THE RECENT LOCATION OF FOREIGN-OWNED R&D ACTIVITIES BY LARGE MNCs IN THE EUROPEAN REGIONS: THE ROLE OF SPILLOVERS AND EXTERNALITIES

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ABSTRACT

This paper examines the role of spillovers and externalities in influencing the recent siting of foreign-owned R&D activities in European regions. In accordance with the literature on knowledge creation in MNCs, we find that location of foreign-owned research tends to agglomerate, depending upon the potential for the following different sources of spillovers and externalities: (i) intra-industry spillovers or specialisation externalities, associated with the presence of a wide-ranging collection of firms active in the same sector; (ii) inter-industry spillovers or diversity externalities, associated with the co-presence of firms working in different fields; and (iii) science-technology spillovers and externalities stemming from the presence of a munificent scientific and educational infrastructure. Additionally, we find that benefits from spillovers decline with distance, but this holds especially for intra- and inter-industry spillovers.

Key words: multinational corporations, R&D activities, spillovers, externalities, European regions.

1. Introduction

The theory of the multinational corporation (MNC) has traditionally highlighted the role of technological innovation in explaining the determinants of foreign direct investment. However, while technological innovation had been seen mainly as the source of an ex-ante advantage that allows firms to expand abroad (DUNNING, 1988), in the most recent literature the focus of attention has shifted to the creation of new technological competencies through the international dispersion of corporate activities (CANTWELL, 1995; PEARCE and SINGH, 1992; KUEMMERLE, 1997). In particular, according to this approach, the firm's international expansion can be considered not only as a consequence of ownership advantages to be exploited in foreign markets (HYMER, 1960; VERNON, 1966; BUCKLEY and CASSON, 1976), but also as the means of further augmenting the company's competitive advantage (FROST, 1998, 2001; KUEMMERLE, 1999).

This internationalisation strategy is substantially different from the international strategy adopted in the early post-war period, in which the primary aim was the conquest of new markets abroad through the adaptation of products to local consumer preferences. Conversely, the closer international corporate integration that has occurred in the leading MNCs since the 1960s, aims to establish geographically dispersed networks for the purpose of the transfer of technology, skills and assets across national borders between the parent company and its affiliates. The sustainable competitive advantage built on this transfer lies in the two-way interaction between parent and subsidiaries. Local laboratories play a new role within the whole corporate structure by sourcing new knowledge from the local environment rather than carrying out merely demand-oriented activities (ZANFEI, 2000). Starting from the idea that increasing returns are essentially a regional and local phenomenon arising from regional economic agglomeration and specialisation (KRUGMAN, 1991), different approaches emphasising the role of local spatial areas for the purpose of global competitiveness, have flourished in recent economy theory. Specifically, in analysing the internationalisation strategy of MNCs, it emerges clearly that multinationals target local spatial areas where they can enjoy externalities and spillovers (see BOSCHMA and LAMBOOY, 1999 and MARTIN, 1999, for a critical overview).

Indeed, innovative activity tends to be highly agglomerated (JAFFE et al., 1993; AUDRETSCH and FELDMAN, 1996; KELLER, 2002), and agglomeration can be largely explained by the existence of technological spillovers. As distance hampers the exchange of tacit knowledge, proximity becomes relevant in order to be able to absorb spillovers.[1] However, the existing knowledge base of a region plays an important role in the decisions of the largest foreign-owned firms as to where to locate their technological activities (CANTWELL and IAMMARINO, 2001). For these reasons, the local technological efforts of foreign-owned MNCs tend to be strongly agglomerated at a sub-national and regional level (BRAUNERHJELM and SVENSSON, 1998; BARREL and PAIN, 1999). Accordingly, with reference to the locational regional choice of foreign-owned MNC technological activities in the European regions over the period 1987-1995, our hypotheses concern the relevance of intra- and inter-industry spillovers, and externalities stemming from the local scientific and educational base.

The empirical investigation uses patents granted in the US to the world's largest industrial firms for inventions achieved in their European-located operations, classified by the host European region in which the research facility responsible is located. Specifically, we examine corporate research activity in Germany, the UK, France and Italy, as they host almost 75% of the total innovative activities carried out in Europe by foreign-owned firms in the period considered. The model developed aims to explain spatial patterns of activity by foreign-owned firms through variables related to the potential for intra- and inter-industry spillovers, to the local knowledge base and to the local market size, once having controlled for random and cumulative agglomeration effects. The model has been estimated through count data techniques.

The paper is organised in the following way. Section 2 sets out the conceptual framework and develops the hypotheses about the role of spillovers and externalities on the MNC location choice. Section 3 reports data on the extent and evolution of the internationalisation of technological activity in the European regions in the period 1987-95. Section 4 details the econometric model and the variables employed in order to econometrically test the hypotheses, while Section 5 shows and discusses the results obtained. Finally, Section 6 presents some summarising and concluding remarks, draws out some of the policy implications of our argument, and indicates an agenda for future research.

2. The location of foreign technological activities by MNCs

Traditionally, innovation in MNCs has been understood as largely the domain of the parent company. Indeed, traditional analysis in the International Business field emphasises the central role played by the latter in the development of technological know how. According to this literature, any incidence of technological activity located overseas was considered to be primarily adaptive in nature and heavily reliant on the centralised knowledge base of the organisation. This type of overseas technological development has been referred to as Asset Exploiting R&D (DUNNING and NARULA, 1995) or Home Base Exploiting activity (KUEMMERLE, 1997).

