The Value of Innovation: The Interaction of Competition, R&D and IP*

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Abstract

This paper analyses market valuations of UK companies using a new data set of their R&D and IP activities (1989-2002). In contrast to previous studies, the analysis is conducted at the sectoral level, where the sectors are based on the technological classification originating from Pavitt (1984). The first main result is that the valuation of R&D varies substantially across these sectors. Another important result is that, on average, firms that receive only UK patents tend to have no significant market premium. In direct contrast, patenting through the European Patent Office does raise market value, as does the registration of trade marks in the UK for most sectors. To explore these variations the paper links competitive conditions with the market valuation of innovation. Using profit persistence as a measure of competitive pressure, we find that the sectors that are the most competitive have the lowest market valuation of R&D. Furthermore, within the most competitive sector ('science based' manufacturing), firms with larger market shares (an inverse indicator of competitive pressure) also have higher R&D valuations, as well as some positive return to UK patents. We conclude that this evidence supports Schumpeter by finding higher returns to innovation in less than fully competitive markets and contradicts Arrow (1962), who argued that, with the existence of IP rights, competitive market structure provides higher incentives to innovate.

Keywords: R&D, intellectual property, market valuation, competition

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1 Introduction

This paper contains an empirical analysis of the market valuation of innovative activities by UK production firms. Whilst there have been many earlier studies of this phenomenon, this literature is dominated by US studies with rather little evidence for the UK (see for example Hall, 2000). The analysis in this paper uses a new panel data set (1989-2002) on the R&D and intellectual property (IP) activity of UK production firms and we extend the standard approach to analysing the market value of innovative firms in a number of ways. Most importantly, we analyse the extent to which the stock market's valuation of firm-level innovation varies across firms by sector and, finding that it does, we investigate what factors are associated with relatively high or low returns to innovation.

To define our sectors we use the classification system first mooted in Pavitt (1984). Pavitt put forward a taxonomy based on differences in the process of innovation, rather than a product-based industrial classification. Tidd et al. (2001) augmented this taxonomy to include modern service sectors, as well as manufacturing. Using these two contributions this paper defines 'Pavitt' sectors and conducts the analysis on these separately. Although this approach is new to the market valuation literature, it seems entirely appropriate to analyse the market value of innovation using this taxonomy and, indeed, our results confirm this.

Another distinction in comparison with many previous studies is the breadth of IP data available in this study, which allows an investigation of the role of UK trade mark activity as well as of UK and European Patent Office patent activity.[1] A third novel contribution is to investigate the role of the competitive conditions that firms face as an explanation for variations in their returns to innovation. Specifically we introduce profit persistence analysis, a dynamic measure of market structure, into the market value literature.

The structure of the paper follows these objectives. The next section outlines the nature of the data and Pavitt's typology. In particular, and in agreement with Pavitt's observations, we observe substantial differences across sectors in the extent and composition of innovative activity. The third section presents some initial results using the market value approach. The main result is that the market valuation of R&D, patents and trade marks do vary substantially across Pavitt sectors. A

[1] Exceptions include analysis of productivity on an older version of these data by Greenhalgh and Longland (2002) and an analysis of trade marks on Australian data by Bosworth and Rogers (2001).

further finding is that the stock market appears to place no significant valuation on firms obtaining UK patents, although there is a positive premium for patents from the European Patent Office.

The fourth section deals with the role of competition in explaining the variation in returns using three different approaches. We begin with analysis linking industry rents to the returns to innovative activity. Next, we introduce the use of profit persistence analysis, arguing that this is a superior means of gauging competitive conditions, which has not been tried in this literature. Finally, we analyse the role of product market share as a proxy for market power; this approach has been used in the literature, yielding contradictory results at times, and our analysis provides some insight into this debate. The last section of the paper summarises our conclusions.

2 Data overview

2.1. The OIPRC database

The database was constructed using firms' financial information obtained from Company Analysis (Extel Financial, 1996, and Thomson, 2001) and also from FAME (Bureau van Djik, 2004). The financial data includes the usual items, such as sales, profits and also R&D expenditure, where separately reported, and the end of accounting period share price for publicly quoted companies, together with information on the industrial classification (SIC) for the principal product. These data span the period 1989 to 2002. Since the coverage of R&D data in FAME is poor, additional data on R&D is taken from the Department of Industry R&D Scoreboard 2003.[2] Data on three forms of IP are also available for various sub-periods (as explained below). The IP data include counts of the number of patents published via the UK, patents published via the European Patent Offices (which designated the UK *inter alia*), and trade mark applications via the UK office. These IP data were obtained from a range of sources (European Patent Office, 1996, 2001, 2002; Patent Office, 1986-95, 1997, 2002; Search Systems Ltd, 1996; and Marquesa Search System, 2002). In order to accurately assess the IP assets acquired by these companies we needed to know which firm names formed part of the group reporting the accounts (in case a subsidiary's name was on the IP application). "Who Owns Whom" information at two points in time was obtained (Dun and Bradstreet International, 1994, 2001) to determine the family trees of the (mainly UK based) parent firms. Searches for patent and trade mark records were then conducted for the names of each parent

[2] This is downloadable at http://www.innovation.gov.uk/projects/rd_scoreboard/home.asp.

and all of its subsidiary companies using these two snapshots of ownership (the 1994 family tree is used for counts in the period to 1995 and the 2001 family tree is used for later years).[3]

2.2. Pavitt's sectoral typology

As indicated in the introduction, a new approach in our analysis is to use the sectoral typology in Pavitt (1984). Pavitt introduced an industrial classification based on technological trajectories, which has subsequently been used extensively in analysis on innovation. Firms were considered to be in one of four categories: supplier dominated, production intensive (scale intensive), production intensive (specialist suppliers), and science based. The motivation for this typology comes from the observation that the process of technological change varies substantially across firms and industries. Pavitt's original typology has been updated in Tidd et al. (2001) by the inclusion of a new sector called 'information-intensive', which includes firms in finance, retail and publishing. A further change since Pavitt's work in the 1980s has been the rise of information technology companies. Specifically, in the data there are a large number of software-related companies that report R&D, hence these are allocated to a separate sector.[4]

Table 1 provides some more explanation of these six Pavitt-based sectors and shows some simple summary statistics for our database on firm size, profitability and innovation. Needless to say, firms within each sector do exhibit considerable heterogeneity in characteristics and in terms of innovative activity. However, it seems entirely justifiable to use this typology in a study of the market value of innovative activities, rather than pooling all firms or conducting analysis on the basis of (standard) industrial classifications.

Table 1 shows that sectors (3) and (4) have the highest proportion of firms reporting R&D expenditure, nearly twice that of sectors (2) and (6) and more than three times the level of sector (1). The information-intensive sector, which is dominated by finance sector firms (around half of the firms), has the lowest level of R&D activity. It is also important to note that during the period of study there was no legal requirement, and no strong financial incentive arising from UK company

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[3] Further information on the construction of the original dataset to 1995 is given in Greenhalgh and Longland, (2001, Appendix Notes); and for the dataset extension from 1996 in Greenhalgh et al. (2003, Technical Appendix). A full list of data sources is shown after the bibliography.

[4] The number of software companies has increased over the 1989 to 2002 period. For example, in the regression for this sector (see Table 4) 71% of observations are post-1995.

tax rules, for UK firms to report R&D separately in company accounts. Thus the measure of R&D activity is subject to an unknown degree of non-reporting of R&D activities. Nevertheless, publicly quoted firms have an incentive to inform investors of such investment in intangible assets and this will minimise under-reporting for this sample.[5]

Table 2 and Table 3 show some summary statistics for the use of IP across the different sectors. The availability of IP data are limited to 1989-2000 for Pavitt sectors one to four, and for the period 1996 to 2000 for sectors five and six.[6] Three different types of IP activity are shown: UK patents, EPO patents and trade marks. The use of two measures of patent activity reflects the fact that there are alternative ways to obtain patent coverage in the UK and other country markets. Firms can choose to patent by means of separate applications to each national patent office, or they can take the route of applying for patent coverage in several European jurisdictions with one application to the European Patent Office. There are different costs and varying likelihoods of obtaining patent coverage via these routes, so firms may have chosen either route for a variety of reasons, including of course the number of markets to be targeted for sales.

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[5] Further support for this assertion comes from Toivanen et al (2002). In this paper they analyse the market value of R&D and allow for sample selection bias, using the standard Heckman (1979) sample selection model. However, they find no evidence that sample selection is a significant problem (see their page 53).

[6] The IP data for sectors five and six come from a recent project funded by the ESRC award RES-334-25-0002 under 'The Evolution of Business Knowledge Programme'.

