John Cantwell/Ram Mudambi

The Location of MNE R&D Activity: The Role of Investment Incentives

Abstract

- In recent years, MNEs have been consolidating the activities of their subsidiaries. This has typically involved granting wide strategic mandates to some subsidiaries, while at the same time scaling back the activities of others. One consequence of this consolidation is that considerable efforts are now being expended by government inward investment agencies (IIAs) in seeking to attract MNE subsidiaries with broad mandates. This is because such investments are considered to be highly desirable in terms of their effects on local wealth generation.

- Subsidiaries with strong research and development (R&D) mandates are precisely the type of firms that IIAs most wish to attract. However, successful R&D activities require the location to have a rich resource base. An important question is whether IIA investment incentives can directly influence the location of R&D investment by MNEs or whether they are dominated by more basic location considerations of such as risk, local experience and infrastructure. This question is addressed empirically, using a data set constructed from a survey of the UK subsidiaries of engineering and related MNEs.

Key Results

- The results suggest that incentives are dominated by basic location factors. However, they are found to have an incremental effect and with the strongest effects being traced to tax credits. This suggests that locations that have reached MNE location short-lists can gain from the provision of incentives.

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Introduction

One of the most ubiquitous aspects of globalisation has been the increasing consolidation of investment activity by multinational enterprises (MNEs). This has been implemented through rationalising overall operations and siting particular activities to take advantage of local advantages (Cantwell 1995). This has appeared in the form of particular subsidiaries being granted geographic or product range responsibilities (Roth/Schweiger/Morrison 1991, Morrison/Roth 1992, Birkinshaw 1996).

This consolidation has also increased the mobility of foreign direct investment (FDI) by MNEs, as the firms have sought to tailor their investment profiles to take maximum advantage of local resources. As FDI has become more mobile, the efforts of government agencies to attract it have grown in magnitude and diversity. In both developed and developing countries inward investment agencies (IIAs) operate at national, regional and even local level (Young/Hood 1993, Wren 1996).

IIAs recognise that not all FDI is equally valuable. The ideal investment from the IIA point of view consists of a single facility with regional and preferably global research and development (R&D), production and marketing responsibilities. Such a facility is a large employer, with a highly skilled, productive and high-wage workforce and a high level of local purchases to generate macro-multiplier effects (Peck 1990). A look at the European evidence indicates that many MNE subsidiaries are far from this ideal. Subsidiaries are part of larger corporate systems and from the perspective of the local area, they can become truncated and fail to embrace a wide range of corporate functions (Young/Hood/Peters 1994). Therefore, the regional optimum that the IIA is striving for and the corporate optimum may be separated by a substantial gap (Morris 1992, Amin/Malmberg 1992). The objective of the IIA is to locate investments where this gap is likely to be minimised. In order to do this, it must identify the strengths of the local area and play to these strengths (Young/Hood/Wilson 1994).

The fundamental question that must be addressed in this context is: are IIA activities wealth creating or are they mere exercises in rent seeking? If there are bidding contests between different IIAs within a single country, this argument may have some merit. However, at least two counter-arguments may be advanced. First, there is evidence that MNE activity follows a sequential pattern, where successively higher level activities are performed in foreign subsidiaries (Hood/Young 1979, Cantwell 1989). The initial switch may be from exporting to FDI, with the objective of maximising the stream of firm profits (Buckley/Casson 1981). Subsequently, the subsidiary may acquire a broad product or functional mandate. The acquisition of a broad mandate by a subsidiary substantially increases the local benefits from foreign-owned investment (Science Council of
Canada 1980, Rugman/Bennett 1982, Forsgren/Holm/Johansen 1995, Birkinshaw 1996). Thus, IIAs expenditure that advances the progress of a subsidiary or increases the chance of such progress, has a positive expected benefit. Second, given agglomeration effects, IIAs expenditures that prime the pump to begin the flow of FDI may result in a virtuous cycle of further investment (Head/Ries/Swenson 1995, Mudambi 1995).

For the IIAs, the R&D-intensity of the local subsidiaries is particularly highly prized. This is because R&D-intensive activities tend to be associated with highly skilled workforces and high value-added. Such subsidiaries tend to have high levels of responsibility in other areas as well. Of course, R&D activity itself is carried out at many levels and not all R&D investment is equally attractive. This is a valid question, but one which is beyond the scope of this paper. It would be a logical avenue for further research.

The paper is organised as follows. In the next section we provide an overview of the key issues involved in approaching the question of the location of R&D activity by MNEs. Next, we present our formal research hypotheses and discuss our methodology. We then turn to describing our data, estimation procedure and empirical results. Finally, we discuss the implications of our findings and offer some concluding comments.

MNEs and the Location of R&D: An Overview

Historically, MNEs located R&D in their affiliates abroad mainly for the purposes of the adaptation of products to local tastes or customer needs, and the adaptation of processes to local resource availabilities and production conditions. In recent years instead, linked to the closer integration of affiliates into international networks within the MNE – at the heart of what is commonly termed the ‘globalisation’ of production and technology – affiliate R&D has gained a more creative role, to generate new technology in accordance with the comparative advantage in innovation of the country in which the affiliate is located (Cantwell 1995, Papanastassiou/Pearce 1997). This transformation has led to an increase in the level of R&D undertaken in at least some affiliates, and in affiliates in which R&D is expanded there has been an upgrading in the types of research project away from the purely applied towards the more fundamental; although the research undertaken is generally of an (increasingly) specialised kind, to take advantage of the particular capability of local personnel and the other local institutions with which the affiliate is connected.