However, beginning in the mid-1980s, changes in the structure of the global economy as well as an apparent trend toward internationalisation of the R&D activities within major multinational firms motivated researchers to treat more seriously the possibility that foreign subsidiaries could play a crucial role as sources of new ideas and capabilities (ZANFEI, 2000; FROST, 2001). Attention has been increasingly focused on the emergence of the trend for MNCs to establish internal and external networks for innovation (CANTWELL, 1995; KUEMMERLE, 1999; ZANDER, 1999). The new approach has drawn heavily on the evolutionary view of the firm and industry (NELSON and WINTER, 1982) and re-assesses the rationale for the MNC and the role played by its subsidiaries. Viewing the MNC as a repository of knowledge, scholars have come to focus attention on the pressures faced by firms when trying to maintain and continuously upgrade their technological know how. The MNC is believed to offer a superior way of organising technological activities across its dispersed but interconnected international network. Therefore, internationalisation is increasingly motivated also by the wish to tap into the capabilities available in host countries and thus to gain the benefits of localised knowledge spillovers (CANTWELL, 1995; FROST, 2001; LE BAS and SIERRA, 2002; ZEDWITZ and GASSMANN, 2002). This type of overseas technological development has been referred to as Home Base Augmenting (KUEMMERLE, 1997).

In this context, the development of cross-border corporate integration and intra-border inter-company sectoral integration, as new forms of global governance, makes it increasingly important to examine where and how innovative activity by MNCs is internationally dispersed and regionally concentrated. To the multinational firm, the innovativeness of the corporate group as a whole depends upon the extent of the locational diversity that it can manage to combine and sustain in its technological efforts, and the degree to which it can choose to site activity so as to reduce overlapping duplication but enhance technological complementarity between the locations selected. Therefore, the locational choice of MNCs for their technological activities depends upon the interrelationships between their corporate strategy and the location-specific characteristics of alternative contexts in which research may be sited.

However, MNCs' location choice and their location-specific determinants have been so far mainly analysed purely at the country level (HÅKANSON, 1992; FORS, 1996; KUMAR, 1996; ODAGIRI and YASUDA, 1996), and only a minority of studies have recently started to investigate their regional or sub-national dimension. However, some authors have recently highlighted the importance of the sub-national level in delimiting the boundaries of technological capabilities and expertise (KRUGMAN, 1990; PORTER, 1990; STORPER, 1992). Others suggested that regions are increasingly becoming important *milieux* for the competitive-enhancing activities of mobile investors (PORTER, 1996; SCOTT, 1998; DUNNING, 2000), thus replacing the nation state as the principal spatial economic entity (OHMAE, 1995).

Nonetheless, there is still only quite a scant empirical research on the location of MNCs at this sub-national level (CARRINCAZEAUX et al. 2001; FROST, 2001; CANTWELL and

IAMMARINO, 2003). Recent streams of literature have explored extensively the determinants of foreign-owned firms' tendency to concentrate in specific areas, and the nature of the mechanisms which generate a local and cumulative process of knowledge creation (ALMEIDA, 1996). The foreign technological activities of MNCs tend to agglomerate partly due to a random and cumulative process (ELLISON and GLAESER, 1997) essentially related to certain natural advantages, but more especially due to the spillovers and externalities they can enjoy in the foreign location. Indeed, as knowledge is mainly tacit, geographical distance increases the difficulty in both transmitting and absorbing it. Therefore, spatial proximity helps firms in the process of information sharing and knowledge diffusion, and it leads to the creation of technological enclaves. This leads to the general hypothesis that the intensity of spillovers increases with geographical proximity (CANIËLS, 2000; VERSPAGEN and SCHOENMAKERS, 2000). In particular, as far as the latter is concerned, we consider:

(a) Intra-industry spillovers and specialisation externalities;

(b) Inter-industry spillovers and diversity externalities;

(c) External sources of knowledge and science-technology spillovers.

(a) ***Intra-industry spillovers and specialisation externalities***

Intra-industry spillovers are associated with the presence of a wide-ranging collection of technologically active firms within a given industry or sector, all concentrated in the same geographical area (BAPTISTA and SWANN, 1998, 1999). The geographical concentration of firms engaged in similar activities or within a common industry, leads to further local clustering of related firms and the local accumulation of relevant knowledge (BRAUNERHJELM et al., 2000). Intra-industry spillovers relate to specialisation externalities and can be associated with the contribution of MARSHALL (1890), and to what geographers call "localisation economies". The kinds of linkages that grow up between competitors, suppliers and customers in any regional district or area are also, to some extent, peculiar to that location, and imbue the technology creation of its firms with distinctive features. For these reasons, other MNCs 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 innovation (CANTWELL, 1989; KOGUT and 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 *et al.*, 1993; ALMEIDA, 1996; VERSPAGEN and SCHOENMAKERS, 2000).

From these arguments, we derive our first hypothesis:

(H1): If intra-industry spillovers and specialisation externalities are important, foreign-owned MNCs should locate their research facilities in a region where other firms are (technologically) active in the same industry.

However, some difficulties may arise when the local technological strength stems essentially from a long established presence of domestically-owned firms (CANTWELL and NOONAN, 2002; JANNE, 2002). Indeed, when this is the case, foreign-owned MNCs might suffer from a congestion or crowding out effect, due to the limited given stocks of resources (scientists, engineers, etc.). Therefore, our second hypothesis is:

(H2): If specialisation externalities in a region stem essentially from a strong domestic technological presence, the location of foreign-owned MNC research facilities may be discouraged, and therefore, it is less likely.

(b) *Inter-industry spillovers and diversity externalities*

Inter-industry spillovers are associated with the co-presence of firms from different industries, and working in different fields of research. Indeed, the more diverse is the R&D conducted in a region, the more the firm could potentially benefit. Such spillovers relate to diversity externalities, which favour the creation of new ideas across sectors, and go back to the concept of "urbanisation economies" originally suggested by JACOBS (1969).

They are more likely to occur in an all-round 'higher order' centre of excellence,[2] which facilitates a more favourable interaction with indigenous firms, and greater opportunities for inter-company alliances for the purposes of technological collaboration and exchange (CANTWELL and IAMMARINO, 2001). Moreover, there is some evidence relating to cities in the US that diversity across industries may better promote innovation and knowledge spillovers (FELDMAN and AUDRETSCH, 1999). Therefore, our third hypothesis is the following:

(H3): If inter-industry spillovers and diversity externalities are important, foreign-owned MNCs should locate their research facilities in a region where other firms from many different industries are located.

