OXFORD BULLETIN OF ECONOMICS AND STATISTICS, 64, 39 (2002) 0305-9049

Innovation and the Market Value of UK Firms, 1989–1995*

OTTO TOIVANEN, PAUL STONEMAN and DEREK BOSWORTH

Helsinki School of Economics
Warwick Business School
Manchester School of Management

I. Introduction

There is a large and wide-ranging literature that examines various aspects of the impact of innovation upon economic performance. The main driving forces of this literature are a desire to understand the determinants of output and productivity growth and the potential role for, and impact of, policy intervention. Within this general literature a growing body relates to the impact of research and development (R&D) in particular. This literature in turn includes two main strands: one focusing upon the impact of R&D on productivity (for reviews see Griliches, 1995, and Mairesse and Mohen, 1996) and the other on market valuation (for a review see Hall, 2000). The present paper concentrates upon the market valuation approach, the rationale for which, as discussed by Hall (2000) is that, if capital markets operate efficiently, then the market valuation of a company should be a forward looking indicator of firm performance reflecting the discounted sum of future dividends, which, in turn, should be closely related to the discounted sum of future profits. In particular, market values should reflect the future expected

*The research reported upon in this paper has been financed by the Economic and Social Research Council as part of a larger project on Intellectual Property Rights (*Company Performance and the Value of Intellectual Property*, ESRC grant number L325253005). The first author's research was also funded by the Academy of Finland and the Yrjo Jahnsson foundation, which he would like to thank for support. Parts of this work were carried out while the first author was visiting MIT and NBER, whose hospitality is gratefully acknowledged. Particular thanks are due to the UK Patent Office, which provided UK patent information on CD, and to Mark Longland for compiling the data set used in the present study. Thanks also to Christine Greenhalgh for comments on various drafts of the paper and to an anonymous referee. Any remaining errors are the responsibility of the authors.

returns to R&D (and other tangible and intangible capital, such as goodwill)[1] and thus estimates of the market value-R&D relationship will indicate the impact of R&D on firm performance.[2]

Hall (2000) reviewing the literature shows that the return to research and development has been the subject of intensive investigation in the USA, but there have been very few UK studies (these are reviewed in Section II below). The present paper uses a newly created data set that not only refers to the UK but also covers a much more recent period (1989–95) than the limited number of previous UK studies. Moreover, in the sample period the number of UK firms reporting their R&D spend increased considerably, in part because of the introduction of a new code of accounting practice for reporting R&D, SSAP 13 (and some care is taken to address the sample selection issues that result from this) and this "natural experiment" provides a unique opportunity in this context to explore whether "new news" is more valued by the market. The paper uses an existing theoretical framework (Hall, 1993b) that extends the Tobin q model in which the value of companies reflects the market's perception of the flow of future profits and dividends, which in turn are partly driven by firms' tangible and partly by their intangible assets, and in particular the stock of "innovative" knowledge i.e. the intangible assets created by R&D activity.

The paper is structured as follows. The next section considers the relevant existing literature and generates an estimating equation. Section III discusses the measurement of variables and data. Section IV outlines a number of estimation issues and Section V presents and discusses the results of the estimation. Finally, Section VI provides an overview and draws the main conclusions.

II. Literature and Hypotheses

The basic approach employed in the majority of the relevant literature (see Hall, 1992, 1993a) relates the market value of the company (defined as the value of equity plus debt) to the value of its tangible assets and various measures of its intangible assets. For any time t, and suppressing the time subscript, we define MV_i as the market value of company i. The assets of the

[1]For a more sanguine view of why market value and innovativeness may not be related because of information problems and accounting standards see Amir and Lev (1996) and Lev and Sougiannis (1996).

[2]Whether this is a true measure of the contribution of such assets to company performance is of course dependent on the assumption of capital market efficiency. Although there is a substantial and largely unresolved literature on this issue (e.g. Timmerman, 1994, Satchell and Damant, 1995, Miles, 1993 and 1995) there is a widely held view that capital markets are amongst the more efficient of markets. However it is commonly argued that UK equity markets are short termist in which case the estimated impact of R&D on market value will be a downward biased estimate of the true impact on company performance. This issue is discussed further in section 5.

firm are made up of two parts; tangible assets which are recorded and are measured as part of the total assets of the firm; and intangible assets which largely go unrecorded and do not appear in the accounts as part of total assets. The book values of the various recorded assets are defined as A_{ji}, where $j = 1...m$ and $\Sigma_j A_{ji} = A_i$ is the total value of such assets for the ith company. The corresponding measures of the value of the unrecorded assets are defined as K_{hi}, $h = 1...n$. Hall (1992) then writes that,

$$MV_i = q_i[A_{1i} + \phi_2 A_{2i} + \cdots + \phi_m A_{mi} + \mu_1 K_{1i} + \mu_2 K_{2i} + \cdots + \mu_n K_{ni}]^{\sigma} \tag{1}$$

where σ measures departures from constant returns to scale and market efficiency considerations should guarantee that it be unity in the long run (in cross section) and q_i is analogous to Tobin's q, corresponding exactly when σ is unity and there is only one asset.

Dividing within the parentheses of equation (1) by A_i, using the approximation[3] that $\log(1+\eta) = \eta$, and allowing that any disturbance or error term in equation (1) is multiplicative, yields an estimating equation of the following form:

$$\log MV_i = \log q_i + \sigma\left[\log A_i + (\phi_2 - 1)\left(\frac{A_{2i}}{A_i}\right) + \cdots + (\phi_m - 1)\left(\frac{A_{mi}}{A_i}\right) + \mu_1\left(\frac{K_{1i}}{A_i}\right) + \cdots + \mu_n\left(\frac{K_{ni}}{A_i}\right)\right] + \varepsilon_i \tag{2}$$

here ε_i is a normally distributed error term. As Hall (1992) points out, given that σ should take the value of unity, "... the parameters multiplying the stocks that are included in A_i represents the premium (or discount) appropriate for those stocks whereas the parameters multiplying the left out stocks (K_{hi}) is the entire shadow price of those stocks." Given Tobin's q is expected to take a value of unity in long run equilibrium, then, in such an equilibrium, $\log q_i$ will take a value of zero.

A large number of theoretical and empirical variants on the basic model have been explored in the literature, mainly using US data, however, as Hall (2000) has already reviewed this literature, here we focus more on the relatively small number of UK studies. It is however worth starting with Hall's work on the US.

Hall (1993a) reports the results of both pooled and cross section estimates of equation (2), based upon a sample of 2480 US companies over the period 1973–91. A_i is measured by the book value of tangible assets and the K_h are

[3] Hall (1992) points out the size of the errors that can be introduced through this approximation. In the estimation below we have checked whether omitting the approximation and using nonlinear least squares has any significant effect on our results. We find that it does not.

represented by R&D flows (expenditures) or stocks (constructed using an assumed, constant, 15 percent per annum rate of depreciation) and advertising expenditure (proxying for the generation of brand values). In addition, she also includes a two year moving average of cash flow (net of R&D and advertising expenditures) and the growth rate of sales in the current year (as a proxy for future growth prospects). She finds that R&D has a significant positive impact upon market value, however, over time the returns to R&D fell away sharply (the coefficient on the flow R&D/total asset ratio varies from approximately 6 in 1973, rising to 8 in 1979, before falling away to 2 in 1991). This decline in the contribution of R&D is a result that is confirmed by other approaches and explored further in a subsequent paper (Hall, 1993b).

