# AGGLOMERATION AND LOCATION OF FOREIGN R&D ACTIVITIES IN THE EUROPEAN REGIONS.

John Cantwell
University of Reading, Department of Economics
PO Box 218, Whiteknights, Reading RG6 6AA, UK
Tel. +44 118 9875123 Ext. 4061
Fax. +44 118 9750236
Email: J.A.Cantwell@rdg.ac.uk

Lucia Piscitello
Politecnico di Milano, Dipartimento di Ingegneria Gestionale
P.zza L. da Vinci 32 – Milano 20133
Tel. +39 02 2399 2740
Fax. +39 02 2399 2710
Email: lucia.piscitello@polimi.it

*Competitive paper*

**ABSTRACT**

This paper examines the recent siting of foreign-owned corporate technological development in European regions. The data used are patents granted in the US to the world's largest firms in the period 1987-'95. According with the literature on knowledge creation in MNCs, we find that location of foreign-owned research tends to agglomerate, depending positively upon the potential for intra- and inter-industry spillovers, and the local scientific and educational infrastructure. However, some differences do exist when considering different European countries, thus posing different challenges for individual Governments. Results obtained are consistent with the view that foreign subsidiaries could play an important role in the evolution and growth of the MNC.

**Key words**: multinational, innovation, location, regions.

## 1. Introduction

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 competence base of the firm, and of acquiring new technological assets, or sources of competitive advantage.[1]

The corporate outsourcing of new knowledge has a relevant spatial dimension, since the firm may enhance its capabilities by increasingly dispersing geographically its intra-firm network across a range of locations. 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

[1] 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 (Cantwell and Piscitello, 1999; 2000; Cantwell and Janne, 1999).

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 (see Boschma and Lambooy, 1999 and Martin, 1999, for a critical overview) emphasising the role of local spatial areas for the purpose of global competitiveness, have flourished in recent economy theory. In analysing MNCs' internationalisation strategy, it emerges clearly that multinationals target local spatial areas where they can enjoy externalities and spillovers (Cantwell and Santangelo, 2002).

The existing knowledge base of a region[2] plays an important role in the decisions of the largest foreign-owned firms as to where to locate their technological activities (Cantwell and Iammarino, 1998, 2000), as well as other location-specific factors mainly related to the market. Thus, in each country the local technological efforts of foreign-owned firms tend to be strongly agglomerated at a sub-national and regional level (Braunerhjelm and Svensson, 1998; Barrel and Pain, 1999).

In this context, the purpose of the present paper is twofold: (i) to analyse the regional distribution of technological activities carried out by large multinational corporations (MNCs) in four European countries (specifically, Germany, the UK, France and Italy) at the regional level over the period 1987-'95; (ii) to explain the locational regional preferences of foreign-owned firms in each of the four countries considered. Indeed, 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 hypotheses.

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. We examine the regional distribution of 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. The spatial patterns of activity by foreign-owned firms is considered and they are explained 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.

We propose an econometric model based on count data techniques in order to explain locational preferences of MNCs within each of the four European countries considered. Considering different host countries allow to consider major variations in institutional settings. As Nelson (1993) and others have pointed out, national institutions such as labour markets and university-firm linkages are likely to have an important effect on the process and mechanisms through which knowledge travels within technical communities[3].

Our study analyses the issue at a regional level as the most recent research (Frost, 2001) has consistently highlighted the importance of the subnational level in delimiting the

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[2] Tacit knowledge is specific to organisation as well as to geographic locations, thus increasing its internal circulation but impeding its external accessibility (Amin and Wilkinson, 1999).

boundaries of technological capabilities and expertise (Krugman, 1990; Porter, 1990; Storper, 1992).

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, French and Italian regions in the period 1987-95. Section 4 reports the econometric model and the variables employed. Section 5 illustrates the results obtained. Finally, Section 6 presents some summarising and concluding remarks, draws out one 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 have been understood as the domain of the parent firm. 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 (e.g. Hedlund, 1986; Bartlett and Goshal, 1989) to treat more seriously the possibility that foreign subsidiaries could play a crucial role as sources of new ideas and capabilities (see Frost, 2001, for a review of the most recent approaches).