The shift towards internationally integrated strategies within MNEs is partly associated with a change in the economic environment in the post-war period
based on a decline in transport costs and tariffs and the appearance of new communications technologies, which has created a global economic imperative and the emergence of 'heterarchical' organisational structures in many industries (Doz 1986, Hedlund 1986). It is also grounded on a 'life cycle' effect within what have become mature MNEs, which have now created a sufficient international spread in their operations that they have the facility to establish an internal network of specialised affiliates, which each evolve a specific regional or global contribution to the MNE beyond the concerns of their own most immediate market (Cantwell/ Piscitello 1997). Thus, what began as local market-oriented (import-substituting) affiliates are gradually transformed into more export-oriented and internationally integrated operations. While some of the affiliates within such a network may have essentially just an 'assembly' role, others take on a more technologically creative function and the level and complexity of their R&D rises accordingly. Hence, we expect to find that, on average, R&D-intensity increases with the age of affiliates, as the corporate life cycle unfolds. Indeed, the duration of subsidiary operations appears to summarise a number of experience-related concepts and to function as a good predictor of overall MNE investment (Mudambi 1998), i.e., duration affects not only the 'quality' of MNE investment, but its quantity as well.

There is also evidence that R&D-intensive MNEs tend to grant more responsibilities to their subsidiaries. It has been reported that Japanese R&D-intensive firms are more likely to have manufacturing operations in the US (Hennart/Park 1993, 1994). Thus, such MNEs are likely to move along the corporate life cycle more quickly. Given the age of affiliates, those with R&D-intensive parents are likely to be have more highly developed mandates.

The extent to which affiliate R&D grows depends as well on the competitive strength of the MNE and the conditions of its home country environment, on the nature of the international industry of which it is part, and finally (on which we focus in this paper) on conditions in the host country in which it is located, including the economic policies of its government. Historically, it was corporate technology leaders that led the internationalisation of R&D; today, these MNEs lead in the international integration of corporate networks for technology creation (Cantwell 1995). So, competitively stronger MNEs are more likely to locate R&D abroad, and to have a greater variance in the levels of R&D across affiliates, with R&D becoming especially concentrated in sites where local conditions are most conducive to technology creation. The extent of their foreign research depends also on the nature of the industry. The global economic imperative is outweighed in some industries, such as aircraft, by the political imperative to be nationally responsive to governments as customers, or in others such as some kinds of food products, to service highly differentiated local tastes (Doz 1986). The foreign location of R&D increases as well with the extent of international competition in an industry; if there are more centres of excellence, then each major MNE will require a technological base in a wider geographical range of sites outside its
own home centre, and international cross-investments between the leading centres will be more intensive. The absolute size of the MNE's home country matters too, since generally it remains the single most important centre for the firm's technological development (Patel 1995); mainly because of the large technological size of the US and Japan in most industries, US-owned and Japanese-owned MNEs have had much lower shares of foreign-located research than have their European-owned counterparts (Cantwell/Harding 1998).

The extent of international technology dispersion will vary between an industry in which one leading MNE predominates (say, IBM in mainframe computers), and an industry in which groups of major rivals coexist (say, pharmaceutical MNEs based in the USA, Germany, Switzerland and the UK). In the former case, technology will be rather more centrally controlled, and its dissemination tends to run in just one direction. Innovation diffusion outside the MNE is limited to a range of more specialised companies, which typically compete in market segments in which the leader is less involved. In the latter case, the transmission of technology within the MNE way well run in more than one direction, and it may further interact with the efforts of other MNEs including those originating from other centres, for which it becomes an input to their own technology creation.

The location of poles of innovatory capacity in an international industry may affect the nature of the competitive advantages of firms (determining which countries are sources of the strongest MNEs), as well as influencing the location of MNE activity. A shift in the location of innovatory capacity will strengthen the position of the firms, which will increase their stake in the creation of technology. An example of this in recent years is the gradual movement of Japanese firms from the adaptation of existing, to the innovation of new technology in a number of sectors (such as motor vehicles and consumer electronics), and alongside this increased innovativeness they have expanded their activities abroad. In today's international economic environment, MNEs that operate in industries characterised by strong, oligopolistic (or technological) competition normally need a direct presence in each of those countries which hold leading positions in the development of their industry and of associated technologies (Ohmae 1985).

We have suggested that the extent and speed of international technology dissemination by MNEs depends upon the structure of the industry in question, the strengths of the constituent firms and their geographical configuration. Consider first an industry that is located in a number of countries, each of which is home to a group of highly innovative firms. This base of technology creation helps to support a network of exports and international production in each case, though, with the emergence of internationally integrated strategies, each firm also becomes dependent upon the co-ordination of connected activities. Over the last 25 years, this is the kind of industry that has been characterised by the rise of the cross-hauling of investments between these countries harbouring the strongest firms. Such countries become hosts to the greatest levels of international produc-
tion as well as being homes to MNEs of their own. Such intra-industry trade and production are also usually accompanied by intra-industry technology flows as well.

