Research and Development, Intangible Assets and the Performance of Large Australian Companies

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Abstract

This paper analyses two basic questions concerning R&D and the performance of large Australian firms using data from the IBIS data base. First, what factors determine the extent of investment in R&D. Second, what impact does R&D have on the dynamic performance of Australian firms. A review of previous work on these questions is included. In analysing the first question, using a sample of up to 85 firms, we find that technological opportunity is a major determinant of R&D. In addition, it appears that firms which are less "focused" (in terms of diversification of activities) have lower R&D intensities. Firm size appears to have no relationship to R&D intensity. To investigate dynamic performance we use a Tobin q approach which seeks to explain the market value of firms. We find that intangible assets are an important determinant of market value. In particular, we find that contemporaneous R&D expenditure is positively linked to market value. The strength of this relationship depends on the exact sample used. Lastly, firms which have experienced relatively high levels volatility in R&D expenditure appear to have lower market values.

1 Introduction

Technological change has long been recognised as a fundamental force driving company performance. This recognition led to a particular focus on research and development (R&D) activity. The general finding of the resulting literature was that the average private returns to R&D were positive and significant in magnitude (Mairesse and Sassenou, 1991; Mairesse and Mohen, 1995). The existence of formal R&D within a company not only contributes directly to the development of new products and to the reduction in production costs, but also aids the successful adoption of technologies developed outside of the firm.

The aggregate statistics about R&D are well known. In the mid-1990s, for example, R&D expenditure in Australia was over $6 billion per annum. Despite the fact that business R&D grew strongly in the 1980s (with an average increase of 13 per cent per annum), by the mid-90s it still formed only about 0.7 per cent of GDP, which was significantly below the average for OECD countries (Industry Commission, 1995a, p.2). As an overview, Australia looks relatively strong in terms of public support for R&D, but relatively weak in business R&D, ranking about 17th out of the 24 countries (DIST, 1996b, p. 10),

> "... in aggregate Australia appears to perform a disproportionately large amount of basic research and a relatively small proportion of experimental development when compared with other nations. This anomaly is due entirely to the relatively low level of business enterprise R&D in Australia." (DIST, 1996b, p. 11).

It is perhaps not surprising therefore that the Australian Government decided to retain the R&D tax concessions at this stage (albeit at the lower level of 125%), particularly as many of its Asia-Pacific competitors run similar schemes.[1] It also makes the topic of business R&D a particularly interesting one.

Data at the company level about R&D are much less common, despite the introduction of the R&D scoreboard, based upon company surveys (for a recent example, see DIST, 1996a). The "Scoreboard '96 'Top ten'", ranked by total expenditure was headed by Telstra Corporation Ltd, in the telecommunications sector, spending $218 million on R&D. The second and third ranked companies were: Broken Hill Proprietary Company

[1] After this paper had been written the Australian government in December 1997 announced further policies to encourage R&D. These were under the 'R&D Start' program and involved grants rather than R&D concessions. However, the equivalent rates of tax concession are calculated to be in the 150 to 200% range (see *Investing for Growth, The Howard Government's Plan for Australian Industry*).

Limited, in metal product manufacturing, spending $208 million; Ericsson Australia Pty Limited, in telecommunications, spending $98 million. As in other countries, the company spending on R&D is highly skewed, with a few companies doing the vast bulk of R&D. This can easily be demonstrated from the "Scoreboard" data, which shows that the 10th ranked company in 1996 (CSL Limited, in pharmaceuticals) spent $26 million, with a level of expenditure just over one-tenth that of the top-ranked company.

There are, then, at least two issues worthy of detailed consideration in the context of a study of the performance of large Australian companies: (i) what factors determine investment in R&D; (ii) what impact does R&D have on the dynamic performance of Australian companies. This key policy area has been the focus of a recent Industry Commission Report (1995a) which was concerned with the retention of tax concessions for R&D. We propose to investigate these two issues using data from the IBIS data base. Despite a number of key data issues, which we return to below, the IBIS large firm panel data set offers an opportunity to investigate the relationship between research and development, intellectual property, new investment in tangible assets and dynamic performance.

This chapter continues with a brief review of two main areas: one focusing on the determinants of R&D and the other exploring the empirical literature linking firm performance and technological change. Section 3 examines the data relating to R&D activity amongst large Australian companies using the IBIS data base. It also reports the econometric results from a number of equations which attempt to explain the extent of R&D across companies. Section 4 undertakes an exploration of the links between R&D and firm performance, before reporting on a series of econometric estimates based upon the Tobin q model. Finally, Section 5 draws together the main conclusions of this study.

2 Previous Findings: a Brief Review

In this section, therefore, we review two main areas of the mainly empirical literature which are relevant to this chapter. In Section 2.1 we explore the explanation of R&D, which is primarily based upon the Schumpeterian hypothesis. In Section 2.2 we turn to the explanation of company performance and, in particular, the role of R&D and innovation.

2.1 Determinants of R&D and Innovative Activity

2.1.1 Schumpeterian Hypotheses

We have a special interest in R&D activity because in-house, formal R&D is an important contributor to the stock of knowledge and has been linked to the extent and degree of success of innovative activity. In addition, as we have pointed out, there are important policy issues here concerning both the role of market structure and the inducement effects of tax concessions for R&D. There is a long tradition of research in the structure-conduct-performance (S-C-P) area that should, in principle, provide insights about the role of firm size and market power. Existing reviews are fairly comprehensive and we can be fairly brief (Kamian and Schwartz, 1982, Baldwin and Scott, 1987, Cohen and Levin, 1989, Cohen, 1995 and Symeonidis, 1996). The literature on the effects of tax incentives on R&D is more limited (Bernstein, 1986; Industry Commission, 1995a). The general view is that tax incentives give rise to positive social gains, although there is considerable dispute over the magnitudes involved. While this is a potentially important policy area, the lack of information about R&D in the IBIS data base, for the period around the time of the introduction of tax concessions in Australia preclude a detailed analysis of this topic.

It is always difficult to summarise what a particular writer, such as Schumpeter, had in mind, particularly in terms of a set of testable hypotheses. Put simply (and perhaps not wholly correctly), Schumpeter argued that, while larger firms with greater market power might be associated with greater static welfare losses, they were also (and more importantly) likely to be dynamically efficient. Whatever the outcome, it is worth adding that the vast majority (if not all) of the tests of the Schumpeterian hypothesis have been based upon recent data and not at the time (around 50 years ago) when the theory was proposed. On the other hand, it is still a fascinating problem with important policy implications.

It is perhaps useful to spell out the potential sources of the 'Schumpeterian effect' (Symeonidis, 1996, pp. 3-4). Innovation may increase more than proportionally with size because, large firms: (i) spread the high fixed costs of R&D across a large volume of sales; (ii) exploit economies of scale and scope; (iii) may be diversified and can exploit the unforeseen outcomes of R&D[2]; (iv) undertake a number of R&D projects and 'spread their risk'; (v) have better access to external finance. Innovation may increase with concentration because, firms with greater market power are able to: (i) finance R&D from their own profits; (ii) more fully appropriate the benefits. However, it is well known from the early work by Arrow (1962) that the profit incentive for innovation may be lower under monopoly than competition; an assertion that has created considerable theoretical debate in the literature.

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[2] Early research by Allen and Norris (1970) indicates just how uncertain the outcomes of R&D can be.

2.1.2 Econometric Issues in the S-C-P Literature

Most of the literature notes the problems associated with the measurement of inventive and innovative activity, where neither R&D expenditure or employment (input measures) nor patents, innovation counts, etc. (output measures) are entirely satisfactory. The focus solely on formal R&D, as defined in the Frascati manual, and the 'industrial' orientation of patents, are two common measurement issues referred to. It should be noted that both the R&D and, perhaps more especially patents, provide a 'declining yardstick' as economies have shifted their industrial structure away from manufacturing towards services (Griliches, 1990). Measurement problems also occur in other variables, for example, as Symeonidis (1996, p.12) points out, the problem is that the Schumpeterian hypotheses have generally been tested using measures of market structure, which are a highly imperfect proxy for firm level market power.

In addition, there is a tendency to focus on either R&D or innovation. These are clearly different things, not only conceptually, but also empirically. European Commission survey data, for example, suggest that, for an average firm, R&D forms only about one-third of total innovation expenditures (Bosworth, Stoneman and Sinha, 1996). Australian data suggest a similar figure (DIST, 1996b).

