

INTERNATIONALISATION OF TECHNOLOGY AND THE MARKET VALUE OF LARGE FIRMS

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The recent World Investment Report (UNCTAD 2005) shows that the period since the beginning of the 1990s has witnessed significant increases in both the volume and spread of international R&D activities amongst the world's largest firms. Against this background the aim of this paper is twofold. The first is to investigate the characteristics of firms that undertake a growing volume and spread of foreign knowledge creating activities. The second is to investigate the extent to which foreign technological activities have influenced the long-term profitability of firms. Based upon an empirical analysis of 163 large US firms during the period 1990-2000, distributed over 15 industrial sectors, we find strong evidence that firms with higher levels of productive efficiency have a relatively lower volume of overall technological activities in foreign locations, but spread in a larger number of locations. While the volume of foreign knowledge creating activities has no influence on market value of the firm, the number of locations of such activities does matter. The direct effect of an increase in the number of foreign locations of technological activity on market value is negative but this is offset by a positive indirect effect arising from such locations augmenting the firm's R&D stock. Thus, firms and sectors that have a larger scale of R&D relative to physical capital gain more from spreading their knowledge creating activities.

Keywords:

market value; R&D scale

1. INTRODUCTION

As the latest World Investment Report (UNCTAD (2005)) shows the period since the beginning of the 1990s has seen significant increases in the foreign R&D activities of large multinational corporations. For example the R&D undertaken by US-owned TNC affiliates abroad rose from \$11.8 billion in 1994 to \$21.1 billion in 2002 (UNCTAD (2005) p. 122). It is not only the volume of international R&D that has increased, but such R&D has also spread to newer regions of the world, such as Developing Asia. Thus, in 2001 the main hosts for US- affiliate R&D expenditures were Europe (\$11.6.5 billion) followed by Developing Asia (\$2.4 billion) and Canada (\$2.1 billion).²⁶ The share of Developing Asia rose rapidly from under 3.4% in 1994 to 12.1% of all US affiliate R&D undertaken in foreign locations. Much of this R&D is concentrated in specific sectors in manufacturing, viz. computers, transport equipment and chemicals (in decreasing order of importance).²⁷

In a seminal paper Patel and Pavitt (1991) argued that despite the increasing globalisation of business, technological activities of large firms tended to stay in their countries of origin and have a close relationship to country competences. This 'non-globalisation' of technological activities accords with many known features of major innovations that make the management of R&D difficult: the person embeddedness of multidisciplinary scientific research, the largely tacit nature of technological knowledge, the strong need for coordination in decision making in the face of uncertainty of innovation, all of which make proximity to headquarters important. These reasons for locating R&D facilities close to the headquarters also suggest that moving some R&D to foreign locations might incur substantial management costs for the firm. The spread of R&D to newer regions has also meant handling the 'costs of distance and foreignness' traditionally discussed in analyses of international expansion of production.

Another tradition of scholarship has however argued that internationalisation of R&D results in considerable efficiency gains for large firms. Drawing on the OLI paradigm which predicts that foreign investment takes place to profit from Ownership, Location and/or Internalisation (OLI) advantages, they argue that internationalisation of R&D is the result of the interaction between the ownership advantages of MNCs and the location advantages of regions. Cantwell (1995) for example, argues that in a global world, MNCs will locate to exploit regions of differential

²⁶ See UNCTAD (2005) p. 129.

²⁷ Beausang (2004), page 2 and Table 2.

2.2 Characteristics of firms that engage in foreign knowledge creating investments

The motivations for undertaking foreign R&D also imply some characteristics for firms and sectors that are likely to undertake such internationalisation of their knowledge creating activities. In particular we can derive the following two hypotheses in a straightforward way.

Hypothesis 1a: Firms with greater (geographic) market penetration will internationalise their R&D more. Since the larger size of the firm gives us some indication about their greater market penetration we can expect larger firms to have more foreign R&D.

Hypothesis 1b: Firms that are in technologically dynamic sectors have a greater need to access cutting edge technology from foreign locations. They will therefore undertake more foreign R&D.