Hall does not include a patent variable in her market valuation equation although there is a significant literature that relates market valuation to patenting activity. Griliches (1990, pp. 1679–88) contains a useful review of the earlier literature. Griliches *et al*. (1991) explore whether there is additional information on the rate and output of inventing activity in patent numbers above and beyond that already contained in R&D expenditure data. Except in the pharmaceutical industry, they find little evidence of such a "second factor".[4] However, more recent work in the US attempts to include weightings for patents that in some sense reflect their "importance" and, hence, their value. For example, Hall *et al*. (2000), use patent citations as a proxy for the importance of the knowledge contained in a patent and find that the average number of citations per patent appears to add significantly to the explanation of market value. The results also confirm the highly skewed nature of the importance and commercial value of patents (and hence the "noisiness" of simple patent counts) that are more widely explored in the literature (see, for example, Harhoff *et al*., 1999). Unfortunately, equivalent citation data are not currently accessible from UK or EPO patent data in the same way as for the USA. In the work below therefore, although patents are included we cannot use citations weightings and thus results more like those found by Griliches *et al*. (1991) should be expected.

For the UK, Stoneman and Bosworth (1994) estimated a very similar model to that of Hall (1993), but used a balanced panel data set of 180 UK companies over the period 1984–92. The principal differences were the omission of an advertising variable (given the degree of under-reporting of this variable in UK company accounts), but the inclusion of patent grants and investment in physical capital (to reflect innovation assets generated by the use as opposed to the generation of technology) as regressors. In general, the results suggested that innovative activity and R&D in particular impacted

[4]Bosworth and Mahdian (1999) find evidence that R&D, patents and trademarks all play a significant role in explaining the market value of UK pharmaceutical companies.

positively on market value, but R&D and patents did broadly the same job, with patents the "noisier" of the two measures.

The study by Blundell *et al.* (1999) is built around equation (2) but measures innovative activity of the firm by a count of innovations taken from the SPRU innovation database, rather than the R&D and patent count variables (although patent count data is used in a variant). The time period covered terminates in the early 1980s making the study somewhat historical from a current perspective. In addition to the innovation variable(s), the market value equation includes market share, concentration, import penetration and union density variables. The authors also undertake some "new news" explorations. The results suggest that the innovation variables have a significant positive impact on market value. The authors particularly emphasize the fact that a variable interacting market share with innovations generally carries a positive and significant coefficient and, as such, "... innovations of high market share firms receive a greater value on the stock exchange".

Following the studies of Connolly and Hirshey (1984, 1990) for the US, one of the few other UK studies, that of Green *et al.* (1996), explored a variant of equation (2), writing the model in terms of a dependent variable reflecting the difference between market value and the book value of assets. They provide cross section and pooled estimates using UK data for 1990, 1991 and 1992. However, no specific methods are employed to deal with issues of sample selection bias (see below). In addition to R&D, their model allows excess market value to be affected by market share, concentration, the debt-equity ratio of the firm and industry (and its square) and the annual variability of stock market returns. The variables other than R&D are found to have little impact on excess market valuation and even the findings on the impact of R&D are somewhat guarded. They state, "... it would be difficult to accuse the market of totally ignoring the valuation relevance of past R&D expenditures".

On the basis of these previous studies we write an expanded version of equation (2) as (3) below. Equation (3) contains four groups of explanatory variables (a) those carrying α and γ parameters and referring to the determinants of Tobin's q, these being the firms debt equity ratio (DEBTEQ), the change in log of sales of the firm (dlogS), the firm's market share (MS), a constant, and industry specific (and in the panel data estimates, firm specific) effects ($\Sigma\alpha_k I_k$) to pick up the impact of other relevant factors such as imports, concentration and union density[5]; (b) those carrying β parameters and referring to the level and composition of the book value of assets, these being the log of the book value of measured assets logA, a separate term reflecting the ratio of the firm's financial to total assets, FIN/A, and a term in the ratio of

[5]Including risk, the one variable not included here but commonly found in the US studies reviewed by Hall (2000) although not by Hall (1993a,b) herself.

cash flow to A_i, CF/A, as suggested by Hall (a finer disaggregation of A_i was not possible from our data sources); (c) those carrying τ parameters and referring to innovation assets, in particular, the ratio to A_i of R&D, RD/A, patents, PAT/A, and the change in tangible fixed assets (net investment), Dtfa/A; (d) a final term which reflects the earlier findings of Blundell *et al.* (1999), in the form of a cross product term between market share and the R&D of the firm, MSRD.

$$\log \mathrm{MV_i} = \sum \alpha_k \mathrm{I_k} + \beta_1 \log \mathrm{A_i} + \beta_2(\mathrm{FIN/A})_i + \beta_3(\mathrm{CF/A})_i + \gamma_1 \mathrm{DEBTE\ Q}_{i,-1} + \gamma_2 \mathrm{d} \log \mathrm{S_I} + \gamma_3 \mathrm{MS_i} + \tau_1(\mathrm{RD/A})_i + \tau_2(\mathrm{PAT/A})_i + \tau_3(\mathrm{dTFA/A})_i + \delta \mathrm{MSRD_i} + \varepsilon_i \quad (3)$$

The industry specific constant term can be interpreted as a value of (the log of) Tobin's q (see the discussion relating to Hall, 1992 and 1993a above) when γ_1DEBTEQ$_I$ +γ_2DlogS$_i$ + γ_3MS$_i$ (plus possibly δMSRD) is zero and thus the value relative to unity is of some interest. Previous results suggest that γ_2 and γ_3 should be positive but there is no definite prediction on the sign of γ_1. The coefficient on logA equals σ and as stated above should be unity in the long run. τ_1 is predicted on the basis of past results to be positive and will reflect the shadow prices of R&D stocks, whereas τ_2 may on the basis of past work be positive or negative. It is expected that τ_3 will be positive. The coefficient on MSRD, based on the work of Blundell *et al.* (1990), should be positive.[6]

The innovation related variables included in this are measured as flows. There are several reasons for this. First, as Hall (1993a, b) and Stoneman and Bosworth (1994) point out, it actually makes very little difference to the estimates which is used. Second, it is not immediately clear that the standard procedure of applying an assumed fixed depreciation rate to the flows (usually 15 percent per annum) in order to generate the stocks is much improvement on using flows in a world where depreciation rates may well be endogenous (Bosworth, 1996). Third, the nature of the data we have is that for many firms the time period over which R&D is reported is too short for the calculation of R&D stocks and, as such, the use of flows is the only course open to us.

