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Abstract

Two parallel streams of research investigating the determinants of corporate R&D exist: one from economics and the other from management. The economists' variables tend to reflect the firm's external environment while the explanatory variables used by management scientists are commonly internal to the firm. This paper combines both approaches to test for the relative importance of each type of factor using firm-level data on large Australian companies from 1990 to 2005. Our evidence suggests that most of a firm's R&D activity can be explained by time-invariant factors which we believe relate to internal and specific characteristics such as the firm's managerial style, competitive strategy and how it communicates with employees. Of the remaining time-varying portion, we find that past profits, the rate of growth of the industry and the level of R&D activity over the firm's industry is pertinent. These results are suggestive since we cannot clearly identify the extent to which the firm's internal behaviour is conditioned by its external environment.

1. INTRODUCTION

Two parallel streams of research investigating the determinants of corporate R&D exist: one from economics and the other from management. The early economics literature primarily considered the structural determinants of R&D such as market concentration and firm size, while later studies investigated systemic forces such as opportunity and appropriability. Papers in the management tradition, on the other hand, tend to test for internal and operational factors such as the firm's strategic posture, dynamic capabilities and human resource practices. As a simplification, the economists' variables reflect the firm's external environment while the explanatory variables used by management scientists are internal to the firm. Despite the correspondence between the two research questions, few papers combine both approaches into a single estimation (an exception is Nieto and Quevedo 2005). This bifurcation in the literature is not helpful since it hinders the ability of policy makers to make sensible evidence-based policy decisions. If experience and internal corporate culture are the key causes of R&D activity, then trying to influence it through pro-competitive market-based policies may be ineffectual. Policies to change the corporate culture and the orientation of the business will be more pertinent. Alternatively, exhorting managers to become more innovative will be ineffectual if R&D is primarily governed by the scientific environment or the state of the economy.

Studies, which combine both external and internal – or economic and management – determinants, should assist policy makers bridge this gap in understanding. This study aims to do this. It estimates the effects of standard economic variables on R&D using data from several sources including a 16-year panel of large Australian firms. Subsequently, it regresses the estimated firm-level fixed effects on a series of external market conditions and internal management variables obtained from a specific company-level survey. While a third type of factors – relationship factors such as inter-firm networking – may also be important, our data set does not allow us to test for their significance and we leave aside their consideration in this paper.

Our results suggest that most of a firm's R&D activity is explained by time-invariant factors which we believe are predominantly characteristics that are internal and specific to the firm. Time-varying factors such as growth in the industry appear to have some effect, but essentially, time-invariant factors dominate. Significant internal factors might include the firm's managerial style, its competitive strategy and appropriation strategy. These findings are suggestive rather than conclusive however since we cannot clearly identify the extent to which the firm's internal behaviour is conditioned by its external environment.

The paper begins with a discussion of existing inductive findings on the determinants of innovation. In section 3, we present the data and, in particular, we discuss estimation issues that arise from the use of accounting, administrative and survey enterprise data sets. Bearing these complications in mind, in Section 4, we discuss estimation issues. In section 5, we present estimates of the determinants of enterprise R&D. Section 6 concludes.

2. THE DETERMINANTS OF FIRM-LEVEL R&D

Explanations for the variation in the intensity of R&D across firms originally evolved as a response to the theories purported by Schumpeter (1976) on the interaction between profits, innovation and market power. The first empirical studies focussed on whether firms acquired market power <u>because</u> of successful innovation or whether market power <u>enabled</u> firms to make innovation profitable (i.e. Kamien and Schwartz 1982; Mansfield 1984; Levin and Reiss 1984; Acs and Audretsch 1987, 1988, 1991; Van Dijk et al. 1997).[1] Intermingled with this issue was the question of whether firm size enabled or resulted from higher levels of R&D. Tests of these competing hypotheses were not helped by the lack of panel data sets, but the 'final' word on the issue appears to be that both size and market structure are unlikely to be the dominant determinants of innovation since the findings commonly depend on which control variables are included in the model (Phillips 1966; Sutton 1991; Scherer 1967; Cohen 1995; Bosworth and Rogers 1998).

Since then, economic research has re-orientated itself towards more deep-seated determinants such as the opportunities proffered by the scientific sector and how easily firms can appropriate their R&D profits (Levin and Reiss 1984; Pakes and Schankerman 1980). This avenue of research appears to have found more consistent results than the earlier studies (Caves 1982; Jaffe 1986; Cohen, Levin and Mowery 1987; Dunning 1988; Cohen and Levinthal 1989; Sterlacchini 1994; Griliches 1995; Oltra and Flor 2003), in part because the

[1] Many studies that do find market structure and/or firm size are a significant determinant of R&D intensity do not control for the underlying conditions of opportunity and appropriability.

theoretical direction of effects are less ambiguous. However, it still leaves open the question of what governs scientific opportunity and natural appropriability. [2]

Another smaller but concurrent stream of economic research has concentrated on the financial hurdle for firms inventing from highly uncertain and collateral-free projects such as R&D (Branch 1974; Kamien and Schwartz 1978; Himmelberg and Petersen 1994; Cumming and Macintosh 2000; Hall 2002; Bloch 2005; Rafferty and Funk 2008). Similar to the scientific opportunity and appropriability theories, there is a clear a priori prediction of the effects of retained earnings and gearing levels, and therefore not surprisingly, reasonably consistent empirical findings. Higher levels of retained earnings facilitate higher levels of R&D, *ceteris paribus*.

Some what apart from this economic stream, a corresponding series of studies have been undertaken from within the management school. Some of this has followed the resource-based theory of the firm which roots outcomes to the dimensions of firm capabilities – that is, the skills and knowledge of the workforce – (Grabowski 1968; Nelson and Winter 1982; Pavitt 1991; Souitaris (2002); Lee 2002; Rothwell *et al*. 1974 among others); other studies have arisen from the strategic management side (Medina et al. 2005). Almost without exception, these studies are undertaken without reference to firm size, market structure, scientific opportunities, the conditions of appropriability and the firm's finances. Almost without exception, the economic studies are undertaken without consideration of firm capabilities and managers' strategic posture.

This lack of integration between economic and management studies is most likely due to the scarcity of firm-level data sets that offer the analyst both types of data. Since both areas of the literature offer equally plausible explanations, there is clear value in being able to simultaneously test for the effects of all factors.

3. DATA

The preceding discussion serves to inform the model used in this paper to estimate the main determinants of R&D.[3] The external explanatory variables which we include in this study consist of the opportunities arising from science in the firm's technology area; knowledge

[2] For example, it may be that size, and the underlying financial resources it implies, enhances the scope of an enterprise's opportunity and appropriability sets.

