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 (1989-1999). In contrast to previous studies, the analysis is conducted at the sectoral level, where the sectors are based on the technological classification in Pavitt (1984). The first main result is that the valuation of R&D and IP varies substantially across these sectors. To explore these variations the paper links competitive conditions with the returns to 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'), firms with larger market shares (an inverse indicator of competitive pressure) also have higher R&D valuations. Another important result is that, on average, firms that receive only UK patents tend to have no 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.

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1 Introduction

This paper contains an empirical analysis of the market valuation of innovative activities by UK production firms. Investment in innovation is proxied by R&D expenditures, patent publications and trade mark applications. The main issue investigated is whether the market valuation of innovative activities varies across firms and industries and, if so, why this occurs. To motivate what follows consider a perfectly competitive economy where firms and financial markets have perfect information. In such an economy the valuation of innovative activities should be equalised at the margin across firms and industries, otherwise it would be profitable to reallocate investment. In reality we might expect to find differences in valuations for two basic reasons.

The first reason concerns 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 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.

Any assessment of competitive conditions must include many different aspects. One is whether firms can use intellectual property rights to increase appropriability and lessen competition. More generally, however, competitive pressure will also 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 may be 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 a static economy, economists might expect to approach equilibrium where these supernormal profits are removed; however, in a dynamic economy there may be permanent disequilibrium profitability differences. Given these issues, the likelihood of an economy being ‘perfectly competitive’ with respect to innovation and technological change seems very improbable. Despite this, the existing market value literature tends to assume the returns to innovative activities, and associated valuations, are equalised across firms. Clearly the policy interest in such issues is in a better understanding of the resource constraints involved, the effect of the intellectual property system and appropriability issues in general.

The second reason for variations in valuation to occur 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.

The analysis in this paper uses a new panel data set (1989-1999) on the R&D and intellectual property (IP) activity of UK production firms. An important contribution of this paper is to extend the standard approaches to analysing the market value of innovative firms in a number of ways. Most importantly, as discussed above, we analyse whether the market's valuation of firm-level innovation varies across firms and industries. In order to do this we use the classification system in Pavitt (1984), which analyses patterns of technical change. Pavitt put forward a taxonomy based on differences in the process of innovation, rather than a product-based industrial classification, and it seems entirely appropriate to analyse the market value of innovation using this taxonomy. A second distinction with many previous studies is breadth of IP data available, which allows an investigation of the role of trade mark activity and UK and European Patent Office patent activity.[1] A third difference is to incorporate an analysis of the competitive conditions that firms face and, specifically, introducing profit persistence analysis 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 find 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 further finding is that the stock market appears to place no significant

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

valuation on firms obtaining UK patents, although there is a positive premium for patents from the European Patent Office. This section also considers whether lags in stock market valuation can explain these results, finding little evidence for such a view. The fourth section deals with the role of competition 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. Thirdly, 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 final section concludes.

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). We extracted firms deemed to be in the production, construction, utilities and commerce sectors, and which had reported their financial accounts in the UK. The financial data included the usual items, such as sales, profits and also R&D expenditure, where separately reported, and the end of year share price if the company was publicly quoted, together with information on the industrial classification (SIC) for the principal product. We then constructed and matched to these data the counts of three forms of IP: patents published via the UK, patents published via the European Patent Offices, and trade mark applications via the UK office.

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 (consolidated) accounts, in order to include all the IP that might have contributed to the overall performance of the financial group. We obtained "Who Owns Whom" information at two points in time (Dun and Bradstreet International, 1994, 2001) to determine the family trees of the (mainly UK based) parent firms. (Difficult cases were resolved with the help of the Fame database, Bureau van Dyk, 2003.) Searches for patent and trade mark records were then conducted for the names of each parent and all of its subsidiary companies using these two snapshots of changing ownership, with the 1994 family tree being used for counts in the period to 1995 and the 2001 family tree used for later years.[2]

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. In Pavitt's original typology the first category included several types of manufacturing together with non-manufacturing firms, whose technological trajectories were supplier-dominated. Given their rather different natures in respect of R&D and patenting, in what follows we have distinguished between manufacturing and other supplier-dominated firms to create five sectors. Table 1 provides some more explanation of these five technological sectors and shows some simple summary statistics for our database on firm size, product diversification 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.

Before discussing the evidence from Table 1, it is important to discuss the nature of the measures of R&D and IP. During the period of study there was no legal requirement, and no strong financial incentive arising from UK company tax rules, for firms to report R&D separately in company accounts. Thus our measure of R&D activity is subject to an unknown degree of non-reporting of R&D activities. Nevertheless publicly quoted firms would have had an incentive to inform investors of their activity to register the extent of their investment in intangible assets and this will minimise under-reporting for this sample. The use of two

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[2] 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.

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.

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 (5) and more than three times the level of sector (1). The difference between manufacturing sectors (1) to (4) is less marked in terms of IP activity, reflecting the presence of trade marks in this overall IP incidence indicator, but the non-manufacturing sector (5) stands out as being less IP active although more R&D active than (1), thus justifying their separation. Table 2 and Table 3 show some additional summary statistics for the data. Table 2 separates out the IP activity into UK patents, EPO patents and trade marks. Trade mark activity is more common than patenting; it is present in one third to one half of firms in every sector and shows less variation across sectors than patenting. Note also that UK patenting is more prevalent than EPO patents, by a factor of around two in sectors (1) and (5), but by a smaller factor between 1.5 and 1.3 for the production intensive and science based sectors.

Table 1 Pavitt technological sectors

Pavitt category	Description	SIC (US)	Relative balance between product & process innov	Median firm sales (million £)	Net profit before tax / sales (for sector as %)	Diversification Index*	Proportion R&D active	Proportion IP 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, 27, 30, 31	Process	80	6.5	0.134	0.181	0.318
(2) Production Intensive, Scale Intensive	Large firms producing standard materials or durable goods, inc. cars.	20, 21, 32, 33, 34, 37	Process	109	8.4	0.090	0.365	0.465
(3) Production Intensive, Specialised Suppliers	Machinery and instruments. Tend to be smaller firms which are technologically specialised.	35, 38, 39	Product	70	6.6	0.095	0.630	0.489
(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	116	9.7	0.125	0.621	0.529
(5) Supplier Dominated, Non-manufacturing***	Users of technology, whose innovations mainly come from suppliers of equipment or materials.	SIC > 39		66	14.8	0.222	0.327	0.192

Notes: The table is based on 16,846 observations over the period 1989-1999. The concordance between the two-digit SIC (US) available in the data and Pavitt's categories is based on Vossen (1998) and Dewick et al (2002). * the diversification index represents the proportion of firms active in only one 4-digit SIC code. ** IP active means the firm has at least one trade mark application or UK patent publication or EPO publication. *** This includes some firms in distribution, utilities, business services, etc which are in OIPRC database; in Pavitt's original 1984 taxonomy these were included with manufacturing firms in category (1).

Table 2 Proportion of firms undertaking innovative activity (average 1989-1999)

Pavitt Industrial Categories	Observations	R&D active	UK patent active	EPO active	Trade mark active
(1) Supplier Dominated, Manufacturing	4,209	0.181	0.217	0.120	0.335
(2) Production Intensive, Scale	3,218	0.365	0.329	0.213	0.501
(3) Production Intensive, Specialist	1,741	0.630	0.413	0.301	0.428
(4) Science based	2,124	0.621	0.442	0.341	0.516
(5) Supplier Dominated, Non-manufacturing	4,965	0.327	0.161	0.086	0.443
Total	16,257	0.368	0.293	0.193	0.434

Note: 'Active' refers to a firm having some R&D expenditure or at least one patent or trade mark in a given year.

Table 3 Median intensity for firms undertaking innovative activity (average 1989-1999)

Pavitt Industrial Categories	R&D/sales	UK Patent/Sales	EPO patent/Sales	Trade Mark/Sales
(1) Supplier Dominated, Manufacturing	0.006	0.009	0.006	0.022
(2) Production Intensive, Scale	0.006	0.008	0.005	0.017
(3) Production Intensive, Specialist	0.025	0.016	0.011	0.022
(4) Science Based	0.020	0.011	0.010	0.019
(5) Supplier Dominated, Non-manufacturing	0.018	0.003	0.003	0.015
Total	0.013	0.010	0.007	0.019

Note: The median is for the distribution of 'Active' firms only.