The current features of innovation as well as the current modes and forms through which it generates major systemic techno-socio-economic changes (which can be identified in the increasingly complex character of technology and the consequent rise in technological interrelatedness) have emphasised the role of the firm as the main actor in the development of new knowledge. However, in the most recent literature they have

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[3] It is worth observing that other Authors (e.g. Frost, 2001) chose instead to consider a single host

also led to the re-discovery of the significance of the local dimension in the creation of new knowledge (Cantwell and Santangelo, 2002).

Increasingly, attention has been 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).

Specifically, internationalisation of R&D may be motivated by several considerations, and namely (Kumar, 2001): (i) to support foreign production by adaptation to host country markets (home-base exploiting R&D, HBE, in the words of Kuemmerle, 1999), and (ii) to tap into the capabilities available in host countries thus benefiting from the localised knowledge spillovers (home-base augmenting, HBA).

Therefore, while in the first case MNCs are led mainly by the wish of accessing local markets, the most recent MNCs' attitude to access the host country's capabilities (Cantwell, 1995; Frost, 2001; Le Bas and Sierra, 2002), is strongly influenced by the potential access to science and local spillovers as the principal location driver (Zedwitz and Gassmann, 2002).

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

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country (the US) exactly to rule out those variations.

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; Frost, 2001, 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. 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 empirical research on multinational location at this subnational level (e.g. Cantwell and Iammarino, 1998, 2000; Carrincazeaux et al. 2001; Frost, 2001).

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. Patents belonging to foreign subsidiaries tend to be concentrated in technical fields of host country specialisation, suggesting that innovating subsidiaries build upon local technological trajectories (Cantwell, 1992).

Therefore, the locational 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.

Recent streams of literature have explored extensively the determinants of firms' tendency to concentrate in specific areas, and the nature of the mechanisms which generate a local and cumulative process of knowledge creation (Paci and Usai, 2000). MNCs' technological activities tend to agglomerate partly due to a random and cumulative process[4] (Ellison and Glaeser, 1994) essentially related to certain natural advantages, but especially due to spillovers and externalities. 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). They materialise as an appropriate agglomeration pattern which facilitates assets sharing. In

[4] The prototypical example put forward by Ellison and Glaeser (1994) is the wine industry. Clearly, the localisation of the industry is in large part due to California's climatic natural advantage in growing grapes.

fact, 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). 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. 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).

Conversely, Shaver and Flyer (2000 propose that technological strong MNCs may sometimes have disincentives to enter into knowledge clusters because they may less benefit from knowledge spillovers compared to weaker firms. However, Cantwell and Janne (1999) and Frost (2001) argue that MNCs that are technologically strong possess so high absorptive capacities that they are indeed able to benefit from knowledge-related agglomeration economies in clusters (Lorenzen and Mahnke, 2002). Indeed, technologically strong MNCs locate explorative R&D abroad as they have better possibilities for tapping knowledge into local clusters.

Therefore, when there is already a strong existing (either domestic or foreign) technological presence 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.

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

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 (Paci and Usai, 2000). This leads to the hypothesis that the intensity of spillovers increases with geographical proximity (Caniëls, 2000; Verspagen and Schoenmakers, 2000). Specifically, we relate diversity externalities to general purpose spillovers, entailing inter-industry spillovers (Lipsey et al., 1998) associated with the existence of firms working in several different fields of research. Indeed, the more diverse the R&D conduced 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, as 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. 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 (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 (Feldman and Audretsch, 1999).

**(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 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 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).

The bulk of the analysis on overseas R&D argue 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). Specifically, 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. Locational effects related to spillovers relate instead especially to the attraction of localised R&D in the newer competence-creating types of subsidiaries. As a matter of fact, "the orientation of a subsidiary's activity toward the exploitation of existing capabilites or the exploration of new ones is the primary driver of the geography of its external sources of innovation" (Frost, 2001). 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.