[3] Nieto and Quevedo (2005) provide a good summary of empirical studies on the relation between innovative activity and technological opportunities, spillovers and absorptive capacity.

externalities arsing from R&D in related firms; the technical conditions of appropriability; growth in industry demand; industry concentration and access to high-risk investment finance. The internal explanatory variables used in this study comprises the calibre of the firm's internal capabilities; the firm's management style, its competitive strategy, its approach to human resource management and methods used to prevent imitation (or expropriation).

We model these relationships in a basic linear form as:

$$RD_{it} = \alpha_i + \mathbf{X}_{i,t-1}\beta + \varepsilon_{it} \quad (1)$$

where *RD* is R&D expenditure, α is a firm-level fixed effect, **X** contains time-varying determinants, ε is the random error term and the subscripts *i* and *t* refer to the *i*-th firm in the *t*-th time period. While the fixed effects have the advantage of capturing the unobserved determinants that are specific to each firm over the estimation period, they also encapsulate much of the explanatory power of relatively time-invariant explanatory variables.[4] Accordingly we undertake a second-stage estimation to analyse the make-up of the fixed effects as the dependent variable. Hence we model:

$$\alpha_i = \delta\mathbf{Y}_i + \nu_i \quad (2)$$

where **Y** contains time-invariant determinants and ν is a random error term.

Combining the broad spectrum of explanators – outlined in the previous section – into a single data set has required us to link data from four separate sources. Table 1 presents a summary of the variables to model the dependent variable *RD* and independent variables **X** and **Y,** their measures and their sources. Availability (whether in panel or only cross-sectional form), has dictated whether a variable is included in the panel estimation (as an **X**) or the cross sectional estimation (as a **Y**) rather than strict theoretical prescription. As such, **X** consists of firm size, scientific opportunity, industry R&D, industry growth and access to internal finance. **Y** comprises time invariant measures of the firm's ownership, industry competitiveness, managerial style, competitive strategy, human resource management practices and methods employed to prevent expropriation by the imitation of the firm's new

4 This can occur when linking panel data with cross-sectional data and can render the relatively time-invariant explanatory variables statistically insignificant even when they are economically significant. While the researcher may employ a random-effects estimator, this approach may be contra-indicated if the individual effects represent omitted variables which are likely to be correlated with the other regressors. See Beck and Katz (2004).

products and processes. This is not a wholly satisfactory approach since we could envisage situations where the **Y** variables change over time. Nonetheless, it is the only practical way we have at hand to combine both sources of information pending the collation of better company data sets.

TABLE 1

Variables, measures and sources

Variable	*Measure (firm level unless otherwise specified)*	*Source*
R&D	R&D expenditure	IBISWorld
X VARIABLES (AVAILABLE IN PANEL FORMAT)		
Firm size	Employees	IBISWorld
Scientific opportunity	Lagged length of technology cycle by tech class	CHI Research
	Lagged patent citations by tech class	CHI Research
Industry R&D	Lagged R&D expenditure over whole industry	ABS
	Lagged R&D personnel over whole industry	ABS
Growth in customer demand	% change in industry value added	ABS
	% change in firm revenue	IBISWorld
Access to internal finance	Lagged net profits before tax	IBISWorld
	Lagged debt ratio	IBISWorld
Y VARIABLES (AVAILABLE ONLY AS CROSS-SECTION)		
Ownership	Foreign ownership	IBISWorld
Industry competitiveness	Herfindahl (1 or 2-digit industry)	ABS
	Volatile product market	MI Survey
	Contestability	MI Survey
Management style	Bold	MI Survey
	Aggressive	MI Survey
	Systematic	MI Survey
	Communicates	MI Survey
	Learns from others	MI Survey
Competitive strategy	Increase efficiency	MI Survey
	Customer orientated	MI Survey
	Product leader	MI Survey
	Price cutter	MI Survey
Human resource management practices	Keeps talented staff	MI Survey
	Team work	MI Survey
	Pay rewards	MI Survey
Prevent expropriation	Patents	MI Survey
	Secrecy	MI Survey
	Lead-time	MI Survey
	Moving down the learning curve	MI Survey
	Control over distribution	MI Survey
	Brand name and marketing	MI Survey
	Organisational know-how and capabilities	MI Survey
	Product and production complexity	MI Survey

The four data sources comprised: IBISWorld and the Melbourne Institute (MI) Survey for company-level data, CHI Research for technology-level data and the Australian Bureau of Statistics (ABS) for industry-level data.

IBISWorld is a 16-year company-level panel data set of all Australian organisations that have an annual turnover over A$50m. Data is aggregated to the 'parent' level, that is, the highest Australian-based entity.[5] Only public and private companies, associations and cooperatives were included for the estimations. As shown in Table 2, our sample split evenly between public and private companies with a few associations and cooperatives. Over the period 1990-2005, there were 4802 such entities of which 66.1 per cent recorded profits. Twenty-five per cent of firms had 15 or 16 observations and 50 per cent had at least 7 observations.[6]

The IBISWorld database contains standard data on R&D, debt, net profits before tax, employees and industry. Firms access to (internal) finance was represented alternatively by a three-year moving average (centred on the current year) of firm's net profits and a three-year moving average (centred on the current year) of firm's debt to total assets ratio.

TABLE 2

Companies by type, 1990-2005

Company type	Number	Percentage	Percentage reporting profits
Association	30	0.6	66.7
Cooperative	37	0.8	59.5
Private company	2,698	56.2	56.6
Public company	2,037	42.4	78.8
Total	4,802	100	66.1

Source: Companies selected from the IBISWorld dataset.

To this data, we added annual data from a US based organisation, CHI Research, on the length of the technology cycle and number of patent citations in 30 specific technology areas. Measuring opportunities from science for the purposes of estimation is difficult and there is no consensus in the literature on how to make it empirically operational (see Cohen 1995 for a discussion, Oltra and Flor 2003). To ensure that these variables were exogenous from the Australian research environment, we used technology-specific data from the USA (the average of the previous 5 years).[7] The first indicator, the technology-cycle time, represents how fast the technology is turning over, defined as the median age in years of

[5] It includes Australian owned companies and the highest accounting unit of Australian-located foreign-owned multi-national companies.

[6] Generally firms enter the dataset when their annual reports become publically available (due to either incorporation or a growth in size). However, firms may exit for several reasons – merger, administrative delays in accessing the information, reduction in size, de-corporatization or closure. We have no information on the reason why firms cease to be reported in the data base.