Table 3 shows the median intensity for the active firms only. Median R&D intensity and patent intensity is much lower in sectors (1), (2) and (5) than in sectors (3) and (4), as might be expected. However, trade mark intensity is much more even across sectors. A final issue of interest is the relative shares for each sector for overall innovative activity. Figures 1 to 4 in Appendix 1 show how the shares of R&D, UK patents and trade marks have changed over time. In summary, total R&D is dominated by the 'science based' sector and this has grown over the 1989 to 1999 period from around 50% to 60%, with a loss of R&D in the 'supplier dominated' sector accounting for most of this rise. For UK patent activity, again the science based sector accounts for the largest share (around 40% of total patents), but it is the 'productive intensive (specialised)' sector that has grown most over time (to around 30% in 1999). For EPO patents, again the science based sector has the largest share, but for EPO activity the science based sector has rapidly increased its share (from 38% to 56%). For trade mark activity it is the ‘supplier dominated’ sector that has shown a growth in total share (from around 16% to 25%).

3 The market value of innovation

This section provides an analysis 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

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

where A is the stock of tangible assets of the firm, K is the stock of intangible assets, q is the ‘current market valuation coefficient’ of the firm's assets, σ allows for the possibility of non constant returns to scale, and γ is the ratio of shadow values of intangible assets and tangible assets

(i.e. $\frac{\partial V}{\partial K} \Big/ \frac{\partial V}{\partial A}$).

Taking natural logarithms of [1], and using the approximation log(1+ε)≈ε, we can rearrange [1] to yield

$$\log V_i = \log q_i + \sigma \log A_i + \sigma\gamma \frac{K_i}{A_i} + u_i \quad . \qquad [2]$$

A major problem facing empirical studies is how to proxy K. In this paper we use data on R&D expenditure, patent applications (both UK and EPO) and trade mark applications as proxies for such capital. As in other studies we also use a number of other control variables including sales growth, the debt to equity ratio, the book value of intangible assets and industry dummies.[3] 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] For a review of market value studies and this methodology see Hall (2000).

3.1. Basic market value regressions

Table 4 shows some OLS regressions on all available data for the period 1989-1999. In particular, regressions are run separately on the full sample and on each technology sector. Looking only at the full sample regression in the first column, the major results are as follows. R&D has a significant and positive relationship with market value. Firms with higher relative rates of UK patenting appear to command no market value premium; a result that is found even if the other innovation-based variables (R&D, EPO patents and trade marks) are excluded from the regression.[4] In contrast, the rate of EPO patenting has a positive partial correlation with market value, as does trade mark activity.[5]

To provide an economic interpretation of the coefficient on R&D/assets, recall that the coefficient is $\sigma\gamma$ in [2], hence for the full sample regression, γ has a value of 3.51. The parameter γ can be interpreted as the ratio of shadow values (i.e $\frac{\partial V}{\partial K} \Big/ \frac{\partial V}{\partial A}$). However, since R&D is current expenditure, not the stock of R&D, this cannot be taken as direct evidence of under investment in R&D. For example, suppose that R&D is (suddenly) obsolete after 3 years and that R&D is constant through time at level R, hence the stock value would be 3R. Thus, the coefficient estimate from using R as a proxy will be three times as high (in this case the 'true' ratio of shadow values would be 1.17). In an earlier study using part of this database, 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. The uncertainty over the depreciation rate of R&D by sector means it is not possible to assert that shadow values are different.

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[4] The regressions excluding the other innovation proxies are conducted as there is sometimes a concern that the various innovation proxies are highly correlated; hence multicollinearity may occur. For the full sample the correlation coefficient between the variables is between 0.11 and 0.38.

[5] The results on EPO patenting are similar if regressions are run excluding R&D, UK patents and trade marks, although the coefficient on EPO activity is now significant in sector 1 and not significant for sector 5. Entering trade mark activity as the sole innovation proxy also produces similar results to those in Table 4.

Table 4 Market value regressions, by Pavitt category

	Full sample	Supplier dominated manufacturing (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Supplier dominated non-manu-facturing (Pavitt 5)
			OLS			
Log of total assets	1.055	1.016	1.045	1.095	1.032	1.095
	(96.68)***	(23.38)***	(59.76)***	(42.00)***	(45.20)***	(22.39)***
R&D expend / total assets	3.703	10.880	5.027	7.098	3.216	17.867
	(6.16)***	(2.70)***	(2.14)**	(5.41)***	(5.02)***	(3.05)***
Patent / total assets	-1.035	-2.618	-0.439	0.426	-1.937	-10.592
	(2.44)**	(1.06)	(0.93)	(0.51)	(1.97)**	(3.27)***
EPO patent / total assets	2.501	6.411	2.332	2.536	2.112	20.275
	(3.79)***	(0.90)	(1.99)**	(4.31)***	(2.02)**	(1.39)
Trade mark / total assets	0.447	0.570	0.601	0.349	0.263	2.557
	(2.73)***	(0.98)	(1.48)	(0.70)	(1.31)	(2.36)**
Growth in sales (t, t-1)	0.637	0.758	0.446	1.142	0.330	0.728
	(5.85)***	(2.28)**	(2.95)***	(6.34)***	(1.97)**	(2.76)***
Debt / shareholders' equity	-0.003	-0.012	-0.001	-0.014	0.005	0.056
	(2.01)**	(0.51)	(1.18)	(0.89)	(0.79)	(0.60)
Intangible assets / total	1.416	1.659	1.240	1.921	1.774	0.124
	(5.27)***	(2.13)**	(2.98)***	(2.63)***	(3.30)***	(0.18)
Constant	-1.767	-3.815	-1.104	-3.405	-0.631	-1.634
	(5.86)***	(3.47)***	(2.71)***	(6.00)***	(1.49)	(1.74)*
Observations	2472	348	600	596	617	311
Number of firms	347	55	79	81	82	50
R-squared	0.89	0.90	0.93	0.83	0.89	0.93
Industry dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.00
Year dummies (prob.)	0.00	0.21	0.00	0.00	0.01	0.00
Test of H_o: ln(assets) = 1	0.00	0.71	0.01	0.00	0.16	0.05

Notes: The dependent variable is log 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 industry (year) dummies are equal. A Chow test on whether the sub-samples can be pooled yields a F-statistic of 7.5 (rejecting the null hypothesis that the samples can be pooled at the 1% level).

The main interest in Table 4 concerns the sub-sample regressions on the different technology sectors. Focusing first on the coefficient on the R&D variable, it can be seen that, although it is always significant, the magnitude varies substantially across Pavitt's technology sectors. Perhaps unexpectedly, the lowest return to R&D is for sector 4, which is seen as benefiting from university science, while the highest magnitude is for sectors 1 and 5, both of which are supplier-dominated. Given that these results run counter to prior expectations, it is vital to explore the role of influential observations in these results. Appendix 2 shows leverage plots for all the innovation-based variables in the Pavitt sector 1 regression. The graphs indicate that a few observations appear critical in determining the coefficient. For the R&D variable the main outlier is a firm called Applied Optical Technologies PLC and, if this firm is omitted from the regression, the R&D coefficient becomes insignificant. Given this result, further analysis was conducted on all the results to assess if any other coefficients were as sensitive. For the R&D coefficients, the main conclusion was that most of results are unaffected (with, as stated, the exception of sector 1). For the IP variables there are various influential observations that do alter the estimated coefficients, although not in a way that changes the basic pattern of results.[6]

As a further check on the results, all the regressions in Table 4 were re-estimated using a robust regression procedure, which uses an algorithm to eliminate influential observations.[7] As shown in a table in Appendix 3, the broad results from using the robust estimator are similar to the results discussed above; they are particularly close for the pooled total sample, but there are some variations for particular sectors. Specifically, for sector 1, the robust estimator finds the coefficient on R&D to be still significant, but with a reduced magnitude; however, sector 4 continues to have the lowest coefficient and once again sector 5 has the highest coefficient on R&D.

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[6] Leverage plots were used to identify possible influential observations and then these firms were omitted from the regression. The results from this procedure suggest that the negative and significant coefficients on the UK patent variable tend to be driven by one or two firms, although omitting these from the sample makes the coefficients insignificantly different from zero. For trade marks, the insignificant coefficients in Pavitt sectors 2 and 3 tend to be caused by one or two firms. Omitting these firms tends to raise the coefficient and make it significantly different from zero. The significance of the EPO patent variables do not appear to be affected by influential observations.

[7] 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 $M=med(|e_i-med(e_i)|)$, 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 7.0 reference manual under 'rreg' (www.stata.com).

The results for EPO patents show consistency of the positive effect for the full sample between the OLS and robust regression results, but with some variation in the significance of sector-level parameters, with the robust regressions downgrading their significance in sectors 2 and 4, but improving their impact and significance in sectors 1 and 5. Even so the relative size of the sector coefficients for EPO patents and their rank order across the five sectors is consistent across the two sets of estimates. The highest returns to EPO patents are observed in the two supplier-dominated sectors, with patent returns in 5 (non-manufacturing) exceeding those in sector 1 (manufacturing), and the lowest returns in the science-based sector 4. Note that these returns to patents are in reverse rank order to the incidence of IP active and EPO active firms in these sectors (see Tables 1 and 2 above).