The problem of the treatment of zero formal R&D for the bulk of firms has also been increasingly discussed in the literature, though most of the estimates do not deal with issues of unobserved heterogeneity and sample selection bias (see, however, Bound, *et al*. 1984 and Cohen and Mowery, 1987). Such estimates do have the advantage of explicitly focusing on the question of the size at which firms undertake formal R&D, as well as the R&D intensity. Interestingly, the literature which has adjusted for selectivity appears to conclude that the OLS results are probably not too seriously biased. Work on company level statistics raises a further issue about "zero" reported R&D. In practice, until the general adoption of the accounting standards by companies, R&D reported in the accounts could be zero because no R&D was carried out or because the firm chose not to disclose this information. A recent study by Toivanen and Stoneman (1997) deals with this issue.

The literature also points to the potential problems associated with the endogeneity of firm size and market structure. This is fairly clear in the simplest case, where R&D improves firm performance, making the company grow *vis à vis* its competitors in a particular market. However, the endogeneity problem seems weaker the longer the period between the expenditure on R&D and the resulting benefits. Symeonidis (1996, p. 6), for example, points to the range of lags between R&D and the associated revenue stream as being 2-4 years. The potential simultaneity with profits may also be worrying (current economic profit is a measure of the ability to fund R&D), if the impact of R&D

on profits is immediate. Symeonidis (1996, p. 6) notes that there is some empirical evidence to suggest that the lag between completion of the project and its effect on profits may be less than 1 year. This may be true in many sectors, bearing in mind that most inventions and innovations are not radical in nature and that firms now place considerable emphasis on ‘speed to market’ in order to appropriate the returns to R&D. However, it is clearly not the case in some specialist markets, such as pharmaceuticals where medical control agency testing drives a wedge between invention and product launch.

Note that the generation of subsequent profit streams is indicative of a changing market structure and increasing monopoly power. In Section 2.2 below, for example, we argue that if a firm’s R&D is successful, it creates new intellectual property, which increases its future profits. The relationship between IP and innovation is brought out by Metcalf (1995, pp. 412-413),

> "In quite a fundamental sense, innovations and information asymmetries can scarcely be termed market imperfections when they are necessary conditions for any technological change to occur in a market economy".

The links through to market structure, however, are potentially complex, depending on the innovatory activity of all firms in the market, the growth of the market and the links between innovation and diversification. Indeed, theoretical work suggests that more intensive competition may cause firms to merge or exit, increasing the degree of concentration (Sutton, 1991).

Authors have suggested the need to include dummies to control for 'industry effects' (Cohen and Levin, 1989). This is especially important insofar as firm size is likely to be correlated with industry-level factors, including technological opportunity. The earlier discussion, however, suggests that it may not be sufficient to simply include industry dummies, as lags and feedbacks may differ from industry to industry. Of course, sample sizes may not be sufficiently large to estimate the model industry by industry. In addition, there are unresolved conceptual problems concerned with the linkages between industries and the role of conglomerates, which, by definition, are diversified across industry boundaries (see the discussion of purposive diversification by Scott, 1993).

2.1.3 R&D, Innovative Activity and Firm Size

Given that these problems remain to be solved, individually or in combination, the existing empirical estimates are to some extent open to criticism. On balance, the reviews of the literature tend to suggest little support for the Schumpeterian relationship between R&D and firm size, except, perhaps in certain sectors, such as chemicals

(Kamien and Schwartz, 1982, Patel and Pavitt, 1992). Even the seminal papers of Scherer (1965a and 1965b) tended, if anything, to suggest an inverse 'U-shaped' relationship between R&D and sales. While this is often the stylised view, it has not been universal. Indeed, Bound, *et al*. (1984), based upon a relatively strong data base, report a 'U-shaped' rather than inverse 'U-shaped' relationship. Sectoral differences in the firm-size relationship crop up frequently in the literature, as in the cases of Soete (1979) and Pavitt, *et al*. (1987) and Acs and Audretsch (1987). In essence, the direction of the relationship depends on which sector the firm operates. Even where research using panel data appears to reveal an S-C-P type linkages, the inclusion of firm-specific effects generally seems to undermine, if not entirely remove, the relationship (see, for example, Scott, 1993).

The current state of knowledge about the relationship between R&D and firm size is summarised as,

> "What is then the consensus, if any, on the relationship between firm size and innovative activity? First, the large majority of very small firms do not engage in R&D, although the extent to which some small firms do informal R&D is difficult to assess.[3] Second, above a certain threshold size, R&D seems to rise more or less proportionally, on the whole, with firm size, although there are variations of this pattern across industries, time periods and countries. Third, the evidence on the relationship between innovative output and size is inconclusive; most authors would probably agree that innovative output tends to rise less than proportionately with firm size, although other patterns have also been suggested for particular industries, periods or countries. Fourth, smaller firms seem to produce more innovations or obtain more patents relative to their formal R&D spending than larger firms". (Symeonidis, 1996).

2.1.4 R&D, Innovative Activity and Market Power

As we have noted, there is a complex relationship between innovative activity and market power and, in addition, the concentration ratio is a highly imperfect proxy for firm power. Given these points, the results are again very mixed with: some studies providing tentative support (Scherer, 1965b); others no support (see Kamian and Schwartz, 1982); others suggesting an inverse 'U-shaped' relationship (Scott, 1984 and Levin, *et al*. 1985). Again, we note that, in the main, the studies that have included

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[3] Certainly unofficial surveys that do not restrict firms to the Frascati definition tend to find much more R&D activity (Bosworth, *et al*. 1992).

either detailed industry dummies or, in panel data sets, firm specific effects, have tended to find that these undermine any systematic relationships which appear to hold in their absence (for a good example see Scott, 1993). Geroski (1991) attempted to explore a more complex relationship which distinguished between the 'indirect effects' (relating to the role of market power in aiding appropriation) and 'direct effects' (all other effects of market power), using a range of six different measures of market power. He found that the indirect effect was positive, but the direct effect was negative.

The other main strand of the literature traces the simultaneity between R&D and market structure.[4] A number of examples exist, although they are highly diverse, not only in their choice of data set, but also their model design and equation structure. Lunn (1986), for example, uses a four equation model, estimated using data for 191 US industries. He separated process and product innovations. The results suggested that higher levels of concentration had a significant positive effect on process innovation, but did not influence product innovation. The reverse causation was also significant positive for process innovation, as it raised the degree of concentration; product innovation, on the other hand had a weakly significantly negative impact on concentration. In a three equation model based on rather aggregate data, Levin and Reiss (1984) found concentration had a significant negative impact on R&D.

The recent literature has increasingly focused on the role of international competition in driving domestic innovation. In a study of 308 US firms that were being exposed to increasing levels of high technology imports during the period 1971 to 1987, they found that this had an insignificant negative effect on domestic R&D. In a study of 1270 German firms over the period 1984 to 1988, Bertschek (1995) found that import penetration had a positive impact on domestic product and process innovations.

Based upon a much more detailed review of the literature Symeonidis (1996, p. 16) concludes

> "The main characteristic of the empirical literature on the innovation-market structure hypothesis is its inconclusiveness. However, three results seem to have emerged. First, there is little evidence of a positive relationship between R&D intensity and concentration in general, although there may be circumstances where such a relationship exists. Second, there is even less evidence of a positive relationship between innovative output and market

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[4] As Symeonidis (1996, p. 14) points out, this literature can be traced back to a seminal paper by Almarin Phillips (1976), which effectively explored the effects of R&D on market structure. In this, the scientific stimulus for new aircraft technologies took place largely outside of the industry, but gave the technological opportunity for firms in the industry to develop new designs. The resulting innovations led to higher concentration, but also stimulated further R&D.

structure. Third, industry characteristics such as technological opportunity explain much more of the variance in R&D intensity and innovation than market structure."

2.1.5 Concluding Comments on the Determinants of R&D

The conclusions from Symeonidis (1996) have already been covered. Here we turn to any additional insights that can be gleaned from a very thorough review of empirical studies of innovative activity by Cohen (1995). With regard to the effect of market structure, for example, Cohen (1995, p. 232) concludes,

> "...the literature suggests that its direct influence is small, and it likely reflects the influence of other more fundamental determinants of technical advance, specifically technological opportunity and appropriability conditions."

With regard to the effect of firm size, he concludes, that,

> "...although very important, its influence likely emerges from underlying industry conditions that limit firm growth due to innovation and confine firms to appropriating the returns to their innovations by embodying them in their own output". (*op cit*, p. 232).

