# THE LOCATION OF TECHNOLOGICAL ACTIVITIES OF MNCs IN EUROPEAN REGIONS: THE ROLE OF SPILLOVERS AND LOCAL COMPETENCIES

John Cantwell

University of Reading Lucia Piscitello Politecnico di Milano and University of Reading

# ABSTRACT

This paper examines the relative attractiveness of the Italian, German and UK regions

examine the regional distribution of corporate research activity in Italy, Germany and the UK, distinguishing between domestically-owned and foreign-owned firms in each of these three countries. The spatial patterns of activity in foreign-owned firms is considered while controlling for indigenous firms' patterns. Departures from a linear proportionality between the locational distributions of these two sets of firms constitute differences in their locational behaviour. These differences in the cross-regional distribution of technological development between locally-owned and foreign-owned firms<sup>1</sup> could be explained through variables related to the local market size, to the knowledge base and to the potential for intra- and inter-industry spillovers. We discuss some explanations for these differences, and propose an econometric model based on count data techniques in order to explain these locational preferences of MNCs across regions within each of the three European countries considered.

The paper is organised in the following way. Section 2 sets out the conceptual framework for the analysis of the determinants of locational choice in the technological activities of MNCs. Section 3 investigates the extent and evolution of the internationalisation of technological activity in the German, UK and Italian regions in the period 1969-95. Section 4 reports the econometric model, the variables and the results obtained. Finally, Section 5 presents some summarising and concluding remarks, draws out one of the policy implications of our argument, and indicates an agenda for future research.

# 2. The location of technological activities: a theoretical framework

At a general level, a firm's operations may be dispersed across different types of productive activity (the diversification of technologies or products), or over geographical space (the internationalisation of the same). However, spreading the product markets in which the firm is involved may be a matter of exploiting more effectively established competencies, while moving into new areas of technological development means creating new competence. In order not just to exploit effectively but also to consolidate an existing capability, it is generally necessary for a firm to extend that capability into new related fields of production and technology, and across a variety of geographical sites (Cantwell, 1995). The corporate internationalisation and diversification of technological activity are indeed both ways of spreading the

<sup>&</sup>lt;sup>1</sup> For a similar result in the UK, see also Cantwell and Iammarino (2000).

competence base of the firm, and of acquiring new technological assets, or sources of competitive advantage.<sup>2</sup>

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; Cantwell and Iammarino, 2000) which are characterised by different levels of territorial and social embeddeness with reference to both the motivations for overseas R&D and the location which hosts them. Indeed, the localisation of research activities is partially determined by the specific function which this activity fulfils within a given firm (Carrincazeaux et al., 2001). The internationalisation of R&D may be motivated by several considerations, and specifically (Kumar, 2001): to support foreign production by adaptation to host country markets (home-base exploiting R&D, HBE, in the words of Kuemmerle, 1999), and to tap into the capabilities available in host countries thus benefiting from the localised knowledge spillovers (home-base augmenting, HBA). Despite these suggestions of intra-firm differences in the influences on the internationalisation of R&D, the bulk of analysis of overseas R&D has been carried at the level of the corporate group as a whole rather than the individual subsidiary or laboratory, or at the level of collective groups of firms, and it has focused on the determinants of intensity of overseas R&D in an inter-industry, inter-firm or inter-country context (see Zejan, 1990; Kumar, 1996, 2001; Niosi, 1999, for a number of recent studies). Specifically, firms' locational choices and their location-specific determinants have been mainly analysed at the country level (Håkanson, 1992; Fors, 1996; Kumar, 1996; Odagiri and Yasuda, 1996), and only a minority of studies has recently started to investigate their regional or subnational dimension (e.g. Cantwell and Iammarino, 1998, 2000; Carrincazeaux et al. 2001). In fact, although some authors have recently 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), there is still only quite a scant existing empirical research on multinational location at this subnational level. The development of cross-border corporate integration and intra-border inter-company

<sup>2</sup> The background to this study is the relationship between the diversification and internationalisation of the technological competence of large MNCs, which have been explored extensively in our earlier work

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 the MNC depends upon: (i) the strategy followed by the MNC (the extent to which it has developed a network with home base augmenting facilities, as opposed to the more traditional home base exploiting); and (ii) the location-specific characteristics of alternative contexts in which research may be located. The present paper specifically focuses on (ii). In particular, we claim that the relevant location-specific characteristics are the following.

