and are only available from 1995, hence the panel is restricted to 1995 to 1998. Also data on design applications are not available for 1995. The book value of assets includes both tangible and intangible assets.

Table 1 provides summary statistics for the four years of data available. The sample contains large Australian firms, indicated by their average market value. In 1997 and 1998 the average market value of the firms in the sample exceeded $1.2 billion. Average R&D expenditure exceed $6.6 million for these two years. On average, firms applied for between 4 and 5 patents and between 8 and 11 trademarks during the period in question.

Table 1: Summary Statistics

Year	No. of firms	Mean Market Value ($m)	Mean R&D expenditure ($m)	Mean No. of Patent Applications	Mean No. of Trademark Applications
1995	369	894.61	4.80	4.14	9.98
1996	330	976.29	6.04	4.46	9.41
1997	303	1277.44	6.68	5.09	8.82
1998	249	1218.90	6.63	4.03	10.65

6. Innovation index

In this section we discuss how an innovation index can be constructed using the available data and regression techniques. Using the specification in equation [4], regressions are run using OLS with the log of market value as the dependent variable. The data are pooled to yield a sample of up to 400 observations (for the years 1995 to 1998). The Table below shows regression results. All regressions contain year dummies to capture aggregate movements in market values. Regressions 1 and 2 are run for the years 1996 to 1998 as data relating to designs is not available for 1995. Regression two also contains industry dummies at the two-digit level. These can be thought of as capturing differences in valuation across

[5] This ignores some types of preference shares and other securities, although the latter – for the market as a whole – are relatively unimportant (1% of entire market). Daily share price data are averaged to find the average market capitalisation over the year.

industries not controlled for by the other explanatory variables. The final regression omits the designs based explanatory variable. An additional year of data is utilised in this regression, increasing the sample size. The regression sample only includes those firms that are listed on the Australian stock market.

Table 2: Regressions

Dependent variable: log of market value

Explanatory variable	R1	R2	R3
Log (assets)	1.027* (0.03)	1.045* (0.03)	1.030* (0.02)
Intangible / tangible assets	-0.577~ (0.28)	-0.479 (0.34)	-0.588~ (0.26)
R&D / tangible assets	2.033* (0.68)	2.409* (0.74)	2.705* (0.71)
Patents / tangible assets	6.825* (1.53)	6.822* (1.61)	6.493* (1.57)
Trade Marks / tangible assets	0.942 (0.64)	1.132 (0.63)	1.031 (0.53)
Designs / tangible assets	1.846 (3.39)	0.385 (3.97)	
Year dummies	Yes	Yes	Yes
Two digit industry dummies	No	Yes	Yes
Observations	287	287	400
Adjusted R squared	0.87	0.92	0.92

Notes: The standard errors in brackets are based on White's robust method. The year dummies as a set are significantly different from zero. A * indicates significant at the 1% level, a ~ at the 5% level.

As discussed above, the aim is to use regression analysis to construct weights so that the various elements of innovative activity can be aggregated into a single index. At a theoretical level the most logical choice of weights are the coefficients on the R&D, patent, trade mark and design variables, since these represent the average 'impact' on market value. However, statistically, the coefficients on the trade mark intensity and design intensity are not significantly different from zero, which might suggest they should not be included in any index. For reference, the coefficients for trade mark intensity is significant at the 15% level, while the design coefficient is clearly far from significant.

From a practical point of view, one question is how sensitive an innovation index is to changes in coefficients and the variables included. To investigate this we create an index based on each of the three regressions in Table 2. The indexes are creating according to equation [1] using the regression coefficients. Note that an index value is calculated for all firms in the data (i.e. all firms that have some R&D expenditure or intellectual property activity) and not just those in the regression sample. The first two indexes use the coefficients from regressions 1 and 2, including the coefficient on the design variable. Note that the difference between the two regressions is that the second includes industry dummies. Since the regressions do not include additional explanatory variables (the X variables in [4]) the inclusion of industry dummies is important. The third index excludes the designs coefficient (equivalent to giving designs a zero weight).

This allows us to calculate the correlation between the indexes. In addition, each index is then used to create a ranking for each year of data. The firm ranked one has the highest value of the index. The Spearman rank correlations between the three indexes are then calculated. Both measures of correlation show the indexes are nearly identical (correlation values are above 0.99 in all cases). From this point of view the innovation index is not sensitive to the differences between the regressions in Table 2.

A further issue to investigate is whether firms maintain their ranking in the index over time. To assess this we calculate the Spearman rank correlation between successive years for index three. The results show that the rank correlations are between 0.75 and 0.80. This suggests a reasonably high level of persistence in innovative activities year on year.[6]

Table 3 provides a ranking of the top 20 most innovative firms for the year 1998. The index is calculated as follows using the results from regression R3.

$$I = 2.705R + 6.493P + 1.031T$$

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[6] There is no directly comparable international evidence to reference here. Geroski et al (1997) find low persistence in the patenting activity of UK firms over 1969-88, but here the index includes R&D and trade marks. Analysis on the persistence of profitability in the IBIS data show that around 75% of firms stay in the top quartile of performers year on year (Feeny and Rogers, 1998).