2.2 Market Value as the Performance Indicator[5]

2.2.1 Knowledge Production Function

There are two principal branches of econometric literature linking firm performance with R&D (or other forms of investment in intangible assets). The first is known as the knowledge production function. In essence, this approach argues that the value of current output, controlling for tangible capital and employment, is higher, the greater is earlier investment in R&D, which creates a stock of R&D knowhow (or intellectual property). In other words, total factor productivity is driven by past R&D activities. From the empirical results it is generally possible to calculate both an elasticity of sales to R&D, other things being equal, and the rate of return to R&D. Without going into any detail (as this is not the empirical route we take), the large volume of results vary quite considerably in their magnitude (Mairesse and Sassenon, 1991, Mairesse and Mohen, 1995, Griliches, 1995), but taken over all, suggest a positive and significant role for own R&D and for spillover effects (see Griliches, 1992, for a discussion of

[5] This review draws upon some of the material collected by Hamid Mahdian during the course of his PhD thesis.

spillovers.) Unfortunately, this approach is relatively difficult to operationalise using company accounts data, which rarely publish either value added or raw material and intermediate inputs, in anything like an accessible form. An alternative is to use "Tobins q" although, we will demonstrate below, that this still makes considerable data demands. Elsewhere, we have demonstrated that, at least under certain conditions, the two approaches are consistent and, in principle, should yield identical results (Bosworth and Gharneh, 1996; Bosworth, 1996).

2.2.2 Market Valuation and Tobin's q

Market value is a particularly interesting measure of performance because, at least in principle, it reflects the market's view of the discounted future profits (and dividends) that can be attributed to the intangible assets. It is, therefore, a forward looking, long-run indicator of firm performance. Note, however, that estimation of such functions using the IBIS data set, requires matching on new information about the market valuation of the companies in the sample. This has some important implications for the size of the sample we can work with in the present study.

There has been a strong empirical branch of research focusing on the valuation of intangible assets by the market. The basic idea is that the market value of the company should reflect both its tangible and intangible assets. The most commonly used indicator of intangibles is research and development expenditure, although patent counts have also been increasingly incorporated in the empirical specification. Thus, the basic 'Tobin q' model was extended to include intangible alongside the tangible assets of the firm. The market value of the company is defined as the amount of money investors would have to pay for it as a going concern, and is calculated as the value of equity, plus preference shares plus debt.

Perhaps the earliest example was a study of a panel of 157 US firms, giving 1000 observations in total, in which the influences on the market value of companies included R&D and patenting activity (Griliches, 1981). Both variables were entered with lags. In addition, both R&D and patents were decomposed into 'actual' and 'surprise' elements, where the latter was measured as the difference between actual and predicted values. Other variables included the b coefficient as a measure of risk. The results indicated a significant, positive relationship between the value of the firm (represented by the original measure of Tobin's *q* i.e. the ratio of the market value to book value of tangible assets) and the level of R&D and patents applied for by the firm.

Later studies have followed broadly in this tradition. Connolly and Hirschey (1984) used what they called a measure of 'relative excess value' as their dependent variable.

This was viewed as a measure of the profitability of companies, but is close to being a measure of the ratio of intangible assets to sales.[6] The resulting specification explained relative excess value as a function of R&D per unit of sales, advertising per unit of sales, the concentration ratio, growth rate, diversification index, and b coefficient. A number of the variables were also entered interactively with the concentration ratio. The model was estimated using data for 390 US firms in 1977. The results suggested a positive effect of both R&D and advertising on relative excess value, but a negative R&D-concentration ratio interaction effect.

Ben Zion (1984) used a panel data set for 94 US firms over the period 1969 to 1977. The model explained the market value of the firms by using the book value of their assets, a measure of earnings, R&D expenditure, firm patents, industry patents and investment. Of the various explanatory factors, earnings are probably the most important influence on the firm's book value. However, the market value of the company is also affected by its R&D and investment activity, with the latter a major route by which the firm brings in new technologies from outside.[7] In practice, the patenting activity of the industry has a greater effect on market value than the firm's own patents.[8] A very similar study by Johnson and Pazderka (1993), using a series of short panel data sets for Canadian firms (52 firms during 1985 to 1987; 54 firms for 1986 to 1988; 47 firms for 1985 to 1988) showed a statistically strong relationship between R&D spending and market value. Their results, however, suggest a much higher rate of depreciation of the R&D knowledge stock than historically has been assumed in the literature (50 per cent compared with 15 per cent).

Hall (1993) reports the results of a similar model, but using a much more extensive data base of US companies, involving 2480 companies over the period 1973 to 1991. The independent variable is the log of market value, with the log of the book value of tangible assets appearing on the right hand side of the equation. Thus, Tobin's q again underlies the chosen empirical specification. The main intangibles are R&D (expenditure or stock) and advertising expenditure (which is used as a proxy for brand value). In addition, there is a two year moving average of cash flow (net of R&D and advertising expenditures) and the growth rate of sales in the current year. Finally, the

[6] This is the market value of shares plus the book value of debt minus the book value of tangible assets, normalised by the value of sales.

[7] The result regarding the role of investment is confirmed by the results of a number of different studies, see, for example the *Community Innovations Survey* (Bosworth, *et al.* 1996) and in a UK study based upon the Tobin q model (Stoneman, and Bosworth, 1994) see below.

[8] This is perhaps not too surprising, given the inclusion of both the firm's own R&D and the firm's patents. A similar result was obtained in Stoneman and Bosworth (1994)

model includes several other variables, such as the investment in unconsolidated subsidiaries, year dummies, etc. The results suggest that, although the mean level of R&D and advertising expenditures are almost the same, the associated valuation for the period as a whole is around 4 to 5 times as high for R&D as for advertising. Recent R&D appeared to have a higher explanatory power than the R&D stock, which probably reflects the crude perpetual stock measure based upon a guestimate of the depreciation rate. On the other hand, the very high rates of return to R&D in the earlier period fell away over time and the initially relatively low returns to advertising increased in more recent years.

In a study of a balanced panel data set of 180 UK companies over the period 1984 to 1992, Bosworth and Stoneman (1994) estimated a very similar model. The principal difference was the omission of the advertising variable, given the under-reporting of this variable in UK accounts. The empirical specification, however, included patent grants and/or a patent stock measure. The results suggested positive relationships between both the R&D and patent variables and the market value of the companies. In general, R&D performed more strongly than patents and, when they were both included in the specification, the former tended to dominate the latter, although both had significant positive coefficients when estimated using the full panel data set. An additional finding was that the R&D activities and patenting activities tended to be fairly stable for each firm. Thus, it made little difference to the results whether the flow or stock variables were used. By implication, when firm-specific effects were included, these tended to take up a considerable degree of the explanation.

A number of studies have focused more clearly on the role of spillover effects, such as the work of Jaffe (1986). This study used data from 432 US firms over the period 1973 to 1979. The dependent variable was the logarithm of Tobin's q.[9] The principal variables include the ratio of R&D to assets, the weighted sum of the R&D of all other firms in the industry, market share and a four firm concentration ratio. The R&D to assets variable was also entered interactively with the R&D pool variable. There were also 21 'technological cluster' dummies. The principal conclusion is that, in general, firms undertaking R&D in areas of high R&D activity obtain a higher return to R&D; but, firms with low levels of R&D in the face of relatively high levels of such activity amongst their competitors, experience relatively low returns. The effect of higher concentration at the firm or line-of-business level was, on balance, to reduce profitability.

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[9] Note that the log-linear form generally involves an approximation, which may introduce some bias to the estimated parameters. For a discussion, see Hall (1993b).

2.2.3 Conclusions Relating to the Tobin q Approach

There are many other studies along broadly the same lines. Each of these tends to focus on a slightly different aspect. Megna and Klock (1993), for example, show that the R&D stocks of rival companies have a negative impact on the market valuation of the firm in question.

At the time of writing there are no comprehensive reviews of this area of the literature that we can draw upon. However, some key points emerge. First, that the measurement of the intangibles is far from perfect. R&D knowledge stocks, for example, are generally based on an assumed, exogenous rate of depreciation. We have shown elsewhere, that the true rate is endogenous (Bosworth and Jobome, 1997). Clearly, the problems associated with patent counts have been widely discussed in the literature. In addition it is fairly obvious that even studies that include R&D, patents and advertising only begin to scratch the surface with regard to the possible range of intangibles. A related point is that the firm specific effects again tend to play an important role and certainly, in a study for the UK, tended to undermine the role of patents (and to a lesser degree R&D) in the equation (Stoneman and Bosworth, 1994).

3 Empirical Exploration of the Determinants of R&D

3.1 Introduction and Overview of the Data

This section undertakes an empirical analysis of the R&D expenditure data contained in the IBIS data set. As discussed in the previous section, we are concerned with two basic questions. First, what determines the level of R&D intensity of large Australian firms? Second, how does R&D expenditure affect firm performance? These questions are analysed in sections 3.2 and 3.3 below. In the remainder of this section we provide an overview of the R&D data.