[7] Data was from CHI research. See http://www.chiresearch.com/about/data/tech/indicator.php3#growth.

references cited on the front page of US patents. In fast moving technologies, companies may gain the advantage by innovating more quickly.[8] The second measure is the number of forward-patent cites in each technology area (the number of citations a patent receives from subsequent patents) which indicates how often the technology becomes prior art in future technological advances. Harhoff et al. 1999), among others, have shown that highly-cited patents represent economically and technically important inventions and we expect that firms who operate within technology classes that are more commercially valuable will have a greater incentive to conduct R&D, *ceteris paribus*. Firms were assigned technology classes for each year based on the technologies of the patents they had applied for in that year using the OST classification system. Each firm in each year was then matched across to the CHI Research variables as specified above. Firms with multiple technology classes in any year were averaged. Firms that did not patent, and hence could not be classified to a technology area (using their IPC), were assigned the residual class data.[9]

We linked annual industry-level data from the Australian Bureau of Statistics on the growth on production and the level of R&D activity to our company data. The value-added data was transformed into a three-year moving average centred on the current year. This variable represents prospective demand conditions for the firm. We used the level of Australian R&D activity by industry (alternately R&D expenditure and R&D persons) as a measure of potential knowledge spillovers. While potentially R&D conducted overseas may affect the profitability of conducting R&D in Australia, empirical estimates of knowledge spillovers show that it is geographically bounded and its influence declines with distance (Jaffe et al 1993, Maurseth and Verspagen 2002, Thomson 2006). Accordingly, we use a domestic measure of the level of external R&D activity. Inclusion of this variable does not however allow us to distinguish between 'true' knowledge spillovers and the existence of the third factor causing all firms in an industry to change their R&D activities. Table 3 presents a summary of the main IBISWorld and CHI Research variables used in the regression analysis.

[8] According to CHI Research, cycle times are short (3-4 years) in semiconductors, but long (more than 10 years) in shipbuilding. The average is 8 years.

[9] It is generally accepted that most important inventions around the world are patented in the US (given the importance of the market there). Hence, data extracted from the US patents office is accepted as being a reasonably unbiased assessment of the characteristics of a technological field. The characteristics we are measuring – commercial value and speed of technological change – should not vary by country. An invention that is commercially valuable in the US will also be valuable to commercialise in Australia (even if export of foreign investment are required). The speed of technological change should be the same across countries. If the speed differed by too much then one country would fall so far behind that it would not be able to compete. It would only survive behind high tariff walls. Hence, we are reasonable confident that these US-measured characteristics should be an unbiased measure of the situation in Australia.

TABLE 3

Annual firm characteristics 1990-2005

Employment size	R&D expenditure (A$000)	Net profits before tax (A$000)	Ratio of debt to assets	Industry RD persons	Length of technology cycle	Patent citations
Less than 200	2068	5932	0.761	5.21	10.348	1.184
200-500	1966	7322	0.712	4.91	10.313	1.173
501-1000	3134	12758	0.682	4.82	10.302	1.165
1001-5000	6252	40731	0.669	4.85	10.287	1.159
More than 5000	25232	374858	0.678	5.11	10.274	1.114
Total	5601	35637	0.711	5.02	10.320	1.171

Note: Data are averages over firms and years.

The second firm-level data set was derived from the authors' postal survey of large Australian firms during the period from October 2001 to December 2005. Of the 575 firms that reported R&D in the IBISWorld data set, 164 were successfully matched to all the required variables from the postal survey.[10] Respondents to the survey were asked to answer questions using a seven-point Likert scale with the anchors 1=strongly disagree and 7=strongly agree. Perceptual measures permit comparisons across very different organisations and industries and are easy to collect because they place fewer burdens on respondents than administrative or factual entries. However, they contain a subjective element and thus an undefined error and it would be unwise to over interpret the findings.

Similar to other studies of this type (see for example, Arvanitis 2002; Hollenstein 2002), the majority of variables used from the survey are constructed using a data reduction method and do not rely upon a single variable. The use of a single variable is unlikely to adequately measure the underlying latent construct of interest, such as the management style adopted. However, we do not want to use a data-reduction method that will exclude cases if there is a single missing response. Accordingly, each variable is a mean of a list of items (single questions) which we believed measured our concept. Table 8 in the Appendix gives a descriptive summary of the questions or statements used as items in the factors.

[10] An average of 1250 enterprises each year were chosen from the IBISWorld enterprise database with 943 useable surveys returned from 724 unique organisations. This is a response rate of 18.9 per cent, which is consistent with surveys of this type (see for example, Huselid 1995, Covin, Slevin and Heeley 2001). The distribution of responses across major industry and size does not differ markedly from the initial selected population, implying that the responses should not be biased towards a particular industry. For our use, we have used the organisation as the unit of analysis and have averaged multiple responses from the same firms where they exist.

Data from this survey allowed us to construct a series of variables (which we list in Table 1 as **Y** variables) on external factors (ownership, industry competitiveness) and internal factors (management style, competitive strategy, human resource management methods, and methods for preventing expropriation). Ownership is a simple dummy, and the industry competitiveness variables comprise the published Herfindahl concentration index for each 1 industry (2-digit for manufacturing) in 2000-01.[11] Two Likert scale measures of the firm's markets were constructed from the survey: 'volatile product market' measures the variability in demand, competitors and technologies, and 'contestability' measures ease of entry to the product market.

Five different types of management style were distinguishable *a priori*. The first style, 'bold', reflects managers' attitudes towards risk taking. The second, 'aggressive' reflects how proactive management are and how willing they were to initiate competitive clashes with rival companies (Miles and Snow 1978). The third, 'systematic', measures managerial reliance upon formal, quantitative analysis rather than intuitive information for making decisions. The fourth variable was a measure of how, and to what extent, the firm made an effort to communicate with its employees. This variable, 'communication', gives weight to organisations that have clear strategic missions that are understood throughout the enterprise, use several procedures to communicate with staff, involve employees directly in decisions and act on suggestions of employees. The last management technique variable measured the extent of learning within the firm about new processes and products through external media such as informal networks, publication and technical meetings, *inter alia*.

The firm's competitive strategy was represented along four dimensions: the extent to which it strived to increase cost efficiencies; the extent to which it was customer orientated; the extent to which it was a product leader and the extent to which it competed through price cutting.

Four aspects of the firm's human resource management methods were measured in the survey. First, the variable 'keeps talented staff' measures the effort the firm used to keep talented staff. Secondly, 'team work' measures the firm's use of teams and its willingness to

[11] As published by the Australian Bureau of Statistics Cat. No. 8140.0.55.001 Industry Concentration Statistics, Data Report - Electronic Delivery 2000-2001. More disaggregated Herfindahl measures are not available. While 1 and 2-digit concentration measures are perhaps too broad, we use them in our analysis as we believe they provide more information content than simple industry dummy variables.

act on the decisions and suggestions of employees. Thirdly, 'pay rewards' measures the firm's use of pecuniary incentives to reward employees.