It is in this kind of industry that those countries that have become poles of innovation tend to build up a position of competitive advantage in international trade or as host to foreign-based MNEs. This position is achieved by the continuous innovation and growth of production of its own firms and also of the affiliates of foreign MNEs, which develop their technology in the light of local knowledge, fields of competence or skills, and customer requirements. Indeed, one reason why MNEs may invest heavily in a centre of excellence is to take advantage of the agglomerative economies offered by a flourishing innovatory environment. By so doing they may advance the technological capacity of the country. The firms of each country tend to embark on a path of technological accumulation that has certain unique characteristics and sustains a distinct profile of national technological specialisation (Rosenberg 1976, Pavitt 1987, Cantwell 1991). Moreover, the kinds of linkages that grow up between competitors, suppliers and customers in any one regional district or country are also, to some extent, peculiar to that location, and imbue the technology creation of its firms (which depends on such linkages) with distinctive features. For these reasons, other MNEs often need to be on-site with their own production and their innovatory capacity if they are to properly benefit from the latest advances in geographically localised technological development, to feed their own innovation (Cantwell 1989, Kogut/Chang 1991). Moreover, due to the complexity of technological learning, and the significance of maintaining face-to-face contacts, the localisation of technological contacts tends to occur at a regional level within host countries (Jaffe/Trajtenberg/Henderson 1993, Almeida 1997, Cantwell/Iammarino 1998).

By contrast, where the technological capacity of a host country is weak in the sector concerned, the investments of MNEs may drive out local competition and reduce local technological capability still further (Cantwell 1987). Foreign-owned affiliates tend to import a higher proportion of their inputs than do indigenous firms, particularly in the early years of their operations, or where they constitute the assembly stages of a globally integrated network. Even where host governments set targets for a gradual increase in the local sourcing of components – particularly those which involve high value added activities (e.g., tubes for TV sets, wafers for microchips, chemicals for pharmaceuticals, etc.) – subsidiaries of foreign companies supplying the parent MNE in its home country may be established to fulfil this function. While this may result in a greater international dissemination of technology, it is quite possible that the design, research and development work remains concentrated in the parent company. Indeed, in supply activities upstream from the original investment (e.g., in Japanese firms operating in the motor vehicles or electronics components sectors in the UK), this is potentially very serious, as the expanding global sales of supplying MNEs allows them to increase
their own technological capacity at the expense of local suppliers who are then driven out even more effectively.

This has brought us to the consideration of the host country conditions in which the R&D of foreign-owned affiliates is most likely to become substantial, and to gain a creative role with respect to the global technological development strategy of the MNE as a whole. One factor is clearly an adequate local infrastructure, educational system, and science base. The US biotech industry is one example where strong evidence of the effect of this factor has been uncovered (Coombs/Deeds/Mudambi). Another is the innovative and competitive stimulus provided by a local centre of excellence in the industry concerned, which facilitates a more favourable interaction with indigenous firms, and greater opportunities for inter-company alliances for the purposes of technological collaboration and exchange. Within a host country, an all-round regional centre of excellence is likely to attract the research-based investments of a wide variety of foreign MNEs, while more specialised regional centres are attractive mainly as a location for the location of affiliate R&D within the industries for which the local region is best known. Thus, in the Italian case, Lombardia attracts a broad range of foreign-owned R&D facilities, while Piemonte attracts mainly the R&D of foreign-owned motor vehicle companies (Cantwell/Lammarino 1998).

Inter-company technology co-operation and diffusion is more likely to occur where some related technological capacity already exists amongst local firms. Otherwise the presence of MNE subsidiaries may act solely as low value satellites of their parent companies. With reference to the *Le Défi Americain* (Servan-Schreiber 1968) that threatened the long-term competitiveness of European firms in the 1960s, Cantwell (1989) found that a necessary condition for indigenous revival in Britain, Germany and France was the existence of strong technological advantages on the part of local firms. In such cases, inward direct investment led to local technology creation and diffusion, and the competitive stimulation of a new wave of local innovation; the pharmaceutical industry provides an excellent illustration in the UK.

The extent of technological interchange between foreign-owned affiliates and indigenous firms depends upon the impact of affiliate R&D on competitors that have local operations, and upon the impact on suppliers and customers, which in turn relates to the strategic decision of the MNE to buy in certain inputs locally rather than importing them. It also depends upon which products the MNE decides to produce locally, and the technology it chooses to use in its local operations. The potential for a virtuous cycle in which technology diffuses to local firms, whose innovative efforts have spillover benefits to the MNE and cause it to further increase its own R&D, may be greater where it is attracted to locate higher value added activities of a research-intensive kind in the host country, which in turn may well be influenced by the technological traditions of local industry and by the industrial policies of the local government.
In sum, localised technology creation and exchange will be affected by the number and strength of indigenous competitors, the form of linkages with local firms, the relevant host country government’s policies towards sourcing inputs and encouraging a higher local proportion in value added, local technological capacity and infrastructure, local managerial skills and the destination of exports from the MNE affiliate.

It is, perhaps, not always well appreciated, the value that foreign investors place on a strong and vibrant industrial economy; and the crucial role which governments have to play in bringing this about. Inter-country differences in wage, raw material and transport costs are no longer the crucial locational factors in determining the siting of research-related production in the industrialised countries. These have been replaced by the quality of economic management, and an educational, technological and industrial policy that promotes entrepreneurship, innovation and efficiency; a realistic and positive attitude of mind towards work, rewards and competitiveness; and a unity of commercial and social purpose. These are all important influences which will determine, for example, how much R&D companies like Sony, NEC, Sharp and Nissan will eventually undertake in Europe and where they will locate their laboratories. Equally to the point, they are shaped, if not directly determined, by the actions or non-actions of governments.