The data set for our analysis contains four years of firm data from the IBIS data base (for each of the financial years ending in 1991 to 1994). There are only 85 firms that have non-zero R&D expenditure data for each of these four years. With only 85 firms it might appear that the R&D carried out by these firms is a very small proportion of total R&D carried out in Australia. Table 1 considers this by comparing our 85 firm data set with Australian Bureau of Statistics (ABS) figures for R&D expenditures (which is based on a survey of about 3,000 firms[10]). The table shows the total amounts of R&D

[10] The survey size was based on a "complete enumeration of businesses identified by the ABS as potential R&D performers" (ABS, 1995, Cat. No.8114.0, p12). There was a 91% response rate and the ABS considers that non-respondents did not perform R&D.

expenditure for both the ABS and the 85 firm data set (in the single year 1994). For example, in the data set used here there is a total of $555.1 million dollars of manufacturing R&D expenditure, compared to $1,686.6 million in the entire ABS data set, and $755.5 million for the ABS sub-sample of large firms (firms with employment over 1000). Our sample has even higher coverage for the mining sector. However, the coverage is poor in the wholesale and retail sectors, as well as the property and business services sector. Similarly, our data set has no coverage of the finance and insurance sector, whereas the ABS report $93.3 million being spent by large firms. In summary, the data set represents a substantial proportion of total Australian R&D expenditure, especially in the mining and manufacturing sectors.

Table 1 Comparison of IBIS R&D data set with ABS data

Sector	*No. of firms in IBIS data set with non-zero R&D*	*R&D expenditure (1994 $ millions)*		
		IBIS 85 firm total	*ABS All firm total*	*ABS Firms with employment > 1000*
Mining	6	162.3	309.4	171.7
Manufacturing	65	555.1	1686.6	755.5
Wholesale and retail	9	33.8	221.4	81.9
Property and business services	2	7.6	435.9	24.8
Electricity, gas and water	2	9.5	na	na
Construction	1	1	na	na
Finance and insurance	0	0	112.0	93.3
Total	85	769.3	2765.3	1127.2

The panel data set allows us to analyse how R&D expenditure has changed over time.

Hall, Griliches and Hausman (1986) assert that R&D expenditures are relatively stable in a sample of 642 US firms over the 1972-79 period.[11] To study this issue for the Australian firms, Table 2 reports the sample means, medians and standard deviations for the 85 firm sample. There are two sub-sections to the table. The first contains R&D expenditures in thousands of dollars, the second looks at R&D intensity (defined as the ratio of R&D expenditure to total revenue). The table alerts us to the fact that the distribution of R&D – for both expenditure and intensity – is likely to be skewed, since the mean and median are very different. Furthermore, the dramatic changes in R&D intensity in the last two years of data suggest a high level of volatility.

Table 2 Summary R&D statistics for 85 firm sample

	Year			
	1990-91	*1991-92*	*1992-93*	*1993-94*
R&D expenditure ($ 000s)				
Mean	6213	7245	8884	9034
Median	2042	2110	2000	1879
Standard deviation	12146	13830	17710	19895
R&D intensity (%)				
Mean	1.8	2.3	3.0	1.7
Median	0.7	0.7	0.8	0.8
Standard deviation	3.0	5.0	11.3	2.6

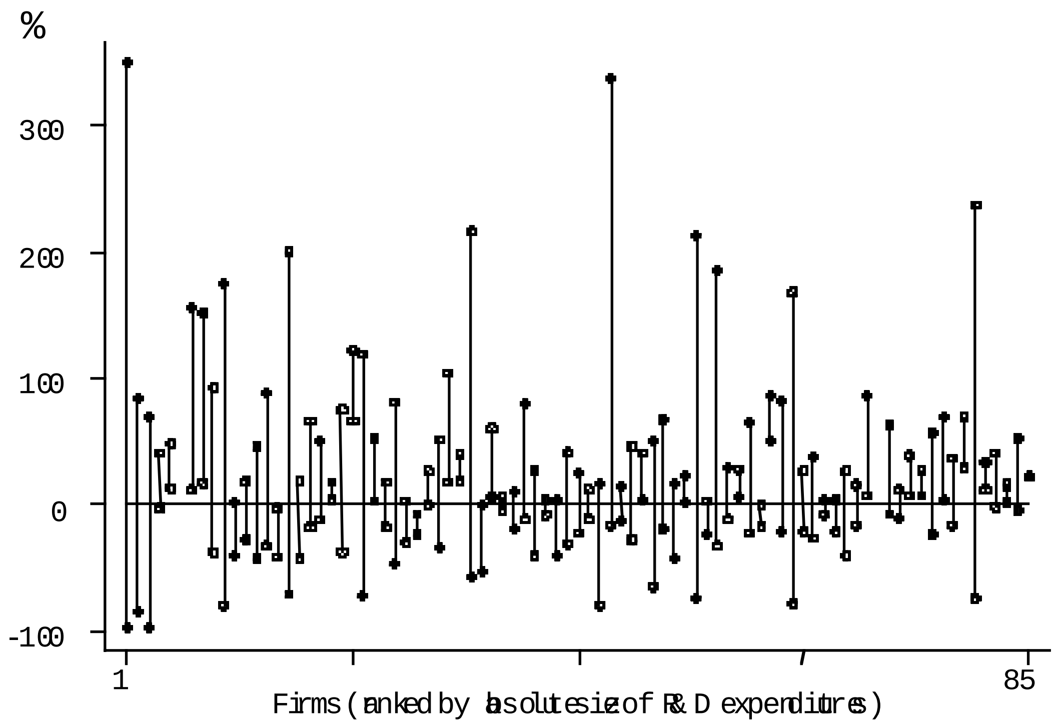
Note: R&D intensity is the ratio R&D / total revenue expressed as a percentage.

To investigate the variation over time of R&D expenditures we calculate the percentage change in R&D expenditure for each firm for the three possible year on year calculations (1990-91 to 1991-92, 1991-92 to 1992-93, and 1992-93 to 1993-94). Figure 1 then plots the maximum and minimum percentage change for each firm in the sample, and then joins the maximum and minimum points with a vertical line. Two firms are omitted from the figure since their percentage changes dominate the scale of the figure (these firms are Orbital Engine Company and Blackmores). To interpret Figure 1, note that a long vertical line indicates that R&D expenditure has changed substantially. A horizontal line is marked on the figure at 0%. If a vertical line extends below this line it means that the firm decreased its annual level of R&D at some point.

[11] They conclude. "R and D budgets over this short horizon (8 years) are roughly constant or growing slightly (in constant dollars)" (p.281, 1986). It should be noted, however, that Hall et al excluded from their sample firms which experienced a large increased in capital stock or employment (>100%), or large decreases (>50%), over the period (p.268, 1986).

As can be seen from the figure, many firms have high levels of volatility in R&D expenditure and many have reduced their expenditure at some point. In the figure, firms are ordered on the horizontal axis according to absolute size of average R&D expenditure over the four years (with the smallest R&D spending firm at the far left). This allows us to see that there is no obvious variation in volatility according to size of R&D expenditure.