## 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; 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. 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” (Verspagen and Schoenmakers, 2002). 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[5] (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.

Table 1 indicates the share of European host countries in the foreign-located research of large firms, 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, 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%). The proportion of European research activity undertaken by foreign-owned companies has increased overall from 25% to 29%, consistently with the general increase in the internationalisation of

[5] 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 500th US firm (hence, the original 792 includes 292 non-US firms).

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 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[6].

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[7], in the present context considering NUTS 2 assures a more uniform distribution of patent data across regions in the period considered. The one exception is that in the case of Lombardia, which is comfortably the largest region for technological development in Italy, we created a sub-division between Milano and the

[6] 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).

[7] 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.

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 whole period considered, i.e. 1969-1995. In the present paper we consider Germany, the UK, France and Italy. The four 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 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).

Tables 2-5 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 2) it is worth noting that the number of patents granted to domestic firms (27,916) is about five times that for foreign-owned firms (5,991), while for the UK (Table 3) the efforts of foreign-owned firms is about two thirds that of indigenous firms (4,073 as against 6,063), for France (Table 4) the domestic effort (7,589) is 2.5 times the foreign one (2,958), while for Italy (Table 5) the proportion is inverted (1,186 as against 1,173), thus confirming the chronic comparative weakness of very large indigenous companies in the Italian industrial structure. In Italy, just as for indigenous Italian firms, foreign-owned firms record the highest concentration of research (38.95 percent) in Milano. Outside of this very striking geographical agglomeration however, as highlighted by Cantwell and Iammarino (1998), foreign-owned research appears to be relatively more dispersed than that undertaken by their indigenous counterparts. Whilst foreign-owned firms locate approximately 64 percent of their R&D in the two core regions of Lombardia and Piemonte, 85 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 their indigenous counterparts (57.84 against 43.94). Also as in Italy (Piemonte), indigenous firms locate a substantial proportion of their innovative activity outside of the core as well, in the North West (15.93) and the West Midlands (10.32) - regions which, relative to their overall shares, have failed to attract so much foreign-owned activity (8.30 and 3.27, respectively). 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 17 percent, this region represents the prime location for foreign-owned firms, which undertake 35 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 domestic activity (under 3 percent) - but where foreign-owned firms locate over 6 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 (28 percent), but only represents the second most popular location for foreign-owned research. Foreign-owned firms, as noted above, record their highest concentration of innovative activity in the South West region of Baden Wuerttemberg (35.22 percent). 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, 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. As far as France is concerned, foreign firms locate almost half of their research activity in the Ile-de-France, as well as domestic firms do. Foreign firms then locate the 14% of their activity in the Bassin Parisien (vs. the 11% of domestic firms) while only the 10% in the Centre-Est regions, which instead constitute the second favourite regions for the domestic firms (17%). Conversely, the former are attracted by the Mediterranéenne regions (12%) although their scarce overall share of total domestic activity (6%).

The sectoral forms of innovative activities is shown in Tables 6-9, 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 (38.39 vs. 16.63 percent) and in mechanical engineering (8.15 vs. 5.17 percent), but relatively little in chemicals (15.26 percent), the area of greatest indigenous strength (44.56 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 foreign-owned 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 (7.00 vs. 2.41 percent) and instruments (4.84 vs. 0.00 percent); they have also participated well in the British success in pharmaceuticals research (18.66 vs. 10.49 percent), and they have made a roughly average contribution in chemicals (19.03 vs. 23.17 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 Iammarino, 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 France (Table 8) foreign-owned firms contribute relatively much in electrical equipment (31.61 vs. 24.38 percent). Chemicals (22.05 vs. 17.01) and motor vehicles (10.04 vs. 6.51), but relatively little in coal and petroleum products (4.80 vs. 17.79) and aircraft (0.74 vs. 11.71).

In the Italian case (Table 9) as well foreign-owned firms make their greatest contribution to the domestic research base in mechanical engineering (5.40 vs. 0.0 percent), electrical equipment (38.87 vs. 1.62 percent) and in pharmaceuticals (6.41 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 companies are keen to access the regional infrastructure, as latecomers (compared 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).