In today’s global economy, many firms and particularly those supplying markets dominated by international oligopolists, cannot compete effectively, unless they are able to reap the full economies of scale and scope of their activities. At the same time the costs of structural adaptation to new patterns of consumption and technological advances are often too great for individual firms to bear. Increasingly, the prosperity of modern industrial economies rests in their ability to create new technology, skills and provide the appropriate institutional machinery and incentives to foster wealth-creating activities. These are not things a *laissez faire* philosophy or ‘hands off’ approach to resource enrichment or allocation can readily do. Technology is not a natural resource; it has to be created. Increasingly, governments, by a variety of policies, are determining the amount of technology created and designated for use in their territory. A government that creates a basis for the domestic location of investment and living standards should also have some guidelines for the way in which domestic industry can be restructured in the light of its previous experience. This is the kind of outlook that has been embodied in Japanese (and more recently that of the Singaporean and South Korean) government policy, in order to engineer the continual upgrading of domestic industry and the further progression of its technological development. Countries can encourage new investment and technology dissemination in those activities in which the prospects for local innovation and diffusion are greatest, while allowing MNEs to strengthen innovative linkages between technology creation in the domestic economy and other countries that have similar or related advantages.
Governments cannot ignore the implications of recent developments both in international innovation and in the cross-border organisation of its fruits, in which technology creation and dissemination have become progressively more intertwined, with globally-oriented MNEs at the forefront of this process (Dunning 1996).

**Research Hypotheses and Methodology**

Our objective in this paper is to focus on the link between government investment incentives and the location of R&D activities by MNEs. Both the design and implementation of investment incentives and the location of R&D by MNEs are areas where substantial research exists. We have attempted to summarise the main findings of these research efforts in the previous sections. In seeking to study the linkage between these two topics, we address the following questions: do government investment incentives have a direct effect on the location of R&D investment or is the effect better modelled as an incremental one, after accounting for firm-specific and area-specific variables?

These questions give rise to two related research hypotheses, which may be stated as follows:

*Hypothesis 1:* Government investment supports have a direct or primary effect on the MNE R&D investment location decision, along with firm- and location-specific variables.

*Hypothesis 2:* Government investment supports have an incremental or 'second-stage' effect on MNE R&D investment, after accounting for firm- and location-specific factors.

*Hypothesis 1* and *Hypothesis 2* are based on different assumptions regarding the decision processes within MNEs. Under *Hypothesis 1*, MNEs view government investment supports as key variables in the R&D location decisions, along with firm and location variables. Thus, the decision process involves a general appraisal of all variables simultaneously. However, under *Hypothesis 2*, MNEs view investment supports as marginal variables. Under this scenario, the MNE decision process is a two stage one, in which firm and location variables determine the bulk of the investment, with investment supports exerting incremental influence on residual investment. A rejection of *Hypothesis 1* implies that government investment supports are not primary variables in MNE R&D investment decisions. However, a rejection of *Hypothesis 2* implies that government investment supports are totally ineffective in influencing MNE R&D investment.

Assuming that government investment incentives have a direct effect on MNE R&D investment, we may set up a general equation determining R&D expendi-
ture at a particular location as:

\[ Y_i = f [\text{FIRM}, \text{LOC}, \text{AID}] + u_i, \quad (1) \]

where \( Y_i \) = R&D-intensity of investment by firm ‘i’ in a given period

- \( \text{FIRM} \) = vector of firm-specific variables
- \( \text{LOC} \) = vector of location-specific dummies
- \( \text{AID} \) = vector of government investment supports

The estimation of (1) may be used to test Hypothesis 1.

On the other hand, if as postulated in Hypothesis 2, government investment incentives have an incremental effect on the location of R&D, we may model the process as follows:

\[ Y_i = f_1 [\text{FIRM}, \text{LOC}] + v_i, \quad (2) \]
\[ v_i = f_2 [\text{AID}] + w_i \quad (3) \]

Thus, the major influence on the local R&D-intensity of investment emanates from firm and locational characteristics, while investment supports are influential are the margin, affecting the residuals. This is not to say that investment supports are unimportant. Under Hypothesis 2, in a decision between locations in which the major firm and locational parameters are very similar, investment supports will play a key role. Such situations are likely to be the rule rather than the exception in R&D investment location.

**Data, Estimation and Results**

R&D is a very industry-specific activity and comparing R&D expenditure across industries is very difficult. Thus, firm A in industry 1 may spend considerably more on R&D than firm B in industry 2. However, this tells us little about the relative importance of R&D in the two firms if industry 1 is a technology-driven industry and industry 2 is not. With this in mind, we restrict our focus to a single industry, so that the expenditure figures are generally comparable.

**Data**

Data was obtained from an in-depth postal survey supported by on-site interviews. A list of MNE engineering and engineering-related operations in the Midlands region of Britain was compiled from business directories. All the firms were non-UK firms with subsidiaries operating in the UK. The region was chosen because
it has been one of Britain’s most successful regions for attracting inward investment. After phone confirmations, a final list of 224 companies with personal contact names was assembled for the purpose of a directed mail survey.

The questionnaire was accompanied by a cover letter explaining the aims of the study, guaranteeing confidentiality and urging response. In order to improve the response rate, the questionnaire had to be short, concise and of current interest (salient) to the respondent (Heberlein/Baumgartner 1978). Ten days after the survey was mailed out, a reminder postcard was sent to all companies that had not yet responded.

Overall, 85 responses were received to the mail survey (37.9%). Of these, four were found to be national firms mistakenly identified as MNEs and seven were unusable for various other reasons, leaving 74 (33.0%) valid responses for evaluation. The response rate is well within the range expected for an unsolicited mail survey. The survey collected information on firm characteristics and details of government investment supports received.