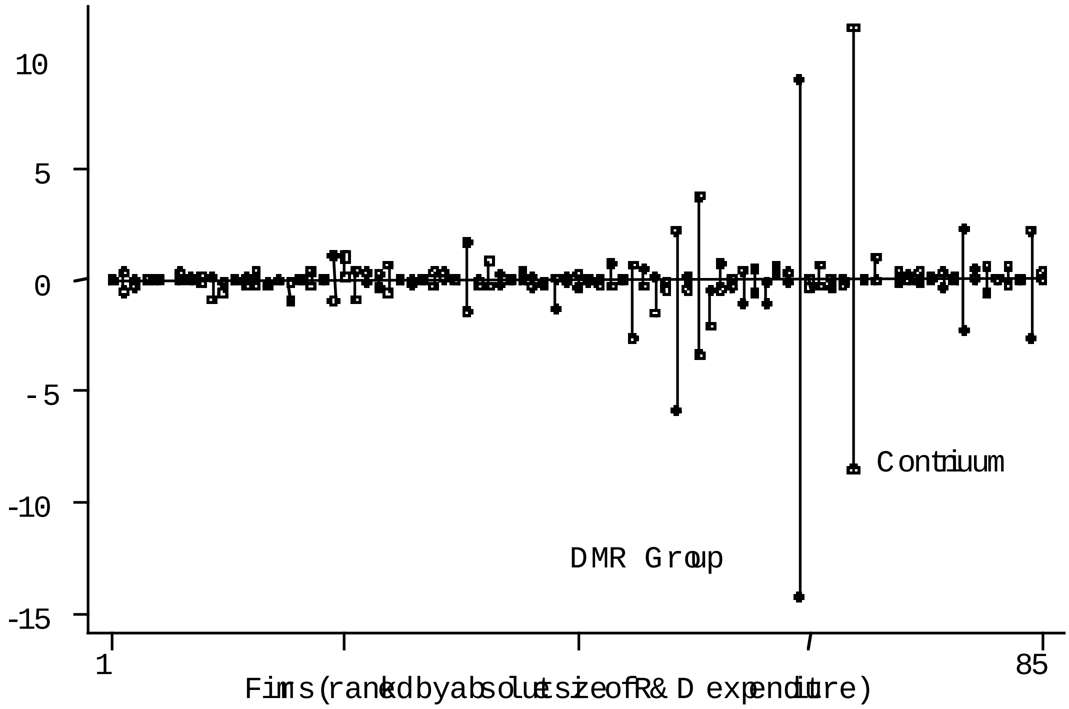
Figure 1 Volatility of R&D expenditure



A similar figure can be produced for the change in R&D intensity over time for each firm.[12] In this case, the change in R&D intensity is calculated in percentage points (i.e. if a firm had a 2% R&D intensity one year, and this rose to 3% in the next, then the change is +1%). For each firm we then plot the highest and lowest change in intensity and, as before, join these with a vertical line. Again, long vertical lines indicate that R&D intensity has changed a lot, and lines that go below the 0% horizontal line indicate that R&D intensity fell at some point during the 4 year period. Figure 2 again excludes the two firms with the highest level of R&D volatility (Orbital and Blackmores). Even so, the figure is still dominated by a few firms. In our sample, therefore, there are a number of firms that have dramatically altered their R&D intensity.

[12] Since R&D intensity equals R&D divided by revenue we would expect R&D intensity to also be volatile over time. However, volatility could be increased or decreased according to the behaviour of revenue.

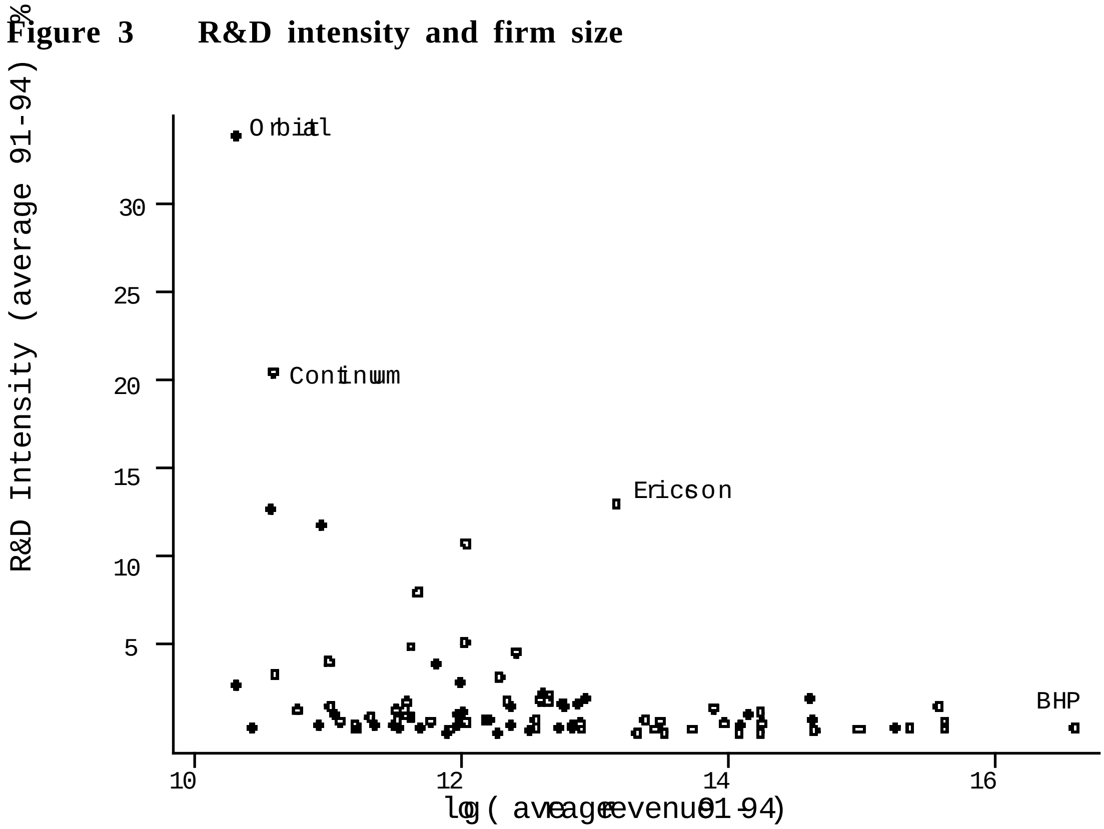
Figure 2 Volatility of R&D intensity



The volatility in the R&D could be due to a number of factors: the "lumpiness" of R&D projects; tax and policy changes; data reporting and accounting changes; mergers or acquisitions and, economic and competitive factors. Trying to separate out these factors is not something we attempt in the present paper. However, the volatility of the data suggests that any empirical analysis must consider the potential role of influential observations and outliers.

The last aspect we will consider in this overview section is the relationship between firm size and R&D intensity. Figure 3 plots the average R&D intensity (over the four years in the sample) against the log of the average revenue for each firm in the sample. The figure is dominated by a relatively small number of firms that have high R&D intensity (above 0.1, equivalent to 10%). The presence of these firms suggests a negative relationship between R&D intensity and total size. However, the bivariate plot may hide other important influences on R&D intensity which, when included in the analysis, may alter this negative relationship. The next section uses regression analysis to investigate these issues.

Figure 3 R&D intensity and firm size



3.2 Determinants of R&D Intensity

As discussed in Section 2, economists have considered a large number of variables that are thought to be important determinants of R&D intensity. Table 3 below lists the explanatory variables that have been collated for the present empirical analysis. The table is split into firm specific variables and industry specific variables. The industry specific variables, which are collated from ABS and Industry Commission sources, are only available for the manufacturing firms in our sample. Hence, we run two sets of regressions: a full sample that includes only the firm specific variables, and a sub-sample of manufacturing firms. The dependent variable is R&D intensity defined as R&D expenditure divided by total revenue.[13] The full sample regressions are reported in Table 4.

[13] Total revenue was used since, the more normal, total sales was not available for all firms. The correlation coefficient between R&D/revenue and R&D/sales is 0.99 for the 76 firms that have sales data. Some regressions were run with R&D/sales as the dependent variable and there was no appreciable difference in results.

Table 3 Explanatory variables

Variable Name	*Description*
Firm variables	
Foreign	Dummy for whether firm is foreign owned (50% level or higher stake)
Diversification proxy	Number of 4 digit ANZSIC industry sectors in which the firm's subsidiaries operate
Firm size	Various measures including total revenue and assets
Industry variables	
Technology opportunity dummies	Three dummies for low, medium and high technological opportunity
Effective assistance	Effective rate of assistance given to industry (3 digit level)
4-firm concentration	Share of industry turnover accounted for by the 4 largest firms (2 digit level)
Industry share	Firm's share of industry revenue (2 digit level)

Notes: Technological opportunity classification is at 2 digit level and is taken from B.I.E. (1993, p.214). Effective rate of assistance for 3 digit ASIC code from Industry Commission (1995b). 4-firm concentration ratio and industry turnover taken at 2 digit level from various years of A.B.S. Catalogue 8221.

Table 4 Regressions for full sample

Dependent variable: average R&D intensity over 1991 to 1994

Explanatory variable *n = 80*	*R1* *(no industry dummies)*	*R2* *(includes industry dummies)*
constant	0.0476 (1.113)	-0.0538 (-1.276)
foreign owned	0.0072 (1.092)	-0.0007 (-0.103)
log (revenue)	-0.0025 (-0.736)	0.0046 (1.380)
diversification proxy	-0.0005 (-1.082)	-0.0011* (-1.965)
R^2	0.07	0.64

* 10% significance level

Notes: Industry dummies are included for each separate 2 digit ANZSIC sectors. The t-statistics reported in brackets are calculated using White's robust method since heteroscedasticity tests were failed in the simple OLS. The diversification proxy is the average number of ANZSIC codes over 3 or 4 years in which a firm has subsidiaries. Five firms are omitted from the regression sample since data on subsidiaries is for 2 years or less. Log revenue is averaged over 4 years.

Table 4 shows that including industry dummies makes a substantial difference to the regression results.[14] The R^2 rises to 0.64 and coefficients change in sign and significance. The results from the regression with industry dummies suggest the following: there is no significant effect of foreign ownership on R&D intensity, that increased firm size (as proxied by log of revenue[15]) has no significant partial correlation with R&D intensity, and increased diversification (as proxied by the number of 4 digit ANZSIC codes that a firm has subsidiaries in) reduces R&D intensity. These results have been investigated for robustness by running additional regressions that exclude observations with extreme values of R&D intensity, diversification or revenue. In all cases the results in Table 4 appear reliable. As a further check on the results, a larger

[14] As might be expected, the industry dummies were highly significant as a group (F(13,63) = 73,140).