Table 1 Pavitt technological sectors

Pavitt sector	Description	SIC (US)	Relative balance between product & process innovation	Median firm sales (million £)	Profit before tax / turnover (for entire sector)	R&D active*
(1) Supplier Dominated, Manufacturing and Mining	Traditional manufacturing. Generally small firms with weak in-house R&D and engineering capabilities. Innovations come from suppliers of equipment or materials.	12, 13, 15, 16, 22, 23, 24, 25, 26, 30, 31, 7300, 7312, 7336, 7361	Process	74	0.066	0.176
(2) Production Intensive, Scale Intensive	Large firms producing standard materials or durable goods, inc. cars.	20, 21, 32, 33, 34, 37	Process	103	0.079	0.344
(3) Production Intensive, Specialised Suppliers	Machinery and instruments. Tend to be smaller firms which are technologically specialised.	35, 38, 39	Product	69	0.045	0.624
(4) Science Based	Electronics, electrical and chemicals. Often large firms. Technology from in-house R&D but based on basic science from elsewhere.	28, 29, 36	Mixed	110	0.094	0.612
(5) Information-intensive	Includes finance, retail, communications and publishing industries. In-house software or systems development, plus IT hard- and soft-ware purchases.	27, 48, 50-67, 7313 and 7383 (media)	Mixed	75	0.137	0.045
(6) Software-related firms	Computer software and services firms.	All SIC 73 sub-codes not shown above	Product	13	0.027	0.307

Notes: The table is based on 28,447 firm-year observations over the period 1989-2002. The concordance between the two-digit SIC (US) available in the data and Pavitt's categories is based on Vossen (1998), Dewick et al (2002) and Tidd et al (2001). * R&D active means the proportion of firm-year observations where the reported accounts contain a positive R&D value.

Table 2 shows that trade mark activity is more common than patenting; it is present in around one third to one half of firms in sectors (1) to (5), and is only slightly lower in sector (6). Note also that UK patenting is more prevalent than EPO patents, by a factor of around two in sectors (1), (5) and (6); but by a smaller factor for the production intensive and science based sectors. The software-related firms have the lowest proportion of patenters, reflecting the fact that computer software is not generally patentable under EPO or UK rules.

Table 2 Extent of innovative activity (1989-2000)

Pavitt Sector	Observations	UK patent active	EPO active	Trade mark active
(1) Supplier Dominated, Manufacturing	4,288	0.207	0.116	0.323
(2) Production Intensive, Scale	3,556	0.319	0.207	0.489
(3) Production Intensive, Specialist	1,869	0.393	0.293	0.426
(4) Science based	2,273	0.415	0.327	0.498
(5) Information-intensive*	5,597	0.066	0.030	0.380
(6) Software-related*	1,115	0.035	0.013	0.274

Note: Pavitt sectors 1-4 are based on 1989-2000 data; *Pavitt sectors 5 and 6 on 1996-2000 data. 'Active' refers to the firm-year observation having some reported R&D expenditure in accounts or at least one patent or trade mark.

Table 3 Median intensity for firms undertaking innovative activity (average 1989-2002)

Pavitt Sector	R&D/turnover	UK Patent/turnover	EPO patent/turnover	Trade Mark/turnover
(1) Supplier Dominated, Manufacturing	0.006	0.008	0.005	0.020
(2) Production Intensive, Scale	0.007	0.008	0.005	0.018
(3) Production Intensive, Specialist	0.026	0.016	0.012	0.025
(4) Science Based	0.021	0.011	0.010	0.022
(5) Information-intensive	0.011	0.009	0.009	0.034
(6) Software-related	0.097	0.010	0.027	0.196

Note: R&D data based on 1989-2002. For IP data, Pavitt sectors 1-4 are based on 1989-2000 data, while Pavitt sectors 5 and 6 on 1996-2000 data. The median is for the distribution of 'Active' firms only. For IP measures, turnover is in millions of pounds.

Table 3 shows the median intensity for the active firms only. Median patent intensity is lower in sectors (1), (2) and (5) than in sectors (3) and (4), as might be expected. For sectors (5) and (6) median patent intensity is relatively high, although Table 2 has shown that very few firms actually patent in these sectors. In terms of trade mark intensity, the high figure for software firms is noticeable. The data show that, although only 27% of such firms trade mark, these firms have relatively high numbers and are also relatively small in size.[7]

A final issue of interest is the relative shares for each sector for overall innovative activity. Figure 1 in Appendix 1 show how the shares of R&D has changed over the 1989-2002 period (equivalent

[7] For example, Eidos PLC – a company that develops software games – averaged 29 trade mark applications per year over the 1996 to 2000 period (it had an average turnover of 144 million in these years).

graphs for the IP variables are problematic since all data are not available over this period). The graph shows that total R&D is dominated by the 'science based' sector, fluctuating between around 45% to 55%.[8] Over the period the 'supplier dominated' sector's share fell from around 6% to 2%, with falls of around two percentage points in both the production intensive sectors. In contrast, the software-related sector's share has increased from approximately zero to 3.5%. In terms of patent activity, if we exclude Pavitt sectors five and six (since data are only available from 1996), the following results are found. UK patent activity is again dominated by the science based sector (around 30-40% of total patents), but it is the 'productive intensive (specialist)' sector that has grown most over time (from 19% to 33% in 1999). For EPO patents, again the science based sector has the largest share, and for this activity the science based sector has rapidly increased its share (from 38% to 56%).

3 The market value of innovation

3.1. The model

This section summarises the standard model of market value and its relationship with R&D and intellectual property activity. Most previous empirical studies use an empirical specification based on Griliches (1981) who assumed that the market value (*V*) of the firm is given by

$$V = q(A + \gamma K)^{\sigma}, \qquad [1]$$

where *A* is the book value of total assets of the firm, *K* is the stock of intangible assets not included in the balance sheet, *q* is the 'current market valuation coefficient' of the firm's assets, σ allows for the possibility of non constant returns to scale, and γ is the ratio of shadow values of intangible assets and tangible assets (i.e. $\frac{\partial V}{\partial K} \Big/ \frac{\partial V}{\partial A}$).

Most authors take natural logarithms of [1], and use the approximation $\ln(1+\varepsilon) \approx \varepsilon$, to rearrange [1] into:

[8] The final year (2002) shows a jump in science-based share to 62%. However, since these data come from an unbalanced panel we are reluctant to read too much into any specific year's data.

$$\ln V = \ln q + \sigma \ln A + \sigma\gamma \frac{K}{A} \ . \qquad [2]$$

Perhaps the major issue facing empirical studies is how to proxy K. This paper follows previous studies in using flow data on R&D expenditure (R) as the main proxy for K. However, the various IP measures are also used as proxies for such capital in some analysis. While the use of patent data is relatively common, data on trade marks is less so.[9] Note that since we are using flow variables to proxy stock variables, our coefficient estimates cannot be related directly to [2]. To understand this issue, consider a simple case where the stock of R&D equals n times current R&D, where n>1.[10] This would, in turn, imply that our coefficient estimate equals $\sigma\gamma n$. Given that we do not know n, we cannot directly calculate γ. However, this is not of central interest since it is the combination of both n and γ that determine the attractiveness of investing in R&D. For these reasons we calculate the implied γn value from the R&D coefficients. For the IP based variables interpreting the coefficients in this way is not possible. The coefficient estimates on these flow variables are best thought of as an estimate of the (average) market valuation of such activity and, as will become clear, our main interest is in comparing these valuations across sectors. These issues mean that the estimation equation is:

$$\ln V_{it} = \alpha_j + \alpha_t + \sigma \ln A + \sigma\gamma n \frac{R_{it}}{A_{it}} + \alpha_1 \frac{UKP_{it}}{A_{it}} + \alpha_2 \frac{EPOP_{it}}{A_{it}} + \alpha_3 \frac{TM_{it}}{A_{it}} + \eta X + u_{it} \ . \qquad [3]$$

Where i indexes a firm and t a year; and α_j and α_t are sets of industry and year dummies. Note that [3] allows ln$q$ from [2] to vary across industries and over time (i.e. $\ln q=\alpha_j+\alpha_t$), to allow for variations in the 'current market valuation coefficient'. Since the data set is a panel we can also estimate a fixed effect model (which means replacing α_j with firm specific fixed effects in [3]). As in other studies we include a number of other control variables, represented by the matrix X in [3],

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[9] Previous analysis of market value and trade marks include Bosworth and Rogers (2001), who do not find a significant role of trade marks in the mid-1990s in Australia firms. Seethamraju (2003) analyses the value of trade marks in 237 US firms from selected industries in 1993-97, finding a positive role for trade marking on sales and also market values. Medonca et al (2004) argue that trade marks can and should be used as indicators of innovation. The analysis in the paper can be viewed as an empirical test of the relevance of trade marking to firm performance.