The index is then constrained to take values between 0 and 100. The firms innovative activities are also provided in the table. Sola International Holdings Limited tops the table. The company manufacturers opthalmic lenses. It ranks higher than Aristocrat Leisure Limited despite having a lower R&D expenditure and fewer intellectual property applications. This is because the innovation index takes account of firm size and Sola International has assets valued at $73.5 million compared to Aristocrat's $223 million. Aristocrat Leisure Limited is the leading supplier of gaming machines in Australia and currently the second largest supplier in the world. AMRAD Corporation Limited, ranked third on the index is a biotechnology research and development company, while Keycorp is a global provider of secure electronic transactions.

Other high performers include Varian Holdings which researches, designs, manufactures and markets scientific instruments, Alcatel Australia which is a telecommunications and internet company, Britax Rainsfords which supplies rear vision mirrors to Australian motor vehicle manufacturers, and Cochlear which manufactures hearing implants.

In general, we would expect the nature and extent of innovation is sector and industry specific. This fact is highlighted in the index, with 14 of the top 20 most innovative firms operating in the manufacturing sector. Given the industry specific nature of innovation it may be necessary to benchmark innovation for firms operating in the same industry. This issue is addressed in the next section.

Table 3: Innovation Index (1998)

Company Name	Index	R&D ($'000)	Patent Applications	Design Applications	Trademark Applications
Sola International Holdings Limited	100	10,651	8	0	0
Aristocrat Leisure Limited	90	27,890	13	0	58
AMRAD Corporation Limited	68	27,243	7	0	2
Keycorp Limited	57	17,156	0	0	1
Varian Holdings (Australia) Pty Limited	56	8,862	4	0	0
Alcatel Australia Limited	54	95,287	1	0	0
Britax Rainsfords Pty Ltd	52	7,705	2	0	0
Cochlear Limited	50	11,567	1	0	0
AWA Limited	45	1,263	0	0	44
Aspect Computing Pty Ltd	42	10,200	0	0	0
Intellect Holdings Limited	42	12,338	0	0	0
NEC Australia Pty Ltd	40	32,467	1	0	9
Ericsson Australia Pty Ltd	39	65,219	3	0	4
Farmoz Pty Limited	32	314	0	0	12
SDS Corporation Limited	31	50	3	0	1
Australian Wool Research and Promotion Org.	31	22,308	0	0	3
CSL Limited	27	39,082	5	1	15
Green's Foods Limited	26	182	0	0	25
Retravision (WA) Ltd	21	14	1	0	5
ERG Limited	19	29,353	0	0	1

Notes: The weights for the components where derived from regression R3. Only results for the year 1998 are shown

7. Performance benchmarking

As discussed in section 3, other methods of benchmarking are also possible if we restrict our attention to only those firms in the sample (i.e. those listed on the stock market). Rearranging equation [4] yields

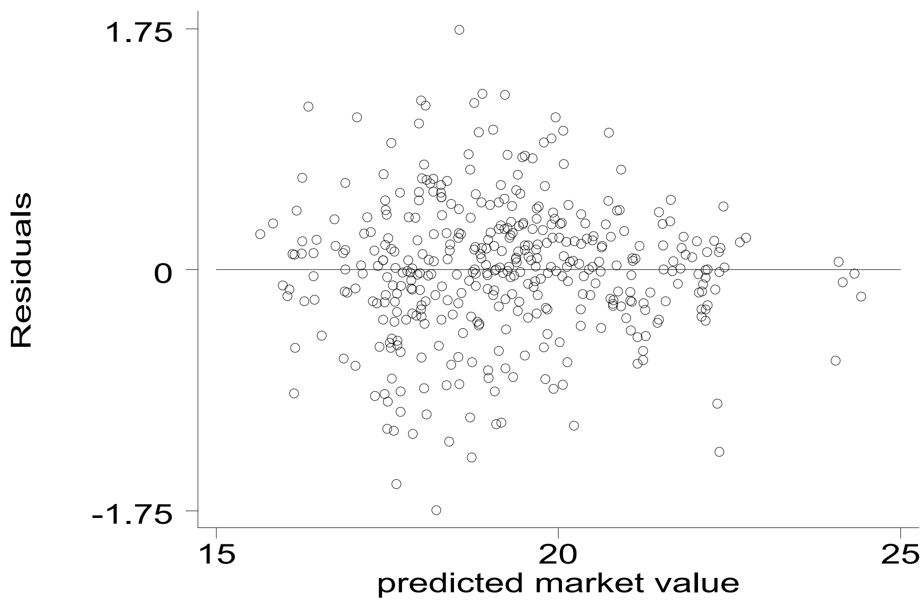
$$\log V_{it} - ind_i - d_t - \sigma \log A_{it} - \sigma\gamma_1 \frac{K_{it}}{A_{it}} = \sigma\left(\gamma_2 \frac{R_{it}}{A_{it}} + \gamma_3 \frac{P_{it}}{A_{it}} + \gamma_4 \frac{T_{it}}{A_{it}} + \gamma_5 \frac{D_{it}}{A_{it}}\right) + u_{it}$$