Survey responses were cross-checked against company annual reports where possible. Some variables could be checked for the entire received sample (employment, functional scope of the UK subsidiary’s mandate and duration of UK operations). Others could only be checked for a majority of firms, while some very specific variables were not reported in published data. A high degree of correspondence between published data and survey responses was found, supporting the veracity of the survey responses. Published data is generally considered reliable since most MNEs minimise risks of being penalised by authorities by following a ‘whiter than white policy’ (Coates/Davis/Longden/Stacey/Emmanuel 1993).

Non-response bias was investigated with the most widely used method in the literature (Armstrong/Overton 1977). This involved comparing early and late respondents. Late respondents were defined to be those who responded after receiving the reminder postcard. Six sample measures were compared using a $\chi^2$ test of independence. The responses from early and late respondents were virtually identical.

The variables assembled for use in the study correspond to the requirements of estimating equations (1), (2) and (3). The primary dependent variable is the subsidiary’s R&D/sales ratio. The details of all variables extracted and used in the study are provided in Appendix 1.

In addition, several international statistics were computed for the home countries of the MNEs in the sample. These statistics were obtained from the World Bank’s World Development Report and the IMF’s International Financial Statistics. In addition, country risk indices were drawn from the capital markets publication Euromoney. However, none of these variables proved to be useful in estimation. It would appear that country-wide variables are too crude for use in an industry-specific study.
Estimation and Results

Base-line estimates were obtained using ordinary least squares (OLS). These involved estimating equation (1) and are presented in Table 1. Since the firms varied considerably in terms of size, heteroscedasticity was a very real concern. Running the Breusch-Pagan test confirms this fear, as the null hypothesis of homoscedasticity is strongly rejected. We deal with this problem by using White’s heteroscedasticity-consistent variance-covariance matrix in estimating the ‘t’ statistics.

The overall fit of the equation is quite good, with an adjusted $R^2$ value in excess of 75%. The influence of the variables appears to be in line with the predictions of the theoretical literature. The UK subsidiary’s R&D-intensity decreases

<table>
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<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>‘t’ Statistic$^{(1)}$</th>
<th>‘p’ Value</th>
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<tr>
<td>Constant</td>
<td>1.5038</td>
<td>2.67</td>
<td>0.010</td>
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<td>CRSK1</td>
<td>-0.0853</td>
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<td>LDTI</td>
<td>0.6747</td>
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<td>WEXPORT</td>
<td>0.0280</td>
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<td>0.8907</td>
<td>5.76</td>
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<td>EMPL</td>
<td>-0.0013</td>
<td>0.12</td>
<td>0.902</td>
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<td>IN94</td>
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<td>$R^2$(Adj.)</td>
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<td>ANOVA: F(14, 59)</td>
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<tr>
<td>Log-Likelihood</td>
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<tr>
<td>(Restricted Log-Likelihood)</td>
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<tr>
<td>$(S_a)^2$</td>
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<tr>
<td>Amemiya PC</td>
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<tr>
<td>Breusch-Pagan $\chi^2(15)^{(2)}$; (‘p’ value)</td>
<td>30.3656; (0.0068)</td>
</tr>
</tbody>
</table>

Heteroscedasticity-corrected base-line regression results

Regression: $Y_i = 1994$ R&D/Sales ratio of UK subsidiary (%)
Notes: (1) ‘t’ statistics computed using White’s heteroscedasticity-consistent variance-covariance matrix. ‘t’ statistics significant at the 5% level are shown in **bold type**.
(2) The Breusch-Pagan test for heteroscedasticity.
as the financial risks involved in operating it go up. Similarly, it increases with the duration of the subsidiary’s operations, the functional scope of its mandate, and the volume of total inward investment from its MNE parent. The size of UK labour force and the export-intensity of the subsidiary? operations do not appear statistically significant. The level of subsidiary exports has been reported to have a strong effect on R&D-intensity (Cantwell 1989). However, it has also been reported to be strongly linked to the duration of subsidiary operations (Lipsey 1991). We suspect that the insignificance of the export-intensity variable is due to its high correlation with the duration variable.

None of the locational dummies emerges as significant. Amongst the investment support variables, only aid in the form of infrastructural supports appears to positively influence R&D-intensity.

Proceeding to equation (2), we now drop the investment support variables from the original specification. This results in a more parsimonious model. The estimates of this model are presented in Table 2. The overall fit of the equation as measured by the adjusted $R^2$ value of almost 70% is nearly as good. Further,

### Table 2. Estimation of the R&D/Sales Ratio

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>‘t’ Statistic$^{(1)}$</th>
<th>‘p’ Value</th>
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<tr>
<td>Constant</td>
<td>0.6774</td>
<td>1.53</td>
<td>0.130</td>
</tr>
<tr>
<td>CRSK1</td>
<td>−0.0839</td>
<td>2.15</td>
<td>0.035</td>
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<tr>
<td>LDTI</td>
<td>0.4902</td>
<td>2.25</td>
<td>0.028</td>
</tr>
<tr>
<td>WEXPORT</td>
<td>0.0225</td>
<td>1.32</td>
<td>0.190</td>
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<tr>
<td>FSCOPE</td>
<td>0.8504</td>
<td>5.38</td>
<td>0.000</td>
</tr>
<tr>
<td>EMPL</td>
<td>−0.0015</td>
<td>0.13</td>
<td>0.894</td>
</tr>
<tr>
<td>IN94</td>
<td>0.0452</td>
<td>5.21</td>
<td>0.000</td>
</tr>
<tr>
<td>REGDUM</td>
<td>−0.4058</td>
<td>2.51</td>
<td>0.024</td>
</tr>
<tr>
<td>USDUM</td>
<td>−0.2365</td>
<td>0.56</td>
<td>0.577</td>
</tr>
<tr>
<td>JAPDUM</td>
<td>0.9600</td>
<td>2.85</td>
<td>0.006</td>
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</tbody>
</table>