For UK patents, the robust estimator again finds that the coefficient is either negative or insignificant. The positive effect of UK trade marks for the full sample is also confirmed in the robust regressions, and across sectors the coefficients on trade mark activity are larger and more significant in sectors 2 (production intensive - scale) and 3 (production intensive - specialist), but they remain insignificantly different from zero in sectors 1 and 4, and the coefficient in sector 5 is now insignificant.

Other coefficients estimated in Table 4 and Appendix 3 are also of interest. The coefficient on log of total assets represents σ, which is equal to one if there are constant returns to scale in the market valuation of tangible and intangible assets. Testing for whether the coefficient on total assets equals one, the null hypothesis of constant returns to scale is rejected (in both the OLS and the robust regression results) for sectors 2 and 3, the two production-intensive sectors, in favour of increasing returns to scale. The coefficients on sales growth suggest firms with faster growth have higher market valuations. The results for the book value of intangible to total assets ratio are generally positive, but the debt to equity ratio is generally rather insignificant. The book value of intangible assets reflects the accounting values of goodwill, and possibly patents and brands, obtained via takeovers.[8]

The major result from Table 4 is that the market's valuation of different measures of innovation varies substantially across sectors. Why does the valuation of R&D and IP vary so much? There are

[8] 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.

two broad classes of answers to this question. The first is that the issue is essentially econometric, with various estimation issues ‘causing’ the instability of coefficients across sub-samples. We have already reported on an investigation of the role of influential observations and multicollinearity, finding that these issues do not alter the basic pattern of results. A further econometric issue concerns the use of firm specific effects to control for unobserved heterogeneity (e.g. management ability). Although panel estimators can offer advantages there are also drawbacks. First, removing firm specific effects may obscure the impact of innovative activities to 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. To investigate these issues, all the regressions shown in Table 4 were estimated using a fixed effect (FE) estimator (see Appendix 4), which estimates a time invariant effect for each firm (i.e. enters a dummy variable for each firm). The results for the full sample (column 1) show that, 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 more frequently insignificant for the IP variables. Across the sectors these variations in coefficients and significance make it hard to discern the systematic differences seen in the results obtained without firm fixed effects.[9] This said, the coefficient on R&D in Pavitt 4 is still has the lowest magnitude, with Pavitt 5 now the second highest.

The other class of explanation considers economic reasons for the differences and assumes that the econometric estimation is qualitatively correct. A first issue to be stressed is that the coefficients are estimates of the average, not marginal, returns, and it is the marginal returns that should, theoretically, should be equalised across firms. If we assume, however, that the marginal returns do vary then the explanation should lie in the inappropriateness of the ‘perfectly’ competitive model. As mentioned in the introduction, the resources for innovation – including knowledge – may be highly specialised and hence are 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

[9] Our interpretation of the fixed effects results is that measurement error in the variables is substantial and that this makes FE or similar estimators inappropriate. Concerning the innovation-based variables, the underlying variable we wish to measure is investment in intangible assets through innovative activities. R&D and IP data are likely to be ‘noisy’ proxies for this variable, hence measurement error will be present. In a panel estimator the effect of measurement error can be magnified if variables are correlated through time. The R&D and IP measures are highly correlated through time, with correlations from 0.30 to 0.82.

universities. This might suggest that firms in this sector can (relatively) easily access the basic knowledge required and hence compete (relatively) intensively, which in turn reduces the average return to R&D. 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-based sector may have higher spillovers, which tend to reduce returns. However, it is also clear that competitive conditions can vary due to differences in industry characteristics (e.g. entry barriers, sunk costs) and firm-level characteristics (e.g. market share). These issues are explored in the next section.

The other important result from Table 4 is that the market valuation of patenting via the UK patent office seems to generate no market premium. Again, our analysis suggests that this result is robust to influential observations and some alternative specifications. There are a number of possible explanations for this result including:

a) The market value of EPO patents may be genuinely higher than that of UK patents since the number of jurisdictions applied for is typically higher, reflecting the firm's desire to export its product and/or licence its technology widely.

b) The impact on market value of a patent occurs after the publication date; the interesting issue here is whether the stock market is myopic in respect of UK patents, but more instantly reactive to EPO patents. We can explore this hypothesis using lags in the IP variables.

Evidence in favour of a) 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.

To investigate b) we estimate regressions using the lagged values of UK and EPO patent activity as explanatory variables (to test the idea that any share market valuation comes after publication). Including variables for UK patent activity in t-1 and t-2 years, alongside the current patent activity variable, we find only in sector 3 is there a (net) positive coefficient (the t-2 coefficient is 1.9 and is significant at the 10% level). The lack of significance of the coefficient on UK patent activity is similar across other specifications, such as dropping other innovation proxies and current patent activity. In contrast, a parallel analysis of EPO patenting shows that the coefficients on current and t-1 patent activity are often significant. Moreover, if we omit the other innovation proxies, the results for EPO patent activity become stronger. In conclusion, there is little evidence that firms that patent in the UK receive any current or future share market premium. The implication is that there may be a quality effect whereby better patents are filed through the EPO. However, it could also be that larger companies are more likely to patent via the EPO and that only these companies command an increase market value, an issue we investigate below.

4 Competitive conditions

One of the most fundamental concepts in economics is competition and, in particular, how rivalry between firms may create socially optimal outcomes. Looked at from a dynamic perspective, the critical issue is how the intensity of competition affects innovation and growth. Although contributions to this question have a long history, it is normal to set the scene by comparing the (stylised) Schumpeterian view with the Arrow view. Schumpeter is often associated with 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.[10]

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 should be inversely related to competitive conditions. The alternative hypothesis is the Arrow view that, as

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[10] 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, which are the incentives. 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 (1990) is 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).

firms are able to use IP as effective protection for returns, then the link between competitive conditions and market valuation would be broken. To test the 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 industry- and firm-level proxies for competitive pressure. The initial proxy considered is a measure of rents at the industry-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 industry-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, Panzar and Willig, 1982). Lastly, in Section 4.2, we use product market share as a firm-level proxy for competitive conditions. This is an established approach in the literature and allows us to investigate intra-industry differences in competitive conditions.

4.1. Sector-based measures of competition

Within the empirical innovation literature the main proxy for competition has been industry profitability (rents). Initially, we follow this approach by using the ratio of net profits before tax to total sales as a proxy for rent.[11] Table 1 shows the average rents by sector and reveals that the least competitive sector according to this measure is sector 5, non-manufacturing, with a profit ratio of 14.8%; interestingly this is also the sector with the highest estimated value of R&D from Table 4.

[11] Aghion at el (2002) use a similar measure, namely operating profit to sales, while Nickell (1996) uses a more complex measure, which accounts for the user costs of capital employed. The data available here does not allow us to exactly match either of these two ratios.

However, across the four manufacturing sectors there is no strong correlation between returns to R&D and profit share, as the most competitive sectors by this measure are sectors 1 and 3 with low profit ratios (6.5% and 6.6%) but middle levels of returns to R&D, while sectors 2 and 4 have intermediate levels of rents (8.4% and 9.7%) but lower estimated returns to R&D.

One possible reason for these conflicting findings is that profitability is a poor proxy for competitive conditions. In fact, 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

$$\pi_{i,t} = \alpha_i + \beta\pi_{i,t-1} + \varepsilon_{it} \ , \qquad [3]$$

where π_{it} is firm *i*'s profits in year *t*, α_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 [3] 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 compute the value of β for each Pavitt sector (over the period 1989-99).[12] Table 5 shows these β-coefficients in comparison

[12] The regressions were conducted on a balanced panel of firms present in the full Company Analysis/Thomson data over the ten year period 1989-1998. To allow sufficient sample size, only those industries with an average of more than five firms in each year for the period were included in the analysis. Moreover, 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). Analysis at the level of Pavitt sectors may hide differences in competitive conditions at the industry level, hence we have also investigated competition at the 2-digit SIC level. For many of these industries there are sufficient observations to estimate the market value regressions by industry. However, Appendix 5 details all the results

with the simple profit ratios and we see that the ranking of the four manufacturing sectors is considerably altered, although sector 5 remains the least competitive on this new measure. So does this new measure correlate more closely with the return to R&D?