Finally, to measure appropriation methods we included eight survey variables on the way firms chose to protect their profits from imitation and expropriation. These include the use of patents, secrecy, lead-time, moving down the learning curve, control over distribution, brand names and marketing, organisational know-how and capabilities and product and production complexity. Table 4 presents the mean, standard deviation, minimum and maximum of these variables for the sample of 164 firms included in the second-stage regression.

TABLE 4

Survey data descriptives, 2001- 2005

	Survey variables	*Mean*	*Std dev.*	*min*	*max*
Ownership	Foreign	0.409	0.493	0.000	1.000
Industry competition	Herfindahl (1 or 2-digit industry)	0.077	0.151	0.000	0.944
	Volatile product market	3.936	0.887	2	6
	Contestability	4.063	0.887	1	7
Management style	Bold	4.011	1.126	1	7
	Initiates	4.493	0.999	1	7
	Systematic	4.683	0.844	1	7
	Communicates	4.925	1.049	1	7
	Learns from other firms	3.972	0.811	2	6
Competitive strategy	Increase efficiency	5.309	0.847	3	7
	Customer orientated	5.325	1.086	2	7
	Product leader	4.605	1.227	2	7
	Price cutter	3.770	1.211	1	7
Human resource management	Keeps talented staff	4.805	1.156	1	7
	Team work	4.956	0.895	3	7
	Pay rewards	4.861	0.932	2	7
Prevent expropriation	Patents	3.456	1.670	1	7
	Secrecy	3.938	1.452	1	7
	Lead-time	4.398	1.291	1	7
	Moving down the learning curve	4.506	1.142	1	7
	Control over distribution	4.286	1.488	1	7
	Brand name and marketing	4.557	1.404	1	7
	Organisational know-how and capabilities	5.259	1.083	1	7
	Product and production complexity	4.585	1.228	1	7

4. ESTIMATION ISSUES

The major modelling issue for estimating the R&D expenditure decision is how to treat missing R&D data. In our data set, R&D expenditure is collected from company annual reports, supplemented with telephone survey information. However, there still remains a very large proportion of missing R&D data (81.0 per cent of firms never report R&D expenditure) and it is not possible to discern whether these represent true zeros, R&D spending below a threshold limit or the non-reporting of values above this threshold.[12] Most likely, missing values are a combination of all three. According to Table 5, 1.2 per cent of the firms over our study period report R&D intermittently and a further 8.7 per cent of firms never report R&D expenditure but had made patent applications during the same period. Both these cases most likely represent non-reported, positive R&D values. Furthermore, we cannot be sure that the firms which neither report R&D or file for a patent (representing over three quarters of our sample) were accurately reporting their R&D. It is unlikely that no firms in this group are undertaking R&D.

TABLE 5

Firm characteristics of R&D observations, 1990 - 2005

Type of R&D records	Freq.	Percent
Number firms which report R&D at some time in its history	910	19.0
- complete set of R&D observations (over reported time span)	854	17.8
- gaps in set of R&D observations	56	1.2
Number firms which never report R&D in its history	3892	81.0
- has no history of patent applications	3475	72.4
- has a history of patent applications	417	8.7
Total	**4802**	**100.0**

Most existing studies of the determinants of R&D do not discuss or explicitly treat missing R&D data points. However, missing R&D data are endemic in accounting-based data sets and these omissions can be important if there are selection issues. It seems reasonable to assume that missing values for R&D expenditure for firms which are also patenting, do not constitute true zeros. A cross-sectional multinomial logit model relating each of the categories of R&D reporting to industry type, company type and type of ownership suggests that firms reporting R&D, compared with those that neither report or apply for patents, are most likely to be in manufacturing, electricity, gas and water, communications and agriculture, and least likely to be in education, accommodation, cafes and restaurants. They are also more likely to be medium size, foreign-owned or public companies, *ceteris paribus*.

[12] Despite it being a requirement of accounting standards, in practice, only subsets of this R&D are formally recorded (often to obtain special tax treatment), or reported in published accounting statements. Stoneman and Toivanen 2001) for example, found that among listed UK firms, that large companies were most likely to report R&D. We find that manufacturing, public and foreign owned companies are more likely to report R&D than other companies.

The large number of firms who never report R&D raises questions about how to handle the zeros when estimating an equation to explain R&D expenditure. In particular, does omission of these firms leads to sample selection bias? It turns out that, if the panel nature of the data is accommodated by estimating a fixed-effects model with fixed effects for the firms, then the fixed-effects term will capture any sample selection bias caused by the omission of observations from firms who never report R&D. This fact can be demonstrated by considering a panel-version of the conventional two-equation sample selection model (see, for example, Verbeek 2000 p.206). In the context of our model, we have the R&D equation

$$RD_{it} = \alpha_i + \mathbf{X}_{i,t-1}\boldsymbol{\beta} + \varepsilon_{it} \,. \qquad (1)$$

In addition, there is a participation, or selection, equation

$$w*_i = \mathbf{z}_i\boldsymbol{\gamma} + u_i \qquad (3)$$

where a firm reports R&D when the latent variable w_i^* is positive and does not report R&D for $w_i^* \leq 0$. The vector $\mathbf{z}_i$ contains time-invariant firm characteristics including variables such as industry, type of corporation and type of ownership. It is assumed that the error terms (ε_{it}, u_i) have a bivariate normal distribution with zero mean, $\text{var}(\varepsilon_{it}) = \sigma^2$, $\text{var}(u_i) = 1$ and correlation ρ. Then, given that firms that never report R&D are discarded, the relevant expectation for estimating the R&D equation is

$$E(RD_{it} \mid RD_{i,t-1}, w_i^* > 0) = \alpha_i + \mathbf{X}_{it}\boldsymbol{\beta} + E(\varepsilon_{it} \mid w_i^* > 0) \qquad (4)$$

where, following the standard textbook treatment,

$$E(\varepsilon_{it} \mid w_i^* > 0) = \rho\,\sigma\, \phi(\mathbf{z}_i\boldsymbol{\gamma}) / \Phi(\mathbf{z}_i\boldsymbol{\gamma}) \qquad (5)$$

and $\phi(.)$ and $\Phi(.)$ are the standard normal density and distribution functions, respectively. Since the term $\rho\,\sigma\, \phi(\mathbf{z}_i\boldsymbol{\gamma}) / \Phi(\mathbf{z}_i\boldsymbol{\gamma})$ is time-invariant, it can be incorporated into the fixed effect α_i. Relaxing the assumption of normality (as would be necessary if, for example, non-reporting was explained by a logit model) changes the exact expression for $E(\varepsilon_{it} \mid w_i^* > 0)$, but does not alter the fact that it is time-invariant. As discussed above, most of the 'decision' to report R&D depends on time invariant characteristics such as the industry and ownership of the firm. We ignored the very small number of observations (accounting for 1.2 per cent of all firms) where non-reporting of R&D was time varying.

