Innovation and Performance: a Selective Review of the Evolution of one Area of Research – the Market Valuation Literature

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Abstract. This contribution examines the evolution of one area of the innovation and performance literature – the market valuation of intangible assets. This was chosen because it was initiated in the UK by a DTI funded project carried out by Paul Stoneman and myself. The paper outlines the areas of research out of which the market valuation literature evolved, it discusses how the market valuation literature has developed since Griliches' pioneering work in 1981 and outlines a number of areas that need further research, especially if the results are to be of more use to the strategic decision making of managers. The paper is not intended to be a comprehensive review of the literature, but uses particular references to illustrate the points being made.

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1. Introduction

I have chosen this topic because DTI were instrumental in initiating this line of research in the UK. The contribution attempts to set the line of work that stemmed from the DTI project into the context of the broader development of the literature. This literature relates the market value (MV) of the firm to the replacement book value of tangible assets, discretionary investments (e.g. R&D and advertising expenditures) and intangible assets that arise from such investments (e.g. patents, trade marks, etc.). The literature has a long history and this is a rather personal and idiosyncratic account of where it has got to and what areas of research still need investigating.

Section 2 outlines the beginnings of the MV literature, and the earlier lines of research that it drew upon. Section 3 considers the main lines of development in more recent years, including functional form, sectoral and cross-country comparisons, missing variables and the skewed distribution of returns. Section 4 provides the main conclusions, including a brief review of the need for further research.

2. The beginnings of the Market Valuation Literature

The MV literature evolved as a coming together of a number of major areas of on-going research. One was the Tobin q literature, in which net investment depends upon the ratio of the market value of the company to the replacement value – the so-called "q" (Tobin, 1969). Another was the literature is that of the measurement of technological change, and the associated debate about the relationship between patent counts, invention and innovation. The patent count literature had been driven by a large number of papers by Schmookler, culminating in his 1966 book (Schmookler, 1966). Although Schmookler was not the first to use these statistics, he was the first to do so systematically and apply econometric techniques.[1]

It was Griliches (1981) seminal paper that linked these various areas of research, which led to a spate of subsequent work either using Tobin's "q" as the dependent variable or MV as the dependent variable with the replacement value of assets as an explanatory variable.[2] The underlying idea was simple – that differences in "q" should be driven by the intangible assets of the firm, which, in turn, would be the result of activities such as research and development (R&D). Griliches' paper was all the more remarkable because it argued that the market would have already accounted for the anticipated levels of R&D or patents of the company, which would

[1] The early development of this literature and the debate surrounding it is discussed in detail in Bosworth (1987).

[2] For reviews of the literature see Hall (2000) and Bosworth (2005, pp. 183-209).

enter as a firm fixed effect.[3] What Griliches (1984) showed was that it was the unanticipated ("surprise") changes in the intangibles that influenced MV, rather than the anticipated – something supported by almost all subsequent studies.

The link with John Barber and the DTI is that it was John's group at DTI that funded, as far as we know, the first work on this form of empirical work in the UK. The DTI wanted "catchall" measures of both the extent of innovative activity and the success of innovative activity. Paul Stoneman had the idea of using the MV equation to produce these measures. The weighted sum of the contribution of R&D and patents to the explanation of MV was to represent the extent of innovation, and the remaining residual error was to represent the success of innovation. Our work together on this showed that both the extent of innovation and the success of innovation were skewed right, with: a small proportion of companies undertaking a large proportion of the innovatory activity and a large proportion undertaking little or no such activity; a small proportion of companies being very successful and a large proportion relatively unsuccessful (Stoneman and Bosworth, 1994). As we will see below, other work came to this conclusion by other, different routes.