Table 5 shows the coefficients on the R&D variables from Table 4 (OLS regressions) and Appendix 3 (robust regressions) respectively and compute estimates of the returns to R&D, correcting for the fact that each the regression coefficients is the multiple of the returns to R&D and returns to scale (see equations 1 and 2 above). We can now see a strong degree of rank correlation between the β-coefficients and the returns to R&D, with the only significant exception being for Pavitt 1 in the OLS regressions, which we have seen above was driven by one outlying firm and is resolved in the robust regressions. So, if a low β-coefficient is accepted as indicating relatively high competitive pressure, these results are consistent with the idea that rents are rapidly competed away; in the context of R&D investments, this means that appropriability is relatively low.

Table 5 Competitive conditions and the return to R&D, by Pavitt sector

Sector:	Pavitt 5 Supplier Dominated Non-manufacturing	Pavitt 3 Production Intensive Specialist	Pavitt 2 Production Intensive Scale	Pavitt 1 Supplier Dominated Manufacturing	Pavitt 4 Science Based
Profit/Sales %	14.8	6.6	8.4	6.5	9.7
Profit persistence (β-coefficient)	0.52	0.51	0.47	0.36	0.27
$\sigma\gamma$ R&D OLS	17.867	7.098	5.027	10.880	3.216
$\sigma\gamma$ R&D Robust	14.425	8.313	8.302	5.026	3.995
γ R&D OLS	16.317	6.482	4.810	10.709	3.116
γ R&D Robust	14.689	7.806	7.869	5.422	3.758

What is also striking is that the lowest profit persistence and the lowest return to R&D, is seen in Pavitt 4, the science-based manufacturing sector, which draws on university and other science for its innovation and exhibits the highest incidence of IP active firms (Tables 1 and 2). As seen above, this sector also does not command high returns to patents; the highest gains from EPO patents were

from this analysis. The main result is that the coefficients on R&D and the IP variables are rarely significantly different from zero. Where they are significant, the coefficients appear highly unstable across industries suggesting that the small samples in many industries raise standard errors and influential observations drive the results. For these reasons we are more confident of the results at the Pavitt sector level and focus on these in the main text.

by the two supplier-dominated sectors 1 and 5. Another way of interpreting these results is to consider the lack of profit persistence and low returns to patents in sector 4 as reflecting R&D spillovers. Thus firms in the science-based sector may undertake extensive R&D, but much of its value spills over to other firms (indeed undertaking R&D increases a firm's ability to absorb others knowledge, Cohen and Levinthal, 1989).

4.2. Market share and the value of innovative activities

While the strong link between competitive conditions and returns to R&D at the Pavitt sector level is of interest, it is unrealistic to assume that firm-level differences 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), find that higher market share raises the market valuation of an innovation.[13] 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).[14] 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 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

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[13] 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.

[14] To be more accurate, Toivannen 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).

whether market share is important is also related to the debate over whether small firms can benefit from the IP system.

Table 6 shows that market share itself is not rewarded by higher market valuation for the whole sample.[15] However, the sectoral differences are substantial, ranging from negative in sector (5) 'non-manufacturing' to a positive effect for (1) 'supplier dominated' and sector (2) 'production, scale', with insignificant effects in other sectors. At the same time, the interaction between market share and R&D expenditure shows insignificant positive gains in market value in the full sample of firms, but here too there are very diverse experiences within sectors. Market share and R&D are significant strong complements in the 'science based' sector (4). Thus it seems that market share is deemed most valuable, ceteris paribus, within the sector with the lowest average levels of returns R&D and patenting activity. In contrast sectors (1), (2) and (5) show negative interactions between market share and R&D. Investigating whether these results are driven by a few influential observations we find that the negative coefficients on the interaction term in sectors (1) and (2) are affected: omitting one firm makes these coefficients insignificant. However, the significant coefficient on the interaction term in sector (4) appears robust: omitting influential observations tends to raise the magnitude and significance of the coefficient on R&D interacted with market share.

[15] Market share is expressed as a ratio and is defined as firm sales / industry sales (4 digit level), where 'industry sales' are based on all firms in the OIPRC database. The mean market share for the full sample is 0.47, the median 0.39 and the s.d. 0.38. We also estimated an alternative value of market share based on 3 digit level industry and estimates using this variable confirmed the main findings reported here for the 4 digit level definition of the market.

Table 6 Market share and R&D

	Full sample	Supplier dominated (Pavitt 1)	Prod. (scale) (Pavitt 2)	Prod. (spec) (Pavitt 3)	Science based (Pavitt 4)	Non-manufacturing (Pavitt 5)
Log of total assets	1.057	0.977	1.050	1.123	1.022	1.224
	(88.08)***	(26.02)***	(56.93)***	(33.70)***	(42.74)***	(17.39)***
R&D expend / total assets	3.447	14.360	14.117	6.816	2.940	26.861
	(5.36)***	(3.00)***	(4.40)***	(4.24)***	(4.24)***	(3.46)***
Market share (4-digit) (ratio)	-0.072	0.623	0.248	-0.235	-0.032	-0.509
	(1.25)	(4.12)***	(2.01)**	(1.33)	(0.23)	(2.65)***
R&D/Assets * Market share	2.006	-8.903	-18.383	0.908	5.972	-74.950
	(1.26)	(0.91)	(2.82)***	(0.24)	(2.25)**	(3.18)***
UK patent / total assets (mill)	-1.039	-2.431	-0.786	0.404	-1.738	-10.194
	(2.46)**	(1.05)	(1.70)*	(0.48)	(1.76)*	(3.47)***
EPO patent / total assets (mill)	2.425	4.423	1.702	2.451	1.446	1.992
	(3.61)***	(0.68)	(1.45)	(4.01)***	(1.11)	(0.14)
Trade mark / total assets (mill)	0.460	0.572	0.611	0.405	0.366	2.649
	(2.78)***	(1.03)	(1.41)	(0.81)	(1.74)*	(2.41)**
Growth in sales (t, t-1)	0.633	0.737	0.415	1.166	0.288	0.548
	(5.82)***	(2.10)**	(2.75)***	(6.52)***	(1.72)*	(2.29)**
Debt / shareholders' equity	-0.003	-0.006	0.000	-0.013	0.004	0.127
	(2.06)**	(0.23)	(0.03)	(0.85)	(0.71)	(1.41)
Intangible assets / total	1.433	1.367	1.038	1.974	1.863	-0.532
	(5.33)***	(2.03)**	(2.59)***	(2.69)***	(3.50)***	(0.87)
Constant	-1.747	-3.495	-1.241	-3.769	-0.504	-3.877
	(5.62)***	(3.27)***	(3.03)***	(5.92)***	(1.14)	(3.28)***
Observations	2472	348	600	596	617	311
R-squared	0.89	0.91	0.93	0.83	0.89	0.94
Industry dummies (prob.)	0.00	0.00	0.00	0.00	0.00	0.00
Year dummies (prob.)	0.00	0.10	0.00	0.00	0.02	0.00

Notes: Robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. Other notes as per Table 4.

Table 7 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 in order to save space (full results available from authors). The interaction term between UK patent activity and market share is always positive and significantly different from zero in the full sample and in three of the five sectors. A positive coefficient indicates that higher market share tends to increase the association between UK patent activity and market value.[16] 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 (the coefficient on market share itself is not significant). For a firm in this sector with average market share (0.54), these coefficients imply a net coefficient on 'UK patent/assets' of 2.02. 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 - scale) the threshold level of market share is 0.19 (around 33% of firms in this sector have market shares less than 0.19). For the sector 4 (science based) the equivalent market share threshold level is 0.28 (around 48% of firms in this sector have market shares less that 0.27).[17] The UK patent results show more evidence of interaction effects than the trade mark or EPO patent regressions, although the results for these again suggest that larger market share can raise the market valuation of IP in some sectors. We can relate these results back to Arrow's theoretical model of the incentive to innovate. If perfect IP rights existed we would not expect to find any significant coefficients when interacting market share and IP. Instead, the results indicate that for UK patent activity market value is only generated if UK patents and traditional market power are combined.

[16] Once again leverage plots were used to investigate the present of influential observations on the interaction term. Pavitt sectors 1 and 2 show no substantial change if potential influential observations are omitted; the result in Pavitt sector 3 depends on a single firm in the sample; and omitting possible influential firms from Pavitt 4 tends to increase the positive coefficient on the interaction term and its significance.

[17] For reference, the 10.6 coefficient on the interaction between UK patent and market share in Pavitt 4 is only significantly different from zero at the 14% level.