### (a) Agglomeration and industry-specific spillovers

The firms of each country tend to embark on a path of technological accumulation that has certain unique characteristics and sustains a distinct profile of national technological specialisation (Rosenberg, 1976, Pavitt, 1987, Cantwell, 2000). The kinds of linkages that grow up between competitors, suppliers and customers in any regional district or country are also, to some extent, peculiar to that location, and imbue the technology creation of its firms with distinctive features (Mariotti and Piscitello, 2000). 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, 1997, Cantwell and Iammarino, 1998, Verspagen and Schoenmakers, 2000). It is therefore typically when there is already a strong existing domestic technological presence that the R&D of foreign-owned affiliates is most likely to become substantial, and to gain a creative role with respect to the global technological development strategy of the MNC as a whole. 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

<sup>(</sup>Cantwell and Piscitello, 1999; 2000; Cantwell and Janne, 1999).

deterrence effect, both in terms of bidding for local resources and in terms of the availability of potential local technological spillovers.

### (b) 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 educational 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). Thus, in an earlier study it was shown that foreign-owned firms in the UK are relatively more drawn (than are UKowned 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). Therefore, we expect that compared to indigenous firms that have a certain locational inertia around their major centre of technological activity which is already situated in their home base, foreign-owned research facilities are relatively more attracted by external sources of knowledge, and science-technology spillovers.

# (c) Localised inter-company spillovers

As knowledge is mainly tacit, geographical distance increases the difficulty in both transmitting and absorbing it. In other words, tacit knowledge travels easily over small distances, but far less easily over longer distances (Caniëls, 2000). This leads to the hypothesis that the intensity of spillovers increases with geographical proximity (Verspagen and Schoenmakers, 2000). Specifically, we distinguish three different types of inter-firm spillovers as follows.

i. Cluster-based spillovers, 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

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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);

ii. General purpose spillovers, entailing inter-industry spillovers (Lipsey et al., 1998) associated with the existence of firms working in several different fields of research, but with a common overlapping interest in certain general purpose technologies (GPTs) which are relevant in most industries - such as machinery or computing. Such spillovers 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 Mudambi, 2000). Within a host country, an all-round regional centre of excellence is likely to attract the research-based investments of a wide variety of foreign-owned MNCs, as the attraction is related to spillovers in core technological sectors (GPTs) which are of an inter-industry kind. Moreover, there is some evidence relating to cities in the US that diversity across industries may promote innovation and knowledge spillovers (Feldman and Audretsch, 1999).

Finally, we argue that, according with the bulk of the analysis on overseas R&D, locational determinants related to the size of the local market have a positive and significant influence on affiliate R&D location (Zejan, 1990; Kumar, 1996, 2001; Braunerhjelm et al., 2000). While the other locational effects we have described relate especially to the attraction of localised R&D in the newer competence-creating types of subsidiaries, the pull of local market demand relates more to the attraction of R&D in the traditional competence-exploiting types of subsidiaries for the purpose of adapting products for local markets. However, when working at the level of firms as a whole or groups of firms we must consider these motives together, so as to assess the relative significance of each of these pull factors on average.

All these considerations suggest that innovative activities tend in general to favour specific locations, and the same rationale explaining location decisions holds in principle both for foreign-owned and domestic firms. Nonetheless, as the former have a home base located outside the country, they might be more mobile within the host country in terms of their choice of location, thus responding more effectively to regional differences. Therefore, we expect the locational choices of foreign-owned

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firms to be especially strongly influenced by the specific features of the region as well as by the potential spillover benefits, as far as their technological activities are concerned.