(c) *External sources of knowledge, and science-technology spillovers*

Firms' efforts to advance technology do not generally proceed in isolation, but they are strongly supported by various external sources of knowledge: public research centres, universities, industry associations, an adequate education system and science base, and other firms (KLINE and ROSENBERG, 1986; NELSON, 1993; ROSENBERG and NELSON, 1996; NELSON and ROSENBERG, 1999; BRESCHI, 2000). There is growing evidence, so far mainly from the US, that these science-technology or university-industry linkages tend to be geographically localised (JAFFE et al, 1993; AUDRETSCH and FELDMAN, 1996; AUDRETSCH and STEPHAN, 1996; ACS et al., 2000; ADAMS, 2001). This is especially likely to be true of foreign-owned firms in an economy, which tend to have a greater degree of locational mobility when siting their corporate research, and so are able to pay greater attention to being close to relevant public research facilities[3] (see GÖRG and STROBL, 2001, on the greater international locational mobility of MNCs). Therefore the last hypothesis we test is as follows:

(H4): If external sources of knowledge and science-technology spillovers are important, foreign-owned MNCs should locate their research facilities in regions with a strong university presence or other sources of publicly funded R&D.

3. The location of foreign-owned MNC research activities in the European regions

In order to analyse the location of foreign-owned MNC research activities at the regional level in Europe, we make use of the Eurostat scheme of classification - the Nomenclature of Territorial Units for Statistics (NUTS). The NUTS classification is based on the institutional divisions currently in force in the member states, according to the tasks allocated to territorial communities, to the sizes of population necessary to carry out these tasks efficiently and economically, and to historical, cultural and other factors.[4] Specifically, to provide a single uniform breakdown of territorial systems we referred to the NUTS 2 level for the four countries considered (see Appendix 1 for the list of the regions considered). The NUTS 2 level (206 Basic Regions) is generally used by the EU members for the application of their regional policies, and thus is the most appropriate level at which to analyse the regional distribution of technological activities.[5]

Corporate research activity has been measured by using patents granted in the US to the world's largest industrial firms for inventions achieved in their European-located operations, classified by the host European region in which the research facility responsible is located (see Appendix 2 for a brief description of the database). The use of corporate patents as an indicator of advanced technological capacity and the ability to develop innovation is one of the most established and reliable methods of estimating the cross-sectional patterns of innovative activities. The advantages and disadvantages of using patent statistics are well known in the literature (PAVITT, 1985, 1988; GRILICHES, 1990). Some of the most well-known problems are that not all innovations are patented, not all patents are commercialised, and that the so-called propensity to patent varies by industry. Nevertheless, most authors surveying these issues tend to conclude that patent statistics can be useful indicators (VERSPAGEN and SCHOENMAKERS, 2002). For example, as a conclusion of an analysis comparing innovation count data and patent data as indicators of innovation at the regional level for the USA, ACS et al. (2002, p. 1080) conclude that their "empirical evidence suggests that patents provide a fairly reliable measure of innovative activity".

The use of patent records provides information on both the owner of the invention to which a patent has been assigned (from which the country of location of the ultimate parent firm has been derived through a consolidation of patents at the level of international corporate groups, where the assignees are subsidiary companies) and, separately, the address of the inventor, thus allowing the identification of the location at which the research and development underlying the invention was carried out in geographical terms. Thereby, each foreign-owned corporate patent has been associated with a NUTS code, according to the location of the first named inventors when they are situated in the EU countries.[6] Moreover, patents can be classified by detailed technological fields,[7] which would not be otherwise possible from other commonly used indicators (such, for example R&D expenditures).

Finally, it is worth observing that the choice of US patenting is convenient, since large firms are especially prone to patent their best quality inventions in the US market, the largest and the most technologically advanced, following more extensive testing in their respective home markets. It is therefore more likely that our data reflect the patenting of inventions that have a significant commercial importance.

Table 1 about here

Table 1 indicates the total number of corporate patents registered in the database as attributable to research conducted in the European host countries over the period 1987-1995, as well as the share within these countries of foreign-owned firms in total corporate patents emanating from locally-based research. Thus, the total number of corporate patents due to German-located activity registered in the database over the period 1987-1995 (33,907) is more than three times that registered for the UK (10,136) or France (10,547), which in turn are each more than four times that registered for Italy (2,359). However, the foreign-owned share of patents is only about 18% in Germany and 28% in France, while for the UK the efforts of foreign-owned firms is about 40% of the total, and in Italy it exceeds 50%. Yet in absolute terms in the period considered the most attractive European host country for the technological activity of foreign-owned MNCs was Germany (31.6% in 1987-95), followed by the UK (21.5%) and France (15.6%), and only to a lesser extent Italy (6.3%).

Table 2 about here

In order to provide some preliminary descriptive evidence about the agglomeration of technological activity, we calculated some traditional concentration indexes. Specifically, Table 2 reports the Gini coefficient and concentration ratios, calculated for both domestically- and foreign-owned large firms' technological activity across regions. Looking at the Gini coefficient, it emerges that research activity is geographically agglomerated (the index is always above 0.5 and it reaches 0.82 in the Italian case). Additionally, it emerges that foreign-owned research activity is more concentrated than that of domestic firms only in the UK, while concentration ratios show a greater variety. Indeed, when considering the first four regions, France reveals a higher share of foreign-owned activity, due to the presence of a few large foreign-owned MNCs located there. However, it is interesting to observe that foreign-owned research activity is in general rather strongly agglomerated. The first eight regions host over 90% of such activity both in France and Italy; while in Germany and in the UK the share is about 65%.

4. The econometric model and specification of the variables used

As the phenomenon under study is the siting of foreign-owned research activities across the European regions, the dependent variable is the following:

$FORPAT\_dep_{ij}$ = number of patents granted to foreign-owned MNCs for research activity carried out in region i and industry j over the period considered (1987-1995).

i = 1, …, 116 regions (38 for Germany, 35 for the UK, 22 for France, and 21 for Italy);

j = 1, …, 17 industries.