Table 7 Market share and IP activity

	Full sample	Supplier dominated (Pavitt 1)	Prod. (scale) (Pavitt 2)	Prod. (spec) (Pavitt 3)	Science based (Pavitt 4)	Non-manufacturing (Pavitt 5)
Patent / total assets (mill)	-1.599	-2.988	-1.096	-0.414	-2.935	-13.416
	(3.34)***	(1.21)	(2.39)**	(0.44)	(2.49)**	(2.72)***
Market share (4-digit) (ratio)	-0.071	0.465	-0.100	-0.276	0.116	-0.735
	(1.28)	(3.31)***	(1.03)	(1.83)*	(0.93)	(3.24)***
Patents/Assets * Market share	3.883	6.222	5.770	3.325	10.636	16.710
	(2.45)**	(0.81)	(1.97)**	(2.02)**	(1.47)	(1.28)
Trade mark / total assets (mill)	0.296	1.102	-0.283	0.237	0.235	2.301
	(1.56)	(1.16)	(0.87)	(0.45)	(1.08)	(1.71)*
Market share (4-digit) (ratio)	-0.056	0.579	-0.128	-0.273	0.158	-0.684
	(1.04)	(3.73)***	(1.29)	(1.80)*	(1.24)	(3.19)***
Trade Marks/Assets *	1.128	-1.612	3.159	1.285	1.128	-0.595
Market share	(2.02)**	(0.71)	(3.06)***	(1.31)	(0.67)	(0.10)
EPO patent / total assets (mill)	2.669	1.322	2.085	1.779	2.456	-13.321
	(3.39)***	(0.16)	(1.54)	(2.04)**	(1.76)*	(0.55)
Market share (4-digit) (ratio)	-0.017	0.438	-0.042	-0.222	0.205	-0.723
	(0.33)	(3.11)***	(0.45)	(1.59)	(1.67)*	(3.30)***
EPO Patents/Assets *	-0.640	11.753	1.601	3.269	-1.349	84.747
Market share	(0.40)	(1.00)	(0.26)	(1.19)	(0.81)	(2.02)**

Notes: Robust t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

5 Conclusions

This paper has analysed the market valuation of the R&D and IP activities of quoted UK firms using a new data set for the 1989-1999 period. The ultimate interest in such analysis is a greater understanding of firm performance and financial market performance, which in turn provides background for policy discussions. A major theme of the paper is that existing market value studies tend to assume that the returns to innovative activities are equal 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. Overall, we find 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 analyse whether the market valuation varies across these sectors, finding large differences in the market valuation of R&D and IP activity across sectors. This result is robust to further analysis containing lagged values of R&D and IP, which suggests that the stock market evaluates new R&D and IP within the year of its occurrence. Overall, we find that the lowest valuation of R&D is in the '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).

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 direct 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, single country patenting via the UK Patent Office appears to have a very limited future, but UK financial markets do recognise multi-country 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 study the effects of competition on both market value and the returns to innovative activity under varying market structure. At a basic level we might expect higher levels of competition within a sector to lower market valuations, ceteris paribus. To investigate this issue we utilise two industry-based (inverse) proxies for competitive conditions: the simple average industry rate of profit and a more sophisticated profit persistence approach. The second measure uses time series analysis of the response to profit 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 industry profit and profit persistence is low; hence there is value in comparing the two approaches to measuring competitive conditions.

While the average profit measure yields no consistent explanation of the sector differences in returns to innovation, the profit persistence measure is highly (rank order) correlated with the returns to R&D. 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 the lowest returns to R&D in that sector; however, this is not the sector with the lowest average industry profits. At the other extreme, the ‘supplier-dominated (non-manufacturing)’ sector reaped the highest market valuation of returns to R&D within a market structure exhibiting high profit persistence (i.e. low competitive pressure).

We also examine the role of firm-level factors in explaining sectoral differences in rates of return to R&D and IP assets by using market share as a third (inverse) proxy for competitive pressure. For the full sample of firms, the results suggest no significant role for market share, however, when we analyse by Pavitt sectors we find a diverse pattern of results. These range from a positive benefit of greater market share in ‘supplier dominated - manufacturing’ and ‘production intensive – scale’, to a negative effect in ‘supplier dominated - non-manufacturing’. We extend the analysis to allow for the interaction of market share and R&D. This analysis suggests that only in the ‘science based’ sector does higher market share raise the valuation of R&D. The magnitude of the effect appears economically important: the coefficient estimates imply a 10% increase in market share is associated with a 20% increase in the market valuation of R&D activity.

This paper also conducts analysis on the link between market share and IP activity. If the IP system was 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. For example, in the Pavitt 4 sector the results indicate that the market share threshold level is around 0.28: only when market share rises above this level does UK patenting appear to attract a stock market premium.

The findings on the role of market share offer much food for thought for the regulatory authorities concerned with competition (the Office of Fair Trading and the Competition Commission), concerning the need to stay their hand in promoting competition, which may be achieved at the expense of maintaining incentives for innovation. Broadly our results give much more support for Schumpeter than for Arrow on the relationship between market structure and innovation: the returns to R&D are higher in sectors with relatively low competitive pressure. Clearly, the results do not imply that lowing competitive pressure would always raises the return to R&D; only that this occurs within the range of competition observed in the data.[18] The returns to IP vary across sectors, with the lowest returns to EPO patents in the most competitive science-based sector, and, in the case of UK patents, returns are enhanced by higher market share. Our findings are of considerable relevance too for all the government agencies engaged in re-shaping industrial policy following the Lambert Review of Business-University Collaboration (HM Treasury, 2003). Our findings suggest that a key reason for the slow rate of exploitation of scientific discovery in the UK is 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 returns to R&D generate high rates of productivity growth. 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.

[18] In contrast, current UK government policy appears to assume that the link between competition and performance is straightforward and monotonic. 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 above suggests that the competition and performance relationship is much more complex that this.

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Appendix 1 Time trends in innovative activity, by Pavitt sector