[10] For example, if R&D depreciated at a straight line rate of 20% per year, n would equal 3. Greenhalgh and Longland (2002) found rather short durations of real returns to R&D and intellectual property assets for all firms, measuring returns through the increase in value added. Other papers assume that the depreciation rate of R&D is 15%.

including sales growth, the debt to equity ratio and the book value of intangible assets.[11] This basic specification is later augmented with the various measures of market structure to investigate the role of competition in the determination of market value in the presence of intangible assets.

3.2. Basic market value regressions

Table 4 shows some OLS regressions on all available data for the period 1989-2002. In particular, regressions are run separately on the full sample and on each Pavitt sector. Looking only at the full sample regression in the first column, the coefficient on R&D is significant and positive. The coefficients on ln of assets, growth of sales and intangible to tangible ratio are also significant. The main interest in Table 4 concerns the sub-sample regressions on the different Pavitt sectors. Looking across the table, it is clear that the coefficient on R&D retains its significance, although the magnitude of the coefficient varies by a factor of over three. Since the value of σ is embedded in the coefficient on R&D (recall that the coefficients equal $\sigma\gamma n$ from equation [3]), Table 4 contains a row that calculates the implied γn value. The coefficient on log of total assets represents σ and is equal to one if there are constant returns to scale in the market valuation of tangible and intangible assets. Testing this condition shows that the null hypothesis of constant returns to scale is rejected (at 5% level) in sector 5 and the full sample.[12]

[11] For a review of market value studies and this methodology see Hall (2000).

[12] This implies that for sectors 1 to 4 and sector 6 we could use the log of Tobin's q as a dependent variable (i.e. impose σ=1 by using log(market value/assets) = log(q) as dependent variable). If this is done, the estimated coefficients are little changed (it is, in fact, close to the implied γn value shown in Table 4). Using the log(q) as dependent variable and including only the R&D variable – as a method of investigating the explanatory power of R&D – indicates that the adjusted R^2 is between 0.06 and 0.13 for all sectors and the full sample, except for Pavitt 1 where it is only 0.01. For future reference, when the IP variables are added as explanatory variables (see section 3.4), the adjusted R^2 increases by between 0.01 and 0.08.

Table 4 Market value regressions, by Pavitt sector

	Full sample	Supplier dominated manufacturing (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Information-intensive (Pavitt 5)	Software firms (Pavitt 6)
Ln of total assets	1.023	0.994	1.006	1.032	1.027	1.071	1.038
	(123.46)***	(32.78)***	(56.41)***	(55.38)***	(63.49)***	(51.35)***	(28.80)***
R&D expend / total assets	3.509	3.428	7.974	4.626	3.499	6.137	2.340
	(14.65)***	(2.21)**	(8.23)***	(6.27)***	(8.18)***	(8.26)***	(6.74)***
Growth in sales (t, t-1)	0.312	0.407	0.487	0.447	0.247	0.321	0.204
	(6.66)***	(3.50)***	(3.42)***	(4.14)***	(3.06)***	(2.31)**	(2.22)**
Debt / shareholders' equity	-0.001	0.005	0.002	-0.010	0.003	-0.002	-0.003
	(1.60)	(0.25)	(1.36)	(1.29)	(1.54)	(2.81)***	(1.12)
Intangible assets / total Assets	0.685	2.079	1.747	1.124	0.947	-0.025	-0.579
	(5.01)***	(3.50)***	(5.89)***	(3.47)***	(3.18)***	(0.08)	(2.04)**
Constant	-1.175	-1.332	-1.366	-0.885	-0.787	-0.941	-0.642
	(14.08)***	(3.30)***	(3.82)***	(3.56)***	(3.68)***	(1.61)	(1.36)
Observations	4367	481	886	969	984	538	509
Number of firms	619	75	123	146	160	111	100
R-squared	0.85	0.87	0.9	0.8	0.86	0.88	0.71
Industry dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.00	Na
Year dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Implied γn value	3.43***	3.45**	7.93***	4.48***	3.41***	5.73***	2.25***
Test of H_o: $\sigma = 1$	0.00	0.85	0.75	0.08	0.10	0.00	0.30

Notes: The dependent variable is ln of market value (mv), where 'mv' is defined as shares outstanding (average in year) x price (end accounting period) plus creditors and debt less current assets (see Chung and Pruitt, 1994). Estimator is ordinary least squares (OLS) with robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. The industry and year dummies rows show the probability of a type 2 error in rejecting the hypotheses that all 2-digit industry (year) dummies are equal. A Chow test on whether the sub-samples can be pooled yields a F-statistic of 7.0 (rejecting the null hypothesis that the samples can be pooled at the 1% level).

As stated above, the magnitude of the coefficient on R&D to assets varies substantially across Pavitt sectors. Perhaps unexpectedly, the lowest coefficient on R&D is for software-related firms (sector 6), followed by the science-based firms in sector 4. The highest magnitude for the R&D coefficient is for sectors 2 and 5, both of which are supplier-dominated.

Other coefficients estimated in Table 4 are also of interest. The consistently positive coefficients on sales growth suggests stock markets expect that firms experiencing faster growth will have higher future profitability. The results for the book value of intangible to total assets ratio are also generally positive; this variable reflects the accounting value of goodwill, and possibly patents and brands, obtained via takeovers.[13] The structure of the firm's finance as reflected in the debt to equity ratio is generally a negative influence, and significantly so for information intensive firms, suggesting that the shares are marked down due to risk when firms relying on knowledge capital are using debt to finance their activity.

3.3. Robustness analysis of R&D coefficient

The basic OLS regression analysis above can be criticised in a number of ways and it is important to check the robustness of the results in Table 4. An initial important issue is to explore the role of influential observations. Appendix 2 shows leverage plots for the R&D to assets variable in each of the Pavitt sector regressions in Table 4. The graphs indicate that in some sectors a few observations appear critical in determining the coefficient. For example, there is a single firm in Pavitt sector 1 that appears influential (the observation is for Ingenta Plc in 2002; this firm has R&D of around £2.5 million in both 2001 and 2002, but its reported assets are 75% lower in 2002). Given the leverage plots, all the regressions in Table 4 were re-estimated using a robust regression procedure, which uses an algorithm to eliminate influential observations.[14] Table 5 below shows the coefficients on R&D from the robust regression estimator. The first row of Table 5 shows the OLS results for ease of comparison and it is clear that, in general, the results from the robust estimator are similar. The exception is Pavitt sector 1 where, as might be expected, the coefficient is now not significantly different from zero.

A further econometric issue concerns the use of firm specific effects to control for unobserved heterogeneity (e.g. management ability). If these fixed effects are correlated with R&D intensity then OLS estimates will be biased. However, there are also drawbacks in using panel data estimators. First, removing firm specific effects may obscure the impact of innovative activities to

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[13] Further analysis was conducted omitting the book value of intangible assets from the set of explanatory variables. The results suggest its inclusion does not substantially affect the other coefficients.

[14] More specifically, the procedure is: (1) calculate Cook's D for each observation from OLS, (2) observations with values greater than one are given zero weight, (3) re-run regression, (4) calculate $M=\text{med}(|e_i-\text{med}(e_i)|)$, where e_i is the residual, (5) any observation with an absolute residual greater than 2M receives a downweight of $2M/|e_i|$ (called Huber weights), (6) repeat procedure until maximum change in weights drops below 0.01 (called 'convergence'), (7) based on final regression in step 6, repeat procedure using 'biweights', which are downweights given by $[1-(7e_i/M)^2]^2$, until convergence. The procedure is described in more detail, with appropriate references, in STATA 8.0 reference manual under 'rreg' (www.stata.com).

the extent that these are time invariant. Second, when the data contain measurement error, the use of panel data estimators can increase attenuation bias, especially when variables are persistent through time. In any event, all the regressions shown in Table 4 were re-estimated using a fixed effect (FE) estimator, which estimates a time invariant effect for each firm (i.e. enters a dummy variable for each firm). The coefficients on the R&D to assets variable from the FE regressions are shown in the third row of results in Table 5. In comparison with either the OLS or the robust regressions, the coefficient sign for each regression variable still holds although, as expected, the coefficient estimates tend to be smaller and are insignificant for sectors 1 and 5.[15] More specifically, the fixed effect estimations show that the implied γ_n coefficient on R&D is still lowest in Pavitt sector 4 and 6.