There is no legal requirement for UK companies to separately declare their R&D expenditures, but the introduction of a new recommendation of

[6]In addition, we have experimented with the inclusion of terms that measure the R&D intensity of the industry in which the firm is located. Such variables were included in order to pick up possible spill-over effects of innovation from one firm to another or, alternatively, competitive effects between firms or, finally, analysts' valuation of companies on the basis of their R&D intensity relative to that of other firms in the industry. A number of studies in the literature have suggested that such effects may be important e.g. Jaffe (1986) and Megna and Klock (1990). In our own results, however, the inclusion of such variables did not improve the performance of the specification (a result broadly consistent with Geroski (1994), which reports a lack of apparent spillover effects in the UK) and, thus, such terms are not further discussed in this paper.

accounting practice (SSAP13) in 1989 led to a considerable increase in the numbers of firms reporting R&D. The short data runs on R&D reflect the relatively late start dates for the reporting of this variable. The fact that firms can choose whether or not to report R&D raises a number of sample selection issues that we address further below. However, the increasing number of firms that report R&D for the first time within the sample period also opens up an opportunity. In particular, a firm reporting R&D for the first time can be argued to be providing "new news" to the market, information that the market did not previously have (although it may have previously formed expectations on the firm's R&D). Cockburn and Griliches (1988), Blundell *et al*. (1999), Griliches (1981), and Connolly and Hirshey (1990) all find that new news or "unexpected" innovation impacts more upon market value than "old" information.[7]

In the sections below, therefore, two samples are distinguished: the first includes all announcers of R&D at a point in time; the second relates to only those companies that first announce at that time. The first sample generates results that are directly comparable with most of the US literature and especially those of Hall (1992, 1993a) and the second generates results that are more comparable with the "new news" approach. Insofar as the effects of the continuing (future) reporting and conducting of R&D are already discounted in the current firm value and may become subsumed as part of firm fixed effects, the second estimates may more accurately reflect the true impact of R&D on market value.

III. Data

The data set derives from an original sample of 1519 companies taken from Extel's Financial Company Analysis (from which all data was sourced, except that on patents) chosen using the criteria that the companies were: (i) British,[8] with accounts in pounds sterling;[9] and (ii) classified as having their principal activities in the mineral extraction, general manufacturing, consumer goods or utilities sectors. Restricting the sample to quoted companies because of the

[7]A closely related literature (e.g. Zantout and Tsetsekos, 1994) also indicates that "surprise" announcements of increased R&D spending significantly positively impact upon market valuation.

[8]Around 1 in 5 of our companies are likely to be (partially owned) subsidiaries of foreign parents. This raises some issues if the R&D is located in the parent and not in the UK subsidiary for the market value of the subsidiary may be higher because of innovation assets generated outside the subsidiary. Such effects can be picked up to some degree by the firm specific fixed effects in the panel data estimates below, but to the extent that they do exist would tend to bias downwards our direct coefficient estimates of the impact of R&D on market value.

[9]At the time of constructing the sample, very few companies reported their UK accounts other than in pounds sterling, and it was not clear why a small number of companies chose to report in other currencies. More recently, however, some large companies have started to report in either US$ or Euros – so we would not apply such a restriction when up-dating the data.

TABLE 1

Descriptive Statistics

Variable	*Whole sample*	*Announcers of R&D*	*First announcers of R&D*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*
logMV natural log of market value (in 1000 000 GBP)	11,018	12,116	11,522	10,922	10,828	10,864	10,917	11,144	11,082	11,935
	(2,000)	(2,1044)	(1,824)	(1,956)	(1,974)	(2,011)	(2,085)	(1,999)	(1,933)	(1,997)
logA natural log of the accounting value of total assets (in 1000 000 GBP)	11,072	12,041	11,476	10,967	11,028	11,027	11,034	11,059	11,074	11,355
	(1,912)	(2,092)	(1,801)	(1,896)	(1,908)	(1,909)	(1,945)	(1,900)	(1,889)	(1,927)
Rddum (1 if firm reports R&D, 0 otherwise)	0,350	1,000	1,000	0,271	0,322	0,342	0,359	0,378	0,373	0,399
RD/A R&D spending divided by total assets	0,012	0,033	0,023	0,005	0,007	0,008	0,008	0,010	0,012	0,013
	(0,171)	(0,2885)	(0,040)	(0,014)	(0,016)	(0,023)	(0,025)	(0,030)	(0,034)	(0,040)
CF/A cash flow divided by total assets	1,090	1,032	0,860	0,837	1,012	1,168	1,236	1,155	1,082	1,093
	(0,937)	(0,748)	(0,900)	(0,742)	(0,755)	(0,908)	(1,003)	(1,036)	(1,049)	(0,894)
FIN/A financial assets divided by total assets	0,123	0,059	0,053	0,089	0,085	0,075	0,092	0,089	0,296	0,100
	(2,558)	(0,149)	(0,148)	(0,393)	(0,358)	(0,280)	(0,391)	(0,430)	(6,142)	(0,481)
dTFA/A change in tangible fixed assets divided by total assets	0,023	0,019	0,029	0,049	0,026	0,012	0,019	0,008	0,023	0,030
	(0,112)	(0,087)	(0,088)	(0,124)	(0,090)	(0,116)	(0,121)	(0,112)	(0,117)	(0,096)
$DEBTEQ_{-1}$ value of debt divided by the stock market value of the firm in year *t*−*1*	0,234	0,206	0,205	0,208	0,268	0,262	0,271	0,213	0,209	0,209
	(0,198)	(0,161)	(0,169)	(0,162)	(0,203)	(0,212)	(0,229)	(0,191)	(0,179)	(0,183)
dlogS two year moving average change in log(Sales)	0,109	0,095	0,143	0,147	0,092	0,028	0,141	0,067	0,179	0,106
	(0,667)	(0,449)	(0,960)	(0,396)	(0,451)	(0,407)	(1,088)	(0,405)	(0,989)	(0,208)
$INDREPR_{-1}$ proportion of firms in firm *i*'s industry that disclose their R&D spending in year *t* − *1*	0,322	0,449	0,316	0,171	0,287	0,320	0,359	0,360	0,375	0,379
	(0,219)	(0,204)	(0,181)	(0,145)	(0,199)	(0,194)	(0,226)	(0,227)	(0,227)	(0,236)