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

The phenomenon under study is the regional preference of foreign-owned firms as between alternative European regions (within the 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 t (1987-1995).

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

j = 1, …, 17 industries.

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] This kind of linear exponential model offers an improved

[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

methodology for count models for the cases of patents and innovation counts (Hausman et al., 1984; Blundell et al., 1995; Cameron and Trivedi, 1998).

The independent variables employed relate to the conceptual model developed in Section 2. In order to avoid endogeneity problems we considered lagged independent variables (referred to the period t-1, i.e. 1978-1986). Specifically, the refer to:

(a1 *Intra-industry spillovers and specialisation externalities*, have been proxied by the specialisation of region i in industry j. The proxy considered provides a measure of the technological specialisation of the region derived from indexes of Revealed Technological Advantage (RTAij), which captures the extent to which region i specialises in industry j. Specifically, we considered technological specialisation due to the activities of both foreign-owned (FORRTA) and domestically-owned firms (DOMRTA) in the period (t-1).

Denoting by $P_{ij}$ the number of US patents of firms located in region i and belonging to industry j, the $RTA_{ij}$ is defined as

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

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. Importantly, the use of RTA index allow us to control for inter-sectoral and inter-region differences in the propensity to patent (Cantwell, 1995) .

The distinction between DOMRTA and FORRTA stems from the observation that domestic incumbents might meet foreign MNC with suspicion, and this may rise *social entry barriers*. The severity of such a barriers depends upon how incumbent view

solves the problem, by introducing an individual unobserved effect into the conditional mean (Greene, newcomers. Consequently, some barriers may apply to all newcomers, while other are more strategic and depend upon whether newcomers are perceived as a potential competitive threat or as a potential source of knowledge (Lorenzen and Mahnke, 2002).

(b) *Inter-industry spillovers and diversity externalities* (DIVERSITYi) 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 (DIVERSITYi = $\mu i/\sigma i$). The profile of regional technological specialisation is measured by the RTA index, RTAik, in region i and technological field k (where k = 1, ..., 56);

The RTAik index is a proxy for specialisation of region i across technological fields k, 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 Iammarino, 2000), 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 (any 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, and especially in GPTs which are those technologies that are relevant to more than one industry.

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1997).

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 proxies both for non-corporate R&D activities and the size of tertiary education in each region. The proxy used for the former are R&D expenditures in the government sector (RDEXP_Gi). Data come from Eurostat  The commitment to higher and further education has been proxied by the number (in thousands) of full-time students (EDUC_TOTOTi). Data come from the Regio dataset (Eurostat);

The local regional market has been proxied by the variable MARKETi (measured by the GDP per capita, in 1992[10]). The data source is Eurostat Regio. 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 MNC investment in research. Nonetheless, data are not available at the European regional level.

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

[10] The base line is EU12 = 100.

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 ($FORPAT_{t-1}$) 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, this has been circumvented by using industry dummies.

**5. Empirical findings**

The summary characteristics of the variables and the correlation matrix are reported in Table 10. As easily predictable the variables proxying local knowledge externalities (RDEXP_G and EDUC_TOT) are always (i.e. for all the four countries) correlated. Therefore, they had to be used separately in the models in order to avoid multicollinearity problems.

Empirical findings obtained for the four countries are reported in Table 11. The Table is divided into four sections by country. Numbers in parentheses represent z-statistics. Interpretation of the negative binomial model follows the normal pattern: positive, significant values indicate that an increase in that variable increases the odds that a patent is localised in the particular combination of region i and sector j, ceteris paribus. Negative values indicate the reverse. The magnitude of the coefficients is more difficult to interpret and is discussed below.