A final econometric issue of concern is endogeneity. As in previous studies, the above analysis has not attempted to control for reverse causation. The specific concern for this paper is that a relatively high market value might cause the firm to invest more intensively in R&D. Since the R&D data used here is flow data for the financial year, whereas the market value is taken at the end of the accounting period, our view is that reverse causation is unlikely to be a major concern. However, we have estimated two stage least squares regressions, using the lagged values of the explanatory variables as instruments. The results show that only Pavitt sectors 3, 4 and 6 have a significant coefficient on the R&D variable with magnitudes similar to those in Table 4.[16]

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[15] An alternative econometric technique is to remove firm specific fixed effects by differencing the data. Again, the presence of measurement error will cause biased estimates using this approach. However, as Griliches and Hausman (1986) have shown, the problem of measurement error is lessoned if 'long' differences are used. Using a first difference estimator on each Pavitt sector finds significant (10% level) coefficients on R&D variable in sectors 2, 4 and 6, but all are lower in magnitude than in FE results; using third differences indicates R&D is significant in sectors 2, 3, 4 and 6 and now the magnitudes are close to those for the FE results. This provides some support for our view that measurement error is a significant issue in panel based estimators.

[16] Estimating an instrumental fixed effect model shows that few coefficients on the explanatory variables, including R&D, are significant. This indicates that the lagged values are poor instruments, supporting our view that measurement error is a problem in panel estimations.

Table 5 Additional regression results for R&D variable

	Full sample	Supplier dominated manufacturing (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Information-intensive (Pavitt 5)	Software firms (Pavitt 6)
OLS (from Table 4)	3.509	3.428	7.974	4.626	3.499	6.137	2.340
	(14.65)***	(2.21)**	(8.23)***	(6.27)***	(8.18)***	(8.26)***	(6.74)***
Robust estimator	3.413	0.053	8.152	4.954	3.496	5.382	2.218
	(21.99)***	(0.05)	(11.65)***	(9.63)***	(13.05)***	(8.76)***	(6.34)***
Fixed effect estimator	1.48	1.041	4.274	1.79	1.352	2.196	1.487
	(7.20)***	(0.61)	(2.59)***	(2.64)***	(3.33)***	(1.35)	(4.18)***
Implied γ_n							
OLS (from Table 4)	3.43***	3.45**	7.93***	4.48***	3.41***	5.73***	2.25***
Robust estimator	3.32***	0.06	7.94***	4.82***	3.37***	5.01***	2.11***
Fixed effect estimator	1.74***	1.01	5.92***	2.30***	1.62***	3.00	1.72***

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%.

3.4. The role of intellectual property

A unique aspect of the OIPRC database is that it contains intellectual property (although these data are limited to the 1989, or 1996, to 2000 period). Previous analysis of market value and innovation often uses patent data as a further proxy for intangible assets (*K*). In this paper we also use trade mark data as a further proxy for innovative activity and the creation of intangible assets. As per equation [3], each of the IP measures is entered as a ratio to total assets. The main part of Table 6 shows coefficient estimates using a basic OLS estimator.

The first result from Table 6 is that the addition of the IP variables does not detract from the central role of R&D in explaining market value. The coefficients on R&D are all significant and have magnitudes similar to those in Table 4. Looking at the results on the new IP variables, Table 6 indicates that firms with higher relative rates of UK patenting appear to command no market value premium. In contrast, EPO patenting appears to be associated with higher market value in the full sample and sectors 3 and 4, while the trade marking variable has a significant coefficient in all but one of the Pavitt sectors. An initial concern is that influential observations may affect the coefficient estimates for the IP variables. Using the robust estimator as defined above we find that the coefficient on the EPO patent variable is now positive and significant in all regressions except sector (6). The results on the trade mark variable are similar to Table 6 (except that the coefficients in sectors (1) and (6) lose their significance. Perhaps most surprisingly, the robust regressions find no positive role for UK patents (in fact, the coefficients are significant and negative in sectors (2) and (5)).[17,18]Another possible explanation for the lack of significance of coefficients on all of the IP variables, and the UK patent variable in particular, is that the variables may be highly correlated. The correlation coefficients for the IP variables are between 0.02 and 0.36, with the highest correlations between the UK and EPO patent variables. To assess this issue, separate regressions were run entering only one IP variable at a time. The results indicate that the lack of significance on the UK patents variable may be due to multicollinearity: when entered as the sole IP variable, the coefficient on UK patent variable is significant for the full sample and sectors (2), (3) and (4). However, the magnitude of the coefficient on UK patents is always less than that on the EPO patent variable (when this is entered separately). Thus, the results suggest that EPO patenting is a more important determinant of market value that UK patents. Evidence supporting this is contained in a related paper by Greenhalgh and Longland (2002), who investigated the impact on firm level net output of both UK and EPO patents using an earlier version of this database reflecting a shorter time period. They found a consistently stronger impact of EPO than of UK patents in terms of both the size and duration of their impact on productivity, confirming the idea of qualitative differences in the two patents that are recognised by the market.

[17] Although not shown, the results for the IP variables from using a fixed effect estimator are generally weak, which we interpret as indicating that measurement error is a problem. One exception is that the coefficient on the UK patent variable is significant and positive in sector (4) (this is the only positive and significant coefficient we have found for UK patents).

[18] We also investigated whether there could be a slower reaction by the stock market to UK patents as compared with EPO patents by using lagged IP variables, but we found no evidence to support this hypothesis of a slower response time.

Table 6 Regression analysis with IP variables

	Full sample	Supplier dominated manufacturing (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Information-intensive (Pavitt 5)	Software firms (Pavitt 6)
Ln of total assets	1.032	1.002	1.021	1.071	1.032	1.077	1.083
	(109.82)***	(23.69)***	(56.46)***	(52.12)***	(54.55)***	(40.56)***	(24.77)***
R&D expend / total assets	3.374	1.770	7.329	5.274	3.091	7.544	2.103
	(9.82)***	(0.44)	(8.33)***	(5.36)***	(5.84)***	(4.88)***	(3.91)***
UK patent / total assets (millions)	1.078	-10.936	1.932	0.445	1.133	0.286	1.733
	(1.62)	(2.06)**	(1.48)	(0.56)	(0.64)	(0.29)	(0.86)
EPO patent / total assets (millions)	1.733	4.555	0.440	1.453	2.188	-0.253	-6.263
	(3.83)***	(0.94)	(0.24)	(2.15)**	(2.86)***	(0.38)	(0.49)
Trade mark / total assets (millions)	0.073	0.349	0.288	0.658	0.492	-0.174	0.103
	(1.14)	(2.95)***	(1.68)*	(2.18)**	(2.35)**	(2.62)***	(1.86)*
Growth in sales (t, t-1)	0.286	0.544	0.444	0.373	0.239	0.483	0.166
	(4.35)***	(3.55)***	(3.27)***	(2.78)***	(2.44)**	(2.11)**	(0.90)
Debt / shareholders' equity	-0.001	-0.009	0.005	-0.013	0.004	-0.002	-0.002
	(0.55)	(0.46)	(1.92)*	(1.06)	(2.36)**	(3.13)***	(0.51)
Intangible assets / total Assets	0.926	2.101	1.800	1.144	1.162	0.213	-0.769
	(5.60)***	(4.11)***	(5.24)***	(2.78)***	(3.92)***	(0.66)	(1.88)*
Constant	-0.343	0.418	-1.213	-1.530	-0.965	0.838	-0.835
	(1.09)	(0.65)	(3.56)***	(5.43)***	(3.86)***	(1.75)*	(1.56)
Observations	3227	380	714	756	793	320	264
Number of firms	532	58	97	117	126	63	72
R-squared	0.86	0.88	0.9	0.81	0.86	0.91	0.76
Industry dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.00	na
Year dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.46	0.00
Test of H_o: $\sigma = 1$	0.00	0.95	0.24	0.00	0.09	0.00	0.06
Other estimators							
Coefficient on R&D/Assets							
Robust	3.631***	-9.942***	7.786***	5.414***	3.536***	7.403***	1.983***
FE	1.888***	1.948	4.611***	3.998***	1.432***	6.881**	1.543**

Notes: The dependent variable is ln of market value (mv). Other notes as per Table 4.

3.5. Summary and implications for further analysis

The main result of the analysis above is that the market valuation of innovative activities varies significantly across Pavitt sectors. In a perfectly competitive economy where firms and financial markets have perfect information, the valuation of innovative activities should be equalised at the margin across firms and industries, otherwise it would be profitable to reallocate investment. Here the analysis shows that the valuation of R&D is lowest in the science-based and software-related sectors and is three or more times higher in the information intensive and scale intensive sectors. So why might such differences occur?

We might explain the observed differences in valuations for two basic reasons. The first is that stock markets may have imperfect knowledge of the likely returns to innovative activities for certain firms or industries. There is an on-going debate concerning the problems of financing innovative and start-up firms, including the role of venture capital and the market funding of equities. A central issue is whether financial markets are biased against funding innovative, and especially high technology, firms due to a lack of specialist knowledge in evaluating such investments. Given that we are already differentiating firms by sector, it is not clear how we can evaluate this hypothesis further with econometric testing but it remains a possible contributory explanation.