The scoreboard was never produced in the UK. Christine Greenhalgh and Mark Rogers produced a scoreboard for the UK Patent Office, but I understand that it has not been published as such. However, discussions with Peter Dawkins, then Director of the Melbourne Institute for Economic and Social Research, led to Mark Rogers developing the idea for Australia. This was published both as a Melbourne Institute report (MIAESR, annual) and by Business Week in Australia. It has become an annual feature that now allows the reader to track changes in the extent of innovative activity over time (but not the success of innovative activity) (MIAESR, annual).

The DTI funded project was not lost, however, as an ESRC funded further work on the evaluation of the MV approach, followed by Leverhulme, UK Patent Office and further ESRC funding. The work was taken over my Greenhalgh and Rogers, working out of OIPRC, details of which can be found on the OIPRC website.[4] Other research groups around the country, such as SPRU and IFS, developed similar, company-level panel data sets, although each has somewhat different characteristics.

Before leaving this discussion of the background, it is worth noting that there is a parallel literature which uses a production function approach. In this, real output is regressed on tangible inputs (e.g. physical capital and labour) and past investments in intangible assets (e.g. past R&D), which is either amortised or allowed to enter with a lag structure. In effect, writing the equation in a somewhat different way, total factor productivity is regressed on past discretionary investments in future performance. Bosworth and Garneh (1996) showed that, under certain

[3] The latter is something we subsequently demonstrated using the Oxford Intellectual Property Research Centre UK panel data set (Bosworth, *et al*. 2000; Greehalgh, *et al*. 2001).
[4] www.oiprc.ox.ac.uk.

assumptions, the two approaches should give identical results. Greenhalgh and Rogers (2005a) produce some interesting empirical results using trade marks as the IP variable, where trade mark activity proxies for a range of unobservable firm-level characteristics that raise the level of productivity. The paper also finds that higher trade mark intensity for manufacturing firms is associated with more rapid rate of growth in productivity, although there is no significant association for service sector firms.

3. Developments in the Literature

3.1 Role of Large-scale, Micro-level Datasets

This literature owes a great deal to the development of large-scale, micro databases. When I began similar work on UK IP statistics in 1969 for my MSc and, then, MPhil dissertations, this involved traveling regularly from Warwick University to the British Library in London and manually collecting the data. Now we have access to massive on-line, global, IP databases at virtually zero cost, which, with some ingenuity can be electronically matched to financial and other relevant data. Griliches' (1984) work was really at the fairly early stage of this new large-scale data set era, which has mushroomed ever since. Bronwyn Hall's work, along with a number of other US colleagues has been an important stimulus in both developing these large scale data sets and making them available to other academic users, as well as taking forward the work of Griliches in new ways (e.g. Hall, 1993).

There are three lines of development that I will deal with here, none of which are yet completed: (i) functional form; (ii) sectoral analyses and cross-country comparisons; (iii) explanatory variables; (iv) skewed distributions.

3.2 Functional form

The functional form estimated by the early literature was based upon an accounting tautology. The functional form, which was non-linear was generally replaced by a linear approximation, perhaps best described by Bronwyn Hall (1992, pp. 6-8). This was a worry in the sense that, the higher the relative importance of R&D or other intangible assets, the poorer the approximation. However, subsequently there have been a number of studies that directly estimate the non-linear form (e.g. Czarnitzki, *et al*. 2006), but often such studies did not reveal substantial differences despite the problems with the approximation. Nevertheless, there appears some way to go in terms of functional form. In particular, the broader firm performance literature stresses the importance of various kinds of synergies between the influences on performance (Bosworth, 2005). This suggests that ideally some flexible functional form should be estimated, although the need to estimate the equivalent to the production function (because of the absence of measures for the dual cost function) make this cumbersome and the degree of flexibility may be restricted.