MS market share	0,032	0,066	0,038	0,035	0,034	0,032	0,032	0,030	0,027	0,040
	(0,098)	(0,150)	(0,087)	(0,108)	(0,103)	(0,097)	(0,096)	(0,09)	(0,084)	(0,110)
MSRD interaction between	0,003	0,008	0,003	0,002	0,002	0,003	0,006	0,004	0,004	0,003
MS and R&D/A	(0,027)	(0,045)	(0,016)	(0,012)	(0,012)	(0,018)	(0,049)	(0,026)	(0,028)	(0,023)
RDind/A average *RD/A*	0,111	0,157	0,129	0,043	0,067	0,080	0,247	0,104	0,116	0,106
for those firms in firm *i*'s industry that disclose their R&D	(0,278)	(0,257)	(0,239)	(0,057)	(0,078)	(0,113)	(0,610)	(0,170)	(0,195)	(0,195)
SALES (1 000 000 GBP)	106,169	156,390	135,284	98,495	105,117	103,150	104,978	108,314	106,851	117,256
	(175,174)	(229,622)	(190,638)	(158,864)	(175,423)	(172,025)	(174,936)	(181,642)	(177,349)	(183,939)
TFA/S total fixed assets	0,851	0,476	0,471	0,725	0,959	0,627	0,814	1,481	0,644	0,628
divided by sales	(9,994)	(0,709)	(0,677)	(5,318)	(10,279)	(1,086)	(5,333)	(22,044)	(1,422)	(1,552)
W/S total wage bill of the	0,127	0,251	0,150	0,0938	0,113	0,123	0,127	0,134	0,134	0,167
firm divided by sales	(0,431)	(0,587)	(0,448)	(0,326)	(0,375)	(0,414)	(0,429)	(0,467)	(0,461)	(0,508)
PATdum 1 if data on the number of patents of the firm, 0 otherwise	0,831	0,892	0,818	0,873	0,871	0,862	0,846	0,821	0,773	0,775
PAT the number of	2,065	4,794	3,899	2,902	2,370	2,226	2,089	1,727	1,624	1,669
patent applications filed at the UK patent office in year *t*	(10,925)	(15,470)	(19,996)	(16,407)	(12,810)	(11,726)	(10,957)	(8,576)	(7,780)	(5,341)
PAT/A	0,0008	0,0013	0,0013	0,0011	0,0009	0,0008	0,0060	0,0008	0,0009	0,0005
	(0,0031)	(0,0040)	(0,0033)	(0,0033)	(0,0027)	(0,0025)	(0,0487)	(0,0032)	(0,0042)	(0,0019)
Number of announcers of R&D	1729	1729	225	169	220	243	237	293	313	229
Number of first announcers of R&D	225	225	225	84	44	23	24	30	13	7
Number of observations	4939	1729	225	622	683	711	728	780	840	574

NOTE: numbers reported are mean and (standard deviation).

need to construct market values, reduced the number of firms to 890. A further reduction to 877 occurred because of missing data (i.e., missing explanatory variables other than R&D and patents).

Data were collected for the period 1988–95, although our estimation period starts in 1989 (the 1988 data enabled first differences to be calculated for 1989). There are too few firms declaring their R&D spend prior to 1988 to make it worthwhile extending the data collection exercise to earlier periods. Of the 877 firms, annual samples varied between 574 and 840 as detailed in the descriptive statistics presented in Table 1, with a pooled sample over the whole period of 4939. Comparison of the cross sectional descriptive statistics suggests that, although the sample changes quite substantially over the years, its statistical properties stay very much the same.

The proportion of firms in the sample that disclose their R&D spending increases over time from 28 percent in 1989 to 40 percent in 1995. The decision to declare R&D appears to be irreversible (see Toivanen and Stoneman, 2001). The number of new announcers in each sample year peaks at 84 in 1989, the year SSAP13 came into effect, and then falls away through 44 in 1990 to only 7 in 1995.

Market value is defined as the (nominal) value of the firm's equity as of December 31st, plus the value of its debt. Primarily because of the short data series, total assets are measured by their book value instead of using a constructed value based on an (*ad hoc*) depreciation formula as in Hall (1993a, b) and Blundell *et al.* (1999). However, these authors report that, in practice, there is no significant difference between the two measures. From the descriptive statistics, it is clear that $\log MV_i$ and $\log A_i$ are very closely correlated. Indeed, for any of the sub-samples that we have used, the difference between the two is insignificantly different from zero. This is a fact that will be reflected in the results reported below.

For firms reporting R&D, the R&D to assets ratio is around 1 percent on average, but with large variation over firms and years. The investment variable is calculated as the change in the value of the tangible assets of the firm. The value of the average firm's investment to assets ratio is 2 percent, but, as in the case of R&D, there is again substantial variation across firms and over time. For each year we have patent data for more than 80 percent of firms and, for those firms undertaking patenting, the average number of patents applied for is just over 2 per annum, with little temporal but a wide cross section variation.

We have information on the main industry of every firm based upon its principal product, and have created industry dummies using this information.[10]

[10]A large proportion of the firms operate in several industries, but we were not able to compile detailed data on how a given firm's sales are spread over industries.

Average market share is low at 3 percent.[11] The firms are large, however, with average annual sales of over £100 million, and also grow rapidly, at an average rate of 10 percent per annum (in nominal terms). The debt-equity ratio is on average 23 percent and the share of financial assets in all assets (FIN/A) 12 percent. The moving average of cash flow is very close to unity.

IV. Econometric Methodology

It is clearly only possible to estimate the market value equation at any point for those firms on which data is available on both R&D expenditure and patents at that time. The key issue that this raises is that, if the provision of R&D data or patent statistics is a choice variable for the firm and thus endogenous, unless some means is adopted to account for this, the estimates of the market value equation may exhibit sample selection bias. We have already argued that announcing R&D is an endogenous variable, however, the missing patent statistics are much more an issue of data source coverage rather than firms choosing not to declare such statistics. Although we have explored modelling in which patent data availability is treated as endogenous in the same way as we treat R&D data availability, we find that the introduction of this further complexity does not affect our market value equation estimates and thus firms for which patent data are not available are simply omitted from the sample used to estimate the market value equations.

Past work on the estimation of market value equations has generated both yearly cross section estimates (Hall 1993a, b) and panel (pooled time series cross section) estimates (Hall 1993a, b and Blundell *et al*., 1999) and both types are also produced here. The cross section approach has the advantage of enabling all parameters to differ across time and for tests to be carried out to see if sample selection biases exist. For the panel, there are problems of determining the appropriate estimation method in the presence of sample selection bias.[12] Fortunately, our cross section estimates suggest that sample selection effects do not appear to be significant, and thus in generating the panel data estimates we have decided to not explicitly take account of sample selection problems, allowing instead that the fixed effects included in the estimation will account for sample selection issues. The opportunity to include firm fixed effects is of course a general advantage of the panel data approach.

[11]Market share of firm i in period t is defined as firm i's proportion of industry sales in period t, within our sample.

[12]The one existing method for estimating panel data models with endogenous sample selection (Kyradzidiou, 1997) relies on first differencing the data. However as is well known, the signal to noise ratio in variables such as R&D is low and thus first differencing leads to a loss of information.

The sample selection issue in the cross section estimates is addressed using the standard Heckman (1979) sample selection model (see, for example, Greene, 1993). Thus for each annual cross section sample we estimate a first stage probit model in which the dependent variable is (1,0), reflecting whether (or not) the unit of observation is included in the market value estimating equation (i.e. whether R&D is reported or not). From this probit model we calculate the Mills ratio for each observation. The inverse of the Mills ratio, MILLS, is then included as an explanatory variable in the second stage market value estimation.