**Diagnostics**

- $R^2$(Adj.) 0.7616
- ANOVA: F(9, 64) 26.92
- Log-Likelihood $-112.7955$
- (Restricted Log-Likelihood) $(-170.7212)$
- $(S_p)^2$ 1.4274
- Amemiya PC 1.620
- Breusch-Pagan $\chi^2(10)^{(2)}$: (‘p’ value) 12.8461; (0.1696)

*Results excluding investment support regressors*

Regressand: $Y_i = 1994$ R&D/Sales ratio of UK subsidiary (%)

Notes: (1) ‘t’ statistics significant at the 5% level are shown in **bold type**.
(2) The Breusch-Pagan test for heteroscedasticity.
the problem of heteroscedasticity disappears, suggesting that the investment support variables are correlated with the error variance. The pattern of statistical significance of the firm-specific regressors is generally unchanged.

However, the significance of the locational dummies considerably altered. It would be expected that the regional dummy relating to whether the subsidiary is in an area attracting special support would be highly correlated with the investment support variables. This would explain why it does not appear significant in the original specification, but emerges significant when the investment support regressors are dropped. It appears to be strongly negative, suggesting that assisted areas actually attract lower R&D-intensive operations. This appears in line with the predictions of Cantwell (1995).

The dummy identifying the MNE parent as Japanese now appears to be statistically significant and positive. The alteration in the significance of this dummy is also based on its high positive correlation with the investment support regressors. This suggests that Japanese MNEs have availed of the investment supports relatively more than non-Japanese MNEs. The dummy appears to be positive, suggesting that Japanese MNEs also have a relatively higher R&D-intensity in their UK operations than non-Japanese MNEs.

Finally, we examine the estimates of equation (3), which are presented in Table 3. The salient feature of these estimates is that the pattern of statistical signifi-

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>'t' Statistic($^{(1)}$)</th>
<th>'p' Value</th>
</tr>
</thead>
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<tr>
<td>Constant</td>
<td>0.5001</td>
<td>1.16</td>
<td>0.252</td>
</tr>
<tr>
<td>GRANTS</td>
<td>0.1617</td>
<td>0.24</td>
<td>0.807</td>
</tr>
<tr>
<td>INFRA</td>
<td>-0.1463</td>
<td>0.49</td>
<td>0.626</td>
</tr>
<tr>
<td>TAX</td>
<td>0.7015</td>
<td>2.92</td>
<td>0.005</td>
</tr>
<tr>
<td>LOANS</td>
<td>-0.1361</td>
<td>0.33</td>
<td>0.741</td>
</tr>
<tr>
<td>GLOANS</td>
<td>0.1613</td>
<td>0.37</td>
<td>0.710</td>
</tr>
</tbody>
</table>

Diagnostics

R²(Adj.) = 0.1429
ANOVA: F(5, 68) = 6.98
Log-Likelihood = -147.0638
(Restricted Log-Likelihood) = (-161.4130)
$S_a^2 = 3.7475$
Amemiya PC = 4.051

Effects of investment support regressors on residuals
Regresand: $e_i = Y_i - \hat{Y}_i$ (Residuals from equation (2))
Notes: (1) 't' statistics computed using White's heteroscedasticity-consistent variance-covariance matrix. 't' statistics significant at the 5% level are shown in **bold** type.
(2) The Breusch-Pagan (1979) test for heteroscedasticity.
The Location of MNE R&D Activity

Table 4. Comparing Estimates of the R&D/Sales Ratio

<table>
<thead>
<tr>
<th></th>
<th>Estimates including investment support variables – Equation 1</th>
<th>Estimates excluding investment support variables – Equation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>F Statistic; (d.f.)</td>
<td>18.34; (14, 59)</td>
<td>26.92; (9, 64)</td>
</tr>
<tr>
<td>Amemiya Prediction Criterion</td>
<td>1.665</td>
<td>1.620</td>
</tr>
<tr>
<td>Akaike Information Criterion</td>
<td>3.342</td>
<td>3.319</td>
</tr>
</tbody>
</table>

Joint exclusion restriction tests on investment support regressors

| F(5, 58); ('p’ value) | 1.3951; (0.2396) |
| Likelihood Ratio; $\chi^2$(5); (p value) | 8.2694; (0.1418) |

Significance of the regressors changes. Infrastructural supports are no longer significant, while tax concessions are strongly significant and positive. This supports the findings of earlier studies of the determinants of overall inward investment (Grubert/Muti 1989, Shah/Slemrod 1990, Wheeler/Mody 1992, Mudambi 1995, Devereux/Griffith 1996).

We now turn to examining the competing merits of hypotheses Hypothesis 1 and Hypothesis 2. We do this by comparing the specifications of equations (1) and (2). This involves comparing the estimates presented in Table 1 with those presented in Table 2. We carry out this comparison using five separate measures. The first three are measures of fit, while the remaining two are tests of specification. These results are presented in Table 4.