More recent literature argues that the latest trends in foreign R&D reflect a more important underlying interaction between ownership and location advantages that is not restricted to the acquisition of technology alone. The contention here is that as the world became progressively more globalised, maintaining ownership advantages often required MNCs to tap into location advantages of a different kind. During the second half of the 1990s major concerns emerged over the scarce availability of scientific talent in Western economies, resulting from increased technological change. This resulted in many US firms in the Electronics sector moving their R&D operations to newer locations in developing regions where such talent was abundant and local competition to their products was likely to be weak. Examples include the opening of Texas Instruments software subsidiary in Bangalore and the move of Intel R&D facilities to Israel. These investments may be viewed as simply resource seeking, where the resource that is being sought is scientific talent.

Hypothesis 2: Firms that employ larger numbers of scientific personnel may be more likely to undertake foreign R&D from multiple locations to bring down their scientific labour costs.

However, recognition of the strategic nature of international R&D also points to the important role that managerial ingenuity plays in the spotting of such new opportunities to extend ownership advantages by spreading technological activities in new locations. Yet the literature does not offer clear clues about the impact that relative managerial efficiency of a firm has upon the decision to undertake R&D abroad.

Though asset-seeking R&D investment is usually associated with leading companies in technologically dynamic sectors maintaining listening posts for new developments in technology, it may be a strategy adopted by less efficient firms in an industrial sector to enhance their competitiveness. Another type of asset seeking R&D undertaken by relatively less efficient firms is the buying up of hi-technology firms in another country by larger firms in the same sector (as in the case of biotechnology acquisitions by pharmaceutical companies) or by user firms that want to secure the further development of new technology producers exclusively for their own product development (e.g. the buying up of small Cambridge hi-technology companies by firms in the US). In both cases, the buying up of technology firms allows an extension of some ownership advantages by spending money on buying R&D intensive firms rather than increasing own R&D outlays in direct investment, but is clearly motivated by a desire to improve own efficiency and investments.

On the other hand, the costs of coordination of international R&D such as those highlighted by Patel and Pavitt (1991) also suggest that only the more efficient firms will undertake R&D in distant locations. Thus, the decision to extend the number of locations from which to undertake international R&D may involve an implicit assessment of the firms' own managerial competence relative to that of others as these costs will increase the larger the number of locations. Such an interpretation is also consistent with the listening post -asset augmenting – view of international R&D discussed earlier.

Hypothesis 3a: Less efficient firms may turn to asset seeking R&D in new locations (whether through direct investment or acquisitions) to enhance their ownership advantages.

Hypothesis 3b: Given the coordination costs of R&D in several locations, only more efficient firms will extend their international R&D from many locations.

The database used in this paper consists of 178 large US firms, defined as those with sales over \$800 million per annum in the period 1998-2000. For these firms we have matched patent data available from the USPTO to the financial data available from Compustat over the period 1990-2000. Since patent data are more infrequently observed than financial data, we divided the data into three sub-periods, viz. 1990-93, 1994-97 and 1998-2000. Average values for financial and balance sheet variables were added using the Compustat database. In order to ensure robust results according to industrial sectors we eliminate industries³⁰ with less than 4 firms. We thus have a balanced panel of data for 163 firms for 3 time periods distributed over 15 industrial sectors.

Dependent variables

The research questions outlined in the previous sections can be tested on the basis of two different dependent variables: one measuring the extent of foreign knowledge creating activities and the other measuring the firm's market value.

In measuring the extent to which firms invest in international technological activities, we distinguish between both the volume and spread of such activities. The rationale for the two measures is that the management implications of spreading knowledge creation over many locations are different from that of managing a limited number of locations.

The two main measures of knowledge creating activities at the firm level are R&D and patenting. Their main strengths and weaknesses as measures of internationalisation of technology have been discussed elsewhere (e.g. Patel and Pavitt (2000)). The main practical problem is that firm-level data on foreign R&D expenditures (or employment) are not available. However, in earlier work (Patel (1995), table 2 and page 4) one of us has shown that the correlation between US firms' foreign R&D expenditures and the geographic origin of patents granted to US based firms is high, with a correlation coefficient of 0.97.