We estimate equation (1) via both a cross sectional OLS and a panel LSDV estimation. The OLS estimation includes dummy variables for industry type, company type and foreign ownership but no fixed effects for firms. This model is considered for two reasons. First, it permits across-firm variation in R&D within each industry and company type (in addition to within-firm variation over time) to be explained by corresponding variation in the explanatory variables; and, secondly, it seems reasonable to hypothesize (as we do in what follows) that the magnitudes of the fixed effects for each firm can be related to industry, company type and foreign ownership.

5. RESULTS

The results from estimating (1) are presented in Table 2. All continuous variables are measures in logs. In this specification most of the identified variables represent conditions external to the firm and therefore almost all the internal environment factors in the panel estimation were bundled into the fixed effect. The latter comprises all unobservable and time-invariant effects. Most notable for our study, the variable Rho, which represents the proportion of the residual variance in R & D explained by firm-specific effects, was over 0.8 in both LSDV regressions. This high proportion suggests that the combined time-invariant firm-specific aspects of R&D behaviour, which we partly attributed to the firm's managerial style, competitive strategy, human resource management techniques and expropriation strategy issues, are very important. This dominance of time-invariant firm-specific determinants has also been found by Pakes and Schankerman (1980), Scott (1984), Lee (2002), Martinez-Ros and Labeaga (2002) and Duguet and Monjon (2004).

The level of R&D expenditure was positively related to firm size – as we would expect – but inelastic (~0.4) which suggests that medium size firms are more R&D intensive than large firms (we have no small firms in our sample). The coefficients on the technology cycle were only significant in the cross sectional estimation and suggest that enterprises apparently working in fast moving technological areas tended to undertake more R&D, ceteris paribus. This finding is consistent with the Geroski, Van Reenen and Walters (2002) results which support the view that conditions of technical opportunity are important. However, the patent citation variable was significant but incorrectly signed which tempers this conclusion somewhat. The variable to represent the effects of exogenous demand conditions was consistently significant and positive which supports the demand-pull version of innovation.

Of the two access-to-finance variables, only net profits before tax was significant (the debt ratio was either incorrectly signed or insignificant and is not reported). The net profits outcome is consistent with the findings in Himmelberg and Petersen (1994), Bloch (2005) and Rafferty and Funk (2008) which show that cash flow (retained earnings) had a substantial effect on the level of R&D expenditure.

As discussed, the second stage of our analysis seeks to disaggregate the elements bundled into the fixed effects. The overall importance of these fixed effects is high: as mentioned over 80 per cent of the total variation of R&D can be explained by individual firm differences other than those represented by the variables in Table 6. If we had time-varying firm-level internal variables we would include these in the Table 6 regressions but this data is not available. Accordingly, we take a second-best approach and regress the fixed effects from this first stage on a series of time-invariant but firm-specific external (ownership and industry competition) and internal qualitative data using OLS. Most of this cross sectional data was obtained from a separate survey conducted over the period 2001 to 2005 (see the appendix for details of this survey). Since our survey data does not precede our accounting and IP data in time, findings from these second-level estimations merely suggest an association rather than argue a causal nexus.

TABLE 6

Determinants of R&D expenditure (A$000) among large companies, Australia, 1990 to 2005.

Dep var: R&D expenditure ('000)(a)	*OLS*	*LSDV-1*	*LSDV-2*
Firm size			
Employees[b]	0.395***	0.366***	0.364***
	(12.79)	(7.886)	(7.826)
Scientific opportunity[e]			
Lagged length of technology cycle	-1.619***	0.127	0.0875
	(-5.897)	(0.548)	(0.381)
Lagged patent citations	-1.426***	-0.0204	0.000139
	(-3.918)	(-0.0820)	(0.000559)
Knowledge spillovers			
Lagged industry R&D exp [d]		0.107**	
		(2.370)	
Lagged industry R&D personnel	0.260***		0.153**
	(7.147)		(2.061)
Demand conditions			
Change industry value added (3-year MA)	0.174	2.086**	2.361**
	(0.0983)	(1.984)	(2.246)
Access to Finance			
Net profits before tax (3-year MA)[c]	0.469***	0.0932***	0.0986***
	(18.04)	(3.205)	(3.423)
Industry dummies	yes		
Foreign ownership dummy	yes		
Public company dummy	yes		
Constant	2.265***	2.012**	2.273***
	(2.926)	(2.257)	(2.624)
No. companies		575	575
No. observations	2400	2402	2402
R^2 – within	0.458	0.055	0.054
Industry dummies jointly=0	F(10,2381)=15.96, Prob > F = 0.00		
Rho (proportion of the variation in the dependent variable explained by the fixed effect)		0.847	0.848
Estimation method	OLS	LSDV	LSDV

Notes: (a) All financial variables have been deflated by the CPI (1989-90=100). (b) Missing values for employees have been imputed from lagged employees and current sales revenue. (c) Denoted in A$millions (d) Denoted in A$10millions (e) Missing values for the scientific opportunity variables have been imputed as the residual technology category '30' in the CHI data base. (f) Significance: ** 1%, *5%, †10%. Standard errors for the LSDVC estimation has been bootstrapped using 1000 draws.

We were able to match 164 of the 575 firms which reported R&D to a complete set of the survey information. We present the results from these regressions, in Table 7, as both the raw coefficient and to give an indication of the relative importance, the marginal effect. The latter is the size of the change in the dependent variable when the independent variable changes from one standard deviation below the mean to one standard deviation above the mean. These marginal effects reveal that managerial style with respect to how aggressively managers initiate competition, the extent to which the firm communicates with its employees, whether it is a product leader and, its use of patents, and product and production complexity to protect its competitive advantage are the main attributes associated with a high fixed-effect R&D firm. The less aggressive firms are towards their competitors but the more they strive to become product leaders, the more R&D activity, *ceteris paribus*. The greater is the use of communication procedures and the more reliance on patents, know-how and production complexity, the higher is the R&D, *ceteris paribus*. While these relationships are suggestive we must bear in mind that the cross sectional nature of the dataset does not permit us to draw conclusions about the causal direction. It is possible for example that patents are considered more important for the firm simply because it conducts a higher level of R&D. We cannot therefore infer that innovating in a sphere which falls within patentable subject matter, causes the level of R&D to be higher than otherwise. Similarly, firms that are more predisposed towards a research environment may also want to develop clear and open lines of communication among its employees.