We first note that fit as measured by adjusted $R^2$ does deteriorate slightly when we move from the estimates of equation (1) to the estimates of equation (2). However, it is generally accepted that adjusted $R^2$ does not adequately penalise the model for loss of degrees of freedom (Greene 1993). Thus, we turn to more sensitive measures. The F statistic increases considerably, while both the Amemiya Prediction Criterion and the Akaike Information Criterion perform better in the estimation of equation (2). We also run two joint exclusion tests on the investment support regressors – a generalised F test and a likelihood ratio test. Both tests fail to reject the null hypothesis of regressor exclusion.

We therefore conclude that we have uncovered strong evidence favouring Hypothesis 2 over Hypothesis 1. Government investment supports seem to function as incremental variables, affecting R&D investment decisions at the margin. The primary determinants appear to be the firm and location variables identified in the literature.
Implications and Concluding Remarks

Our findings are consistent with other studies that have pointed to the emergence of global networks for innovation within MNEs in recent years (Cantwell 1995). In this literature, it has been proposed that an affiliate can contribute more creatively to technology generation within such a network, the better is the local infrastructure in the location in which it is sited, which increases its potential skill base and local linkages with other innovative firms and research institutions; the wider is the functional scope of its mandate, which broadens its potential role within the MNE network; and the more mature it is, having had time to evolve away from a principally domestic orientation and towards more closely internationally integrated relationships.

While we do not explicitly estimate the effects of local infrastructure, we find strong support for the proposed effects of functional scope and maturity. More importantly, we find that these effects are dominant, placing limits on the influence that specific policy measures can have in the attraction of a local R&D presence by the foreign-owned affiliates located in a country.

Locations in which indigenous firms have an innovative tradition will best attract firms from the leading foreign centres in the industry in question, with a view to the extension of their R&D-intensive networks. Governments matter in the maintenance of such a regime, but their efforts are likely to be more productive if they take a longer-term approach. This would involve activities aimed at preserving and enhancing the standing of the local scientific and educational base, the favourable environment for conducting business in the relevant area, and the context provided by the country’s national system of innovation. Such efforts are likely to yield higher returns than the more specific (and short-term) measures we have examined this paper which are aimed directly at attracting R&D investments from foreign-owned firms.

However, this is not to say that these latter kinds of policy measures have no effect. On the contrary, they seem to have a significant ‘second order’ impact on the location of R&D within MNEs. In particular, tax credits have an important incremental effect on the location of R&D, and thereby encourage MNEs to upgrade somewhat the technological role expected of the local affiliate in their international network. Our empirical evidence here is consistent with the work of Hall (1993) – who found that firms increased their R&D in response to tax credits in the US – and Hines (1993), who suggested that R&D locational decisions are influenced by changes in tax rates (see also the discussion of van Reenen 1995).

The effect of local infrastructure on the R&D decision is apparent from the significantly greater R&D-intensity of operations in affiliates outside the assisted areas. Away from these areas firms can rely on better scientific, educational and
skills base, which encourages them to develop a more extensive local R&D contribution (Casson 1991). As indicated in the recent literature on the geography of innovation (Jaffe/Traftenberg/Henderson 1993, Almeida 1997, Cantwell/Iammarino 1998), linkages between innovating firms, and between the technology of firms and scientific activity, tend to be quite strongly localised, owing to the continuing significance of face-to-face interactions. As further anticipated, the local affiliate is also more likely to be drawn into a technologically creative role in an internationally integrated network, if it has had time to mature beyond its likely early local market orientation, and if it is part of a substantial and on-going investment commitment on the part of the parent company. This is consistent with the argument of Lipsey (1991), that foreign-owned affiliates tend to increase their exports as they age, and other work which has suggested – with particular reference to the experience of US MNEs in Europe, and notably in the UK – that the rise in affiliate exports is often associated with a greater local technological commitment (Dunning 1970, Cantwell 1989).

Beyond this general context for the evolution of R&D within foreign-owned affiliates, tax incentives have some further effect in encouraging an upgrading of local investments, just as other incentives (such as infrastructural supports) can affect the initial location of MNEs at an earlier stage in their investment strategies – an effect we have observed in the case of the Japanese-owned companies in our study. Hence, we conclude that governments have a twofold influence on the location of R&D in MNEs’ international networks for innovation. First, and primarily, they affect the climate for innovation in the host country, and the form and extent of local linkages between science and technology. Secondarily, but significantly, their more specific policy measures for corporate R&D and the attraction of foreign-owned MNEs can encourage some upgrading at the margin in the types of operations that MNEs site locally.

It should be noted that our results are based on a sample of MNE investments in a single location, namely the UK. While this makes the study empirically tractable, it has some inevitable costs. It is not possible to include some important factors such as cross-country choice variables and agglomeration effects. Further, it is possible that the effects of particular variables may be country-specific. However, we believe that our basic finding, namely that specific investment incentives have an incremental rather than a primary effect on R&D location decisions, is likely to be robust. Testing the model on data for another investment destination would be the next, confirmatory step in this research programme.
Appendix

Appendix 1. Details of Variables Used in Empirical Analysis

Investment Supports:

GRANTS = Pecuniary value of grants received from all government investment attraction agencies, 1990–94 (‘000 GBP)
INFRA = Pecuniary value of infrastructural supports received from all government investment attraction agencies, 1990–94 (‘000 GBP)
TAX = Pecuniary value of tax concessions received from all government investment attraction agencies, 1990–94 (‘000 GBP)
LOANS = Value of loans received from all government investment attraction agencies, 1990–94 (‘000 GBP)
GLOANS = Value of loan guarantees received from all government investment attraction agencies, 1990–94 (‘000 GBP)