In this paper we use information obtained from US patent documents to proxy foreign knowledge creating activities. In particular we use the country address of the first inventor named on the patent as a reflection of the location of international technological activity underlying that patent. Thus we use the number of patents granted from non-US locations as a measure of the volume of international knowledge creation. This is of course an underestimation of the extent of foreign technology creating activities, as some of these activities may result in no patents at all. However given the homogeneous nature of the sample (large US firms) one would expect the propensity to patent across firms to be very similar. Moreover the measure used in our analysis is the *share* of total patents accounted for by foreign locations, which accounts for some of the variations in the propensity to patent across firms

As a measure of the spread of foreign R&D we use the number of non-US locations from which patents are drawn (NUMFOR). This shows whether R&D activities of a particular firm are concentrated in one particular country or located in multiple countries. The correlation between the two measures FORSH and NUMFOR is only moderately positive at 0.38. Thus, for telecommunications and IT related industries low foreign shares co-exist with many locations. This is in contrast to the pattern observed in Chemicals and Pharmaceuticals, where large shares coexist with many locations suggesting that different types of activities and motivations may be at play in the two kinds of sectors.

Table 1: Trends in foreign sourcing of technology by industrial group and year

³⁰ Industries are defined according to the principal product group of the firm. Most represent 2-digit SIC categories.

- (iii) The R&D intensity of firms, i.e. the R&D expenditures as a percentage of sales (RDINT) is likely to be highly positively correlated to the employment of scientific labour. Since we cannot observe the employment composition of firms we use this as a proxy for firms that might be most effected by the rising employment costs of conducting R&D. Firms with a larger R&D employment may take more recourse to foreign R&D to alleviate shortages of skilled labour.
- (iv) Firm size (LNSIZE) measured by the log (Employment). We expect firm size to be positively related to the extent of foreign R&D.

In order to examine the second set of hypotheses concerning international R&D and market value we use the following explanatory variables:

- (vi) The R&D stock³² normalised by the book value of capital assets (XRD). We expect this variable to reflect the knowledge capital of the firm and influence market value positively.
- (vii) The patent stock of the firm (PATSTOCK) relative to the book value of capital assets. We expect this variable to influence market value positively.
- (viii) Measure of the firm's foreign patent stock relative to its capital assets and the number of locations foreign patents are drawn from (FPSTOCK and NUMFOR). We expect these variables to influence market value positively.

3.2 Methodology employed

In order to test the first set of hypotheses on the determinants of the extent of globalisation of R&D, we employ a latent variable model where the propensity to source technology from foreign sources (f^*) is an unobservable latent index which is triggered by a favourable vector of explanatory factors X . For values of $f^* > 0$ we observe a positive value for the share of foreign patents (FORSH) which may in addition come from more than one foreign location (NUMFOR).

FORSH is a continuous variable censored at 0 and with an upper limit at 100, while NUMFOR is a count variable that takes discrete values and is also skewed to the left. The appropriate statistical model for each dependent variable is thus different. For estimating the proportions of FORSH we use the Tobit model, described by equation (1) below. The subscripts i, j and t stand for firm, industry and time period respectively and ϵ_{ijt} is a random error term, distributed normally, with expected value equal to zero and constant variance.

$$\text{FORSH}_{ijt} = \alpha_0 + \alpha_1 \text{DEA}_{ijt} + \alpha_2 \text{TECH}_{ijt} + \alpha_3 \text{RDINT}_{ijt} + \alpha_4 \text{LNSIZE}_{ijt} + \alpha_j + \epsilon_{ijt} \quad (1)$$

Fixed effects are hard to estimate in the Tobit model because of the incidental parameters problem. For this reason we also report the results of the fixed effects linear regression model. In the case of NUMFOR the appropriate statistical model to use is the negative binomial with one way fixed effects for industry described by equation (2) below. As before, the subscripts i, j and t stand for firm, industry and time period respectively while ϵ_{ijt} is a random error term, with expected value equal to zero and constant variance. Both models are estimated using maximum likelihood methods.

$$\text{NUMFOR}_{ijt} = \alpha_0 + \alpha_1 \text{DEA}_{ijt} + \alpha_2 \text{TECH}_{ijt} + \alpha_3 \text{RDINT}_{ijt} + \alpha_4 \text{LNSIZE}_{ijt} + \alpha_j + \epsilon_{ijt} \quad (2)$$

The sign and significance of coefficients $\alpha_1, \alpha_2, \alpha_3$ and $\alpha_1, \alpha_2, \alpha_3$ constitute a direct test of hypotheses H1-H3. In addition the inclusion of industry effects allows us to control for the influence of unobservable variables such as the extent of vertical integration in different industrial sectors and the nature of technology.