[15] The total assets of the company were also used as a measure of firm size, there appeared to be little difference between the results.

data set was compiled for companies that have non-zero R&D data for 1993 and 1994. Since the IBIS data set has increased its coverage of R&D expenditures over time this allows a regression with 146 firms to be run (i.e. an additional 66 firms). The equivalent specification to regression R2 again shows that the coefficient on the diversification variable is negative (-0.0005) and significantly different from zero at the 13% level.[16] The coefficients on the foreign ownership and the log of revenue variables are insignificantly different from zero in this enlarged regression, again confirming the results in Table 4.

Table 5 contains the regression results for the sub-set of manufacturing firms. The difference between the two regressions is that regression R4 has two firm specific dummies for the two highest R&D intensity firms (these firms are CSL and Ericsson, coefficients on these dummies are not reported). As discussed above, the firm dummies are included since the presence of a few firms with high R&D intensities may distort the results of the regression. The two firm specific dummies are both highly significant and positive, and increase the R^2 dramatically. However, reassuringly, they do not alter the broad pattern of results. Regressions R3 and R4 again show that foreign ownership is not a significant explanator. As in the full sample, the level of diversification of manufacturing firms (as proxied by the number of ANZSIC codes a firm has subsidiaries in) has a negative and (marginally) significant association with R&D intensity.[17] Similarly there is no evidence that firm size is significantly related to R&D intensity. This result holds even when alternative proxies for firm size are used (e.g. the log of assets, the level of revenue, or the level of assets).[18]

The coefficients on the industry specific explanatory variables indicate that the four firm concentration ratio and the share of industry output have no significant relationship with R&D intensity (omitting either of these variables from the regression has no effect on the magnitude of the coefficients on the remaining variables). The coefficient on the effective rate of protection does, however, appear to have a negative and significant partial correlation with R&D intensity, although this is only the case in the regression

[16] The enlarged regression averages the variables over 1993 and 1994.

[17] A concern is that the diversification proxy is picking up the fact that subsidiaries in non-manufacturing sectors may do little R&D (as it is normally defined) and that this effect gives rise to the negative association. To test this a dummy variable was created for firms that had all of their subsidiaries within the manufacturing sector (there are only 4 manufacturing firms that satisfy this requirement). When added to the regression the coefficient on this dummy variable was insignificantly different from zero. This implies that the coefficient on the diversification proxy is not driven by the non-manufacturing subsidiary issue.

[18] Regressions were also run using the square of log of revenue in case there is a non-monotonic relationship. All coefficients were highly insignificant.

with the two firm specific dummies. As a further check of this result, the regression R4 was run with industry (2 digit level) dummies. The addition of the industry dummies reduces the significance of the coefficient on the effective rate of protection variable to the 10% level, although the coefficient increases in magnitude to –0.0004.[19] Thus the result on the effective rate of protection variable does not appear to be caused by the variable proxying industry differences (e.g. older industries, with lower technological opportunities, may have higher rates of protection). If this coefficient represented a causal link between protection and R&D intensity the magnitude of the effect is such that a 10% fall in effective protection would lead to a 0.2 to 0.4% rise in R&D intensity. As a further check on this results, the larger sample of firms (with positive R&D data for 1993 and 1994) was again used to run the equivalent regressions shown in Table 5. These regressions have a total of 101 manufacturing firms with variables averaged over the two year period. The results from these regressions show the expected sign and significance on the two technological opportunity dummies, however, the other coefficients are all insignificantly different from zero at the 10% level. In the larger sample, therefore, there is no evidence of a negative relationship between the effective rate of protection and R&D intensity.[20]

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[19] The addition of the industry dummies causes the coefficients on the medium and high technological opportunity dummies to become insignificantly different from zero (as would be expected since the industry dummies pick up the variation across industries). Omission of the technology dummies increases the significance on the effective rate of protection coefficient.

[20] As with the smaller sample, various regressions were run with dummy variables for high R&D intensity firms. The results of such regressions still showed all coefficients were insignificantly different from zero (apart from the technological opportunity dummies).

Table 5 Regressions for manufacturing firms

Dependent variable: average R&D intensity over 1991 to 1994

Explanatory variable *n = 61*	*R3*	*R4* *(with dummies for 2 high R&D intensity firms)*
constant	-0.0222	0.0148
	(-0.499)	(0.830)
foreign owned	-0.0027	-0.0027
	(-0.488)	(-0.908)
log (revenue)	0.0023	-0.0006
	(0.630)	(-0.443)
subsidiaries	-0.0008	-0.0003
	(-1.571)	(-1.622)
dummy for medium technology opportunity	0.0078*	0.0077**
	(1.922)	(2.4573)
dummy for high technology opportunity	0.0312**	0.0164**
	(2.957)	(4.346)
effective assistance	-0.0002	-0.0002**
	(-1.193)	(-2.087)
4-firm concentration	0.0249	0.0099
	(0.874)	(0.739)
industry share	-0.0016	0.0065
	(-0.122)	(0.692)
R^2	0.31	0.88

* significant at 10% level ** significant at 5% level

Notes: The t-statistics reported in brackets are calculated using White's robust method since heteroscedasticity tests were failed in the simple OLS. Regression R4 has a dummy variable for Ericsson and CSL, these have by far the highest average R&D intensities in the sample (0.13 and 0.11 respectively). The mean R&D intensity for the 61 firms in the regression is 0.015.

4 Empirical Exploration of the Determinants of Firm Performance

4.1 R&D and Firm Performance

In this section we analyse how expenditure on R&D is related to firm performance. The main focus of the section is empirical work using the market value of a firm as a dependent variable in simple regressions. However, it is worthwhile inspecting a few graphs that show other aspects of firm performance. Below are three graphs showing the level of a firm's R&D intensity (averaged over 1991 to 1994) against its growth rate of employment, revenue and profits over the 1991 to 1994 period.