# **3.** Evidence on the globalisation of corporate technology at the European regional and sectoral level

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 (Schmookler, 1950, 1966, Pavitt, 1985, 1988; Griliches, 1990; Archibugi, 1992). The use of patent records provides information both on 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.

The database used for the study 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<sup>3</sup> (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, as is explained further below.

<sup>&</sup>lt;sup>3</sup> Fortune provided two separate listings, one for the largest US and one for the largest non-US firms. While we included all the 500 US firms, non-US firms were then included so long as they were larger than the 500<sup>th</sup> US firm (hence, the original 792 includes 292 non-US firms).

Table 1 indicates the share of European host countries in the foreign-located research of large firms. In particular, it is shown that overall the most attractive European host countries for the technological activity of foreign-owned MNCs were Germany (29% in 1991-95), the UK (21%) and France (16%), and only to a lesser extent Italy (6%). Since 1969-72 the UK has lost some of its earlier share (29%) to most other countries. Table 2 reports figures by European host country on the share of foreign-owned firms in total corporate patents emanating from locally-based research. The proportion of European research activity undertaken by foreign-owned companies has increased overall from 23% to 29%, having fallen slightly during the 1970s and then risen during the 1980s, before rising sharply in the 1990s. This is consistent with the general increase in the internationalisation of technological development in major firms already acknowledged elsewhere (e.g. Dunning, 1994; Cantwell, 1995).

In order to analyse the location of corporate R&D activities at a more detailed level of geographical disaggregation, we focused on the sub-national entities<sup>4</sup> that derive from normative criteria, as classified by Eurostat in 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.

To provide a single uniform breakdown of territorial systems we referred to the NUTS 2 level for the three 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. 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<sup>5</sup>, in the present context considering NUTS 2 assures a more uniform distribution of patent data across regions in the period considered. The one

<sup>&</sup>lt;sup>4</sup> There is evidence that it is in Europe in which cross-border MNC networks have reached their most advanced state (Cantwell and Janne, 1999), and so examining the determinants of the geographical pattern of MNC innovation in these regions offers a good test of our alternative hypotheses outlined above.

<sup>&</sup>lt;sup>5</sup> For example Paci (1997) considers 109 regions corresponding to NUTS 0 for Denmark, Luxemburg, Ireland; NUTS 1 for Belgium, Germany, Netherlands, and the UK; and NUTS 2 for Italy, France, Spain, Portugal and Greece. Likewise, Cantwell and Iammarino (1998) and Breschi (1999) consider NUTS 1 for the UK and NUTS 2 for Italy.

technological development in Italy, we created a sub-division between Milano and the rest of Lombardia. The empirical investigation uses patents granted to the world's largest industrial firms for inventions achieved in their European-located operations, classified by the host European region in which the responsible research facility is located.

The regionalisation of our US patent database consists of attributing a revised, although still compatible, NUTS 2 code for each patent record, according to the location of inventors in the EU countries, with reference to the period 1969-1995 (Cantwell and Iammarino, 1998; 2000; Cantwell et al., 2001). That has been extended to cover Germany, UK and Italy. The three host countries substantially differ each other in terms of the magnitude of the phenomenon under investigation. The total number of corporate patents due to German-located activity registered in the database over the period 1969-1995 (91,433) is more than twice that registered for the UK (45,136), which in turn is more than six times that registered for Italy (7,030).

Tables 3-5 report the total number and the percentage share of patents granted to the domestic firms and to foreign-owned firms in each region considered. Concerning Germany (see Table 3) it is worth noting that the number of patents granted to domestic firms (76,215) is about five times that for foreign-owned firms (15,218), while for both the UK and Italy the efforts of indigenous firms is about twice that of foreign-owned firms (23,350 as against 11,786, and 4,490 as against 2,540 respectively). However, in the UK this is due to a high degree of both inward and outward internationalisation, while in Italy it is due in large part to the comparative weakness of very large indigenous companies in the Italian industrial structure.