One of the important features of a number of the empirical studies has been the estimation of spillover effects – the benefit that each firm receives freely from the general pool of all R&D undertaken in the areas of technology relevant to those firms (Griliches, 1992). However, given the lack of data currently available on licensing, patent-pooling (where payments are made)[5], and the like, a number of authors are not convinced that these benefits are entirely or even mostly costless, with implications for public support for R&D (Bosworth, 2005, p.197). This is an area where further research, perhaps of a case study or survey nature is required. One other item should be considered in terms of the possible functional form to be estimated – very few studies have looked at the effects of competitor R&D on firm performance (Bosworth, 2005, pp.185-186). This is important because when a competitor makes a significant technological breakthrough, the counterfactual for the firm, other things being equal, is unlikely to be the status quo, but reduced MV. Proper testing of this hypothesis requires re-specification of the model.

3.3 Sectoral Analyses and Cross-country Comparisons

There have been two fairly recent and important developments in the literature regarding the focus of the MV studies. One has been the estimation of MV equations for different sectors or groups of sectors (e.g. by level of technology) and the other has been the comparison of MV equations across countries. While there have been previous examples of investigation of individual sectors (e.g. Megna and Klock, 1993), the more recent work has tended to compare results across sectors. Likewise, while MV estimates sprang up in a number of countries, recently a number of international comparative studies have been reported.

The OIPRC research, for example, which developed out of the original DTI project, has carried out a considerable amount of work broken down by sectors, grouped by level of technology. Greenhalgh, *et al*. (2001), for example, modify the standard derived demand for labour function to include technology variables (note this is not a MV study). It demonstrates that employment is positively related to R&D and UK patents. While the impact of R&D on employment is greater in high technology sectors, the employment impact of UK patenting is bigger in mature technology sectors. In a MV context, for example, Greenhalgh and Rogers (2006) compare the different results for three sectors: manufacturing; finance, insurance and real estate; and transport, communications, electricity, gas and water. This is interesting in part because, of these three sectors, only manufacturing is a reasonably extensive user of patents, while all three use trade mark protection. The results indicate some interesting differences in the MV of trade mark users and non-users in the services sector and between the value of domestic (UK) and Community marks. In Rogers and Greenhalgh (2006b), the authors conclude that, "Across all firms a variety of measures of firm performance were positively correlated with being active in acquiring trade marks; within the financial services sector, trade mark active firms showed higher rates of investment and faster growth of employment."

[5] "Dynamic and Fuzzy Boundaries" pp. 638-639. Book down-loads, www.derekbosworth.com.

To provide just a couple of examples of international comparative research: Hall and Oriani (2004) analyze the market valuation of R&D across continental European countries, comparing it with the Anglo-Saxon countries (e.g. the UK and USA); Hall, *et al*. (2006) investigate the results for France, Germany, and Italy; and Czarnitzki, *et al*. (2006) study the results for the US and Germany, with some comparisons with other countries. These are early days in such comparisons, which face important difficulties both because of cultural, institutional and policy differences, and because of problems of data availability and comparability. Nevertheless, this is a promising line of research. According to Czarnitzki, *et al*. (2006), in most countries an additional 1$ of R&D adds slightly less than 1$ to market value, although there is an alternative interpretation, that R&D assets depreciate somewhat faster than the assumed 15 per cent per year.

3.4 Explanatory Variables

The issue of missing variables is quite serious in existing MV studies. The earlier discussion, for example, covered the issue of estimating the spillovers in the absence of information on licensing and other forms of payment for external technologies. A number of advances have been made in terms of additional IP variables. The work at the OIPRC, for example, has included trade mark data, as well as patents and R&D, almost from the inception of the work on MV (see, for example, Greenhalgh and Rogers, 2005b and 2006). This has led to particular insights about the role of IP in determining the market value of service sector firms, where patents are of little importance.[6] The work of MIAESR, which draws upon data provided by IP Australia, includes trade marks and registered designs, as well as the other variables noted above (Jensen and Palangkaraya, 2006). Trade mark data may be a proxy for the advertising[7] expenditure in Hall (1993), brand value and/or product modification or launch, but both trade mark and design data have similar problems to patent counts.