An interesting finding was found for the influence of foreign ownership. While we found from the first estimation a significant and positive coefficient in the cross-sectional estimate, and a considerably larger average fixed effect in the two LSDV estimations, the foreign explanatory variable was not significant in the second estimation *when* the managerial and other internal variables were included. It appears that the well-known greater propensity of foreign multi-national companies to invest in R&D compared with local firms, *ceteris paribus*, may be explain by their internal managerial styles and techniques.

Of relevance to the question posed in this paper is that none of the variables measuring factors external to the firm, such as its ownership and the competitiveness of its industry were significant once the internal managerial factors are accounted for.

TABLE 7

Determinant of firm-specific effects (R&D equation)

Dep Var: Fixed effect from LSDV-2 estimation Table 6		*Coefficients (1)*	*Coefficients (excludes variable with a level of significance <0.2) (2)*	*Marginal effect (from 2)*
EXTERNAL				
Ownership	Foreign owner (dummy)	-0.508		
Market competition	Herfindahl (1 or 2-digit industry)	0.233		
	Volatile product market	-0.016		
	Contestability	-0.215		
INTERNAL				
Management style	Bold	-0.005		
	Aggressive	-0.345*	-0.289*	-0.573
	Systematic	-0.315	-0.225	
	Communicates	0.632**	0.475***	0.988
	Learns from others	0.171		
Competitive strategy	Increase efficiency	0.061		
	Customer orientated	-0.026		
	Product leader	0.350*	0.297**	0.722
	Price cutter	-0.077		
Human resource management	Keeps talented staff	-0.116		
	Team work	0.100		
	Pay rewards	-0.258		
Prevent expropriation	Patents	0.157	0.209***	0.695
	Secrecy	0.002		
	Lead-time	0.146		
	Moving down the learning curve	-0.192		
	Control over distribution	-0.028		
	Brand name and marketing	0.061		
	Organisational know-how and capabilities	-0.073		
	Product and production complexity	0.243	0.164	0.396
Constant		-1.751	-3.305***	
Sample		164	164	164
R^2		0.20	0.17	

Notes: Explanatory variables (measured on Likert scales) except for ownership dummy variable and Herfindahl index. Significance: *** 1%, **5%, *10%. The marginal effects measure the change in the dependent variable induced by a rise in the independent variable from one standard deviation below the mean to one standard deviation above them mean *ceteris paribus*.

6. CONCLUSIONS

This paper represents a first attempt at estimating the separate effects on R&D activity of internal versus external environmental factors. Addressing this issue has been made possible by the availability of a unique and comprehensive longitudinal database which can be linked through to qualitative data on companies, obtained by directly surveying managers. One of the most consistent findings from our series of estimated equations has been that time-invariant firm-specific are the dominant determinants of R&D. Our exploratory analysis of these firm-specific effects undertaken through linking the estimated coefficients to a separate management survey, suggests that the propensity to undertake R&D is related to the strategic posture of managers – less aggressive managers who nonetheless strive to be product leaders have higher R&D *ceteris paribus*; – the use of communication techniques and the effectiveness of patents, and product and production complexity to protect the firm's competitive advantage. While our results suggest that factors external to the firm have a smaller effect on R&D activity, the most significant effects are the rate of growth of the industry, past profits and externally generated R&D. Opportunities from science did not appear to have a consistently significant. While the finding on strategic posture is consistent with the tenor of Özsomer *et al.* (1997) who find management strategy to be the most important determinant of innovation, over and above other environmental and organisational variables, Özsomer *et al.* find more aggressive firms are more innovative not less.

These results have implications mainly for corporate policy. They suggest that being innovative is a long-term strategy involving a certain managerial style, using extensive intra-firm communication techniques and routines to absorb knowledge spillovers.

Appendix: Variable definitions

TABLE 8

Variable definitions

Variable	*Description*	*Questions / statements*
External product market		
Volatile product market	A 5-item, 7 point scale measuring variability in demand, competitors, technologies	The organisation changes its marketing practices extremely frequently; The rate of obsolescence is very high (as with some fashion goods); Actions of competitors are unpredictable; Consumer demand is unpredictable; The production/service technology often changes in a major way.
Contestability	A 2-item, 7 point scale measuring ease of entry to product market	Entry barriers are very low. It is very easy for new competitors to enter the market; The industry is extremely fragmented. No organisation has a significant market share and the power to influence industry events.
Management style		
Bold	A 3-item, 7 point scale measuring how bold and aggressive managers are	In general, the top managers of my organisation favour a bold, aggressive posture in order to maximise the probability of exploiting. In dealing with its competitors,.
Aggressive	A 3-item, 7 point scale measuring the degree to which managers take initiative	My organisation typically initiates actions to which competitors then respond. Is very often the first organisation to introduce new products/services, operating technologies, etc. Typically adopts a very competitive, 'undo- the-competitor' posture
Systematic	A 6-item, 7 point scale measuring whether managers use systematic analysis rather than intuitive methods for making decisions	Our major operating and strategic decisions nearly always result from extensive quantitative analysis of data; Our major operating and strategic decisions are nearly always detailed in formal written reports; We rely principally on experienced-based intuition (rather than quantitative analysis) when making major operating and strategic decisions; In general, our major operating and strategic decisions are much more affected by industry experience and lessons learned than by the results of formal research and systematic evaluation of alternatives; Our major operating and strategic decisions rely on 'rules of thumb developed from the success of past decisions; Our organisation is able to effectively balance short term and medium term issues and resource requirements.
Communicates	A 4-item, 7 point scale measuring the extent to which management seek to communicate with workers	This organisation has a clear strategic mission that is well communicated and understood throughout the organisation; uses a number of procedures to communicate important information to employees; has transparent systems to address poorly performing employees; has a performance appraisal system that helps to ensure that our reward based pay plan is effective; offers employee assistance programs to help employees deal with personal and job-related issues such as stress, family problems and substance abuse; has human resource practices that are mutually reinforcing and internally consistent; and has aligned employee behaviours with stated organisation values and direction
Learns from others	A 13-item, 7 point scale measuring the extent to which members of the firm learn about new products and processes	This organisation makes extensive use of learning about new processes and products from Licensing technologies; Patent disclosures; Publications or technical meetings; Informal networks with other organisations; Formal cooperation or networks with other organisations; Hiring skilled employees from other organisations; Reverse engineering; Independent R&D (in house or external; Lead customers; Suppliers; Consultants.
Competitive strategy		
Increase efficiency	A 3-item, 7 point scale measuring the organization's competitive strategy	Increases operating efficiencies; Develops new process innovations that reduce costs; Focuses on increasing productivity.
Customer orientated	A 3-item, 7 point scale measuring the organization's competitive strategy	Tailors and shapes products/services to fit customers' needs; Develops customer loyalty; Has the flexibility to quickly respond to customer needs.
Product leader	A 4-item, 7 point scale measuring the organization's competitive strategy	Produces a continuous stream of state-of-the-art products/services; Is 'first to market' with new products/services; Responds to early market signals concerning areas of opportunity; Develops products/services