In Italy (see Table 5), just as for indigenous Italian firms, foreign-owned firms record the highest concentration of research (40.16 percent) in Milano. Outside of this very striking geographical agglomeration however, as highlighted by Cantwell and lammarino (1998), foreign-owned research appears to be relatively more dispersed than that undertaken by their indigenous counterparts. Whilst foreign-owned firms locate approximately 68 percent of their R&D in the two core regions of Lombardia and Piemonte, 82 percent of patenting by indigenous firms is located there.

Some variations in foreign-owned by comparison with indigenous R&D location patterns are also recorded in the UK. Similarly to the case of Italy (Lombardia), foreign-owned firms are more highly concentrated in the core region (the South East), than are

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their indigenous counterparts. Also as in Italy (Piemonte), indigenous firms locate a substantial proportion of their innovative activity outside of the core as well, in the West Midlands and the North West - regions which, relative to their overall shares, have failed to attract so much foreign-owned activity. Interesting also is the ability of regions such as East Anglia or Scotland to attract relatively higher foreign-owned firm innovative activity despite their low overall share in the UK-owned figure. A similar and indeed stronger result is found in the German case. Despite the fact that Baden Wuerttemberg is only the third most popular location for German-owned research, hosting approximately 19 percent, this region represents the prime location for foreign-owned firms, which undertake 31 percent of their research there. The same pattern is recorded in the north west region of Niedersachsen - despite the fact that it hosts a low overall share of total activity (under 4 percent) - but where foreign-owned firms locate over 5 percent of their patenting activities.

Indeed the German case contrasts with patterns recorded for both the UK and Italy on a number of fronts. Whilst both foreign-owned and indigenous firms concentrate their research in the same region in the UK (the South East) and Italy (Lombardia), the same does not hold for Germany. Nordrhein Westfalen (which borders Belgium and the Netherlands in the west of the country) hosts the highest concentration of indigenous activity (29 percent), but only represents the second most popular location for foreignowned research. Foreign-owned firms, as noted above, record their highest concentration of innovative activity in the South West region of Baden Wuerttemberg. This differing pattern for Germany, we believe, can be explained by considering the type of technological activity associated with Nordrhein Westfalen. This region is the traditional home of the German chemical/pharmaceutical industry and continues to record substantial technological advantage for indigenous firms that base their research there (see Table 6 below). This strength is further reflected in the research profiles of the universities and research institutes located in the region. We tentatively suggest therefore that because foreign-owned chemical firms may experience difficulty in trying to access the deeply entrenched technology networks and communication channels that have evolved through time, they disperse their research more widely, and account for a relatively low share of total German research in chemicals. This deterrence effect on foreign-owned firms within the industries of primary indigenous strength is quite common in most countries (Cantwell and Kosmopoulou, 2002), but in Germany it is distinguished by its strong locational influence, given the heavily regionally-specific character of the leading companies in domestic German industry.

The sectoral forms of innovative activities is shown in Tables 6-8, which examine the contribution to local research of both foreign-owned and domestic firms by industry. In Germany (Table 6) foreign-owned firms contribute relatively much in electrical and computing equipment (35.65 vs. 17 percent) and in general engineering (9.9 vs. 5.7 percent), but relatively little in chemicals (14.7 percent), the area of greatest indigenous strength (44.3 percent). This helps to explain why foreign-owned firms may be less attracted to the main centre for chemical research in Germany (in Nordrhein Westfalen). The most attractive macro-region for foreign-owned R&D is Baden-Würtemburg, which is a centre of engineering excellence in the motor vehicle industry (in which sphere of technology creation it is very highly specialised) and which has proved a magnet for foreign-owned development efforts in the areas of electrical and computing equipment, and general engineering (Cantwell and Noonan, 2001). This area is also well known for the innovativeness of local small and medium-sized firms (SMEs), whose expertise in developing specialised machinery, equipment and components and in engineering may also provide a fruitful interaction with the R&D of large foreignowned firms.