However, the inclusion of other IP data is only scratching the surface. The problem is there is a broader literature, which is segmented according to discipline area. To a large extent, researchers from an economics background include R&D and one or more IP variables (Bosworth, 2005, pp. 183-209). Those from an institutional HR background tend to include latent variables constructed using principal component analysis that represents the nature of the human resource system (*op cit*. pp. 210-237). There are very few studies that, for example, include R&D and

[6] It also allows investigation of the determinants of trade mark activity. Greenhalgh and Rogers (2005c) report that the "Firm characteristics that are positively correlated with IP activity include larger firm size, stock market listed status and high product market diversification." In Rogers and Greenhalgh (2006), using a somewhat different sample, however, they found, "… no role for stock market listed status or the extent of product diversification of the firm in the propensity to acquire trade marks." These differences in findings about the propensity to trade mark are worth further exploration.

[7] Advertising is a far from perfect measure of brand development – marketing expenditure, which includes in-house resources, would be better.

HR system variables (e.g. Huslid, 1995). To my knowledge, there are no MV studies that include measures of the skill level of enterprises, although the extent and depth of HR systems may to some degree be a proxy for this. Finally, there is a literature on the role of IT and ICTs in driving performance, which suggests that, when IT variables are included alongside R&D, it is the IT variable that is more robust and significant (see Bosworth, 2005, pp. 284-287). Again, this further emphasizes the need to develop a more holistic approach.

3.5 Skewed Distribution of Patent and Other Values

From the early days of using patent statistics as measures of technological change, it has been recognized that some patents are more valuable than others (for a review of this early literature see Bosworth, 1987). Michael Scherer has been instrumental in stimulating interest in the distribution of patent and other asset values (Scherer, 1965 and 1996; Scherer and Harhoff, 2000; Harhoff, *et al*. 1999a). What is certain is that the distribution of values of the outcomes of all forms of risky discretionary investments are highly skewed, what is less certain is precisely which skewed distribution best fits the observed outcomes.

(i) Patents

Several "weights" have been developed for patent counts to allow for variations in "quality". Two fairly early examples were patent longevity (e.g. Bosworth, 1973; Lanjouw, *et al*. 1996) and the size of patent family (Bosworth, 1980 and 1984; Putnam, 1986) – longer lived and/or those with larger families tend to be more valuable. Pakes and Schankerman took the renewal approach to new heights, when they used an options approach, with the renewal costs and length of life statistics, to produce estimates of the value of patent rights (Pakes, 1986, Schankerman and Pakes, 1986).[8] In both types of approach, the distributions of outcomes are skewed.

Perhaps the most important development in patent weights has been that of citation count data, in which Bronwyn Hall, Manuel Trajtenberg and Adam Jaffe have been the driving force in the USA (Hall, 2000; Jaffe and Trajtenberg, 2002). In essence, the number of times a patent is cited by subsequent patents is used as a measure of its technological significance. What Hall (2000, p. 193) concludes with regard to the citation weighted variable is that it gives similar sized coefficients to the simple patent count, but the coefficient is estimated more precisely. In addition, patent citations also tend to be highly skewed, with a very small proportion highly cited and a very large proportion cited very little if at all. Other countries have recently started

[8] Zvi Griliches once asked me over breakfast, while at a conference in Upsalla, whether, in the light of the success of Pakes and Schankerman, I regretted not continuing to work on patent renewals. I think I deserved this as, much earlier in my career, while at the RES Conference of Economists at Durham, I went awol (with a notable number of my Loughborough colleagues) during Griliches' keynote speech to watch Newcastle play.

to produce citation weightings, although the OIPRC dataset does not currently include this dimension.