Building upon Toivanen and Stoneman (2001) the first stage probit model used here includes as explanatory variables: total sales; the ratio of tangible fixed assets to sales; the ratio of the wage bill to sales; and the lagged proportion of firms in the same industry already disclosing their R&D. In order to save space we do not report the results of these estimates, although they are available from the authors upon request. In Table 2, we present data on the forecasting accuracy of the model by reporting a statistic "CORRECT" which details the percentage of the sample whose reporting behaviour in each year is correctly predicted by the probit model (this averages about 80 percent).

The final econometric issue is simultaneity. We consider that all but one of the explanatory variables can reasonably be argued to be determined independently of market value, however, the debt equity ratio by definition is not independent of market value and as such it is instrumented by its own lagged value.

The form of the market value equation that we estimate may now be stated as that for each period t:

$$\begin{aligned}\log \mathrm{MV_i} = {} & \sum \alpha_k \mathrm{I_k} + \beta_1 \log \mathrm{A_I} + \beta_2 (\mathrm{FIN/A})_i + \beta_3 (\mathrm{CF/A})_i \\ & + \gamma_1 \mathrm{DEBTE\ Q}_{i,-1} + \gamma_2 \mathrm{d} \log \mathrm{S_i} + \gamma_3 \mathrm{MS_i} + \tau_1 (\mathrm{RD/A})_i \\ & + \tau_2 (\mathrm{PAT/A})_i + \tau_3 (\mathrm{dTFA/A})_i + \delta \mathrm{MSRD_i} + \Omega \mathrm{MILLS_i} + \varepsilon_i\end{aligned}$$

where MILLS is the inverse Mills ratio, as defined above and ε_i is an error term.

V. Empirical Results

Our initial estimates of the market value equation are based upon individual cross-sections for each of the years, 1989–95 and use data on all announcers at each point in time. These estimates are directly comparable with those for the US reported by Hall (1992, 1993a). We then consider estimates of the market value equation for the sample of first announcers only. Finally the panel data results are discussed.

TABLE 2
Cross Sectional Market Value Estimations

	1989	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1989 New announcers*
logA	1.0031***	1,0098***	0.9792	1.0125***	1.0060***	1.0185***	0.9952***	0.9987***
	(0.0136)	(0.0127)	(0.0144)	(0.0167)	(0.0120)	(0.0101)	(0.0153)	(0.0544)
RD/A	0.7818	1.8691	3.5349**	0.0306	3.868***	2.5690**	4.1844***	4.9215**
	(2.0702)	(1.5333)	(1.7653)	(0.1655)	(1.118)	(1.1175)	(1.3428)	(2.3504)
DTFA/A	0.3050	−0.3410	0.3598	1.0859	0.6343	0.3503	0.7818	0.4119
	(0.6675)	(0.4517)	(0.8082)	(0.8792)	(0.7297)	(0.5734)	(0.7918)	(0.6683)
dlogS	0.1983	−0.0104	0.2019	0.6053	0.6659***	0.0645	−0.2242	0.0045
	(0.1648)	(0.0676)	(0.3033)	(0.3890)	(0.2669)	(0.1866)	(0.2641)	(0.1530)
CF/A	0.0202	−0.1477***	−0.0019	0.0277	0.0281	−0.1324**	−0.2733**	−0.0973
	(0.0743)	(0.0561)	(0.0727)	(0.0968)	(0.0706)	(0.0581)	(0.0888)	(0.0862)
DEBTEQ	−1.8878***	0.9983***	−0.6396***	−1.5994***	−0.9976***	−1.6154***	−1.5539***	−0.8377***
	(0.2536)	(0.1814)	(0.2410)	(0.2759)	(0.1808)	(0.2101)	(0.2840)	(0.3052)
FIN/A	0.3293	0.0441	0.0659	0.0178	0.1614	−0.1007	0.5385**	0.0579
	(0.2496)	(0.1489)	(0.2853)	(0.2815)	(0.2872)	(0.2095)	(0.2506)	(0.2440)
PAT/A	1.1625	−0.8751	−0.6602	−0.7049	−1.7066***	0.6166	−0.0005	1.5088
	(1.0726)	(0.8326)	(1.2635)	(1.1643)	(0.6559)	(0.4303)	(0.0005)	(1.3398)
MS	−0.0507	−0.8645***	−0.5606	−0.2459	−0.4207	−0.4085	−0.1535	0.6418
	(0.4420)	(0.3251)	(0.4319)	(0.4435)	(0.3104)	(0.2734)	(0.3677)	(0.5596)
MSRD	−0.2802	8.0921	0.1590	−0.0941	−0.6715	−0.1102	0.2275	30.368
	(8.1657)	(5.5972)	(0.7247)	(0.7562)	(0.6552)	(0.5463)	(0.8326)	(50.264)
Mills	−0.0947	−0.1217	−0.1667	0.0002	−0.0627	−0.0626	−0.0017	−0.0482
	(0.1144)	(0.0809)	(0.1245)	(0.1408)	(0.0999)	(0.0859)	(0.1290)	(0.1523)
logL	−63.7499	−48.2866	−164.0896	−207.9359	−139.1951	−99.3569	−87.0177	9.1072
LR	560.259	811.2722	654.9192	628.0292	822,7602	925.958	649.924	290.427

TABLE 2
(*continued*)

	1989	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1989 new announcers*
Correct	94.48	73.16	79.12	79.74	79.106	80.74	78.92	84.80
Tobin's q	6/17	8/20	11/20	1/19	3/19	7/19	13/20	12/16
Nobs2	162	210	227	238	254	261	191	82

Notes: dependent variable is logMV. Mills is the inverse Mills ratio calculated from the first stage probit estimation.
Numbers given are coefficient and heteroskedasticity robust (standard error).
*** = sign. at the 1% level.
** = sign. at the 5% level.
* = sign. at the 10% level.
LR = a LR test of joint significance of RHS variables.
Correct = the percentage of announcements that are correctly predicted by the first stage probit regression.
Tobin's q = number of industry specific constant terms that are significantly different (5% level) from zero/number of industries.
Nobs2 = number of observations in the second stage.

Cross-section results

The yearly cross section estimates[13] are presented in Table II. We note first that the inverse Mills ratio is never significant in these estimates. Thus, although it is correct to take account of possible sample selection bias, there is no evidence that such bias is a significant problem. The finding can be interpreted as that there is no evidence that the market values firms reporting R&D in a different way than it values non-reporting firms and as a result one may argue that there is no evidence to suggest that firms report (do not report) R&D because they expect a higher (lower) market valuation from this reporting.

The reported results suppress the actual values of the industry specific constant terms in order to save space. The industry specific constant term can be interpreted as a value of (the log of) Tobin's q (see above) when $\gamma_1 DEBTEQ_I + \gamma_2 DlogS_i + \gamma_3 MS_i$ is zero. We report for each year the number of industries that have a constant term significantly different from 0 which varies from 1 in 1992 to 13 in 1995 (all significantly greater than 0). There thus seems to be significant variation both across industries and over time in Tobin's q. Results on Tobin's q have been left unreported in the literature before (see Hall, 1993a, b and Blundell *et al.*, 1999).