Turning now to the British experience (Table 7), foreign-owned firms contribute most to the UK research base again in mechanical engineering (7.12 vs. 4.22 percent), electrical (24.74 vs. 16.4 percent) and office equipment (7.92 vs. 1.23 percent) and instruments (3.33 vs. 0.04 percent); they have also participated well in the British success in pharmaceuticals research (16.99 vs. 8.51 percent), and they have made a roughly average contribution in chemicals (19.11 vs. 22.62 percent). As a general consequence, the development efforts of foreign-owned firms in the UK are most attracted as we have seen already to the wider technology base and infrastructure of the higher order centre of London and the South East, and this is especially true in the fields of electrical equipment and pharmaceuticals (Cantwell and lammarino, 2000). Foreign-owned efforts are relatively much less attracted to the intermediate centres of the North West and the West Midlands than indigenous activity might suggest, but insofar as they are active there they match local specialisation in chemicals in the North West, and in engineering and transport equipment in the West Midlands.

In the Italian case as well foreign-owned firms make their greatest contribution to the domestic research base in general engineering (8.90 vs. 0.0 percent), electrical equipment (25.59 vs. 1.40 percent) and in pharmaceuticals (6.42 vs. 0.0 percent). We know that the development efforts of foreign-owned firms are drawn even in relative terms to the major centre of Lombardia, due to the availability of general technological skills and wider infrastructure there, rather than for any particularly specialised expertise. However, it is Lombardia outside Milano that is relatively most attractive for the siting of R&D by foreign-owned firms, while Milano itself is ranked only moderately by foreign-owned firms. This may be consistent with what we know of the lack of technological co-specialisation between indigenous and foreign-owned firms in Lombardia as a whole (Cantwell and Iammarino, 1998). While foreign-owned to the established domestically-owned firms) they wish to do so while avoiding the costs of congestion within Milano itself.

Foreign investment in innovation has therefore as much a regional scope as it has a national one. In particular, recent trends in the EU support the conjecture that a comparative analysis at the sub-national scale is the most appropriate way to identify the effects of globalisation (Cantwell and Iammarino, 2000).

Having illustrated the geographical and sectoral distribution of the technological activity carried out by domestic and foreign-owned firms across the regions of the three countries considered, the main issue that arises is the determinants of asymmetries between the geographical distribution of foreign-owned firm activity compared to that of domestically-owned firms. In other words, we investigate whether foreign-owned labs mirror domestic location, and if they do not (see Figures 1-3) the question becomes why, i.e. whether a linear proportional mapping from the geographical dispersion of indigenous company activity (a linear agglomeration effect) would exhaustively explain foreign-owned firms' locational patterns, or whether the effect is instead more complex and reinforced by the attraction exerted by other location-specific factors.

### 4. The econometric model and specification of the variables used

The phenomenon under study is the locational preference of foreign-owned firms as between alternative regions once companies have decided to locate their technological activities in a given country. Therefore, the dependent variable is the number of patents granted to foreign-owned firms in each region i and industry j, as follows:

NPAT\_FORij = number of patents granted to foreign-owned firms in region i and industry j over the period 1969-1995.

- i = 1, ..., 38 for Germany;
- i = 1, ..., 35 for the UK;
- i = 1, ..., 21 for Italy;
- j = 1, ..., 17 industries.

The industrial dimension, j, allows us to take into account the sectoral disparities in the innovation-related activities' propensity to cluster.<sup>6</sup> 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). The classification of firms into one of 17 primary industries of output is as shown in Tables 6-8.

As the dependent variable is clearly a count variable, a binomial regression model model was fitted to the data.<sup>7</sup> This kind of linear exponential model offers an improved methodology for count models for the cases of patents and innovation counts (Hausman et al., 1984; Blundell et al., 1995; Cameron and Trivedi, 1998).