		which are considered the best in the industry.
Price cutter	A 3-item, 7 point scale measuring the organization's competitive strategy	Produces products/services at a cost level lower than that of our competitors; Prices below competitors; Produces products/services for lower-priced market segments
Human resource management		
Keeps talented staff	A 7 point scale measuring how well the organization keeps talented staff	Our organisation ensures that talented employees stay.
Team work	A 3-item, 7-point scale measuring the extent of disaggregated decision making within the firm	This organisation utilises teams which have responsibility for decisions, assigning work and determining work methods; involves employees in decisions that directly affect their work processes; acts on suggestions and feedback provided by employees
Pay rewards	A 7-item, 7 point scale measuring the extent firms use pecuniary incentives to reward employees	This organisation regularly conducts formal appraisals of employee performance; has a formal grievance procedure or formal complaint resolution system for employees; has transparent systems to address poorly performing employees; rewards employees based on how well they perform the job; rewards employees based on how well their work group or team; performs rewards employees based on how well the organisation performs; has a performance appraisal system that helps to ensure that our reward based pay plan is effective.
Prevention of expropriation		
Patents	A 2-item, 7-point scale questions measuring the effectiveness of patents for that firm	How effective are patents for protecting the competitive advantages of new or improved products and processes that your organisation has invented?
Secrecy	A 2-item, 7-point scale questions measuring the effectiveness of patents for that firm	How effective is secrecy for protecting the competitive advantages of new or improved products and processes that your organisation has invented?
Lead time	A 2-item, 7-point scale questions measuring the effectiveness of lead time	How effective are lead time for protecting the competitive advantages of new or improved products and processes that your organisation has invented?
Moving down the learning curve	A 2-item, 7-point scale questions measuring the effectiveness of moving quickly down the learning curve for that firm	How effective is moving quickly down the learning curve for protecting the competitive advantages of new or improved products and processes that your organisation has invented?
Control over distribution	A 2-item, 7-point scale questions measuring the effectiveness of control over distribution for that firm	How effective is control over distribution for protecting the competitive advantages of new or improved products and processes that your organisation has invented?
Brand names and marketing	A 2-item, 7-point scale questions measuring the effectiveness of brands for that firm	How effective are brand names and marketing for protecting the competitive advantages of new or improved products and processes that your organisation has invented?
Organisational know-how and capabilities	A 2-item, 7-point scale questions measuring the effectiveness of organisational know how, capabilities for that firm	How effective are organisation know how and capabilities for protecting the competitive advantages of new or improved products and processes that your organisation has invented?
Product and production complexity	A 2-item, 7-point scale questions measuring the effectiveness of organisational know how, capabilities for that firm	How effective are organisation know how and capabilities for protecting the competitive advantages of new or improved products and processes that your organisation has invented?

Source: Melbourne Institute Business Survey 2001 - 2004

References

Acs, Z. & Audretsch, A. (1987) 'Innovation, Market Structure and Firm Size', Review of Economics and Statistics, 69, 567-574.

Acs, Z. & Audretsch, D. (1988) 'Innovation in Large and Small Firms', American Economic Review, 78, 678-690.

Acs, Z. & Audretsch, D. (1991) 'Innovation and Size at the Firm Level', Southern Economic Journal, 57, 739-744.

Arvanitis, S. (2002) Explaining innovative activity in service industries: Micro data evidence for Switzerland. 56, Swiss Federal Institute for Technology.

Beck, N. and Katz, J. (2004) Time-Series–Cross-Section Issues: Dynamics, 2004, mimeo, New York University.

Bloch, C. (2005) 'R&D investment and internal finance: The cash flow effect', Economics of Innovation and New Technologies, 14, 213-223.

Bosworth, D. & Rogers, M. (2001) Market Value, R&D and Intellectual Property: An Empirical Analysis of Large Australian Firms. Economic Record, 77, 323-337.

Branch, B. (1974) 'Research and Development Activity and Profitability: A Distributed Lag Analysis', Journal of Political Economy, 82, 999-1011.

Caves, R. E. (1982) 'Multinational enterprises and technology transfer' in Rugman, A. M. (Ed.) New Theories of the Multinational Enterprise. London, Canberra, Croom Helm.

Cohen, W. M. & Levinthal, D. A. (1989) 'Innovation and learning: The two faces of R&D' Economic Journal, 99, 569-596.

Cohen, W. M. (1995) 'Empirical studies of innovative activity' in Stoneman, P. (Ed.) Handbook of the Economics of Innovation and Technical Change. Oxford UK & Cambridge USA, Blackwell.

Cohen, W. M., Levin, R. C. & Mowery, D. C. (1987) 'Firm size and R&D Intensity: A Re-examination' Journal of Industrial Economics, June, 543-565.

Covin, J. G., Slevin, D. P. & Heeley, M. B. (2001) 'Strategic decision making in an intuitive vs. technocratic mode: structural and environmental considerations' Journal of Business Research, 52, 51-67.

Cumming, D. & Macintosh, J. (2000) 'The Determinants of R&D expenditures: A Study of the Canadian Biotechnology Industry', Review of Industrial Organisation, 17, 357-370.

Duguet, E. & Monjon, S. (2004) 'In innovation persistent at the firm level? An econometric examination comparing the propensity score and regression methods', mimeo, University College London and Université Paris.

Dunning, J. H. (1988) 'International business, the recession and economic restructuring' in Hood, N. and Vahlne, J. E. (Eds) Strategies in global Competition. London, New York, Sydney, Croom Helm.

Geroski, P., van Reenen, J. & Walters, C. (2002) 'Innovations, Patents and Cash Flow' in Kleinknecht, A. & Mohnen, P. (Eds.) Innovation and Firm Performance. Econometric Explanations of Survey Data. Houndmills, Basingstoke and New York, Palgrave.