It is worth observing that the industrial dimension, j, allows us to take into account the sectoral disparities in the propensity of innovation-related activities to cluster as well as in the propensity to patent. Indeed, while innovative activities tend in general to agglomerate within specific locations, the intensity of the geographical concentration and the spatial organisation of the innovative processes may differ remarkably across sectors (BRESCHI, 1999). As the dependent variable is clearly a count variable, a binomial regression model was fitted to the data.[8] Indeed, this kind of linear exponential model offers an improved methodology for count models for the cases of patents and innovation counts (CAMERON and TRIVEDI, 1998).

The independent variables employed relate to the hypotheses put forward in Section 2. It is worth observing that, in order to rule out endogeneity problems, lagged independent variables have been included. Specifically, they have been measured in the period 1969-1977 (see Appendix 4 for description and data sources), with reference to the following:

(a) *Intra-industry spillovers and specialisation externalities*. The variable adopted as a proxy for intra-industry and specialisation externalities is a measure of technological specialisation of each region i in each industry j. The proxy is derived from an index of Revealed Technological Advantage (RTA_{ij}), which allows us to control for inter-sectoral and inter-regional differences in the propensity to patent (CANTWELL, 1995). In particular, as our second hypothesis states that some differences in the location behaviour of foreign-owned

MNCs may arise when intra-industry spillovers originate mainly from domestically-owned firms, we distinguished between technological specialisation due to the activities of foreign-owned companies already located in the region ($FORRTA_{ij}$), and technological specialisation due to the (normally longer established) activities of domestically-owned firms ($DOMRTA_{ij}$). The index RTA_{ij} is defined as:

$$RTA_{ij} = (P_{ij}/\Sigma_i P_{ij})/(\Sigma_j P_{ij}/\Sigma_{ij} P_{ij})$$

where P_{ij} is the number of patents by firms located in region i and belonging to industry j. The index varies around unity, such that values greater than one suggest that a region is comparatively advantaged in the sector of activity in question relative to other regions, while values less than one are indicative of a position of comparative disadvantage.

(b) *Inter-industry spillovers and diversity externalities*. The variable adopted as a proxy for inter-industry spillovers and diversity externalities ($DIVERSITY_i$) relates to the breadth of technological development in a region, which is what increases the opportunity for inter-industry exchanges. Specifically, $DIVERSITY_i$ has been measured by the inverse of the coefficient of variation over the profile of regional technological specialisation across technological fields ($DIVERSITY_i = ?_i/?_i$). The profile of regional technological specialisation is measured by the RTA index, RTA_{ik}, in region i and technological field k (where k = 1, ..., 56). Therefore, RTA_{ik} is a proxy for specialisation of region i across technological fields k, and is calculated in the following way:

$$RTA_{ik} = (P_{ik}/\Sigma_i P_{ik})/(\Sigma_k P_{ik}/\Sigma_{ik} P_{ik})$$

where P_{ik} = number of patents granted in field k to firms for research in region i.

It should be noted that patents associated with some field k may be due to firms in any industry j, and so widespread regional technological development across a broad range of fields k is usually indicative of the existence of areas of technological overlap between industries, and hence indicates the scope for technological spillovers between industries.

A remark on the interpretation of the proxy employed (i.e. the coefficient of variation) may not be out of place here. When CV_i is low, the cross-sectoral distribution of RTA_i is widely dispersed, that is the profile of the comparative technological advantage of region i, is highly diversified across fields, and not highly concentrated in some activities rather than others. On the other hand, when CV_i is high, the RTA distribution is highly concentrated in certain fields and the degree of diversification of the region will be low. Thus, CV_i constitutes an inverse measure of technological diversification of the region.[9]

(c) *External sources of knowledge and science-technology spillovers*. In order to capture the complex character of local knowledge externalities, we considered several proxies for non-corporate R&D activities, and for the education level in each region. Specifically, the proxies used are the following:

$RDEMPPUB_i$ measures R&D employment in the public sector in each region i.

$EDUHIGH_i$ measures the number of full-time and part-time students in higher education in each region i, while $EDUTOT_i$, measures the total number of full-time and part-time pupils and students in each region i.

Additionally, given the recent indication of a wider range of spatial interaction than purely within a region (ANSELIN et al., 1997; PACI and USAI, 2000), we also considered inter-regional spillovers. Specifically, we calculated spatially-lagged spillover variables as follow:

- $RDPU\_BORD_i = \Sigma_h RDEMPPU_h$ is the sum of the public R&D employment in all regions h bordering region i (see Appendix 3); and likewise:
- $DOMRTA\_BORD_i = \Sigma_h DOMRTA_h$;
- $FORRTA\_BORD_i = \Sigma_h FORRTA_h$;
- $DIVERSITY\_BORD_i = \Sigma_h DIVERSITY_h$.

Control variables

The bulk of the analysis on overseas R&D argues that locational determinants related to the size and the characteristics of the local market have a positive and significant influence on affiliate R&D location (ZEJAN, 1990; KUMAR, 1996, 2001; Braunerhjelm et al., 2000). Therefore, we considered the following control variables:

- $GDPPC_i$, measured by the GDP per capita in each region i, in 1992; and
- $POPUL_i$, measuring the population in each region i, in 1992.

In order to control for a random cumulative mechanism and the strong path-dependent character of technological agglomeration, we also included a lagged dependent variable (that is, referring to the prior period 1969-1977) among the explanatory variables. Finally, as using absolute numbers of patents as a dependent variable might pose difficulties associated with differences in the propensity to patent in different industries and countries, this has been circumvented by adding industry and country dummies in the specification of the model. Other conditions, like the availability of skilled labour in a field, financial and fiscal measures, the regulatory and legal environment, and the nature of intellectual property protection, might make a region an appealing location for foreign-owned MNCs to invest in research. Unfortunately, such data are not available at the European regional NUTS2 level, although arguably at least some of these (such as the regime for intellectual property rights) are regulated more at a national than at a regional level, and do not vary greatly between the four large Western European countries under consideration.