According to the conceptual model developed in section 2, the independent variables relate to:

- the agglomeration effect or industry-specific spillovers, has been proxied by the number of patents granted that are attributable to the research of domesticallyowned firms in region i and industry j over the period 1969-95 (IND\_SPILLij);
- (ii) local knowledge externalities (external sources of knowledge). In order to capture the complex character of local knowledge externalities, we considered proxies both for non-corporate R&D activities and the size of tertiary education in each region. The proxies used for the former are R&D expenditures and personnel engaged in R&D in the government sector (RDEXP\_Gi, RDPER\_Gi)

<sup>&</sup>lt;sup>6</sup> The industrial dimension, j, allows us to take into account sectoral disparities in the propensity of innovation-related activities to cluster, as well as in the propensity to patent. The authors are grateful to an anonymous referee for this helpful suggestion.

<sup>&</sup>lt;sup>7</sup> 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).

and in higher education (RDEXP\_Hi, RDPER\_Hi). The commitment to higher and further education has been proxied by the number of full-time students in total (EDUC\_TOTi) and those in higher education (EDUC\_Hi). All these data come from the Regio dataset (Eurostat);

- (iii) localised inter-company cluster-based spillovers have been proxied by a composite variable (CLUST\_SPILLij), taking into account the cumulative impact of a widespread inter-company technological presence (CLUSTERi) in reinforcing industry-specific spillovers (IND SPILLij). Specifically, CLUSTERi is measured by the inverse of the cross-firm concentration of activity in a region, which rises the more widely that technological effort is dispersed across firms in each region. In particular, the variable is the inverse of the coefficient of variation across firm shares of patenting (CLUSTERi =  $\mu i/\sigma i$ , where  $\mu$ i and  $\sigma$ i are respectively the mean and standard deviation over the shares of corporate patenting of all the individual firms active in region i). The composite variable CLUST\_SPILLij has been therefore calculated as CLUSTERi \* IND\_SPILLij;
- (iv) general purpose spillovers (GEN\_SPILLi) relate to the breadth of technological development in a region creating the opportunity for inter-industry exchanges, and therefore they have been proxied by the inverse of the coefficient of variation over the profile of regional technological specialisation across technological fields (GEN SPILLi =  $\mu i/\sigma i$ ). The profile of regional technological specialisation is measured by the RTA index, RTAik in region i and technological field k (where k = 1, ..., 56);<sup>8</sup>
- (v) local market size has been proxied by the GDP per capita (GDP\_PC). Data for this variable come from the Regio dataset (Eurostat).

 $/(\sum kPik / \sum kPwk)$ 

where:  $P_{ik}$  = number of patents granted in field k to firms for research in region i  $P_{wk}$  = number of world corporate patents granted in sector k.

<sup>&</sup>lt;sup>8</sup> The Revealed Technological Advantage (RTA) index is a proxy for specialisation across technological fields, which fields are groupings derived from the US patent class system (for a discussion and a list of the 56 fields used see eg. Cantwell and lammarino, 2000), and is calculated in the following way:  $\mathsf{RTA}_{ik} = \frac{(Pik/Pwk)}{/}$ 

It should be noted that patents associated with some field k may be due to firms in any industry (any i), 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, and especially in GPTs which are those technologies that are relevant to more than one industry.

The summary characteristics of the variables and the correlation matrix respectively are reported in Tables 9 and 10.

# 5. Empirical findings

Empirical findings obtained for the three countries are reported in Tables 11-13. As using absolute numbers of patents as a dependent variable might pose difficulties associated with differences in the propensity to patent in different industries, this has been circumvented by using industry dummies.

The results confirm that the geographical agglomeration of innovation is remarkable (Cantwell and Iammarino, 2000) and demonstrate statistically that foreign-owned firms are even more sensitive than are indigenous companies to agglomeration potential. Nonetheless, the estimated equations confirm the differences already highlighted in Graphs 1-3 among the three countries considered.

