THE RECENT LOCATION OF FOREIGN R&D ACTIVITIES BY LARGE MNCs IN THE EUROPEAN REGIONS.
THE ROLE OF DIFFERENT SOURCES OF SPILLOVERS

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ABSTRACT

This paper examines the role of spillovers and externalities in influencing the recent siting of foreign R&D activities in European regions. According 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 to the presence of a wide-ranging collection of firms active in the same sector; (ii) inter-industry spillovers or diversity externalities, associated to the co-presence of firms working in different fields; and (iii) science-technology spillovers and externalities stemming from the presence of an adequate scientific and educational infrastructure. Additionally, we find that benefits from spillovers do decline with distance, but this hold especially for intra- and inter-industry spillovers.

1. Introduction

The theory of the multinational corporation (MNC) has traditionally highlighted the role of technological innovation in explaining foreign investment determinants. However, technological innovation had been seen as an ex-ante advantage that allows firms to expand abroad (Dunning 1988), while in the most recent literature new technological competencies might be created thanks to the firms' activities international dispersion (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 the means to further augment 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 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 MNCs' internationalisation strategy, 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, the innovative activity is highly agglomerated (Jaffe et al. 1993; Audretsch and Feldman 1996; Keller 2002), and agglomeration is 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. 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 MNCs' technological activities in 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 concentrate on corporate research activity in Germany, the UK, France and Italy, as they host almost the 75% of the total innovative activities carried out in Europe by foreign-owned firms in the period considered. The model developed aims at explaining 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 MNCs' 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 illustrates 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 MNCs' location of foreign technological activities

Traditionally, innovation in MNCs has been understood as 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 adaptive in nature and was 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).

Beginning in the mid-1980s, however, 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-assess the rationale for the MNC and the role played by the subsidiaries. Viewing the MNC as a repository of knowledge, scholars 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 thus benefiting from the 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 location choice of the MNCs' technological activities depends upon the interrelationships between their corporate strategy and the location-specific characteristics of alternative contexts in which research may be located.

However, MNCs' location choice and their location-specific determinants have been so far mainly analysed 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 subnational dimension. In fact, some Authors have recently highlighted the importance of the subnational 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 MNCs' location at this subnational level (Cantwell and Iammarino 2001; Carrincazeaux et al. 2001; Frost 2001). Recent streams of literature have explored extensively the determinants of foreign 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). MNCs' foreign technological activities tend to agglomerate partly due to a random and cumulative process (Ellison and Glaeser 1994) essentially related to certain natural advantages, but especially due to spillovers and externalities they can enjoy in the foreign location[1]. 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 to the contribution of Marshall (1890), and to what

geographers call "location 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 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 domestic-owned firms (Cantwell and Noonan 2002; Janne 2002). Indeed, when this is the case, foreign MNCs might suffer from a congestion/crowding out effect, due to the limited given stocks of resources (scientists, engineers, etc), and/or from discrimination by national and local Government, which may tend to incentive domestic- rather than foreign-owned firms. Therefore, our second hypothesis is:

(H2): If specialisation externalities in a region stem essentially from a strong domestic technological presence, the location of MNCs' 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 the R&D conducted in the region is, 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, 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 promote innovation and knowledge spillovers better (Feldman and Audretsch 1999). Therefore, our third hypothesis is the following:

(H3): If inter industry spillovers and diversity externalities are important, foreign 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 pay greater attention to being close to relevant public research facilities (see Görg and Strobl 2001, on the greater international locational mobility of MNCs).

Therefore the last hypothesis we want to test states as follows:

(H4): If external sources of knowledge and science-technology spillovers are important, foreign 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 MNCs' research activities in the European regions

In order to analyse the location of foreign MNCs' 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. Specifically, to provide a single uniform breakdown of territorial systems we referred to the NUTS 2 level for the four countries 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 to analyse the regional distribution of technological activities[2].

 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.

 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. (2000, 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 (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 group) and, separately, the address of the inventor, thus allowing the identification of where the research and development underlying the invention was carried out in geographical terms.

 Therefore, each patent has been associated to a NUTS code, according to the location of inventors in the EU countries. Moreover, patents can be classified by detailed technological fields, which would not be otherwise possible by using other common 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 indicates the total number of corporate patents registered in the database in European host countries over the period 1987-1995, as well as figures by European host

country on the share of foreign-owned firms in total corporate patents emanating from locally-based research. In particular, 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) and France (10,547), which in turn is more than four times that registered for Italy (2,359). Additionally, the foreign 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%. It is also shown that in the period considered the most attractive European host country for the technological activity of foreign 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%).

In order to provide preliminary descriptive evidence about technological activity agglomeration, 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 domestic firms' only in the UK, while concentration ratios show a greater variety. Indeed, when considering the first 4 regions, France reveals a higher share of foreign-owned activity, due to the presence of few large MNCs located there.