Turning to the other three variables considered to affect Tobin's q, the debt equity ratio (with a one period lag) carries a highly significant and negative coefficient each year, with the coefficient value ranging between –0.64 in 1991 and –1.89 in 1989. While Green *et al.* (1996) do not find any significant impact of the debt equity ratio on market value, our results suggest that the market considers that high debt firms will generate a smaller stream of future returns than low debt firms. Unlike Hall (1993a), no consistent evidence is found that firm growth as measured by dlogS positively impacts on market value, the variable only carries a significant (positive) coefficient in 1993. Market share (MS) carries a marginally significant negative coefficient in 1990, but in general it seems not to impact on firm market value. The interaction variable between market share and R&D (MSRD) that plays a prominent role in Blundell *et al.* (1999), never exhibits a significant coefficient. This suggests that there is only weak evidence, if any, for the hypothesis that firms with high market shares can better internalise the gains from R&D.

As regards the measured assets, $logA_i$ always carries a (significant) coefficient that is insignificantly different from unity, which implies that there are constant returns to scale in the valuation equation. This result is not surprising given the finding reported above with regard to the close correlation

[13]We also experimented with estimating the market value equations in first difference form however in general the results were poor. We consider that this is largely because the signal to noise ratio in variables such as R&D is low and the use of first differencing leads to a loss of information.

between A and market value. The ratio of investments in financial assets to total assets never carries a significant coefficient, implying that financial investments do not yield above average returns to the firms in our sample. On the other hand, cash flow divided by total assets, CF/A carries a significant negative coefficient in three years (in 1990, 1994 and 1995). There is no obvious explanation for the sign, which is opposite to that expected (and found by Hall, 1993a) although it is possible that cash flow is a prime determinant of R&D and investment spending and as such its true impact is picked up in the coefficients on these other variables.

Of the variables reflecting innovation assets, the ratio of conventional investments to total assets (dTFA/A) introduced to reflect possible technology acquisition from external sources never carries a significant coefficient and, thus, such investment does not yield above average returns to the firms in this sample. The coefficient on the ratio of flow R&D to total assets, RD/A, varies considerably in size over the years but is consistently positive. It is significantly different from 0 in four years (1991, 1993, 1994 and 1995) and, when significant, the associated coefficient is in the range 2.5–4.2. These estimates are quite close to those of Hall (1993a) for the US where she estimates annual R&D flow coefficients in the range 2–8 with an average over her whole sample period of 2.44. Unlike Hall however we do not find any particular time trend in the size of the parameter on RD/A. As R&D is not generally capitalised into the firm's total measured assets in the UK, the coefficient on RD/A can be taken as a measure of the total contribution of R&D to market value (it should be remembered that the coefficients on the intangible assets are an indication of their gross contributions at the margin, while the corresponding coefficients on tangible assets reflect the excess rate of impact or return at the margin – a markup *vis-à-vis* the average impact of all such assets). However, one might at this point emphasize (as does Hall) that it is possible that measured assets, A_i, does include some capital assets that are used for R&D purposes and as such it is possible that the coefficient on RD/A underestimates the true additional contribution of R&D to firm market value. The third innovation variable included is the ratio of patent applications to assets (PAT/A). This variable is marginally significant in 1993 (with a negative coefficient) but otherwise not significant, although it carries a negative coefficient in five of the seven years (we also experimented with using a lagged patent variable but the results were similar to those reported). Thus, once other assets are included there is no evidence that patents contribute to market value (as per Griliches *et al.*, 1991).

Pursuing the issue of anticipation or "new news" we define, for each year, a sample of firms that are first announcers. Unfortunately the number of such companies is only large enough to represent a statistically acceptable sample for estimating the market value equation in 1989. Table 2 presents the results of this estimation. Now the inclusion of a firm into the sample is conditioned on it not having declared R&D in 1988. Comparing these results with those derived using the sample of all 1989 announcers, the pattern of coefficient signs and significance levels are very similar except that the coefficient on RD/A jumps from 0.782 (with standard error 2.070) to 4.922 (and standard error of 2.350). This is an almost seven-fold increase in value. At the same time the standard error only increases by about 13 percent. As a consequence, the coefficient on RD/A for first announcers is significant at the 5 percent level. As with all 1989 announcers, of the other variables included only logA and DEBTEQ obtain significant coefficients; the former are within one standard deviation of each other, the latter changes from –1.888 for all announcers to –0.838 for first announcers.

The interpretation of the finding that the R&D spend of a newly disclosing firm is more highly valued than the R&D of a firm that has previously disclosed its R&D spend is not obvious. One possibility is that the market thought that firms that did not previously disclose did not undertake R&D and the disclosure of positive R&D spending (i.e. that the firm is technologically active) is a valuable piece of information. This seems however to underplay the market's prior expectations on the activities of new disclosers. A second possibility, which is really only a variant on the first, is that for existing announcers, the latest R&D data only contains a small amount of new information whereas for new announcers there is greater information content. For previous announcers the information content of the latest R&D data is thus already capitalised in to the share price whereas for new announcers much less of the information content of the R&D announcement has been so capitalised. This would tend to generate a greater impact of the R&D spend of new announcers than for existing announcers[14].

Panel Data Set Results

Three sets of panel data estimates are reported in Table 3. The specification in the first column includes firm, but no year dummies; the year dummies have been added in column 2; in column 3 the R&D coefficient, our major interest, is allowed to vary by year. This latter experiment was carried out in the light of the cross section results that suggested that there is year-to-year variation in the R&D coefficient (and in the light of Hall's, 1993a, results for the US). The reported test statistics indicate that the year dummies are jointly significant,

[14]The results present a slight puzzle with respect to "new news". The coefficient on the Mills ratio was insignificantly different from zero in the market valuation equation suggesting that firms that do not declare their R&D spend are valued in a similar manner to those that do. On the other hand, we find that when a firm declares R&D for the first time, the market values this more highly than an equivalent amount of R&D reported year on year. These results do not appear consistent.