5. Empirical findings

Table 3 about here

The summary characteristics of the variables and the correlation matrix are reported in Table 3. As may have been easily predictable, the variables proxying local knowledge externalities (RDEMPPUB, EDUHIGH and EDUTOT) are highly correlated. Therefore, they had to be used separately in the models in order to avoid multicollinearity problems.

Table 4 about here

The empirical findings obtained from the estimation are reported in Table 4. Specifically, the table reports five amongst the best specifications of the model. Numbers in parentheses represent z-statistics. It may be worth observing that interpretation of the negative binomial model follows the usual pattern: positive, significant values indicate that an increase in that variable increases the odds that foreign-owned research activity is localised in the particular combination of region i and sector j, ceteris paribus. Negative values indicate the reverse.

Overall, the results confirm that the geographical agglomeration of innovation is remarkable, and demonstrate statistically that foreign-owned firms are sensitive to agglomeration potential. Specifically, the location of innovative activities by MNCs is cumulative and path-dependent as well as strongly and positively influenced by both intra- and inter-industry spillovers, thus confirming that the two effects work together in combination (PACI and USAI, 2000).

Specifically, intra-industry spillovers are positive and significant when the specialisation of the region in a particular industry is essentially due to the presence of other foreign-owned firms already located there (FORRTA is always significant at p<.01). The effect becomes instead negative or disappears when specialisation stems essentially from the presence of domestically-owned firms (DOMRTA is negative and significant at p<.10 in Model 3, while it loses significance in all the other specifications of the model). That might indeed be related to the fact that indigenous technological specialisation is often highly concentrated in a few long established major local firms which act as an entry deterrent or raise entry barriers. Thus, where indigenous technological development is highly concentrated in just one or two major local firms of long standing, any industry-specific agglomeration effect may be offset by a competitive deterrence effect, both in terms of bidding for local resources and in terms of the availability of potential local technological spillovers.

Instead, inter-industry spillovers (DIVERSITY), come out as positive and always highly significant (at p<.01), thus confirming that diversity externalities provide a region with a higher likelihood to attract foreign-owned MNC technological activities. As far as spillovers related to the local external source of knowledge, the relevant variables are highly correlated and therefore they had to be considered separately. However, all the estimates obtained show that both the R&D expenditures in the Government sector sustained locally, as well as the educational base constitute a significant pull factor for foreign-owned MNCs. Indeed, RDEMPUB is positive and significant at p<.01 in Model 3, and at p<.10 in Model 1, EDUHIGH is positive and significant at p<.01 in Model 5, and EDUTOT is positive and significant at p<.05 in Model 3 and Model 5.

Concerning inter-regional spillovers, the estimation results show that those related to external sources of knowledge do actually seem to flow across regions (RDPUBORD is always positive and significant at least at p<.10 in all the best specifications, except Model 3). Foreign-owned MNCs' location of research activities in region i is positively influenced not only by the external sources of knowledge in the region itself, but also by the external sources of knowledge in regions adjacent to region i. In other words, allowing for a varying spatial extent of spillovers, our results show that they extend over bordering regions (see also ANSELIN et al., 2000). This may be in line with JAFFE's (1989) suggestion that there is only weak evidence that science-technology spillovers are facilitated by the immediate geographic coincidence of universities and research labs. However, it should be noted that this result has been subsequently criticised because of both an inappropriate level of spatial aggregation (states), and the limits of the co-location index used. For example, ANSELIN et al. (1997) showed that with different indices in models where spatial dependence is corrected for, even in a state-based model local university effects can be detected.

In contrast, regional clustering remains crucial as far as intra- and inter-industry spillovers are concerned. Indeed, both specialisation externalities and diversity externalities do influence the foreign-owned MNC location at the regional level, but only when they concern the region itself (DOMRTA_BORD, FORRTA_BORD and DIVERSITY_BORD never come out as significant in the best specifications of the model). This result suggests that benefits from inter-company spillovers may decline with distance more rapidly than those associated with science-technology spillovers and linkages between industry and universities.

6. Summary and conclusions

Since the late 1970s, large MNCs have increasingly extended or diversified their fields of technological competence through their use of internationally integrated networks for technological development. In each location in such a network MNCs tap into specialised sources of local expertise, and so differentiate their technological capability, by exploiting geographically separate and hence distinct streams of innovative potential.

The recent emergence of internationally integrated MNC networks is best observed in Europe, where the contribution of foreign-owned MNCs to national technological capabilities is much greater than elsewhere. About one-quarter of large firm R&D carried out within in Europe has been conducted under foreign ownership, while the world average is only just over one-tenth. The removal of non-tariff barriers, the completion of the single European market and recent economic and monetary integration have spurred the reorganisation of operations of MNC affiliates located in the EU to a much greater extent than in the case of affiliates based elsewhere.

Our results suggest that the selection of locations by MNCs for the purpose of siting their R&D activities is highly influenced by the potential for capturing spillovers. Specifically, the relative attractiveness of regions in Europe for the technological efforts of foreign-owned MNCs depends upon (i) the presence of industry-specific spillovers and specialisation externalities; (ii) the breadth of local technological activities in the region, that is the opportunity to enjoy diversity externalities and to capture inter-industry spillovers; (iii) the presence of external sources of knowledge and science-technology spillovers. Our results also support (in line with some other recent contributions, such as FROST 2001) a widely debated conjecture in the multinational literature, namely that foreign direct investment may be driven, at least in part, by the desire to gain knowledge from the diverse institutional contexts in which multinational firms operate.

That has some implications in suggesting regional policy forms based mainly on regional infrastructural investments (rather than exclusively on regional incentives), which enhance the attractiveness of the region as an appealing economic environment for potential investors (BRAUNERHJELM et al., 2000). One key contribution of this study, then, is to suggest conditions under which foreign-owned subsidiaries tap into local sources of knowledge. Specifically, the potential for intra- and inter-industry spillovers matters for regions throughout Germany, the UK, France and Italy.