The second reason for variations in valuation to occur is the extent to which competitive pressures vary within the economy: if competition is lower for some firms or in some industries, higher levels of profits may be sustained and, therefore, higher market valuations. The nature of competitive pressure in response to innovation is directly related to the issue of 'appropriability', which refers to the ability of a firm to capture the benefits of an innovation. The issue of appropriability is often discussed in terms of knowledge spillovers, but clearly an important component is whether rival firms are actually present to convert such spillovers into competitive pressure. This will, in turn, depend on whether rival firms can gain access to critical inputs, such as skilled labour or entrepreneurship. For example, it may be that only entrepreneurs with knowledge of the industry's existing technology and product designs are able to exploit a certain technological opportunity. Since the supply of such entrepreneurs is inelastic, this suggests a critical resource constraint and the possibility of supernormal profits. In an economy with static technology, we might expect to approach an equilibrium where these supernormal profits are removed, but in a dynamic economy there may be permanent disequilibrium profitability differences and the likelihood of an economy being 'perfectly competitive' with respect to innovation and technological change seems very improbable.

The resources for innovation – including knowledge – may be highly specialised and hence not easily transferable across sectors. Pavitt's typology highlighted that the science-based sector (4) based its R&D on 'basic science', perhaps generated by universities. This might suggest that firms in this sector can (relatively) easily access the basic knowledge required and hence compete intensively, which in turn reduces the relative return to R&D. In a similar way developments in the software sector may be difficult to protect and may spread rapidly to other firms. Higher rates of return to R&D, however, may be possible in sectors in which knowledge flows are more limited. An equivalent way of viewing this issue is to consider knowledge or R&D spillovers: the science- and software-based sectors may have higher spillovers, which tend to reduce returns. In our view, competitive conditions, which are closely related to the extent of spillovers, are a key factor that need to be considered in exploring the issue of varying returns and it is to this that we now turn.

4 Competitive conditions and the return to innovation

Schumpeter is credited with initiating the idea that large firms, with substantial monopoly power, have both the financial resources and the incentives to undertake investment in innovation. The corollary is that society must accept static monopoly welfare losses in order to gain increased investment in innovation and, ultimately, dynamic welfare gains. In contrast, Arrow (1962) put forward a model where, under certain assumptions, there is a higher incentive to innovate for a perfectly competitive market than a monopoly. A key assumption for Arrow's result is that there are 'perfect' intellectual property rights, in the sense that the innovator can license the innovation at full market value. A raft of subsequent theoretical work has augmented these ideas, much of it theoretical or focusing on the incidence of innovation rather than on the returns (i.e. the incentives).[19]

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[19] Kamien and Schwartz (1976) find that as rivalry increases, R&D per firm may initially rise but will, ultimately, fall as rivalry becomes intense. Loury (1979) considers the firm's decision to invest in R&D when a patent race is underway, finding that in these conditions more competitors reduce R&D per firm. More recently, Boone (2001) models firms as bidding for process innovations and finds that changing the level of competition has ambiguous effects on technical progress. Scherer and Ross (1990) are associated with the idea that the relationship between competition and innovation may be non-monotonic (specifically, 'hill shaped'), something which has received recent empirical interest (Aghion et al, 2002).

In this section we want to link this debate to the value of innovation. The null hypothesis tested here is the Schumpeterian premise, that the stock market's valuation of innovative activities is inversely related to competitive conditions. The alternative hypothesis is the Arrow view that, as firms are able to use IP as effective protection, then the link between competitive conditions and the value of innovation will be broken. To test our null hypothesis requires a method of measuring the degree of competition faced by industries. The existing literature contains a range of potential methods, including measures of concentration, market share, barriers to entry and profitability. All of these have various drawbacks, although all can contribute something to the difficult process of measuring competitive conditions.

In this paper we explore both sector- and firm-level proxies for competitive pressure. The initial proxy considered is a measure of rents at the sector-level (Section 4.1). This type of measure has been used historically but is also common in recent analyses (e.g. Aghion et al, 2002). A potential drawback of this method is that sector-level rents reflect risk and accounting conventions as well as competitive conditions. Given this, we introduce a new methodology into market value studies by using an analysis of the persistence of profit shocks as an indicator of the intensity of competition. Although this method has a well-established literature in its own right, there are no previous studies that attempt to integrate it into an analysis of the market value of innovative activities. The strength of the approach is that it permits a dynamic assessment of the actual competitive process in the spirit of the contestable markets theory, which has argued that actual market share is a poor guide to competitive conditions, as what matters is whether there are potential market entrants able to enter and exit easily (Baumol et al, 1982). Lastly, in Section 4.2, we use market share as a firm-level proxy for competitive conditions. This is an established approach in the literature and allows us to investigate intra-sector differences in competitive conditions.

4.1. Sector-based measures of competition

Within the empirical innovation literature the standard proxy for competition is profitability (rents). We use two different measures of profitability, the first is the ratio of net profit before tax to total sales and the second is the ratio of economic rents to value added.[20] The penultimate row in Table 7

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[20] The first measure follows Aghion et al (2002), who use operating profit to sales. The second method is based on Nickell (1996). Economic rent is defined as profit before tax, plus (imputed) interest payments, less *r* x fixed assets

shows the average profitability by sector and reveals that the least competitive sector – according to this measure – is sector (5) (information-intensive), with a profitability ratio of 13.7%. The results for the economic rent ratio are similar (see last row of Table 7). Although the economic rent ratio is always larger, reflecting the different numerator and denominator, the sectors still have the same rank order. Interestingly, both profitability measures show sector 5 as the most profitable and this is also the sector with the highest estimated value of R&D. Equally, the least profitable sector is software-related (6) and this is has the lowest estimated value of R&D. However, sector 4 – the science-based sector – has a relatively high profitability but a low estimated return to R&D.

There is a strand within the industrial organisation literature that argues that profit persistence studies are a better method of assessing competitive conditions. The profit persistence literature is based on the assumption that all firms will experience profit shocks and that the degree of competition from other firms determines how long this shock will persist (e.g. Mueller and Cubbin, 1990; Waring, 1996; Glen et al, 2001). For example, a positive profit shock due to the launch of a successful new product may be short lived if other firms compete effectively. The average degree of profit persistence for a group of firms can be estimated using

$$\pi_{it} = \phi_i + \beta \pi_{it-1} + \varepsilon_{it} \qquad [4]$$

where π_{it} is firm i's profit margin in year t, ϕ_i is a firm fixed effect, β-represents the persistence to a profit shock and ε_{it} is the standard error term. In these studies a β-coefficient close to zero implies little persistence and, therefore, suggests a competitive environment (i.e. any positive profit shock due, say, to an innovation, is rapidly competed away by rivals). In contrast, when $\beta>0$, profit shocks persist and the implication is that the competitive process is less strong. The advantage of profit persistence studies is that the β-coefficient should encapsulate all aspects of competition, whether from rivals within the same domestic industry, overseas firms, or from the threat of new firm entry.

Equation [4] can be used to analyse profit persistence at the industry, sector or economy level. Using the ratio of net profit before tax to total sales as the measure for π, we estimate the value of β

(where r is the real rate of interest, averaged over 1989-2002). Value added is defined as total staff costs, plus profit before tax, plus depreciation, plus (imputed) interest payments.

for each Pavitt sector (over the period 1989-02).[21] The top row in Table 7 shows the estimated β-coefficients, with the sectors arranged from high to low β-coefficients, which means from low to high competitive conditions.[22] The remainder of the rows in Table 7 show the estimates for the return to R&D (i.e. the value of $n\gamma$ based on the R&D coefficients from the previous section). The two sectors with the lowest intensity of competition – as assessed by the higher β-coefficient – have the highest estimated returns to R&D. There are three sectors with intermediate levels of competition – with β-coefficients of 0.42 or 0.43 – and the returns to R&D for these sectors are lower, although they do vary across the sectors. Finally, the most competitive sector, as adjudged by the lowest β-coefficient, is Pavitt sector 4. The estimated returns for this sector are above Pavitt 6 when using OLS-based estimators, but slightly lower that sector 6 when using the FE estimator. Overall, there is some evidence of an association between competitive conditions and returns to R&D but, as with the profitability based measures, the association is not perfect.

[21] The regressions were conducted on a panel of firms present in the full Company Analysis/FAME data over the period 1989-2002. To avoid problems of influential observations firms with profitability margins below -0.2 and above 0.5 were excluded (a similar condition is imposed by Waring, 1996).

[22] Previous UK studies on profit persistence are limited. Geroski and Jacquemin (1988) find a β of 0.49 for a sample of 51 UK firms (1949-77), while Benito (2001) finds β's of between 0.45 and 0.54 for the period 1975-98. Benito does look at differences across sectors, although these are based on industrial classifications not Pavitt sectors as here. Econometrically, there is a difficulty in estimating dynamic panel models (i.e. [4]) in that there is an asymptotic (downwards) bias in β. Nickell (1981) provides a formula to correct this bias (see his equation 18). However, if we use this formula all the coefficients rise in a similar proportion and the rank order is unaffected. Since our interest is in the rank order across Pavitt sectors, we do not focus on these econometric issues in the main text.