The second set of hypotheses concern the direct and indirect effects of foreign R&D on the market value of firms. To assess this, we estimate the one-way fixed effects linear regression model described by equations (3) and (4) below. We follow the specification used in previous literature, which examines the extent to which knowledge capital affects the Tobin Q . The subscripts are as for (1) above and ϵ_{ijt} is a random error term with constant variance:

$$\text{TOBQ}_{ijt} = \alpha_0 + \alpha_1 \text{XRD}_{ijt} + \alpha_2 \text{FPSTOCK}_{ijt} + \alpha_3 \text{PATSTOCK}_{ijt} + \alpha_1 (\text{FPSTOCK} * \text{XRD})_{ijt} + \alpha_2 (\text{PATSTOCK} * \text{FPSTOCK})_{ijt} + \alpha_j + \epsilon_{ijt} \quad (3)$$

$$\text{TOBQ}_{ijt} = \alpha_0 + \alpha_1 \text{XRD}_{ijt} + \alpha_2 \text{NUMFOR}_{ijt} + \alpha_3 \text{PATSTOCK}_{ijt} + \alpha_1 (\text{NUMFOR} * \text{XRD})_{ijt} + \alpha_2 (\text{NUMFOR} * \text{PATSTOCK})_{ijt} + \alpha_j$$

proportion of their technological activities in foreign locations, albeit located in relatively fewer countries. On the other hand firms with higher levels of productive efficiency have a relatively lower share of overall technological activities in foreign locations, spread in a larger number of locations. This implies that the latter firms are more likely to be engaged in small-scale activities aimed towards monitoring scientific and technological developments in different locations rather than in large scale product development.

4.2: Internationalisation of R&D and market value

In this section we will assess how foreign technological activities affect the market's valuation of a firm. However rather than taking the 'raw' market value as reported in company accounts we follow existing literature and use Tobin's Q. This is simply the ratio of the reported market value divided by the book value of the capital stock and is a reasonable proxy for long term profitability. In the long run the market value of the firm supposed to be just equal to the book value of capital stock so that TOBQ should be equal to 1. Previous studies on technology have used TOBQ as a dependent variable and found that intangible R&D assets of a firm influence this ratio positively. For example Hall and Trachtenberg (2001) show that citation weighted patents has a positive influence on the market value of US firms and Grliches (1981) showed that the R&D expenditures of a firm influence the market value positively.

Table 4 presents the results of estimating equations (3) and (4). Columns (1) and (2) consider the direct effects alone while columns (3) and (4) report the results of estimating the full unrestricted equation, with the indirect effects included.

The results indicate that neither FORSH nor NUMFOR influence market value independently. Moreover indirect effects are not important in the case of FORSH. The joint test of the hypothesis that $\square_1 = \square_2 = 0$ is not rejected at the 5% level of significance. The F-statistic has value 0.61 with degrees of freedom (2,428). However, in the case of NUMFOR, we find that indirect effects are statistically significant. Here we can reject the restriction that $\square_1 = \square_2 = 0$ at the 5% level, showing that indirect effects of foreign patenting are important in explaining the market value of firms.³³ This result implies that increasing the number of foreign locations from which patents are drawn increases market value only for firms and industries with high R&D expenditures relative to capital stock. Moreover the results in column 4 show that when we include indirect effects, the direct effect of NUMFOR is negative and statistically significant. Thus the direct effect of the number of foreign locations of technological activity on market value is negative but it may be offset by the positive indirect effect due to the augmentation of the firm's R&D stock. To get a better understanding of the overall effect, we present some benchmark estimates of the responsiveness of the market value of firms to changes in the number of locations.