TABLE 3
Panel Data Market Value Estimations

	(1)	*(2)*	*(3)*
logA	1.005*** (.001)	0.999*** (.001)	0.998*** (.001)
RD/A	3.830*** (.091)	3.525*** (.093)	–
RD89/A	–	–	2.654*** (.489)
RD90/A	–	–	1.735*** (.100)
RD91/A	–	–	3.371*** (.070)
RD92/A	–	–	3.426*** (.145)
RD93/A	–	–	2.747*** (.100)
RD94/A	–	–	2.811*** (.124)
RD95/A	–	–	6.450*** (.371)
DTFA/A	0.342*** (.030)	0.513*** (.033)	0.472*** (.032)
dlogS	0.133*** (.006)	0.116*** (.006)	0.126*** (.006)
CF/A	−0.038*** (.003)	−0.052*** (.004)	−0.052*** (.003)
DEBTEQ	−1.212*** (.013)	−1.239*** (.015)	−1.242*** (.014)
FIN/A	−074** (.031)	0.103*** (.031)	0.095*** (.002)
PAT/A	−0.320*** (.045)	−0.333*** (.051)	−0.280*** (.044)
MS	−0.049*** (.010)	0.338[a] (10.15)	0.004 (.008)
MSRD	−1.073*** (.373)	−0.549 (.379)	−0.001 (.242)
Nobs	1541	1541	1541
Firm dummies	Yes	Yes	Yes
Time dummies	No	Yes	Yes
R^2	0.943	0.946	0.946
T1	594.91 (42.1498)	545.39 (48,1492)	486.41 (54,1486)
T2	3.760 (32,1499)	3.897 (32,1493)	3.944 (32,1487)
T3	−0.00231	−0.00162	−0.00227
T4	–	12.183 (6,1492)	–

Notes: dependent variable is logMV. Numbers given are coefficient and heteroskedasticity robust (standard error).
*** = sign. at the 1% level.
** = sign. at the 5% level.
* = sign. at the 10% level.
a = coefficient and (s.e.) multiplied by 1000.
T1 = an F test of joint significance of RHS variables (d.f.).
T2 = an F test of joint significance of fixed effects.
T3 = estimated autocorrelation coefficient.
T4 = an F test of joint significance of time dummies.

whereas the null hypothesis of a non time-varying R&D coefficient cannot be rejected at conventional levels. We therefore concentrate on the results in column 2, and provide the other results for comparison purposes.

Generally, the main difference between the cross sectional and panel results is that the latter display markedly more precisely estimated coefficients. The likeliest explanation for this is the dramatically increased number of observations: the largest cross section sample was 261 (in 1994), whereas the panel has 1541 observations. The R^2 for the panel estimates is very high, but this result is primarily driven by the tangible assets variable (logA) on the right hand side. The coefficient on the debt equity ratio variable ($DEBTEQ_{-1}$) is again significantly negative throughout, with a value (-1.24) that is approximately the mean of those which appear in the cross-sectional findings. While the coefficient on the cash flow to assets variable (CF/A) was only significant in three of the years covered by the cross-sectional estimates, in the panel data set results it is highly significant in all three specifications, carrying a negative sign (this still leaves open the issue of interpretation addressed in the discussion of the cross section results). The ratio of financial assets to tangible assets (FIN/A) also plays a significant positive role in the explanation of market value.

The firm growth variable (dlogS) now has a significant positive coefficient (it was only significant in one year in the cross-sectional regressions). This indicates that a 1 percentage point increase in the rate of growth of sales leads to just over a 0.1 percent rise in the market value of the company. The market share variable (MS) and the interaction variable MSRD are insignificant throughout, confirming the results of the cross-sectional estimates.

Again, our principal interest lies in the role played by R&D, patents and investment in the regression. Investment in tangible assets (dTFA/A) carries a positive and very significant coefficient in all three specifications. Current R&D (RD/A) also exhibits a highly significant positive coefficient in all three specifications. When we allowed the R&D coefficient to vary (the p-value of the null hypothesis of no yearly variation in the R&D coefficient is 0.115), we found it to be significant for all years, with values ranging between 1.735 in 1990 and 6.450 in 1995. The coefficient on patents is now significant and negative in all specifications (it was negative in five out of seven the cross-sectional estimations, but only significant at the 10 percent level in one of these). This is consistent with the cross-sectional findings of Bosworth and Stoneman (1994). These results indicate that intangible innovation assets as measured by R&D and gross investment have a significant positive impact upon the market value of UK firms. The negative coefficient on patents we interpret, as do Bosworth and Stoneman (1994), as an indicator of appropriability conditions. The more difficult it is to appropriate returns the lower will be the impact of innovation on market value and the higher will be the level of patenting.

We further experimented with regard to the issue of new news by including an interaction term between an indicator denoting new (old) announcers and RD/A. It was hoped that as the panel data includes firm specific effects, that a positive and significant estimate of the interaction term(s) would confirm a greater impact of new news, the firm specific effects picking up any capitalisation of old news in to market values. In fact the interaction terms never obtained a coefficient that would have been significant at reasonable confidence intervals (p level around 0.8). This may indicate that new news (i.e. the R&D spending of new disclosers) has no extra value over above the data on the R&D spend of existing announcers, however, in our view, the likeliest explanation for the result is the same as that which forced us to estimate the cross section new news model only on 1989 data, i.e., there are very few new announcers in other years (and by implication in the panel).

The cross section and panel results jointly indicate that R&D has a significant and positive impact on firms' market values in the UK, even after taking account of sample selection issues, but that the effect may vary on a yearly basis. However, this still leaves open the possibility that the market is short termist to a degree and as such the estimates of the impact of R&D on market value are downward biased estimates of the true impact of R&D on firm performance. It is essentially impossible to judge whether UK capital markets are short termist. As our estimates of the rate of return to R&D are positive we can say that the market is not "absolutely" short termist, in that it values investment in R&D to some degree, but we have no objective comparator for the correct valuation of R&D and thus we cannot say whether or not the market *relatively* undervalues R&D. As we have already shown, our estimates of the impact of R&D are not out of line with those found by Hall for the US, but to use that as an argument to refute short termism only begs the question as to whether the US also suffers from low valuations of R&D. In fact US and UK financial systems are often considered as similar (being market based as opposed to bank based, see for example Stoneman, 2001) and may thus be similar in short termist attitudes if they do exist. More relevant comparators may be bank based systems (e.g. Germany or Japan) where short termism is considered less likely, however a check in the synthesis of results reported by Hall (2000, pp. 184–5) reveals no comparable results for such countries. The estimates we have produced therefore may be downward biased but we cannot check this in any objective way.

VI. Conclusions

This is one of a small number of studies using UK data which have explored the market valuation of companies' intangible assets, in particular, research and development and patents. A newly constructed data set covering a more recent period than past studies is used and particular attention has been paid to the endogeneity of the firm's decision whether to declare R&D or not, and the potential selection bias to which this decision might give rise. The key result of the paper confirms earlier results for the US – that the market values R&D. However, although the valuation varies year by year we do not find any consistent trend in the valuations of the type reported by Hall for the US. We have found some limited evidence that the market values 'new news' about firms' R&D activities more highly (see Cockburn and Griliches, 1988). In particular, those firms that declared R&D for the first time in 1989 show a greater impact of R&D on market value in that year than those firms who first declared R&D at an earlier date. Problems of sample sizes prevented further conclusive tests of this result using data for other years. We find no evidence to confirm that the market values R&D more highly in firms with larger market shares. We do find that once the impact of R&D is taken into account, patents have a negative impact upon market value. We suggest that this is because patents are acting as an indicator of the difficulties of appropriating the returns to innovation. We find that our other indicator of innovation, gross investment, also has a positive impact upon market value, suggesting that the introduction as well as the generation of new technology is valued by the market. Finally, although the interpretation of the results as a true measure of the impact of R&D on firm performance is still open to the issue of possible short termism in UK capital markets, we at least demonstrate that the coefficients on key variables, such as R&D, are in line with those found in the US.