Table 7 Competitive conditions and the return to R&D, by Pavitt sector

	Information-intensive (Pavitt 5)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Software firms (Pavitt 6)	Supplier dominated (Pavitt 1	Science based (Pavitt 4)
Profit persistence (β-coefficient)	0.52	0.49	0.43	0.42	0.42	0.27
Implied γ_N						
OLS	5.73***	7.93***	4.48***	2.25***	3.45**	3.41***
Robust estimator	5.01***	7.94***	4.82***	2.11***	0.06	3.37***
FE	3.00	5.92***	2.30***	1.72***	1.01	1.62***
OLS (with IP variables)	7.00***	7.18***	4.92***	1.94***	1.77	3.00***
Profit measures						
Profit before tax / turnover (%)	13.7	7.9	4.5	2.7	6.6	9.4
Economic rent / value added (%)	45.4	30.3	16.5	10.8	21.9	34.2

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%.

4.2. Market share and the value of innovative activities

While the associations between sector-level competitive conditions and returns to R&D are of interest, it is unrealistic to assume that firm-level differences in market power do not exist. In fact, the existing literature on the valuation of innovation focuses on whether a firm's market share is important. The standard assumption is that a larger market share implies less competitive pressure. Blundell et al (1999), using a sub-set of the SPRU dataset of major innovations (innovations matched to 340 listed manufacturing firms 1972-82), found that higher market share raises the market valuation of an innovation.[23] In contrast, Toivanen et al (2002) find that there is no significant interaction between market share and R&D activity (they use a previous version of the data used here that ended in 1995).[24] In this section we provide additional insight into this debate in three ways. First, the data used here runs to 1999, making it much more up-to-date than Blundell et al (1999) and adding four years to Toivanen et al (2002). Second, the analysis uses the Pavitt sectors, which have been shown above to be important. Third, unlike Toivanen et al (2002) we also test for any interaction effects between market share and IP activity in addition to R&D activity (i.e

[23] They also note that the impact of market share does appear to vary across industries; however they generally do not allow all coefficients to vary across industries, except for looking solely at the pharmaceuticals industry.

[24] To be more accurate, Toivanen et al (2002) state "The market share variable (MS) and the interaction [with R&D/assets] variable (MSRD) are insignificant throughout [the panel data estimates], confirming the results of the cross-sectional estimates" (p.57). However, in their Table 3, one panel regression is presented which shows MSRD with a negative and significant coefficient (at 1% level).

we do not solely focus on the interaction between R&D and market share). This issue is central to the question of whether firms with low market shares can use the IP system to appropriate the benefits of innovation. Theoretically, it represents a direct link to the Arrow (1962) model. In that model the implicit assumption is that any firm can innovate and (perfectly) license its innovation to all other firms, hence firm size is not an issue. From a more applied perspective, the issue of whether market share is important is also related to the debate over whether small firms can benefit from the IP system.

Table 8 shows that market share itself has a negative association with market valuation for the whole sample.[25] However, the sectoral differences are substantial, ranging from negative in sector (5) and (4), to a positive effect for the sector (1). At the same time, the *interaction* between market share and R&D expenditure shows a significant *positive* coefficient in the full sample of firms, but here too there are very diverse experiences within sectors. Market share and R&D intensity are significant strong complements in the 'science based' (4) and 'information intensive' (5) sectors. In contrast, sector (2) shows a negative interaction between market share and R&D. Checking the results in Table 8 using the robust estimator to control for any influential observations indicates that the results for sectors (4) and (5) are similar, although the interaction term in sector (2) loses its significance. In contrast, using the FE estimator produces insignificant coefficients on virtually all market shares.

To interpret the economic significance of the results in Table 8, consider a firm with average market share in sectors 4 and 5 (0.37 and 0.36 respectively). For such a firm in the science based sector, the implied coefficient on R&D is now 4.6, while for the information-intensive sector the implied coefficient is now 13.9; these are considerably larger than those estimated in Tables 4 and 6 above in which market share was not included, when the coefficients were 3.5, 3.1 (sector 4) and 6.1,7.5 (sector 5).

[25] Market share is defined as firm sales / industry sales (4 digit level) in a given year, where 'industry sales' are based on all firms in the OIPRC database. The mean market share for the full sample is 0.39, the median 0.23 and the s.d. 0.39. Using a 3-digit level market share variable, rather than a 4-digit based variable, the estimations find a positive R&D-market share interaction effect in the full sample, and in sectors 4, 5 and 6, although the coefficient is not significant at the 10% level in sector 4.

Table 8 Market share and R&D

	Full sample	Supplier dominated (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Information-intensive (Pavitt 5)	Software firms (Pavitt 6)
Ln of total assets	1.027	0.964	1.019	1.045	1.029	1.077	1.008
	(110.99)***	(32.33)***	(56.46)***	(48.16)***	(57.30)***	(41.11)***	(22.94)***
R&D expend / total assets	3.337	3.425	8.808	4.852	3.165	5.154	2.214
	(13.55)***	(2.17)**	(7.30)***	(4.89)***	(7.02)***	(7.32)***	(6.18)***
Market share (4-digit) (ratio)	-0.106	0.278	-0.019	-0.068	-0.189	-0.374	0.067
	(2.29)**	(2.65)***	(0.21)	(0.53)	(2.01)**	(2.68)***	(0.23)
(R&D/Assets) * Market share	2.650	2.988	-7.686	-1.184	3.715	24.396	5.330
	(2.82)***	(0.43)	(2.13)**	(0.63)	(2.37)**	(7.20)***	(1.20)
Growth in sales (t, t-1)	0.308	0.434	0.522	0.457	0.237	0.331	0.202
	(6.60)***	(3.62)***	(3.54)***	(4.26)***	(2.95)***	(2.40)**	(2.19)**
Debt / shareholders' equity	-0.001	0.009	0.002	-0.010	0.003	-0.003	-0.003
	(1.48)	(0.47)	(1.52)	(1.22)	(1.68)*	(3.92)***	(1.27)
Intangible assets / total Assets	0.675	1.993	1.623	1.139	0.976	0.030	-0.509
	(4.90)***	(3.44)***	(5.48)***	(3.52)***	(3.28)***	(0.09)	(1.74)*
Constant	-1.153	-1.159	-1.539	-0.990	-0.762	-0.779	-0.412
	(13.60)***	(2.97)***	(4.30)***	(3.78)***	(3.52)***	(1.51)	(0.81)
Observations	4367	481	886	969	984	538	509
Number of firms	619	75	123	146	160	111	100
R-squared	0.85	0.87	0.9	0.81	0.86	0.88	0.71
Industry dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.00	na
Year dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test of H_o: $\sigma = 1$	0.00	0.23	0.30	0.04	0.10	0.00	0.86

Notes: The dependent variable is ln of market value Robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. Additional notes as per Table 4.

Table 9 documents the coefficients from *three* sets of market value regressions that explore the interaction between market value and intellectual property for each IP asset in turn. The table only shows the coefficients on market share, the interaction term and the relevant IP variable from the robust estimator (full results available from authors). The interaction term between UK patent activity and market share is positive and significantly different from zero in the full sample and sectors 2, 3 and 4. A positive coefficient indicates that higher market share tends to increase the association between UK patent activity and market value. Consider, for example, the results for Pavitt sector 2, these show a *negative* coefficient on patent activity but a positive coefficient on the interaction term. For a firm in this sector with average market share (0.53), these coefficients imply a net coefficient on ‘UK patent/total assets’ of 3.33. Another way of viewing the result is to consider the threshold level of market share where UK patenting just starts to have a positive effect. For sector 2 (production intensive - scale) the threshold level of market share is 0.17 (around 32% of firms in this sector have market shares less than 0.17).

In contrast to the UK patent results, the interaction effects for EPO patenting and market share have no significant effect. Given that our measure of market share relates only to the UK, this is not surprising: those patenting in Europe are competing in a wider geographical market, for which their domestic market share is not necessarily the relevant indicator of market strength.

For the interaction of UK trade mark intensity and market share there are a mixed set of results. The full sample results indicates that higher market share boosts the stock market’s valuation of trade marking, but within the Pavitt sectors there are some that follow this result (sectors 2 and 5), whereas others have the converse relationship (sectors 1 and 4). These conflicting results across sectors indicate that the market’s valuation of trade mark activity in its interaction with market power is complex; even so, for most sectors the inclusion of the market share variable in level and interaction does not disturb the positive effect of trade marks already observed in Table 6. In addition, we see the same rank order emerging as in Table 7, with the two least competitive sectors as measured by profit persistence (2 and 5) showing a positive interaction between market share and trade marks, and two of the most ‘contestable market’ sectors (1 and 4) showing the perverse correlation.