Figure 4 R&D intensity and the growth rate of employment

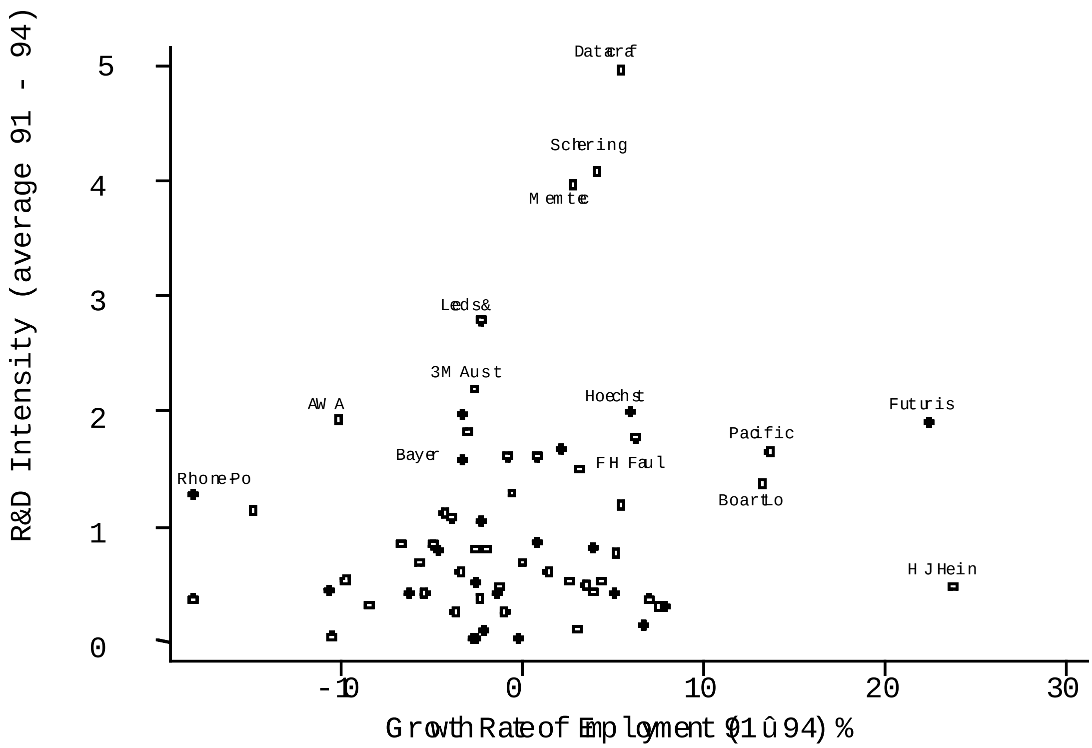


Figure 5 R&D intensity and the growth rate of revenue

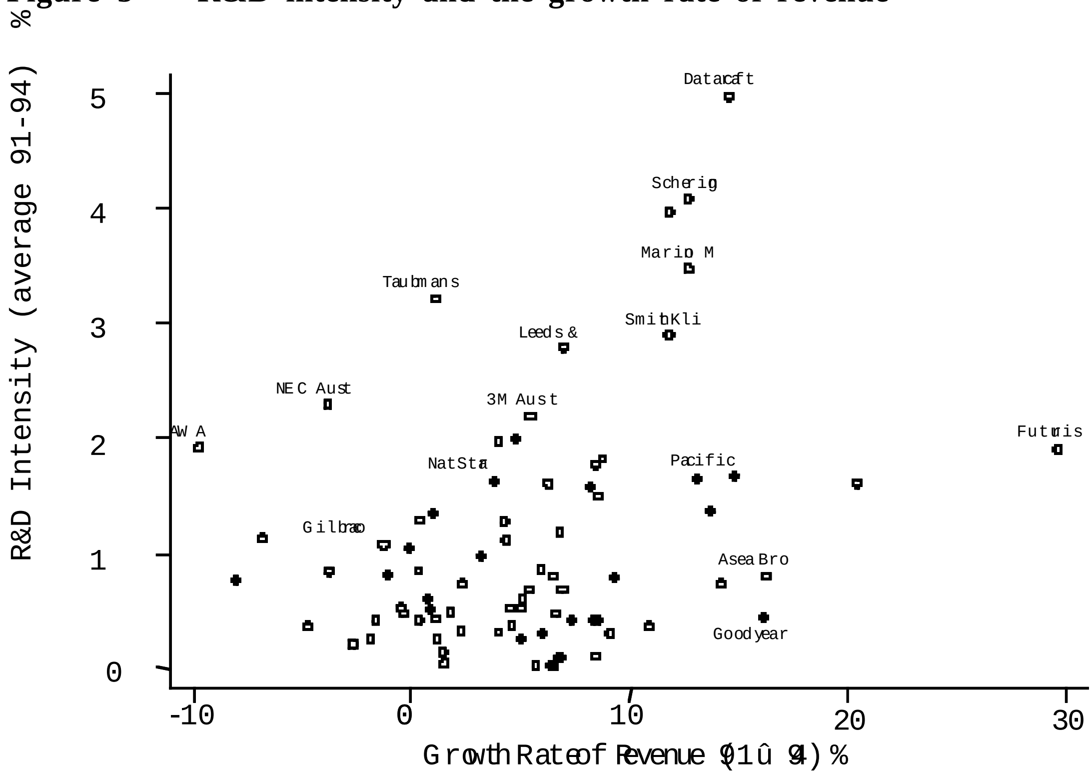
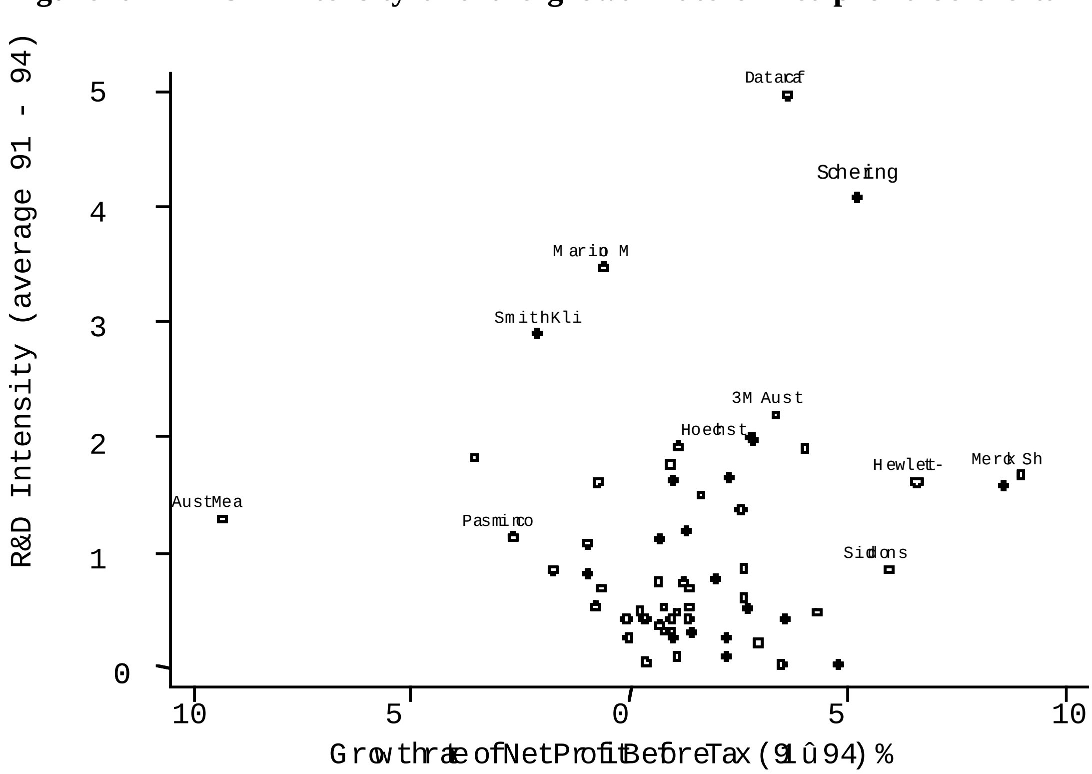


Figure 6 R&D intensity and the growth rate of net profit before tax



The above graphs are suggestive of a positive relationship between R&D intensity and the three aspects of firm performance. However, the relationships are not particularly strong and there is no implication that the causality runs from R&D to firm performance. With data on only four years it is impossible to investigate the issue of causality between these various performance measures effectively (since there are likely to be lags in the effect of R&D expenditures). An alternative method is to use market value information, which is a forward looking valuation of a company.

4.2 Determinants of Firm Performance: Tobin's q

Our formal analysis, based upon the Tobin q approach, follows work by Hall (1993). In the Hall paper the value of a firm is given by

$$V(A, K_1, K_2, \ldots) = Q\left(A + \gamma_1 K_1 + \gamma_2 K_2 + \ldots\right)^{\sigma}, \qquad [1]$$

where *V* is the market value of firm, *A* is the total physical assets of the firm and K_i are intangible stocks that are, presumably, valued by the market but are not directly measurable. As Hall notes, the explicit functional form on the right hand side of [1] is ad hoc, with the presence of parameters *Q* and *s* allowing some flexibility (see the theoretical paper by Hayashi, 1982, for a discussion of these issues). In order to estimate [1] using linear estimators the equation is re-written in log form as,

$$\log V = \log Q + \sigma\left[\log(A) + \log\left(1 + \gamma_1 K_1/A + \gamma_2 K_2/A + \ldots\right)\right], \qquad [2]$$

this allows us to use the approximation log(1+e)≈ e to yield

$$\log V = \log Q + \sigma \log(A) + \beta_1 K_1/A + \beta_2 K_2/A + u, \qquad [3]$$

where *u* is an error term. In order to estimate [3] data are required on physical assets, market value and intangible capital stocks. The data for physical assets comes directly from the IBIS data set. Market value is obtained from the Australian Stock Exchange and represents the total market capitalisation of a firm as at the 30^{th} May in a given year. Using a single date for market value is less than perfect, but average market value data are not readily available. Since many of the firms are not traded on the stock market these data are only available for 35 out of our sample of 85 R&D performing firms.

Our main interest here is the role of R&D expenditure on market value. In principal, R&D expenditures can be used to create a R&D capital stock which could then be entered directly in a regression (this would require an assumption about the appropriate depreciation rate). Alternatively, the lagged R&D expenditures could be added to the regression allowing, effectively, estimation of depreciation rates. With only four years of data it is difficult to undertaken either of these approaches satisfactory. Given this short time period, and also the observations on the volatility of R&D made earlier, we choose to average the data across the four years of the sample and then enter this directly as an explanatory variable. This means we are simply using the average R&D expenditure to proxy a firm's R&D capital stock. No doubt this is an unrealistic assumption but it is difficult to avoid given the data limitations.

In Hall's (1993) paper the level of advertising expenditure is also included as an explanatory variable. Unfortunately, the IBIS data set does not have data on advertising expenditure. Hall also includes variables for cash flow and for the growth in sales. These are intended to proxy past investments in intangible assets that are likely to be associated with higher future profits (and hence higher market value). For our data set we can only obtain a variable for the growth in revenue. However, the IBIS data set does contain data for the value of intangible assets of the firm (as reported in the annual accounts). Intangible assets will include the accountant's valuation of patents, trademarks and other intellectual property.[21] Since the market value of a firm is likely to be determined partly by this asset value we also include this as an explanatory variable.