The empirical findings support the idea that locations which, although characterised by their own industrial specificity, accumulate a wide range of technological competencies and develop the potential for inter-industry spillovers, are more likely to attract foreign-owned research because they represent a general source of skills and expertise rather than a source of specific capabilities in some particular fields (CANTWELL and IAMMARINO, 2000; JANNE, 2002). This is consistent with other literature that has emphasised the growing importance of science-technology spillovers in the current techno-economic paradigm, and which is now paying increasing attention to the central role of inter-industry spillovers and so-called general purpose technologies.

Additionally, it is worth observing that intra-industry spillovers depend critically on the presence of other foreign-owned actors while large domestically-owned firms might even discourage the location of foreign-owned MNCs. We relate this aspect to the need to disperse technological development among a sufficient variety of local actors to attract foreign-owned research to a localised cluster. In fact, indigenous technological specialisation can be highly concentrated in a few major local firms of long standing, acting as an entry deterrent or raising entry barriers. Hence, where indigenous technological development is highly concentrated in just one or two well established major local firms, any industry-specific agglomeration effect may be offset by a competitive deterrence effect, both in terms of bidding for local resources and in terms of the (lack of) availability of potential local technological spillovers.

This can occur in the UK and Italy but when, as is more frequently the case in Germany and France, local development is heavily concentrated in just a few leading firms in a region (i.e. where the leading domestically-owned firms are strongly regionally separated and each have a clear regional identity), then a crowding out effect is likely to outweigh any agglomeration attraction. In Germany each of the major companies, for example in the chemical industry, has 'its own' region, and so in a sense the deterrence effect to technological entry in a region with an existing dominant player is observed even among the large indigenous German firms themselves. Naturally, any deterrence impact affects foreign-owned firms in the same industry (and hence which are competitors of the dominant company in a region) just as much, and so there is much less scope here for an agglomeration effect.

Importantly, our results show also that intra- and inter-industry spillovers are highly region-specific, thus confirming that benefits from spillovers do actually decline with distance (see KELLER, 2002). However, the same does not seem to hold as strictly for science-technology spillovers, which in fact show also a neighbouring inter-regional dimension, thus suggesting that the effects of distance may work differently and be less tightly constrained in this case. Although JAFFE (1989) may have been unduly hesitant about the significance of the role of geographical proximity in science-technology linkages (ANSELIN et al, 1997), it may be that while for certain categories of university-industry knowledge transfer actors must be strictly co-located, for others the somewhat greater distance between neighbouring regions is just as effective. Future research is needed in order to investigate whether and in what circumstances the effect of spillovers from science to industry fades away with increasing distance (for example considering spatially-lagged two regions, and distinguishing between different fields of science and technology).

Future work would certainly benefit also from the extension of the empirical analysis to other European countries in order to add further evidence upon the agglomeration of the innovative activities of foreign-owned MNCs even in smaller countries. Likewise, major benefits would come from more finely grained research (at the firm level) that would shed light on the types of motivations leading foreign investment in each location. In fact, even from the viewpoint of countries and regions seeking to attract MNC activity as a means of improving their locational advantages through spillovers and linkages due to MNC activity, it is worth observing that the quality and the extent of the externalities due to MNC activities depends on the motivation for their investment, which is itself dependent on the kinds of location advantages available to them (NARULA and DUNNING, 2000). There also remain questions about how MNCs set up and organise their international R&D laboratories, as well as the relationship between R&D and the location of other parts of production abroad.

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Table 1- Patenting activity attributable to European-located research, 1987-95 (%)

	Total corporate patents		Foreign-owned patents	
European host country	(No.)	%	(No.)	%
Germany	33.907	47.9	5.991	17.7
UK	10.136	14.3	4.073	40.2
Italy	2.359	3.3	1.186	50.3
France	10.547	14.9	2.958	28.1
Total Europe	70.724	100.0	18.954	26.8

Source: US patent database developed by John Cantwell at the University of Reading.

Table 2 – Concentration of foreign and domestic R&D activities across regions, 1987-1995.

	Germany [38]		UK [35]	
	Foreign	Domestic	Foreign	Domestic
Across regions				
Gini coeff.	0.62	0.68	0.56	0.50
C1	12.74	13.58	11.93	9.35
C2	25.23	26.63	23.15	17.37
C4	46.31	49.11	41.41	32.42
C8	65.45	77.5	65.23	55.94

	France [22]		Italy [21]	
	Foreign	Domestic	Foreign	Domestic
Across regions				
Gini coeff.	0.72	0.74	0.74	0.82
C1	49.43	52.72	38.95	42.11
C2	61.19	68.64	55.39	77.75
C4	82.08	79.8	73.6	88.24
C8	97.33	92.84	93.41	96.94

Source: As for Table 1.