$$Adjusted\ \ q = index + u_{it}$$

where the m_i term has been replaced by the industry dummies (ind_i) and the X variables have been omitted. The second line renames the left hand side as 'adjusted q' and enters 'index' in place of the R&D and intellectual property variables. This version of equation [4] makes it clear that firms can differ from the 'average' valuation implied by the index, and this difference is capture by the error term (u_{it}). Firms that perform better than the average with have positive values for u_{it}, while those that under perform will have u_{it}<0.

Figure 1 below shows a graph of all u_{it} against the predicted market value for all firms in regression 3. Each firm is represented by a small circle and it is clear that at this level of aggregation there is little to be learnt from the graph.

Figure 1 Residuals for regression three



Of more interest are tables for specific industry sectors. As examples, tables 4 and 5 show the residuals for firms operating in 'Metal Ore Mining' and 'Petroleum, Coal, Chemical and Associated Product Manufacturing', in both cases only for 1997. To recap, firms with a positive residual have 'over' performed while those with a negative residual 'under' performed the benchmark, where the performance benchmark is the market value of the firm if its innovation activities attracted the average valuation.

Table 4: ‘Metal Ore Mining’ industry

Company Name	Residual
Normandy NFM Limited	1.21
Resolute Limited	0.37
WMC Limited	0.24
Newcrest Mining Limited	0.19
Aberfoyle Limited	0.18
Pasminco Limited	0.18
Normandy Mining Limited	0.06
Iluka Resources Limited	-0.08
Australian Resources Limited	-0.18
Broken Hill Proprietary Company Limited	-0.19
Amalg Resources NL	-0.23
North Limited	-0.37
Energy Resources of Australia Ltd	-0.42
Rio Tinto Plc - Rio Tinto Limited	-0.66
RGC Limited	-0.68
MIM Holdings Limited	-0.97
Ticor Limited	-1.13

Table 5: ‘Petroleum, Coal, Chemical and Associated Product Manufacturing’

Company Name	Residual
Blackmores Limited	0.44
Incitec Ltd	0.34
Gibson Chemical Industries Limited	0.27
CSL Limited	0.21
Wattyl Limited	0.19
Asia Pacific Specialty Chemicals Limited	0.08
F H Faulding & Co Limited	0.06
Southcorp Limited	-0.01
Arthur Yates & Co Limited	-0.18
Ludowici Limited	-0.31
Australian Chemical Holdings Pty Ltd	-0.46
Bridgestone Australia Ltd	-0.78
Joyce Corporation Ltd	-0.86

In principle, the residuals could be used to construct an index that indicated relative performance. However, we need to be cautious in interpreting the residuals as indicating relative *innovation* performance, since the residuals will include any variables not included in our regression model (e.g. management quality, human capital skills of workforce) plus any random events that occurred in a given year.

8. Conclusions

This paper has empirically analysed the link between innovation and firm performance using a sample of large Australian firms. Innovation is a complex process and is notoriously hard to define and measure. Most previous empirical studies use data on R&D expenditure and, sometimes, patents. This study has extended previous analyses by including trademark and design applications in addition to R&D expenditure and patent applications in regression analysis. Results from regression analysis indicate that R&D expenditure and patent applications are important determinants of the market value of a firm.

The coefficient values are used to construct weights so that the various elements of innovative activity can be aggregated into a single index. The subsequent innovation index benchmarks the innovative activities of large Australian firms and provides an important tool for Australian firms to compare their innovative activities with those of their competitors. Sola International, a manufacturer of opthalmic lenses is ranked first on the innovation index (for 1998) and the index is dominated by firms operating in the manufacturing sector. Further benchmarking analysis identified firms that performed better and worse than average in specific industry sectors. Such an analysis is important due to the industry specific nature of innovation and provides further benchmarking tools for Australian firms.

This study has found that innovation leads to increases in firm performance. So why don't firms undertake more innovation? One explanation is that innovative activity is risky that the high returns are compensation for this risk. An alternative explanation is that firms face financial constraints. If financing constraints are present for firms wanting to invest in innovation, an important policy implication is that innovation projects may need public support. Governments can support innovation in a variety of ways including subsidies, tax concessions, dissemination of information, and intellectual property rights.

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