Figure 1 Shares of R&D activity by Pavitt sector

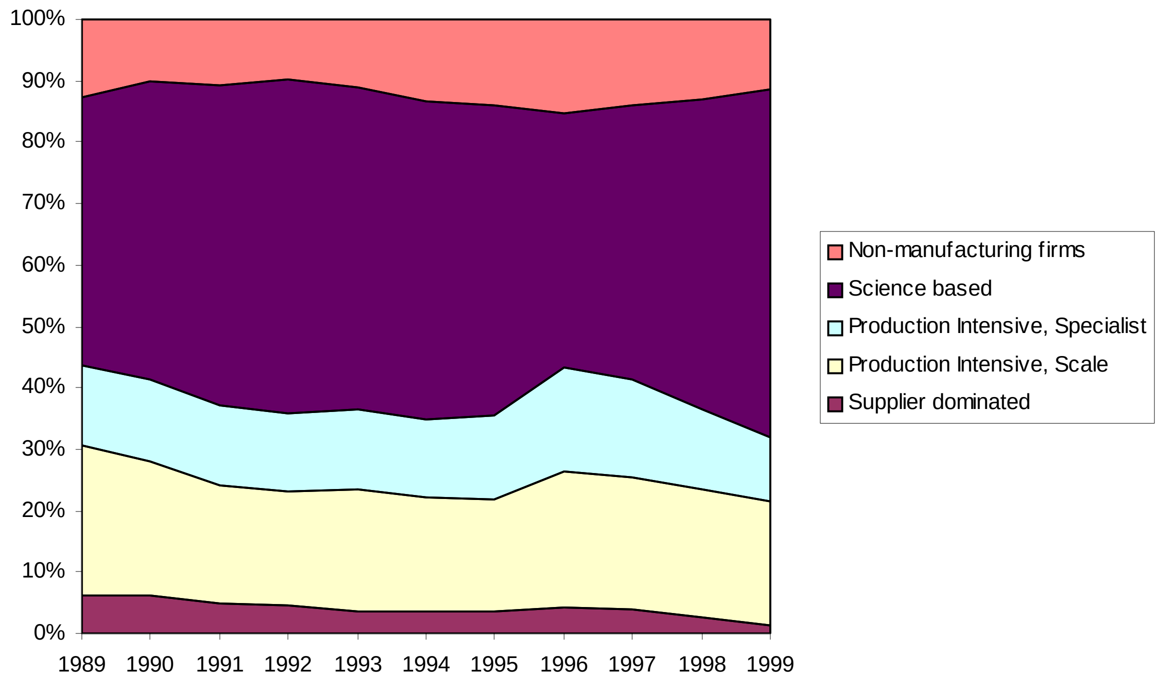


Figure 2 Shares of UK patent activity by Pavitt sector

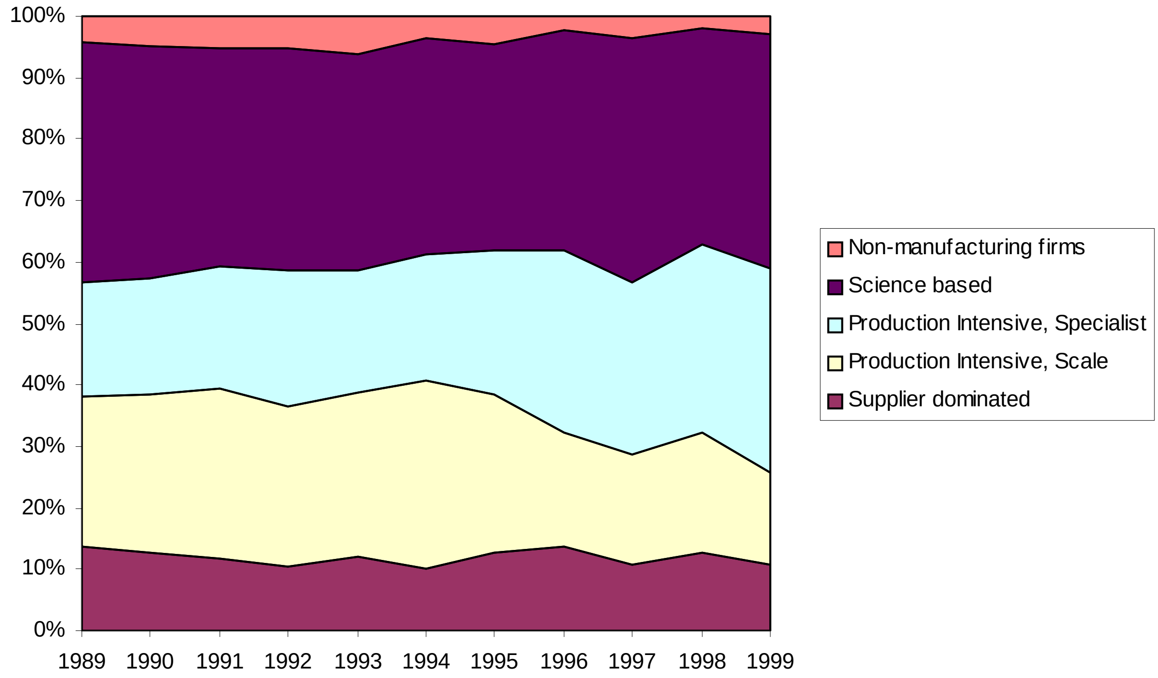


Figure 3 Shares of trade mark activity by Pavitt sector

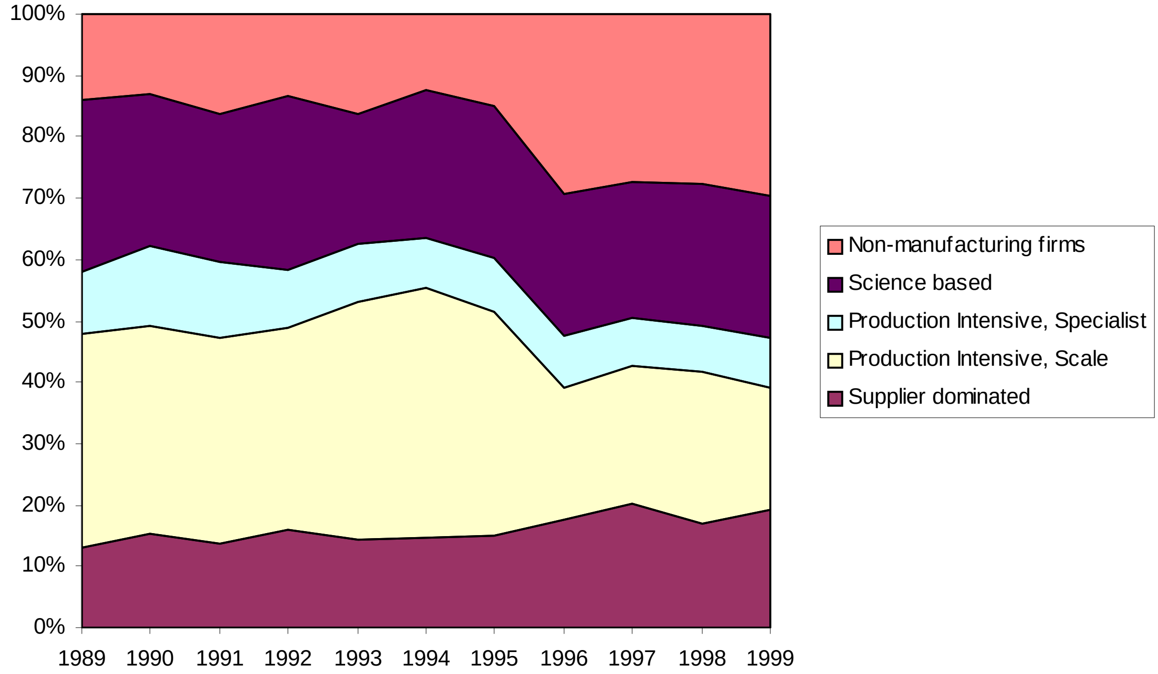
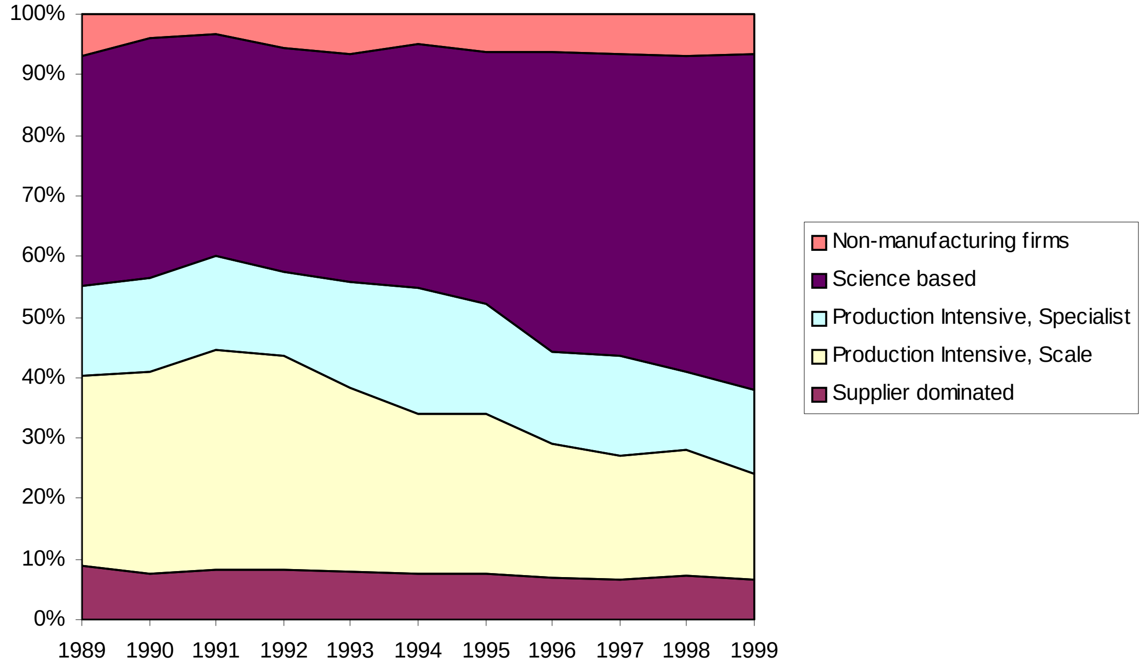
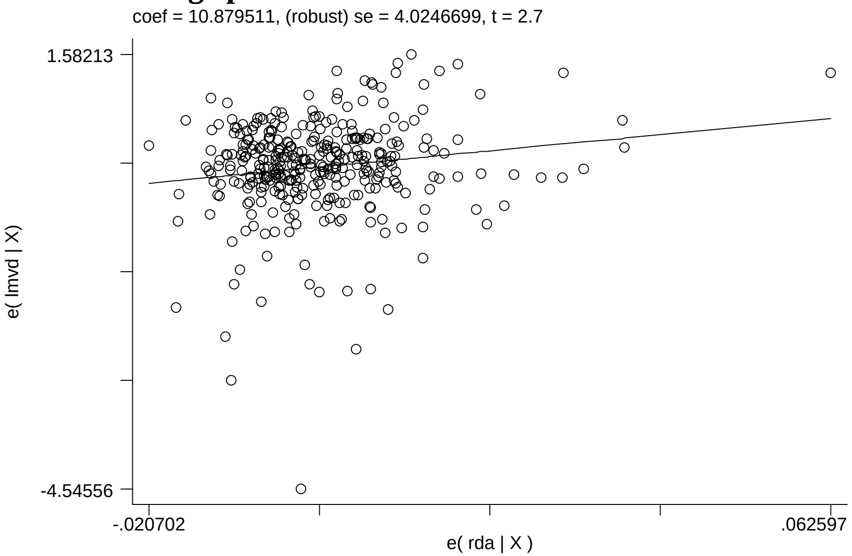
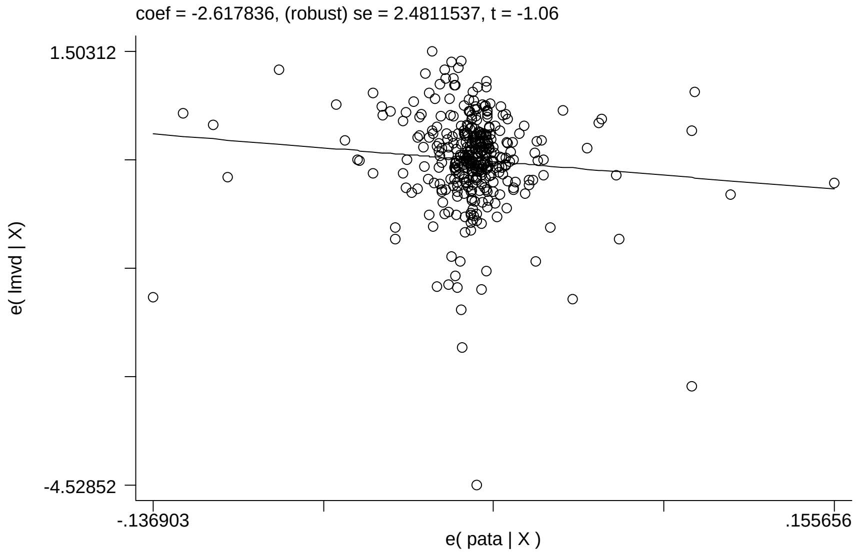