Table 9 Market share and IP activity

	Full sample	Supplier dominated (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Information -intensive (Pavitt 5)	Software firms (Pavitt 6)
UK Patent / total assets (mill)	-0.058 (0.20)	1.436 (0.68)	-1.054 (2.77)***	0.740 (1.11)	-3.459 (5.53)***	0.801 (0.62)	5.219 (1.76)*
Market share (4-digit) (ratio)	-0.121 (2.67)***	0.081 (0.94)	-0.250 (3.37)***	-0.194 (1.86)*	-0.116 (1.28)	-0.361 (2.15)**	0.411 (0.68)
(UK Patents/Assets) * Market Share	3.902 (3.28)***	-5.666 (1.19)	6.292 (3.42)***	3.471 (1.84)*	7.193 (1.95)*	-3.945 (0.45)	-51.270 (1.30)
EPO patent / total assets (mill)	1.870 (5.33)***	3.131 (1.63)	0.199 (0.15)	1.067 (1.42)	2.499 (4.34)***	-0.337 (0.33)	-5.508 (0.34)
Market share (4-digit) (ratio)	-0.070 (1.55)	-0.021 (0.25)	-0.207 (2.72)***	-0.137 (1.31)	-0.040 (0.44)	-0.329 (1.93)*	0.042 (0.07)
(EPO Patents/Assets) * Market share	-1.049 (1.19)	6.560 (1.14)	6.651 (1.52)	1.375 (0.55)	-1.071 (0.82)	0.954 (0.51)	-51.064 (0.35)
Trade mark / total assets (mill)	0.072 (2.35)**	0.871 (1.84)*	-0.058 (0.19)	0.394 (1.83)*	0.570 (3.07)***	-0.110 (1.13)	0.107 (2.13)**
Market share (4-digit) (ratio)	-0.086 (1.94)*	0.115 (1.38)	-0.220 (2.93)***	-0.186 (1.72)*	0.080 (0.86)	-0.390 (2.29)**	-0.037 (0.07)
(Trade Marks/Assets) * Market share	0.587 (3.00)***	-2.873 (1.93)*	0.695 (1.96)*	1.084 (1.35)	-2.212 (1.99)**	2.717 (1.83)*	0.709 (0.50)

Notes: The dependent variable is ln of market value. The results shown are from the robust estimator that controls for influential observations as discussed above. Each regression contains only one IP variable and its interaction with market share (to prevent multicollinearity). Other explanatory variables included in each regression are ln(assets), R&D/assets, growth in sales, debt/equity, intangible assets/assets, year and industry dummies (coefficients on these not shown). * significant at 10%; ** significant at 5%; *** significant at 1%.

5 Conclusions

This paper has investigated the stock market valuation of the R&D and IP activities of quoted UK companies using a new data set for the 1989-2002 period. A major theme of the paper is that existing market value studies incorrectly assume that the returns to innovative activities are similar across diverse firms and industries. This paper follows Pavitt (1984) in arguing that the nature of technological change and innovative activity varies substantially across firms. If this is the case then one might expect that the market valuation of innovative activity would also vary.

The analysis shows that differentiating our sample firms using Pavitt's technology typology is extremely worthwhile. Using Pavitt's sectoral typology, which is based on differences in the process of technological change, we find large differences in the market valuation of R&D and IP activity across these sectors. Overall, we find that the lowest market valuation of R&D to tangible assets is in the Pavitt 4 'science based' sector, which is also a sector where R&D activity is common and R&D intensity relatively high (around 62% of firms report R&D expenditures). This sector also has the highest proportion of firms applying for UK patents, trademarks and EPO patents.

The paper also finds an important result with respect to UK patenting. The analysis shows that while, on average, higher R&D, EPO patenting and UK trade marking (relative to firm size) all tend to increase market value, UK patenting does not have a straightforward impact. These findings are consistent with the observed behaviour of these firms; analysis of trends in IP per firm show a significant fall in patenting via the UK Patent Office, a small increase in EPO patenting, and a rapid increase in trade marks, particularly since the early 1990s (Greenhalgh et al, 2003). For firms wishing to enhance their stock market value, patenting via the UK Patent Office appears to have no impact, but UK financial markets do recognise applications via the European Patent Office and also UK trade marks.

To attempt to explain variations across sectors in market valuations, the main contribution of this paper is to investigate the effects of product market competition on both stock market value and the returns to innovative activity under varying market structure. Following Schumpeter, we might expect higher levels of competition within a sector to lower the stock market's valuation of innovation, ceteris paribus. To investigate this issue we utilise two simple industry profitability measures, and a more sophisticated profit persistence approach, as industry-based proxies for competitive conditions. The latter measure uses time series analysis of the response to profitability shocks to assess the competitive conditions within an industry or sector. To our knowledge this is the first paper to integrate the profit persistence approach with market value analysis. The correlation between average sector profitability and profit persistence is low; hence there is value in comparing the two approaches to measuring competitive conditions.

While simple profitability ratios yield no consistent explanation of the sector differences in coefficients on R&D, the profit persistence measure is highly (rank order) correlated with the coefficients. For example, our results show that the ‘science based’ sector has the most competitive structure according to the profit persistence proxy, something that is consistent with finding one of the lowest market valuations on R&D in that sector. However, this is not the sector with the lowest average industry profitability suggesting the need for compensating returns in a high risk sector. At the other extreme, the ‘production intensive’ (large scale manufacturing) and ‘information intensive’ (services) sectors reaped the highest market valuations of R&D within market structures exhibiting high profit persistence (i.e. low competitive pressure).

We also examine the role of firm-level factors in explaining sectoral differences in market valuations to R&D and IP assets by using market share as a third (inverse) proxy for competitive pressure. The analysis investigates the interaction of market share with R&D and IP. For the full sample of firms, the results suggest a negative role for market share alone, but a positive interaction with R&D assets. When we analyse by Pavitt sectors we again find a diverse pattern of results: These range from a positive benefit of greater market share in ‘supplier dominated’ (manufacturing) with no interaction effect, to negative effects of market share in ‘information-intensive’ services and the ‘science-based’ sectors, but with positive interaction effects for R&D in both sectors. This analysis suggests that in the two sectors with low initial returns due to competitive market structure, higher market share raises the valuation of R&D.

This paper also conducts analysis on the link between market share and IP activity. If the IP system were working effectively for all firms – regardless of market power – we would expect to find no evidence of any link. For UK patent activity we find a positive effect of market share: higher market share appears to raise the valuation of UK patent activity (although the strength and significance of such an effect varies across Pavitt sectors). Since the direct effect of UK patenting is often negative, this suggests the presence of a threshold market share.

Broadly interpreted, our results give much more support for Schumpeter than for Arrow on the relationship between market structure and the incentives to innovate, as the stock market valuation of R&D (the expected value of future profitability) is higher in sectors with relatively low competitive pressure. Clearly, the results do not imply that lowering competitive pressure would always raise the valuation of R&D; only that this occurs within the range of competition observed in the data.[26] The valuation of IP also varies across sectors and, in the case of UK patents and trade marks, valuations are enhanced by higher market share. Our findings suggest that a possible reason for the slow rate of exploitation of scientific discovery in the UK may be an overly competitive science-based sector. A caveat on this concerns the underlying rate of innovation and productivity achieved by the science-based sector: it is possible that high competition and low private valuation of R&D still generate high rates of productivity growth due to spillovers. While there is an on-going concern about the poor productivity and innovation performance in the UK, this question can only be directly addressed by further microeconomic analysis of firm-level data, something we intend to pursue in future research.

[26] In contrast, current UK government policy appears to assume that the link between competition and performance is straightforward and monotonic in the reverse direction. For example, HM Treasury (2001, p.19) states "Competition is at the heart of the Government's strategy to close the productivity gap. Vigorous competition between firms leads to increased innovation and greater efficiency - and in turn to increased productivity growth." The evidence presented here suggests that the competition and performance relationship is much more complex than this.

Bibliography

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P. (2002), 'Competition and Innovation', IFS Working Paper 02/04.

Arrow, K. (1962), 'Economic Welfare and the Allocation of Resources for Invention', in R. Nelson (ed.), *The Rate and Direction of Inventive Activity*, Princeton: Princeton University Press.

Baumol, W., J. Panzar and R Willig (1982) *Contestable Markets and the Theory of Industry Structure*, New York: Harcourt, Brace, Jovanovich.

Benito, A. (2001). "Oscillate Wildly: Asymmetries and Persistence in Company-level Profitability", Bank of England Working Paper 132.

Blundell, R., Griffith, R. and van-Reenen, J. (1999), 'Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms', *Review of Economic Studies,* **66** (3), 529-54.