Firm-specific Characteristics:

RD = UK subsidiary R&D/sales ratio
IN94 = Total MNE investment flows into the UK in 1994 (million GBP)
CRSK1 = Variance of corporate rate of return on capital, 1986–1994
EMPL = Employment in the UK subsidiary
SALES = Sales of the UK subsidiary (million GBP)
LDT1 = Duration of operations in the UK (years)
WEXPORT = Exports as a percentage of the UK subsidiary turnover

FSCOPE = Functional scope of output mandate
1 = Sales & service
2 = Assembly
3 = Manufacturing
4 = Product Development
5 = International Market Development

Location-specific Dummies

REGDUM = 1, if the UK subsidiary is in a Development Area or a Split Development/Intermediate Area*
= 0, otherwise
USDUM = 1, if the parent MNE is a US firm
= 0, otherwise
JAPDUM = 1, if the parent MNE is a Japanese firm
= 0, otherwise

* Based on the Department of Trade and Industry Assisted Areas map (revised, August 1993).
Appendix 2

We have a dependent variable \( y \) and two sets of regressors, \( X \) and \( Z \). Initially we regress \( y \) on \( X \), i.e., the system

\[
y = X\beta + u
\]  
(1)

We then collect the estimated errors, which are denoted by \( e \). Therefore, we can write

\[
e = (y - \hat{y}) = (y - X(X'X)^{-1}X'y) = (I - X(X'X)^{-1}X')y = (I - M)y
\]

where \( M = X(X'X)^{-1}X' \)

We regress these on the second set of regressors, \( Z \), estimating the system

\[
e = Z\gamma + v
\]  
(2)

Collecting the equations (1) and (2), we have the system:

\[
\begin{bmatrix}
  y \\
  e
\end{bmatrix} =
\begin{bmatrix}
  Y & 0 \\
  0 & Z
\end{bmatrix}
\begin{bmatrix}
  \beta \\
  \gamma
\end{bmatrix} +
\begin{bmatrix}
  u \\
  v
\end{bmatrix}
\]

Using the above information, the vector of regression estimators is

\[
\Delta = \begin{bmatrix}
  \hat{\beta} \\
  \hat{\gamma}
\end{bmatrix} = \begin{bmatrix}
  (X'X)^{-1}X' \\
  (Z'Z)^{-1}Z'(I - M)
\end{bmatrix}y
\]

We may call these ‘two-step’ estimators, since the overall estimator is obtained in two steps.

Next, we regress \( y \) on \( X \) and \( Z \) together, estimating the system:

\[
y = X\delta_1 + Z\delta_2 + w
\]  
(3)

We can write this system as

\[
y = [X \ Z]\begin{bmatrix}
  \delta_1 \\
  \delta_2
\end{bmatrix} + w
\]

The vector of regression estimators is now:

\[
\hat{\delta} = \begin{bmatrix}
  \hat{\delta}_1 \\
  \hat{\delta}_2
\end{bmatrix} = ([X \ Z]'[X \ Z])^{-1}[X \ Z]'y = \begin{bmatrix}
  X' \\
  Z'
\end{bmatrix}[X \ Z]^{-1}[X \ Z]'y
\]

\[
= \begin{bmatrix}
  X'X & X'Z \\
  Z'X & Z'Z
\end{bmatrix}^{-1}
\begin{bmatrix}
  X' \\
  Z'
\end{bmatrix}y
\]

We can solve this equation in terms of \( X \) and \( Z \), using results for partitioned inverses.
Define:

\[
\begin{bmatrix}
X'X & X'Z \\
Z'X & Z'Z
\end{bmatrix}^{-1} =
\begin{bmatrix}
A_{11} & A_{21} \\
A_{12} & A_{22}
\end{bmatrix}
\]

The results for partitioned inverses yield the following results:

\[A_{11} = (X'X)^{-1} [1 + X'Z(Z'Z - Z'MZ)^{-1} Z'X(X'X)^{-1}]\]
\[A_{12} = -(X'X)^{-1} X'Z(Z'Z - Z'MZ)^{-1}\]
\[A_{21} = -(Z'Z - Z'MZ)^{-1} Z'X (X'X)^{-1}\]
\[A_{22} = (Z'Z - Z'MZ)^{-1}\]

It now follows that

\[\hat{\delta}_1 = A_{11}X' + A_{12}Z'\]
\[\hat{\delta}_2 = A_{21}X' + A_{22}Z'\]

Substituting for \(A_{ij}\), we have

\[\hat{\delta} = \begin{bmatrix} \hat{\delta}_1 \\ \hat{\delta}_2 \end{bmatrix} = \begin{bmatrix} (X'X)^{-1}X' - (X'X)^{-1}X'Z(Z'Z - Z'MZ)^{-1}Z'(1 - M) \\
(Z'Z - Z'MZ)^{-1}Z'(1 - M) \end{bmatrix} y\]

These estimators may be called ‘one-step’ estimators as they are obtained from a single estimation of (3). It may be seen that they differ from the ‘two-step’ estimators in that they include interaction terms between the \(X\)'s and the \(Z\)'s.

References


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Cantwell, J. A./Iammarino, S., MNCs, Technological Innovation and Regional Systems in the EU: Some Evidence in the Italian Case, University of Reading Discussion Papers in International Investment and Management, no. 247, February 1998.