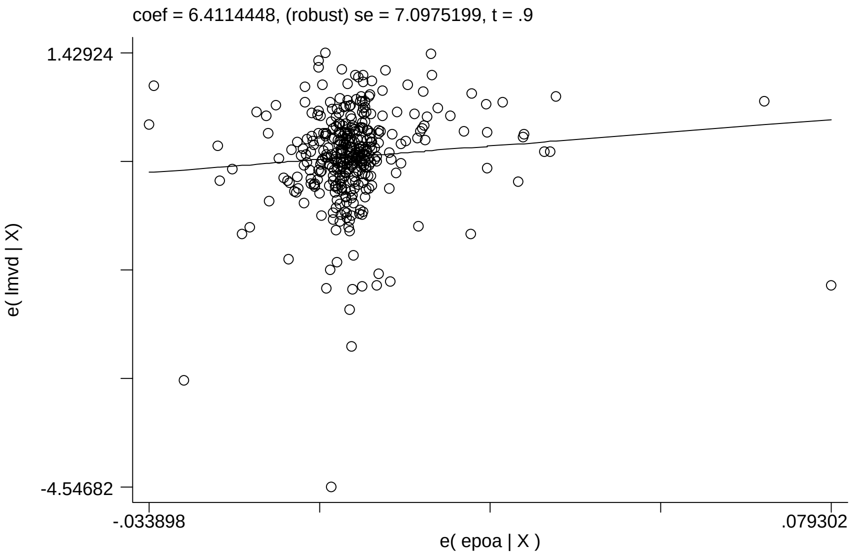
Figure 4 Shares of EPO patent activity by Pavitt sector

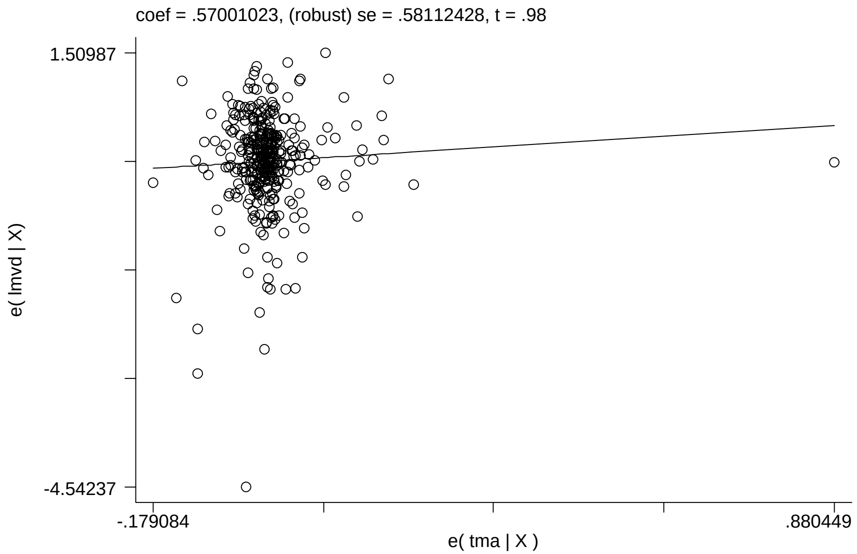


Appendix 2 Leverage plots









Appendix 3 Market value – Results from robust regressions

	Full sample	Supplier dominated manufacturing (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Supplier dominated non-manu-facturing (Pavitt 5)
Log of total assets	1.036	0.927	1.055	1.065	1.063	0.982
	(129.66)***	(39.86)***	(74.32)***	(52.06)***	(57.13)***	(60.37)***
R&D expend / total assets	4.532	5.026	8.302	8.313	3.995	14.425
	(13.60)***	(1.89)*	(4.94)***	(8.73)***	(9.20)***	(6.92)***
Patent / total assets (mill)	-0.646	-3.147	-0.864	-0.208	-3.035	-9.077
	(2.15)**	(3.05)***	(1.84)*	(0.27)	(4.52)***	(7.49)***
EPO patent / total assets (mill)	2.186	12.450	1.903	2.144	0.352	17.445
	(5.66)***	(4.79)***	(1.52)	(2.92)***	(0.64)	(1.81)*
Trade mark / total assets (mill)	0.382	-0.268	0.603	0.500	0.216	-0.520
	(2.94)***	(0.70)	(2.03)**	(1.65)*	(1.05)	(0.98)
Growth in sales (t, t-1)	0.737	0.493	0.431	0.917	0.690	0.158
	(12.82)***	(2.93)***	(3.33)***	(6.48)***	(7.59)***	(1.23)
Debt / shareholders' equity	-0.003	-0.004	-0.001	-0.046	0.001	-0.033
	(1.07)	(0.14)	(0.44)	(5.14)***	(0.07)	(0.79)
Intangible assets / total	1.122	1.031	1.291	1.250	0.726	-1.379
	(5.35)***	(1.55)	(3.17)***	(1.64)	(2.13)**	(3.16)***
Constant	-1.410	-1.241	-1.178	-2.765	-0.998	-0.027
	(2.90)***	(2.37)**	(3.31)***	(5.38)***	(1.98)**	(0.05)
Observations	2472	348	600	596	617	311
R-squared	0.92	0.95	0.94	0.87	0.93	0.98
Industry dummies (prob.)	11.84	18.86	10.24	6.34	5.4	15.83

Notes: As per Table 4.

Appendix 4 Market value - Results from fixed effect regressions

	Full sample	Supplier dominated manufacturing (Pavitt 1)	Production intensive (scale) (Pavitt 2)	Production intensive (specialist) (Pavitt 3)	Science based (Pavitt 4)	Supplier dominated non-manu-facturing (Pavitt 5)
Log of total assets	0.964	1.330	0.853	1.112	0.920	0.733
	(22.88)***	(10.00)***	(9.25)***	(10.06)***	(11.75)***	(8.32)***
R&D expend / total assets	2.369	6.192	8.844	2.972	2.424	8.417
	(4.81)***	(1.09)	(3.01)***	(1.78)*	(3.78)***	(2.18)**
Patent / total assets (mill)	-0.632	-0.684	-0.529	-0.150	-0.913	-7.545
	(1.93)*	(0.55)	(1.11)	(0.18)	(1.26)	(4.23)***
EPO patent / total assets (mill)	0.419	-3.809	2.131	-0.161	0.534	21.889
	(1.01)	(1.22)	(1.88)*	(0.19)	(0.88)	(1.64)
Trade mark / total assets (mill)	0.256	1.305	0.199	-0.098	0.342	0.556
	(1.92)*	(2.48)**	(0.73)	(0.33)	(1.60)	(0.69)
Growth in sales (t, t-1)	0.245	0.141	0.401	0.562	0.094	0.176
	(4.26)***	(0.63)	(3.28)***	(3.62)***	(1.08)	(0.91)
Debt / shareholders' equity	-0.002	0.010	-0.002	0.002	-0.002	0.080
	(0.74)	(0.35)	(0.76)	(0.22)	(0.31)	(1.32)
Intangible assets / total	0.709	-1.794	1.218	0.258	1.247	-0.190
	(2.50)**	(1.86)*	(2.45)**	(0.31)	(2.70)***	(0.19)
Constant	0.243	-7.096	1.939	-2.720	1.364	5.224
	(0.29)	(2.76)***	(1.12)	(1.36)	(0.94)	(2.86)***
Observations	2472	348	600	596	617	311
Number of firms	347	55	79	81	82	50
R-squared	0.40	0.43	0.44	0.40	0.43	0.53

Notes: As per Table 4.