Boone, J. (2001), 'Intensity of Competition and the Incentive to Innovate', *International Journal of Industrial Organization,* **19** (5), 705-26.

Bosworth, D. and Rogers, M. (2001), 'Market value, R&D and intellectual property: an empirical analysis of large Australian firms', *Economic Record,* **77** (239), 323-37.

Bureau van Dijk (2004). "Fame: UK and Irish Company Information". DVD ROM Update 182 August.

Chung, K. and S. Pruitt (1994). "A Simple Approximation of Tobin's q." *Financial Management* **23** (3): 70-74.

Dewick, P., Green, K. and Miozzo, M. (2002), 'Technological Change, Industry Structure and the Environment', mimeo, Manchester School of Management, UMIST.

Dun and Bradstreet International (1994) *Who Owns Whom - Worldwide Corporate Structures*, 4th quarter 1994 CD-ROM.

Dun and Bradstreet International (2001) *Who Owns Whom D&B Linkages*, 2001/4 CD-ROM.

European Patent Office (1996) *ESPACE Bulletin*, Vol. 1996/005, Dec. 1978 - Aug. 1996 CD-ROM.

European Patent Office (2001) *ESPACE Bulletin*, Vol. 2001/001, (August) Dec. 1978 - Feb. 1996 CD-ROM.

European Patent Office (2002) *ESPACE Bulletin*, Vol. 2002/002, (July) Feb. 1978 - July 2002 CD-ROM.

Extel Financial (1996) *Company Analysis*, on-line data.

Geroski, P.-A. and A. Jacquemin (1988). "The Persistence of Profits: A European Comparison." *Economic Journal* **98** (391), 375-89.

Glen, J., Lee, K. and Singh, A. (2001), 'Persistence of Profitability and Competition in Emerging Markets', *Economic Letters,* **72** , 247-53.

Greenhalgh, C. and Longland, M. (2001), 'Intellectual property in UK firms: creating intangible assets and distributing the benefits via wages and jobs', *Oxford Bulletin of Economics and Statistics,* **63,** 671-96.

Greenhalgh, C. and Longland, M. (2002), 'Running to Stand Still? - Intellectual Property and Value Added in Innovating Firms', mimeo Oxford Intellectual Property Research Centre: www.oiprc.ox.ac.uk/EJINDEX.html.

Greenhalgh, C., Longland, M. and Bosworth, D. (2003), 'Trends and distribution of intellectual property: UK and European patents and UK trade and service marks 1986-2000', Report to the UK Patent Office on a Research Project into *The Extent and Value of Intellectual Property in United Kingdom Firms*.

Griliches, Z. (1981), 'Market Value, R&D, and Patents', *Economic Letters,* **7** , 183-87.

Griliches, Z. and J. Hausman (1986). "Errors in Variables in Panel Data." *Journal of Econometrics* 31: 93-118.

Hall, B. (2000). 'Innovation and Market Value', in R. Barrell, G. Mason and M. O'Mahoney (ed). *Productivity, Innovation and Economic Performance*. Cambridge UK, Cambridge University Press: 177-98.

Heckman, J. (1979). 'Sample Selection Bias as a Specification Error.' *Econometrica,* **47**, 153-61.

HM Treasury (2001). *Productivity in the UK: Enterprise and the Productivity Challenge*.

Kamien, M.I. and Schwartz, N.L. (1976), 'On the Degree of Rivalry for Maximum Innovative Activity', *Quarterly Journal of Economics,* **90** (2), 245-60.

Loury, G. (1979), 'Market Structure and Innovation', *Quarterly Journal of Economics,* **August**, 396-410.

Marquesa Search Systems Ltd. (2002) *Marquesa - UK Trade Marks (A)*, CD-ROM March.

Mendonca, S., T. Pereira, and M. Godinho (2004). "Trademarks as an Indicator of Innovation and Industrial Change." *Research Policy* 33: 1385-1404.

Mueller, D. C. and Cubbin, J. (1990), *The Dynamics of company profits : an international comparison*, Cambridge: Cambridge University Press.

Nickell, S.J. (1981). "Biases in Dynamic Models with Fixed Effects." *Econometrica,* **49** (6), 1417-26.

Nickell, S.-J. (1996). 'Competition and Corporate Performance.' *Journal of Political Economy* 104(4): 724-46.

Patent Office (1986-95) *ESPACE UK: United Kingdom Patent Applications on CD-ROM*, CD-ROMs.

Patent Office (1997) *ESPACE ACCESS-EUROPE.* Vol.1997/001 (December).

Patent Office (2002) *ESPACE ACCESS-EUROPE.* Vol.2002 (September).

Pavitt, K. (1984), 'Sectoral Patterns of Technical Change', *Research Policy,* **13**, 343-373.

Search Systems Ltd (1996) *Marquesa UK Trade Marks (A) Applications CD-ROM* October.

Scherer, F. and Ross, D. (1990), *Industrial Market Structure and Economic Performance*, Boston: Houghton Mifflin.

Seethamraju, C. (2003). "The Value Relevance of Trademarks" in J. Hand and B. Lev (ed). *Intangible Assets: Values, Measures, and Risks*. Oxford, Oxford University Press.

Tidd, (2001) *Managing Innovation: Integrating Technological, Market and Organisational Change*

Thomson (2001) *Company Analysis*, on-line data.

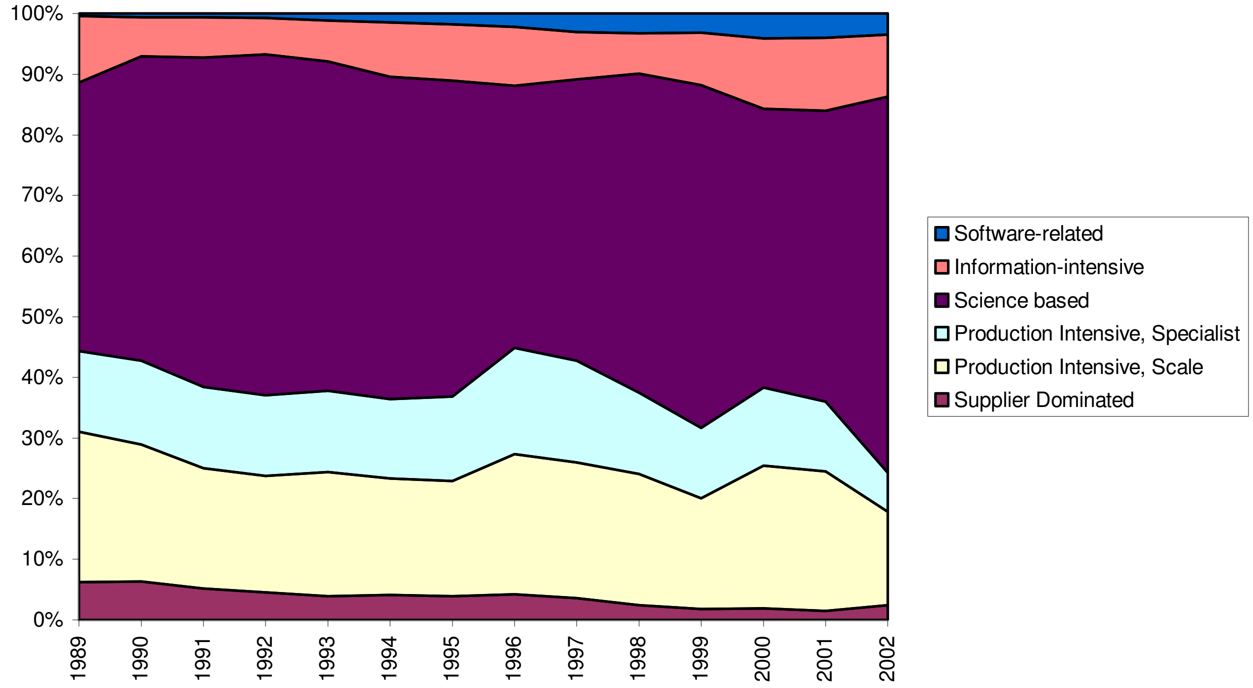
Toivanen, O., Stoneman, P. and Bosworth, D. (2002), 'Innovation and the Market Value of UK Firms', *Oxford Bulletin of Economics and Statistics,* **64** (1), 39-60.

Vossen, R. (1998), 'R&D, Firm Size and Branch of Industry: Policy Implications', Report 98B43, SOM Research Institute, University of Gronningen.

Waring, G.F. (1996), 'Industry Differences in the Persistence of Firm-Specific Returns', *American Economic Review,* **86** (5), 1253-65.

Appendix 1 Time trends in innovative activity

Figure 1 Shares of R&D expenditure, by Pavitt sector



Appendix 2 R&D variable leverage plots for Pavitt sector sub-samples (note: rda = R&D/total assets)