[21] The exact composition of intangibles will vary from firm to firm so it is difficult to check this directly. A major component of intangibles assets is likely to be a valuation for goodwill, however, capitalised past R&D, patent, trademark and licence valuations may also be included.

Table 6 Market value regressions

Dependent variable: log of average market capitalisation over 1991 to 1994

Explanatory variable *n = 35*	*R5*	*R6*	*R7*
constant	0.2250 (0.241)	0.1638 (0.176)	-0.2250 (-0.257)
log (physical assets)	1.0167** (14.991)	1.0185** (15.204)	1.0397** (16.416)
R&D / physical assets	1.6014 (1.208)	1.6994 (1.320)	0.9978 (1.588)
Growth in revenue		0.9996 (0.990)	1.4819* (1.692)
Intangible assets / physical assets			0.4217** (11.555)
R^2	0.84	0.84	0.89

* significant at 10% level ** significant at 5% level

Notes: All variables are averages over the 1991 to 1994 period. The t-statistics reported in brackets are calculated using White's robust method.

Table 6 reports the results from three regressions which include somewhat different explanatory variable. The results in Table 6 show that the coefficient on the log of physical capital is highly significant and close to one, hence, as would be expected, a 1% increase in physical assets tends to raise the market value by 1%. In contrast, the coefficient on the variable that includes R&D is insignificantly different from zero, although it is positive in all regressions (and significant at the 13% level in R7). The addition of the other two explanatory variables in R7 improves the fit of the regression. The coefficient on the ratio of intangibles to physical capital is highly significant, while the coefficient on the growth of revenue is positive and just significant at the 10% level.

As we have stated above, the nature of the R&D data makes it important to investigate influential observations. Using plots of the data and DFBETAs diagnostics we have investigated the robustness of the regressions in Table 6.[22] For the coefficient on R&D/physical assets there are three companies – Scitec, Datacraft and Orbital Engine

[22] DFBETAs measure the difference in the regression coefficient when the *i*th observation is included and excluded.

Corp. – that appear influential. Omitting these three firms and running regression R7 results in a significant (10%) coefficient on R&D/physical capital, with the coefficient rising dramatically to 8.2. For the other explanatory variables, Futuris Corp. is influential in determining the growth in revenue coefficient, while both Memtec and Orbital Engine Corp. are influential in determining the coefficient on the intangible assets/physical assets variable. Omitting Futuris from regression R7 reduces the significance of the coefficient on revenue growth to the 15% level (the coefficient magnitude rises to 2.2). Omitting Orbital and Memtec from regression R7 has no effect on the significance of the coefficient on the intangibles/physical capital variable, although the magnitude rises to 1.56. Hence the basic pattern of results shown in Table 6 is relatively robust to the omission of influential observations, although the magnitudes of the coefficients are sometimes sensitive to the changes.

The results have suggested that R&D expenditure has an impact on the market value of a firm, although this relationship is not highly significant. The magnitude of this impact is hard to determine as it varies considerably according to whether a few influential observations are included. Interpreting the economic significance of the coefficients reported in Table 6 is not straightforward either since the R&D expenditure is entered as a ratio. To assess the economic impact of increasing R&D expenditures we need to set the level of physical assets. An obvious choice is the median level of physical capital, which is $133,471 thousand. The results above suggest that the lower bound for the coefficient on R&D/physical capital is 1, this implies that the 'coefficient' on R&D expenditure itself would be 7.5×10^{-6} (1/133,471). Raising R&D expenditures by $1 million dollars would therefore raise the market value by 0.75%, or if the firm had the median market value, it would raise market value by $2 million.[23] Since this represents a lower bound on the market valuation of R&D it may be that the economic impacts are much greater than this.

Lastly, as discussed earlier, many of the firms exhibit large fluctuations in their level of R&D expenditures. One hypothesis it is interesting to test is whether firms with high volatility of R&D intensity have lower market values. To test this, the standard deviation of R&D intensity for each firm over the four year period was calculated. This represents a basic measure of volatility. Entering this variable as an additional explanatory variable in regression R7 resulted in an insignificant coefficient. However, this result is driven by the Orbital Engine Company – which experienced by far the highest volatility of R&D intensity. Excluding Orbital from the regression results in

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[23] Raising R&D by $1,000 thousand, increases the log of market value by 7.5×10^{-3} (0.0075). Therefore, the ratio of new to old market value is given by log(Mnew/Mold)=0.0075 or Mnew/Mold=$e^{0.0075}$, hence Mn/Mo equals 1.0075.

negative and significantly different from zero (at 12% level) coefficient: higher volatility appears to reduce market value. In this augmented regression the coefficient on the R&D/physical assets variable also improves in significance to the 5% level (with a magnitude of 2.8).

5 Conclusions

The research reported in this chapter had two main aims: first, to investigate the determinants of R&D activity and, second, to explore the effects of R&D on firm performance. In practice, the IBIS data base proved somewhat more limited for the purposes of these analyses than we had first anticipated. There were two principal areas of difficulty. The first concerns the scarcity of R&D data, particularly in early years. In practice, we found only 85 firms in the sample with non-zero R&D in all four of the years from 1991 to 1994. However, this problem decreases significantly in the most recent years and we feel that it will be important to revisit this issue in the near future. The second problem arose from the absence of market valuation data and, while we were able to match information from the Australian Stock Exchange, this further reduced our effective sample size. Again, this is an issue which we need to revisit as we augment the data. Despite these problems, some interesting, if tentative results emerge, particularly (though not exclusively) relating to the role of R&D in firm performance.

In the exploration of the determinants of R&D expenditures, we found considerable variability over the sample period for some firms. While this is not a problem in itself, it was somewhat surprising as experience with other data sets had suggested relatively stable R&D activity (Stoneman and Bosworth, 1994). However, dividing R&D by sales suggests a greater stability, with just a few outliers. None of the market structure variables appeared to play a significant role in explaining R&D intensity. However, two factors appeared to show through. First, the importance of technological opportunity, consistent with Cohen’s (1995) conclusions from his review of the literature. Second, although not quite significant at the 10 per cent level, the lack of focus of the company (as represented by the number of ANZSIC codes the firm has subsidiaries in) has a deleterious effect on R&D intensity.

After some graphical exploration of the relationship between R&D intensity and various dimensions of company performance, which were suggestive of a positive relationship, we examined in some detail the results of estimating a variety of Tobin q specifications. Given the relatively small number of observations, some caution must be exercised in drawing conclusions, nevertheless an interesting picture begins to merge. The picture is one in which past R&D contributes to the current intangible assets of the firm. Not only do the stock of intangibles play a significant part in explaining the market value of the company but current R&D intensity also has a positive role to play (almost significant at the 10 per cent level) as it adjusts the existing stock of intangibles. In addition, we found some evidence for a role for the variability of R&D over time, with the market placing a lower valuation on companies with greater variance in R&D, perhaps reflecting the uncertainty of the magnitude of future profit and dividend flows amongst such firms.

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Appendix 1

Summary statistics for R&D cross-sectional regressions

Variable	Mean	Std. Dev	Min	Max
n = 80				
R&D intensity	0.02	0.03	0.00	0.20
foreign	0.44	0.50	0	1
Average no. of subsidiaries	7.18	6.82	0.75	38.75
log (revenue in 000's)	12.71	1.37	10.31	16.61
n = 61				
R&D intensity	0.01	0.02	0.00	0.13
Effective rate of protection	14.55	9.78	-0.67	44.67
4 firm concentration ratio	0.29	0.11	0.16	0.53
Firm revenue / industry revenue	0.15	0.15	0.00	0.81
foreign	0.49	0.50	0	1
Average no. of subsidiaries	7.24	6.37	0.75	38.75
log (revenue in 000's)	12.61	1.27	10.31	16.61

Notes: All variables are averaged over the 1991 to 1994 period, except for the number of subsidiaries (which for some firms is for only three years), foreign (which is for the single year 1994) and the effective rate of protection (which is averaged over the 1991 to 1993 period since the Industry Commission (1995b) report has no 1994 data).

Summary statistics for market value regressions

Variable Average 1991 – 1994 **n = 35**	Mean	Std. Dev.	Min	Max
log (market capitalisation in 000's)	12.83	2.13	8.35	17.00
log (physical capital in 000's)	12.32	1.99	8.89	16.79
R&D/physical capital	0.0516	0.1217	0.0003	0.6887
Growth in revenue	0.0345	0.1204	-0.1421	0.5148
Intangibles/physical capital	0.3507	1.0792	0	6.3926
Physical assets (in 000's)	1408172	3509285	7240.25	1.96E+07
R&D expenditure (in 000's)	12370	20736	113.5	95450
Intangible assets (in 000's)	117678	278988	0	1343125