Appendix 5 Results from profit persistence analysis at 2-digit industry level

Regressions to analyse profit persistence based on [3] were also run on each 2-digit SIC industry (with five or more firms) over the period 1989-98. 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).The β-coefficients and their t-statistics are shown in the second column of results in the first table below. This table shows that the range of values for β is between 0.17 and 1.04. In almost all cases the coefficients are statistically significant. The column 'industry NBPT/sales' shows the industry average profitability over the same period. The correlation coefficient between these two proxies for competitive conditions is 0.11 (the Spearman rank correlation is also 0.11).

Subsequently, regressions for the basic market value specification were run on each 2-digit industry. The second table below shows the coefficients found for R&D/assets (A), UK patents/A, EPO patents/A and trade marks/A for each industry where there are sufficient observations. There are many 2-digit industries with limited sample sizes due to the data required. The table shows those industries with more than 20 observations in the regression. The industries in the table are ordered by Pavitt sector and then by β-coefficient (i.e. the most 'competitive' industries are at the top). An important result is how large the variation in coefficients is and also that in many industries the coefficients are not significantly different from zero. Some of this appears due to influential observations and the small sample sizes, but overall there is an impression of volatility in the estimated coefficients of the innovation proxies. One possibility is that multicollinearity is more of a problem in the smaller samples; however, if regressions are run with each innovation proxy entered on isolation the results are similar, with only a couple of additional coefficients becoming significant for variable. Equally, a 'robust estimator' also produces similar results. Our interpretation is that the small sample size, and the presence of influential observations not picked up by the robust estimator algorithm, drive these poor results.

Profit persistence and profitability by 2-digit industry

Industry (US SIC)	No. of firms	Coefficient	t-statistic	Industry NPBT/sales (%)
Agricultural production-crops (1)	7	0.27	1.77	1.9
Oil & gas extraction (13)	9	0.17	1.11	11.6
General building contractors (15)	45	0.35	7.74	3.3
Heavy construction (exc building) (16)	5	0.28	1.71	1.2
Special trade contractors (17)	7	0.61	5.07	1.5
Food & kindred products (20)	56	0.44	10.26	8.5
Textile mill products (22)	20	0.41	4.37	4.0
Apparel & other textile products (23)	14	0.59	7.03	6.6
Furniture & fixtures (25)	10	0.42	4.93	5.4
Paper & allied products (26)	14	0.36	3.26	6.0
Printing & publishing (27)	29	0.34	5.15	11.9
Chemicals & allied products (28)	44	0.24	4.00	12.3
Petroleum & coal products (29)	6	0.52	3.00	8.8
Rubber & misc. plastics products (30)	19	0.44	5.42	6.4
Stone clay & glass products (32)	23	0.44	6.43	9.1
Primary metal industries (33)	23	0.55	8.11	5.4
Fabricated metal products (34)	25	0.48	7.96	5.9
Industrial machinery & equipment (35)	38	0.59	11.89	6.1
Electronic & other electric equipment (36)	30	0.36	5.01	7.2
transport equipment (37)	25	0.50	7.02	3.5
Instruments & related products (38)	26	0.39	5.74	9.0
Misc. manufacturing industries (39)	7	0.53	3.48	6.9
Trucking & warehousing (42)	6	0.78	3.46	9.1
Water transport (44)	7	0.28	1.98	9.5
Transport services (47)	8	0.20	1.67	4.6
Communications (48)	10	0.59	5.40	18.6
Electric gas & sanitary services (49)	10	0.60	7.01	15.0
Wholesale trade - durable goods (50)	66	0.61	14.74	2.6
Wholesale trade - nondurable goods (51)	36	0.40	7.08	2.3
Building materials & garden supplies (52)	8	0.23	1.79	3.6
General merchandise stores (53)	13	0.47	5.93	6.6
Food stores (54)	9	0.47	4.07	4.3
Automotive dealers & service stations (55)	16	0.40	4.07	2.1
Apparel & accessory stores (56)	10	0.50	4.82	4.5
Furniture & home stores (57)	5	0.23	1.34	6.2
Eating & drinking places (58)	11	1.00	12.09	8.0
Misc. retail (59)	15	0.73	10.11	8.3
Nondepository institutions (61)	5	1.04	10.10	6.6
Security & commodity brokers (62)	9	0.63	6.04	4.0
Real estate (65)	12	0.50	6.48	8.2
Hotels & other lodging places (70)	6	0.50	3.59	3.6
Business services (73)	50	0.42	9.14	4.9
Auto repair services & parking (75)	5	0.62	5.34	4.4
Amusement & recreation services (79)	11	0.36	2.99	1.8
Engineering & management services (87)	19	0.41	5.42	3.0

Market value regressions by 2-digit industry

SIC (US)	Industry	Obs	Profit/ Sales	Profit persis- tence β	R&D/ Assets	UK patents/ Assets	Trade marks/ Assets	EPO patents/ Assets	R^2
	Pavitt 1								
13	Oil & gas extraction	25	0.117	0.165	ns	-14.8	59.8	ns	0.99
16	Heavy construction (exc build.)	21	0.012	0.283	153.7	ns	ns	-225.5	0.97
27	Printing & publishing	31	0.114	0.337	35.1	ns	ns	ns	0.95
15	General building contractors	19	0.033	0.353	ns	ns	ns	45.3	0.97
26	Paper & allied products	57	0.057	0.364	ns	ns	ns	ns	0.96
22	Textile mill products	50	0.040	0.412	-32.5	ns	ns	ns	0.91
25	Furniture & fixtures	21	0.054	0.418	ns	ns	ns	41.0	0.86
30	Rubber & misc. plastics	86	0.064	0.443	ns	ns	ns	ns	0.84
	Pavitt 2								
32	Stone clay & glass products	71	0.092	0.441	-20.3	ns	ns	ns	0.95
20	Food & kindred products	142	0.088	0.442	ns	-10.1	4.9	ns	0.98
34	Fabricated metal products	154	0.060	0.477	18.3	ns	ns	ns	0.84
37	Transport equipment	161	0.039	0.496	13.7	6.9	7.1	9.3	0.88
33	Primary metal industries	56	0.055	0.551	ns	ns	ns	10.2	0.91
	Pavitt 3								
38	Instruments & related products	235	0.090	0.388	5.9	ns	ns	2.5	0.82
35	Industrial machinery & equip.	341	0.061	0.591	4.7	ns	ns	ns	0.83
	Pavitt 4								
28	Chemicals & allied products	299	0.124	0.236	4.0	ns	0.5	ns	0.87
36	Electronic & other electric equip.	246	0.074	0.363	5.7	ns	ns	3.05	0.82
29	Petroleum & coal products	42	0.088	0.517	-38.0	ns	ns	ns	0.99
	Pavitt 5								
44	Water transport	22	0.097	0.275	ns	ns	43.7	ns	0.92
73	Business services	21	0.069	0.42	ns	ns	ns	ns	0.98
48	Communications	31	0.192	0.585	ns	ns	79.1	ns	0.99
49	Electric gas & sanitary services	127	0.150	0.603	ns	ns	14.9	ns	0.96
50	Wholesale trade - durable goods	60	0.062	0.609	ns	ns	ns	ns	0.91

Note: The β-coefficient is the estimated coefficient from a fixed effect model of [3] using all data in Company Analysis 1989-99 in each 2-digit industry. The next four columns show the coefficients on R&D/assets (A), UK patents/A, trade marks/A and EPO patents/A from an industry market value regression (the other explanatory variables are the same as in Table 4 except for industry dummies; year dummies are included if there are 30 or more observations in the sample). A 'ns' indicates the coefficient is not significantly from zero (the condition is a t-stat of 1.7 or 10% level). The last two columns, 'n' and 'R^2' are the number of observations and R^2 for the market value regression.