Table 3 – Correlation and characteristics of the variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Mean	7.205	5.463	0.850	0.928	0.005	1897.53	60.388	298.873	8688.37	4.179	3.039	0.031	2179.66	95.407
	Std. Dev.	28.68	23.20	2.92	3.05	0.002	2667.5	60.337	205.277	6164.9	4.102	2.638	0.009	1471.9	35.636
	Min	0.000	0.000	0.000	0.000	0.001	10.000	0.000	4.000	0.000	0.000	0.000	0.020	117.00	13.100
	Max	597.0	462.00	53.770	54.250	0.012	19876.0	536.000	1156.24	36992.0	16.580	13.190	0.040	10862.0	215.00
1	FORPAT_dep														
2	FORPAT	0.832													
3	FORRTA	0.109	0.193												
4	DOMRTA	-0.001	0.008	0.202											
5	DIVERSITY	0.246	0.283	0.012	-0.008										
6	RDEMPPUB	0.242	0.258	0.002	-0.008	0.404									
7	EDUHIGH	0.232	0.248	0.012	-0.005	0.309	0.818								
8	EDUTOT	0.120	0.136	0.013	-0.006	0.342	0.547	0.342							
9	RDPU_BORD	0.081	0.044	-0.007	-0.030	0.084	0.207	0.006	0.268						
10	FORRTA_BORD	0.013	0.026	0.028	0.042	-0.074	0.056	0.115	0.074	-0.014					
11	DOMRTA_BORD	-0.035	-0.003	-0.003	-0.018	0.090	-0.102	-0.104	-0.007	-0.062	-0.042				
12	DIVERSITY_BORD	-0.021	0.018	0.010	0.036	0.124	-0.158	-0.300	0.354	0.024	0.034	0.021			
13	POPUL	0.230	0.238	0.003	-0.010	0.331	0.695	0.882	0.435	-0.018	0.052	-0.044	-0.247		
14	GDPPC	0.177	0.177	0.027	-0.047	0.374	0.294	0.229	0.110	0.275	-0.003	0.099	-0.152	0.132	

Table 4 - Estimation results (dependent variable FORPAT_dep)

	Model 1			Model 2			Model 3			Model 4			Model 5		
FORPAT	0.022	***	(6.671)	0.019	***	(6.054)	0.021	***	(6.579)	0.019	***	(6.020)	0.021	***	(6.658)
FORRTA	0.156	***	(6.176)	0.164	***	(6.543)	0.158	***	(6.298)	0.165	***	(6.568)	0.156	***	(6.275)
DOMRTA	-0.035		(-1.578)	-0.034		(-1.561)	-0.038	*	(-1.717)	-0.035		(-1.588)	-0.036		(-1.633)
DIVERSITY	251.55	***	(9.706)	228.52	***	(8.694)	255.47	***	(10.010)	(232.31)	***	(8.918)	252.04	***	(10.065)
RDEMPPUB	5.89E-05	*	(1.759)	3.07E-05		(1.084)	6.95E-05	***	(2.655)						
EDUHIGH	0.003		(1.607)										0.004	***	(3.018)
EDUTOT				0.000		(0.668)	0.001	**	(1.956)	0.000		(1.263)	0.001	**	(2.391)
RDPU_BORD	1.66E-05	*	(1.760)	2.31E-05	**	(2.404)	9.96E-05		(1.110)	2.52E-05	***	(2.687)	1.76E-05	**	(1.993)
FORRTA_BORD	-0.000		(-0.046)	0.002		(0.220)	-0.003		(-0.324)	0.002		(0.207)			
DOMRTA_BORD	-0.012		(-0.712)	-0.008		(-0509)	-0.015		(-0.850)	-0.009		-(0.568)			
DIVERSITY_BORD	7.178		(0.854)	4.510		(0.516)	3.465		(0.400)	2.257		(0.265)			
POPUL				0.000	***	(3.674)				0.000	***	(4.361)			
GDPPC	0.010	***	(5.259)	0.009	***	(5.295)	0.009	***	(5.311)	0.010	***	(5.386)	0.010	***	(5.347)
Constant	-2.596	***	(-8.316)	-2.793	***	(-8.421)	-2.358	***	(-7.731)	-2.807	***	(-8.474)	-2.532	***	(-9.160)
Log likelihood	-3412.52			-3404.91			-3411.87			-3405.50			-3411.24		
LR statistic	53054.69	***		53069.93	***		53055.99	***		53068.73	***		53057.25	***	
LR index (Pseudo-R2)	0.886			0.886			0.886			0.886			0.886		

Notes: Numbers in brackets are z–statistics. *** significant at p<.01; ** significant at p<.05; * significant at p<.10

For the sake of space industry and country dummies have been omitted. Of course, they are available on request.

APPENDIX 1 – The European regions considered

Germany	UK	France	Italy
Stuttgart	Cleveland, Durham	*Ile-de-France*	Piemonte
Karlrushe	Cumbria	Champagne-Ardenne	Valle d'Aosta
Freiburg	Northumberland, Tyne and Wear	Picardie	Liguria
Tubingen	*North*	Haute-Normandie	*North West*
Baden-Wurttemberg	Humberside	Centre	Milano
Oberbayern	North Yorkshire	Basse-Normadie	Lombardia (excl. Milano)
Niederbayern	South Yorkshire	Bourgogne	*Lombardia*
Oberpfalz	West Yorkshire	*Bassin parisien*	Trentino Alto Adige
Oberfranken	*Yorkshire and Humberside*	*Nord-Pas-de-Calais*	Veneto
Mittelfranken	Derbyshire, Nottinghamshire	Lorraine	Friuli Venezia Giulia
Unterfranken	Leics., Northamptonshire	Alsace	*North East*
Schwaben	Lincolnshire	Franche-Comté	*Emilia Romagna*
Bayern	*East Midlands*	*Est*	Toscana
Berlin	*East Anglia*	Pays de la Loire	Umbria
Brandenburg	Bedfordshire, Hertfordshire	Bretagne	Marche
Bremen	Berks., Bucks., Oxfordshire	Poitou-Charentes	*Centre*
Hamburg	Surrey, East-West Sussex	*Ouest*	*Lazio*
Darmstadt	Essex	Aquitaine	Abruzzo
Giessen	Greater London	Midi-Pyrénées	Molise
Kassel	Hampshire, Isle of Wight	Limousin	*Abruzzo-Molise*
Hessen	Kent	*Sud-Ouest*	*Campania*
Meckelburg-Vorpommern	*South East*	Rhone-Alpes	Puglia
Braunschweig	Avon, Gloucs., Wiltshire	Auvergne	Basilicata
Hannover	Cornwall, Devon	*Centre-Est*	Calabria
Luneburg	Dorset, Somerset	Languedoc-	*South*
Weser-Ems	*South West*	Provence-Alpes-	*Sicilia*
Niedersachsen	Hereford-Worcs., Warwicks.	Corse	*Sardegna*
Dusseldorf	Shropshire, Staffordshire	*Méditerranée*	
Koln	West Midlands		
Munster	*West Midlands*		
Detmold	Cheshire		
Amsberg	Greater Manchester		
Nordrhein-Westfalen	Lancashire		
Koblenz	Merseyside		
Trier	*North West*		
Rheinhessen-Pfalz	Clwyd, Dyfed, Gwynedd, Powys		
Rheinland-Pfalz	Gwent, Mid-S-W Glamorgan		
Saarland	*Wales*		
Sachsen	Bord.-Centr.-Fife-Loth-Tayside		
Dessau	Dumfr.-Galloway, Strathclyde		
Halle	Highlands, Islands		
Magdeburg	Grampian		
Sachsen-Anhalt	*Scotland*		
Scheleswig-Holstein	*Northern Ireland*		
Thuringen			