Date of Receipt of Final Manuscript: November 2001

References

Amir, E. and Lev, B. (1996). 'Value-Relevance of Non-Financial Information: the Wireless Communications Industry', *Journal of Accounting and Economics*, Vol. 22, pp. 3–30.

Blundell, R., Griffith, R. and Van Reenan, J. (1999). 'Market Share, Market Value and Innovation in a Panel of British Manufacturing Firms', *Review of Economic Studies*, Vol. 66, pp. 529–554.

Bosworth, D. L. (1996). 'Black Boxes and Russian Dolls: a Research Agenda for the Measurement and Modelling of Firm Performance', Paper given at the *Invention and Growth Symposium*, UMIST, in honour of a visit by Richard Lipsey.

Bosworth, D. L. and Mahdian, H. (1999). 'Returns to Intellectual Property in the Pharmaceuticals Sector', *Economie Appliquè*, Vol. LII, pp. 69–93.

Cockburn, I. and Griliches, Z. (1988). 'Industry Effects and Appropriability Measures in the Stock Market's Valuation of R&D and Patents', *American Economic Review*, Papers and Proceedings. Vol. 78, pp. 419–23.

Connolly, H. A. and Hirshey, A. L. (1984). 'R&D, Market Structure and Profits: a Value-based Approach', *Review of Economics and Statistics*, Vol. 66, pp. 682–86.

Connolly, H. A. and Hirshey, A. L. (1990). 'Firm Size and R&D Effectiveness', *Economic Letters*, Vol. 37, pp. 277–81.

Geroski, P. A. (1994). *Market Structure, Corporate Performance and Innovative Activity*, Clarendon Press, Oxford.

Green, J. P., Stark, A. W. and Thomas, H. M. (1996). 'UK Evidence of the Market Valuation of Research and Development Expenditures', *Journal of Business Finance and Accounting*, Vol. 23, pp. 191–216.

Greene, W. H. (1993). *Econometric Analysis*, Prentice Hall, Englewood Cliffs, NJ.

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

Griliches, Z. (1990). 'Patent Statistics as Economic Indicators', *Journal of Economic Literature*, Vol. XXVIII, pp. 1661–1707.

Griliches, Z. (1992). 'The Search for R&D Spillovers', *Scandinavian Journal of Economics*, Vol. 94, pp. 29–47.

Griliches, Z. (1995). 'R&D and Productivity: Econometric Results and Measurement Issues', in Stoneman, P. (ed.), *Handbook of the Economics of Innovation and Technological Change*, Oxford: Blackwell, pp. 52–89.

Griliches, Z., Hall, B and Pakes, A (1991). 'R&D, Patents and Market Value revisited: Is there a second (technological opportunity factor)', *Economics of Innovation and New Technology*, Vol. 1, pp. 183–202.

Hall, B. H. (1992). 'The Value of Intangible Corporate Assets: an Empirical Study of the Components of Tobin's Q', Working Paper No. 93–207. Hoover Institution, Stanford University; University of California at Berkeley; and National Bureau of Economic Research.

Hall, B. H. (1993a). 'The Stock Market's Valuation of R&D Investment During the 1980s'. *American Economic Review*, Papers and Proceedings. Vol. 83, pp. 259–64.

Hall, B. H. (1993b). 'Industrial Research During the 1980s: did the Rate of Return Fall?', *Brookings Papers: Microeconomics*, Vol. 2, pp. 289–343.

Hall, B. H. (2000). 'Innovation and Market Value', in Barrell, R., Mason, G. and O'Mahony, M. (eds), *Productivity, Innovation and Economic Performance*, Cambridge University Press: Cambridge, pp. 177–98.

Hall, B. H., Jaffe, A. and Trajtenberg, M. (2000). 'Market Value and Patent Citations: a First Look', Working paper 7741. National Bureau of Economic Research, Cambridge, MA.

Harhoff, D., Narin, F., Scherer, F. M. and Vopel, K. (1999). 'Citation Frequency and the Value of Patented Inventions', *Review of Economics and Statistics*, Vol. 81, pp. 511–15.

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

Jaffe, A. (1986). 'Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Value', *American Economic Review*, Vol. 76, pp. 984–1002.

Kyradzidou, E. (1997). 'Estimation of a Panel Data Sample Selection Model', *Econometrica*, Vol. 65, pp. 1335–64.

Lev, B. and Sougiannis, T. (1996). 'The Capitalisation, Amortisation and Value-Relevance of R&D.', *Journal of Accounting and Economics*, Vol. 21, pp. 107–38.

Megna, P. and Klock, M. (l993). 'The Impact of Intangible Capital on Tobin's q in the Semiconductor Industry', *American Economics Association, Papers and Proceedings*, Vol. 83, pp. 265–69.

Mairesse, J. and Mohen, P. (1996). 'R&D-Productivity Growth: What Have We Learned from Econometric Studies?', *Proceedings of the EUNETIC Conference on Evolutionary Economics of Technological Change: Assessment of Results and New Frontiers*, Strasbourg, October 1994, pp. 817–88.

Miles, D. (1993). 'Testing for Short-termism in the UK Stock Market'. *Economic Journal*, Vol. 103, pp. 1379–93.

Miles, D. (1995). 'Testing for Short-termism in the UK Stock Market: a Reply', *Economic Journal*, Vol. 105, pp. 1224–7.

Pakes, A. (1995). 'On Patents, R&D and the Stock Market rate of Return', *Journal of Political Economy*, Vol. 93, 390–409.

Satchell, S. E. and Damant, D. C. (1995). 'Testing for Short Termism in the UK Stock Market: a Comment', *Economic Journal*, Vol. 105, pp. 1218–23.

Stoneman, P. and Bosworth, D. (1994) with Stoy Hayward Consulting. *Feasibility Study for the Development of an Innovation Scoreboard*. Final Report to the Department of Trade and Industry, London.

Stoneman, P. (2001). 'The European Financial Environment', presented at the Second Project Workshop, European Integration, Financial Systems and Economic Performance, Rome, 19–20 October.

Timmerman, A. (1994). 'Can Agents Learn to Form Rational Expectations? Some Results on Content and Stability of Learning in the UK Stock Market', *Economic Journal*, Vol. 104, pp. 777–97.

Toivanen, O. and Stoneman, P. (2001). 'The impact of SSAP13 on R&D Disclosure by UK Firms, 1984–1994', *International Journal of Economics and Business*, Vol. 8, pp. 127–40.

Zantout, Z. Z. and Tsetsekos, G. P. (1994). 'The Wealth Effects of Announcements of R&D Expenditure Increases', *Journal of Financial Research*, Vol. 17, pp. 205–16.