However, it is interesting to observe that foreign research activity seems rather agglomerated. The first 8 regions host more than 90% of it both in France and Italy; 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 European regions, the dependent variable is the following:

FORPAT_dep$_{ij}$ = number of patents granted to foreign 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. 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 considered. Specifically, they have been measured in the period 1969-19

(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 the index of Revealed Technological Advantage (RTA_{ij}), as it allows us to control for inter-sectoral and inter-region differences in the propensity to patent (Cantwell 1995). In particular, as our second hypothesis states that some differences in the foreign MNCs location behaviour may arise when intra-industry spillovers originate mainly by domestic-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 activities of domestically-owned firms ($DOMRTA_{ij}$).

It may be not out of place here to remind that RTA_{ij} is defined as:

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

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 creating 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 ($DIVERSITY_i = \mu i/\sigma i$). 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:

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

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[3].

(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 followings:

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

$EDUHIGH_i$ measures the number of full-time and part-time pupils and students in higher education level 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 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; and likewise:

- $DOMRTA\_BORD_i = \Sigma_h DOMRTA_h;$

- FORRTA_ BORD$_i$ = Σ_hFORRTA$_h$;

- DIVERSITY_ BORD$_i$ = Σ_hDIVERSITY$_h$.

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 the random cumulative mechanism and the strong path-dependent character of technological agglomeration, we also considered the lagged dependent variable (that is, referred to the 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, the financial and fiscal measures, the regulatory and legal environment, the intellectual property protection, might make a region an appealing location for foreign MNCs' investment in research. Unfortunately, such data are not available at the European regional NUTS2 level.

5. Empirical findings

The summary characteristics of the variables and the correlation matrix are reported in Table 3. As 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.

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 reminding that interpretation of the negative binomial model follows the normal pattern: positive, significant values indicate that an increase in that variable increases the odds that foreign 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, MNCs' location of their innovative activities 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 do actually work together (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 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 be indeed related to the fact that indigenous technological specialisation is often highly concentrated in few major local firms acting as an entry deterrent or rising higher entry barriers. However, where indigenous technological development is highly concentrated in just one or two 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 availability of potential local technological spillovers. If this is the case, foreign MNCs might also suffer from discriminating measures by national and local Government wishing to protect domestic-owned firms.

Inter-industry spillovers (DIVERSITY), instead, come out positive and always highly significant (at $p<.01$), thus confirming that diversity externalities provide a region with a higher likelihood to attract foreign MNCs' 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 locally sustained as well as the educational base constitute a significant pull factor for foreign MNCs. Indeed, RDEMPUB is positive and significant at $p<.01$ in Model 3, and at $p<.10$m 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-region spillovers, 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, but Model 3). In other words, foreign 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. This seems to confirm Jaffe's (1989) often cited finding that there is only weak evidence that science-technology spillovers are facilitated by geographic coincidence of universities and research labs. Indeed, allowing for a spatial extent of spillovers, our results show that they extend over bordering regions (see also Anselin et al., 2000).

On the contrary, regional clustering remains crucial as far as intra- and inter-industry spillovers. Indeed, both specialisation externalities and diversity externalities do influence the foreign MNC location at the regional level, but only when they concern the region itself (DOMRTA_BORD, FORRTA_BORD and DIVERSITY_BORD never come out significant in the best specifications of the model). This result shows that benefits from such a kind of spillovers decline with distance more rapidly than those associated to 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 no-tariff barriers, the completion of the single European market and the recent economic and monetary integration have spurred the reorganisation of operations of MNCs' affiliates located in the EU to a much greater extent than in the case of affiliates based outside the area.

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 of capturing spillovers. Specifically, the relative attractiveness of regions in Europe to 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 recent contributions, e.g. 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 mainly based on regional 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 subsidiaries tap into local source 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 that, 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 actors while large domestically-owned firms might discourage MNCs' location. We relate this aspect to the need of dispersion of technological development among a sufficient variety of local actors to attract foreign-owned research to a localised cluster. In fact, indigenous technological specialisation is often highly concentrated in few major local firms acting as an entry deterrent or rising higher entry barriers. However, where indigenous technological development is highly concentrated in just one or two 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 availability of potential local technological spillovers. Additionally, foreign MNCs might also suffer from discriminating measures by national and local Government wishing to protect domestic-owned firms.

This occurs quite often 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, it 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 for science-technology spillovers, which in fact show also an inter-region dimension, thus suggesting that distance is less important in this case. Future research is needed in order to investigate whether the effect fades away with increasing distance (for example considering spatially-lagged two regions)

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 MNCs' innovative activities even in smaller countries. Likewise, major benefits would come from more finely grained research (at the firm level) that would shed light on the type 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 of 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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NOTES

[1] It is worth observing that in the literature on FDI, the first acknowledging of the importance of spillovers goes back to the 60s (MacDougall 1960; Caves 1971).

[2] 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.

[3] 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: $H=(CV^2+1)/N$.

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

European host country	Total corporate patents		Foreign-owned patents	
	(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	100.00	18,954	26.8

Source: University of Reading database.

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

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.