Grabowski, H. (1968) 'The Determinants of Industrial Research and Development: A Study of the Chemical, Drug and Petroleum Industries', Journal of Political Economy, 76, 292-306.

Griliches, Z. (1995) 'R&D and Productivity: Econometric Results and Measurement Issues' in Stoneman, P. (Ed.) Handbook of the Economics of Innovation and Technological Change. Oxford, UK and Cambridge, Mass., Blackwell.

Hall, B. (2002). 'The Financing of Research and Development,' Oxford Review of Economic Policy, 18, 35-51.

Harhoff, D., Narin, F., Scherer, F. M. & Vopel, K. (1999) 'Citation frequency and the value of patented inventions' Review of Economics and Statistics, 81, 511-515.

Himmelberg, C. P. & Petersen, B. C. (1994) 'R&D and internal finance: A Panel study of small firms in high-tech industries' Review of Economics and Statistics, 76, 38-51.

Hollenstein, H. (2002) 'Determinants of the adoption of information and communication technologies (ICT)', Swiss Federal Institute for Technology.

Huselid, M. A. (1995) 'The Impact of Human Resource Management Practices on Turnover, Productivity, and Corporate Financial Performance' Academy of Management Journal, 38, 635-672.

Jaffe, A. B. (1986) 'Technological Opportunity and Spillovers of R & D: Evidence from Firms' Patents, Profits, and Market Value' American Economic Review, 76, 984-1001.

Jaffe, Trajtenberg and Henderson (1993), 'Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations', The Quarterly Journal of Economics, 108(3): 577-598.

Judson, R. and Owen, A. 1999. Estimating dynamic panel data models: a guide for macroeconomists. Economics Letters 65, 9-15.

Kamien, M. & Schwartz, N. (1978) 'Self financing of an R&D Project', American Economic Review, 68, 252-261.

Kamien, M. & Schwartz, N. (1982) Market Structure and Innovation, Cambridge University Press, Cambridge, New York.

Lee, C.-Y. (2002) 'Industry R&D intensity distributions: regularities and underlying determinants' Journal of Evolutionary Economics, 12, 307-341.

Levin, R. and Reiss, P. (1984) 'Tests of a Schumpeterian Model of R&D and Market Structure', in Griliches, Z. (Ed.) R&D Patents and Productivity. Chicago, University of Chicago Press for the NBER.

Levin, R. C., Cohen, W. M. & Mowery, D. C. (1985) 'R&D Appropriability, Opportunity and Market Structure: New Evidence on some Schumpeterian Hypotheses' American Economic Review, 75, 20-24.

Mansfield, E. (1984) 'R&D and Innovation: Some Empirical Findings', in Griliches, Z. (Ed.) R&D Patents and Productivity. Chicago, University of Chicago Press for the NBER

Martinez-Ros, E. & Labeaga, J. (2002) 'Modelling innovation activities using discrete choice panel data models' in Kleinknecht, A. & Mohen, P. (Eds.) Innovation and Firm Performance. Econometric Explorations of Survey Data. Houndmills, Basingstoke and New York, Palgrave.

Maurseth, B and Verspagen, P.B. (2002), 'Knowledge Spillovers in Europe: A Patent Citation Analysis', Scandinavian Journal of Economics, 104(4):531-545

Medina, C., Lavado, A., & Cabrera, R. (2005) 'Creativity and Innovation Management, 2005 Characteristics of Innovative Companies: A Case Study of Companies in Different Sectors' Creativity and Innovation Management, 14, 272-287.

Miles, R., & Snow, C. (1978) Organizational Strategy, Structure and Process, McGraw-Hill, New York, NY.

Nelson, R. & Winter, S. (1982) An Evolutionary Theory of Economic Change, Cambridge Mass. and London, Belnap Press of Harvard University Press.

Nieto, M. and Quevedo, P. (2005) ‘Absorptive capacity, technological opportunity, knowledge spillovers and innovative effort’, Technovation, 25, 1141-1157.

Oltra, M. & Flor, M. (2003) ‘The Impact of Technological Opportunities and Innovative Capabilities on Firms’ Output Innovation’, Creativity and Innovation Management, 12, 137-144.

Özsomer, A., Calantone, R., di Benedetto, A. (1997) ‘What makes firms more innovative? A look at organizational and environmental factors’. Journal of Business & Industrial Marketing, 12, 400-414.

Pakes, A, & Schankerman, M. (1980) ‘An Exploration into the Determinants of Research Intensity’, NBER Working Paper Series, no. 438.

Pavitt, K. (1991) Key characteristics of the large innovating firm, British Journal of Management, 2, 41-50.

Phillips, A. (1966) ‘Patents, potential competition, and technical progress’ American Economic Review, 56, 301-10.

Rafferty, M. and Funk, M. (2008) ‘ Asymmetric effects of the business cycle on firm-financed R&D’, Economics of Innovation and New Technologies, 17, 497-510.

Rothwell, R., Freeman, C., Horlsey, A., Jervis,V. T. P., Robertson, A. B. & Townsend, T. (1974) SAPPHO updated - project SAPPHO phase II. Research Policy, 3, 258-291.

Scherer, F. M. (1967) ‘Market Structure and the Employment of Scientists and Engineers’ American Economic Review, 57, 524-31.

Schumpeter JA (1943) Capitalism, Socialism and Democracy, London, Boston, Sydney: George Allen & Unwin, 1976.

Scott, J. T. (1984) ‘Firm versus industry variability in R&D intensity’ in Griliches, Z. (Ed.) R&D Patents and Productivity. Chicago, University of Chicago Press for the NBER.

Souitaris, V. (2002) ‘Firm-specific competencies determining technological innovation: a survey in Greece’ R&D Management, 32, 61-77.

Sterlacchini, A. (1994) ‘Technological Opportunities, intraindustry spillovers and firm R&D intensity’, Economics of Innovation and New Technologies, 3, 123-137.

Stoneman, P. & Toivanen, O. (2001) ‘The impact of Revised Recommended Accounting Practices on R&D Reporting by UK firms’ International Journal of the Economics of Business, 8, 123-136.

Sutton, J. (1991) Sunk Costs and Market Structure, Cambridge (Mass), MIT Press.

Thompson (2006), 'Patents Citations and the Geography of Knowledge Spillovers: Evidence from Inventor and Examiner-added Citations', The Review of Economics and Statistics, 88(2): 383-388

Van Dijk, B., den Hertog, R., Menkveld, B. & Thurik, R. (1997) 'Some Evidence on the Determinants of Large- and Small-Firm Innovation', Small Business Economics, 9, 335-343.