Table 4: The effect of foreign patenting on the market value of firms

| Variables | Direct effects only | | Direct and indirect effects | |
|-------------------|---------------------|----------|-----------------------------|----------|
| | (1) | (2) | (3) | (4) |
| Constant | 10.80*** | 11.97*** | 10.68*** | 14.53*** |
| XRD | 3.40* | 3.43* | 3.69* | 0.90 |
| PATSTOCK | 3.23*** | 3.54*** | 2.81** | 2.92*** |
| FPSTOCK | 4.23 | | 10.58 | |
| NUMFOR | | -0.24 | | -0.86*** |
| FPSTOCK*XRD | | | -0.85 | |
| FPSTOCK*PATSTOCK | | | -0.03 | |
| NUMFOR*XRD | | | | 0.75* |
| NUMFOR*PATSTOCK | | | | 1.31 |
| R squared: | | | | |
| Within | 0.067 | 0.068 | 0.069 | 0.081 |
| Between | 0.339 | 0.326 | 0.472 | 0.406 |
| Overall | 0.135 | 0.130 | 0.153 | 0.162 |
| F | 9.25 | 9.21 | 5.71 | 6.73 |
| (v1,v2) | (3,434) | (3,434) | (5,428) | (5,432) |

³³ The F-statistic has value 3.22 with degrees of freedom (2, 432).

6. SUMMARY AND IMPLICATIONS

This paper has presented a pioneering attempt at exploring the relationship between the characteristics of firms that undertake internationalisation of knowledge creating activities, and their impact on the long-term performance of the firm as measured by the firm's market value. Two main results emerge from our analysis.

First, we find strong and robust evidence that firms with higher levels of productive efficiency have a relatively lower share of overall technological activities in foreign locations, but spread in a larger number of locations. This implies such firms are more likely to be engaged in small-scale activities aimed towards monitoring scientific and technological developments in different locations rather than in large-scale product development. We also find weaker evidence that suggests that firms that are some distance away from the world frontier in terms of productive capacity have a higher proportion of their technological activities in foreign locations, albeit located in relatively fewer countries.

Our second result is that the volume of foreign technological activities has no influence on the market value of a firm. However, the influence of the number of R&D locations on market value has both a direct and an indirect component. The direct effect of an increase in the number of foreign locations of technological activity on market value is negative but this is offset by a positive indirect effect which increases with the scale of intangible knowledge capital in the firm. We conjecture that the negative direct effect encapsulates the sort of managerial hardships of locating technological activities away from the home base discussed by Patel and Pavitt (1991). However in some R&D intensive sectors firms have learnt to integrate knowledge acquired from various sources to realise economies of scale and scope in their R&D activities. Hence, firms in these sectors that have higher levels of R&D stock relative to physical capital gain from sourcing their technology from multiple locations.

Our benchmark estimates also suggest that the overall effect of changes in the number of locations on market value is higher for some sectors, viz. IT related activities, Pharmaceuticals, Instruments and Medical equipment. These sectors, which we can collectively think as part of engineering based industries, are also very prominent in terms of third party outsourcing. This gives rise to an interesting conjecture (but which is beyond the scope of this paper to pursue) that third party outsourcing and managing far-flung captive subsidiaries may require similar kinds of managerial abilities.

This gives the so-called ‘envelopment’ form of the problem. We are asking the question, how much can inputs be scaled down for firm m such that the existing firm m output can be produced? Note that $\theta \leq 1$ as at the worst $\lambda_m = 1$, $\theta = 1$ satisfies the constraints of the problem.

There is an implicit assumption of Constant Returns to Scale (CRS) in equation 1.2. That is we can

$$\text{have } \sum_{n=1}^N \lambda_n \neq 1 \text{ and } \sum_{n=1}^N \mu_n \neq 1$$

which means that we are not taking a convex combination of the input and output sets of the individual firms. However, we can allow for Variable Returns to Scale (VRS) by imposing this constraint upon the relevant optimisation problems. Comparing the VRS models with the CRS models it is straightforward to see that the efficiency scores under VRS will be higher than under CRS this is because we have added an additional constraint to the problem.

The fact that we get different scores when we use the input or the output measure implies that some sort of averaging of the two methods is required. Taking a geometric mean of the two values seems like a reasonable approach. Thus, we have a firm-level efficiency indices that we use in the paper that are geometric means of the input and output versions of the index under the assumption of VRS

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