Local external sources of knowledge show a positive uniform impact on the locational choice of MNCs for all three countries. Specifically, a larger educational base is attractive to the location of foreign-owned research (EDUC\_TOT<sup>9</sup> is always significant at p<.01) as are region-specific public science externalities. Indeed, the positive and significant signs for RDEXP\_G<sup>10</sup> (at p<.05 in the UK as a supplement to EDUC\_TOT, and p<.05 in Germany and Italy when considered separately rather than in addition to EDUC\_TOT) bear further testament to the role played by the governments in strengthening the regional science base by providing the core general funding. The two effects are jointly positive and statistically significant for the UK, while in Germany and Italy they had to be considered separately. These results confirm that lower-order regions can be highly relatively attractive where they have a good local science base (Cantwell and lammarino, 2000). Even more, they also confirm the importance in Europe of co-location for science-technology linkages, as demonstrated previously from US evidence (Jaffe et al., 1993).

The coefficients of the proxy used for localised industry-specific spillovers (IND\_SPILL) act either autonomously or in harness with the variable built to proxy the existence of localised cluster-based spillovers (CLUST\_SPILL). In Germany these two

<sup>&</sup>lt;sup>9</sup> The same results hold when considering higher education instead of total tertiary education. As a matter of fact, EDUC\_TOT and EDUC\_H are highly correlated (the correlation coefficient is always above 0.9).
<sup>10</sup> Similar results hold for the other variables considered as proxy for government-funded research.

Nonetheless, as RDEXP\_G is the most direct measure, we report results only for that.

spillover effects show a positive but not significant coefficient while foreign-owned firms seem to be much more attracted by the local market size. The latter is consistent with the observation above that indigenous technological development is often highly regionally polarised in Germany, and the qualification that the agglomeration effect can only work where there are a variety of sources of spillovers and the absence of a single dominant firm that acts to competitively deter its major rivals. In contrast, in the UK and in Italy, CLUST\_SPILL and IND\_SPILL are both highly significant (p<.01) attractors to foreign-owned activity. Conversely, the local market size does not seem to particularly influence the foreign MNC's relative locational choice. The combined industry-specific and cluster-based spillover effects show their strongest impact in Italy. In Italy and the UK there seems to be a general agglomeration effect associated with the widespread dispersion of patenting firms in the same region and in the same sector of activity. The presence of general purpose spillovers (GEN\_SPILL) shows a significant positive impact on the location of foreign-owned research facilities especially in Germany and Italy, and only to a slightly lesser extent in the UK. The technological breadth of a region and the presence of innovative overlaps across industries in the development of GPTs is an important factor in the attraction of foreign-owned research facilities.

### 6. Summary and conclusions

Since the late 1970s (Cantwell and Piscitello, 2000), 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 (and this figure had risen to nearly 29% by the early 1990s), while the world average is only just over one-tenth. Part of the reason is that European-owned MNCs are the most internationalised in their strategies for technology development, while much of their foreign-located R&D has remained within Europe,

and their European orientation has increased (from a 30% share of foreign R&D in Europe in the late 1960s, to a 40% share by the 1990s).

Our results suggest that the relative attractiveness of regions in Europe to the technological efforts of foreign-owned MNCs depends upon (i) the presence of external sources of knowledge; (ii) the presence of industry-specific and cluster-based spillovers; (iii) the breadth of local technological specialisation in the region, i.e. the opportunity to capture general-purpose spillovers. 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).

Factors (i) and (iii) seem to matter for regions throughout Germany, the UK and Italy. 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 GPTs. To these latter strands of recent literature what we add here is the dimension of corporate internationalisation: MNCs will develop abroad in the appropriate international centres GPTs alongside the firms of other industries, and technologies that rely on linkages to a good local science base. Factor (ii) depends critically on the dispersion of technological development among a sufficient variety of local actors to attract foreign-owned research to a localised cluster. This occurs guite often in the UK and Italy but when, as is more frequently the case in Germany, local development is heavily concentrated in just a few leading firms in a region (ie. 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 eg. 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 applomeration effect.

The present paper could be extended to consider the type of motivations of foreign investment in each location. Countries and regions seek to attract MNC activity as a means of improving their locational advantages through spillovers and linkages due to

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MNC activity. However, 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; Cantwell and Narula, 2001).

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