The final two other measures of patent quality that we deal with here are evidence of patent opposition activity (e.g. Harhoff, 2006, Harhoff, *et al*. 2003) and business surveys (Harhoff, *et al*. 1999). According to Harhoff, *et al*. (2003), there is no link between the number of international patent classes which the patent cites and value, but patents upheld against opposition and patents representing large international families are particularly valuable. Harhoff, *et al*. (1999) surveyed the German owners of 962 US patents also protected in Germany. The patent holders were estimate the price at which they would have been willing to sell the patent right in 1980 (this was about three years after the filing date in Germany). The study concludes that value is correlated with the extent of subsequent citations of the patent and that more valuable patents are more likely to be renewed to the maximum period possible. Again, the distributions are skewed as relatively few patents reach full term and a very tiny proportion of all patents are very valuable. Finally, we not an extensive study of US patent litigation by Allison, *et al*. (2003), which concludes that, a few valuable patents have a profile that stands out from the mass of ordinary ones. The former are ones that the owners spend considerable time and resource in prosecuting, which competitor recognize as valuable and, therefore, likely to be opposed and/or litigated. They are concentrated in a small number of industries and are more likely to play a significant role in encouraging innovation.

(ii) Other Variables, the Roles of Quality and Risk

The attempts to given the patent variable a quality dimension is admirable, but little seems to have been done about other variables that have exactly the same problem – perhaps nothing can be done? All forms of discretionary investments can differ in quality and in the degree to which they are risky, whether it is advertising and other forms of marketing, training, HR systems, organizational change, etc. Product modification and, more particularly, new product launch are well documented to be risky activities (see Bosworth, 2005, pp. 197-208). The overall distribution of outcomes for the enterprise depends upon the interaction between all of these risks (*op cit*. p. 207).

What the regression results demonstrate is, for example, the marginal return to an activity such as R&D *averaged across all firms in the sample*; what it does not show is what the returns to any one firm would be if it increased it's R&D expenditure, other things being equal. This depends upon the distribution of returns faced by each firm, which, in general will not be the same as the distribution for other firms. In addition, the returns to any one area of investment will depend upon the position of the firm's product (or portfolio of products) in the life cycle (Bosworth, 2005, pp. 352-359). When products are young and there is a large potential demand, the returns to R&D vis a vis, for example, advertising are likely to be low; when products are approaching saturation in the market and

some way towards the end of their life cycle, the returns to advertising vis a vis R&D are likely to be low.

The empirical HR literature has gone some way to address these types of issues (Bosworth, 2005, pp. 210-237). In addition to looking at the impact of the adoption of individual high performance work practices, the literature has used principle component analysis to construct latent variables that can be interpreted as complementary "packages" or HR systems. More importantly, the literature has highlighted different systems, each of which may be more suited to one or another product market strategy.

4. Conclusions

This contribution has highlighted the evolution of a single area of research that DTI was instrumental in initiating in the UK. The discussion has not focused entirely on the developments that have taken place in the UK, but tried to follow the development of the research initiated by DTI in the context of broader developments in the area. The paper has outlined the major developments that have taken place in the areas of:

(i) functional form, suggesting that there is still a need to estimate more flexible functions that allow interaction between key variables. Other problems with the specification are key missing variables – see iii below – and the failure to address the direct effects of competitors (as distinct from spillover effects);
(ii) sector and international comparisons, showing that, in recent years, important developments had taken place, although there is still a considerable way to go in both areas;
(iii) explanatory variables, indicating that a more holistic, often cross-disciplinary approach is required to understanding the relationships between various strategic activities of the enterprise and the returns to various discretionary investments of the firm. In addition, new variables, such as licensing and patent pooling activity, is required before we fully begin to understand the magnitude of spillover effects;
(iv) distribution of returns, arguing that, while the quality-adjustment of patents is important, this is only one of the intangibles in the model. In addition, the whole of the MV approach seems to largely ignore the underlying issue of risk and, currently, can say little about what the returns to the discretionary investments of any one firm will be.

The MV literature has made significant progress across a broad range of fronts since Griliches' pioneering paper of 1981. However, the limitations outlined in this contribution suggest that there is some way to go, especially before some of the results become of use to those managers making strategic decisions for their companies.

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