APPENDIX 2- The database

The database used for the study has been built and updated by John Cantwell and his co-researchers at the University of Reading. It consists of patents granted in the US to the world's 792 largest industrial firms as of 1982, derived from both the Fortune 500 US and the Fortune 500 non-US firms listings (Dunning and Pearce, 1985). Of these 792 companies 730 had an active patenting presence during the period 1969-1995. Another 54 historically significant firms were added to these, making 784 corporate groups in all. The additions include (mainly for recent years, but occasionally historically) enterprises that occupied a prominent position in the US patent records, some of which are firms that were omitted from Fortune's listing for classification reasons (e.g. RCA and AT&T were classified as service companies), and others that reflect recent mergers and acquisitions or new entrants to the population of large firms. Patents have been consolidated at the level of the international group of ultimate ownership, allowing for changes due to mergers and acquisitions since 1982. For patents that are attributable to research facilities located in selected European countries we have identified the precise regional location of research.

APPENDIX 3 –Bordering regions

Bordering regions No.	Frequency (No. regions)	%
0	3	2.59
1	5	4.31
2	9	7.76
3	16	13.79
4	33	28.45
5	22	18.97
6	15	12.93
7	9	7.76
8	2	1.72
9	2	1.72
TOT	116	100.00

APPENDIX 4 – Variables, measures and sources

Name	Measure	Year	Source
FORPAT_dep	Number	1987-1995	Reading Database
FORPAT	Number	1969-1978	Reading Database
FORRTA	Index [0-1]	1969-1978	Reading Database
DOMRTA	Index [0-1]	1969-1978	Reading Database
DIVERSITY	Index	1969-1978	Reading Database
RDEMPPUB	Number	1994	Eurostat (1996)
EDUHIGH	No. (thousands)	1992-93	Eurostat (1996)
EDUTOT	No. (thousands)	1992-93	Eurostat (1996)
RDPU_BORD	Number	1994	Eurostat (1997)
POPUL	No. (thousands)	1992	Eurostat (1996)
GDPPC	ECU (base: EUR12 = 100)	1992	Eurostat (1996)

NOTES

The authors wish to thank the participants in the XXVIII EIBA Conference held in December 2002 in Athens, and in the AIB Annual Conference held in June 2002, in Puerto Rico, for helpful comments and suggestions on earlier versions of this paper. The usual disclaimer applies.

[1] It is worth observing that in the literature on FDI, the first acknowledgement of the importance of spillovers can be traced back to the 60s (MACDOUGALL, 1960; CAVES, 1971).

[2] A higher order centre is defined as a location that has accumulated relatively high levels of innovative activities, and tends to have a relatively broad profile of technological specialisation (CANTWELL and JANNE, 1999).

[3] In an earlier study it was shown that foreign-owned firms in the UK are relatively more drawn (than are UK-owned firms) to locate their research in regions such as Scotland and East Anglia, in which the public research base and higher education infrastructure is also relatively good (CANTWELL and IAMMARINO, 2000).

[4] Comparative analysis of statistics and socio-economic questions at regional level, requires a comparable definition of regions. To meet this need, Eurostat devised the NUTS-coding system - the acronym refers to the classification of territorial areas at national, regional or administrative borders - Niveaux d'Unités Territoriales Statistiques - i.e. Territorial Units. The nomenclature distinguishes between five levels altogether but the commonly used references embrace NUTS levels I to III: (technically, NUTS Level 0 = the EU as a whole).

[5] Indeed, although other studies about various regional issues in the EU consider different sub-national NUTS levels for different countries in order to assure economic homogeneity, in the present context considering NUTS2 assures a more uniform distribution of patent data across regions in the period considered. The one exception is that in the case of Lombardy, which is comfortably the largest region for technological development in Italy, we created a sub-division between Milan and the rest of Lombardy.

[6] We used the address of the first named inventor. It is worth observing that in the overwhelming majority of patents assigned to the largest firms, the address of the inventor corresponds to the address of a corporate research facility owned by the assignee, and the inventor is an employee of the firm to which the patent is assigned who works at that facility. While we have not checked this in every case, in an earlier study we had checked a number of the largest firms historically, and found that the addresses of inventors in general matched addresses at which the relevant firm was known to have an R&D facility (see CANTWELL, 1995). We would like to thank an anonymous referee for stimulating this clarification.

[7] For a discussion and a list of the 56 fields used see CANTWELL and IAMMARINO (2001).

[8] The other possible model normally used for count data, the Poisson model, presents a major drawback related to the fact that the conditional mean is assumed to be equal to the conditional variance, so that any cross-sectional heterogeneity is ruled out. The negative binomial model provides a generalisation that solves the problem, by introducing an individual unobserved effect into the conditional mean (GREENE, 1997).

[9] This measure has often been used also in the analysis of business concentration across firms within an industry, as opposed to concentration or dispersion across sectors within a firm (see HART and PRAIS, 1956). It is worth noticing that for a given number, N, of firms (or technological fields, in our case), there is a strict relationship between the Herfindhal index (H) and the coefficient of variation (CV) (HART, 1971). The relationship is: $H=(CV^2+1)/N$.