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 innovative activities is cumulative and path dependent and it is also strongly and positively influenced by both *intra- and inter-industry spillovers*, thus confirming (see Paci and Usai, 2000) that the two effects do actually work together. Specifically, intra-industry spillovers are positive and significant (always at p<.01) when the specialisation of the region in a particular industry is due to the presence of other foreign firms already located there, while the effect disappears (or becomes negative, as in the German and French case) when specialisation comes from large domestic firms. Inter-industry spillovers instead come out always positive and highly significant (at p<.01). As far as spillovers related to the local external source of knowledge, the two variables considered (RDEXP_G and EDUC_TOT) are highly correlated and therefore they had to be considered separately. 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 location driver for foreign MNCs. Table 11 reports only the models including the variable most significant (RDEXP_G in the German and the UK case, while EDUC_TOT in the French and Italian case). These results confirm that even lower-order regions can be highly relatively attractive where they have a good local science base (Cantwell and Iammarino, 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) as well as the role played by the governments in strengthening the regional science base by providing the core general funding. Finally, the variable related to the local market size shows different incidence for the four countries considered, being positive and significant in Germany and France, negative and significant in Italy, while not significant in the UK.

However, when analysing the four countries separately, some interesting results do emerge.

As far as Germany is concerned, foreign MNCs' location choices are strongly influenced by the potential for both inter-industry spillovers (DIVERSITY significantly positive at $p<.01$) and intra-industry spillovers. However, the latter holds when such industry-specific spillovers stem from other foreign firms already located in that region (FORRTA is positive and significant at $p<.01$), while if they stem from large domestic firms, foreign MNCs seem instead discouraged (DOMRTA is negative, although not significant). That night be 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. These results are 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.

Foreign firms location is also driven by region-specific public science externalities (RDEXP_G is positive and significant at $p<.05$) as well as by the local market (MARKET significant at $p<.01$).

Conversely, the local market size does not seem to influence the foreign MNC's recent location choice in the UK regions where instead both intra- and inter-industry potential for spillovers does matter. Both FORRTA and DOMRTA are positive, although only the former is significant at $p<.01$. Likewise, DIVERSITY is positive and significant at p<.01, thus confirming the crucial role of a widely diversified local technological base. Foreign technological activities are also attracted by the regional educational and science base (RDEXP_G is positive and significant at p<.10).

The combined effects of industry-specific and inter-industry spillovers appear also in French regions. Specifically, both FORRTA and DIVERSITY are positive and significant at p<.01. However, like in the German case, the presence of strong domestic players seem to discourage the foreign entry (DOMRTA is negative and significant at p<.10). Interestingly, foreign firms' research activities in France seem to be less attracted by the regional educational base[11] (EDUC_TOT is positive but not significantly different from zero) while instead by the local market (MARKET is positive and significant at p<.01).

Finally, as far as the location across the Italian regions is concerned, the presence of general purpose spillovers (DIVERSITY) shows a significant (at p<.01) positive impact on the location of foreign-owned research facilities, thus confirming that 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. Likewise, the presence of intra-industry spillovers – especially when stemming from the presence of other foreign firms - as well as the local scientific technological and educational base prove to be significant (EDUC_TOT is significant at p<.01). It is interesting to observe also that market seeking reasons (MARKET) which are still relevant especially for Germany and France, do not seem to hold at all for Italy. In fact, the sign of the variable is negative and significant at p<.05,

[11] It is worth observing that France has a strong public research and educational base but a poor track record of R&D commercialisation. It has identified the financing of technology-based enterprises and labour rigidities as the major impediments to converting its strengths in the basic sciences into

perhaps signalling a possible "congestion effect" from which some Italian higher-order centres (i.e. Milan) are currently suffering.

Although the results presented above generally support the hypothesised relationships, a note on the interpretation of the magnitude of the coefficients might not be out of place here. Specifically, the estimated coefficients $\beta_z$ equals the proportionate change in the conditional mean if the $z^{th}$ regressor $x_z$ changes by one unit (see Cameron and Trivedi, 1998, p. 81). Therefore, estimates reported in Table 11 reveal that (an one-unit increase of) both intra- and inter-industry spillovers induce the greater proportional change in the number of foreign patents in each region i-industrial sector j (i.e. an one-unit increase in FORRTA leads to a .209 proportionate change, or 20.9% change in the expected number of patents in German region i and sector j). Nonetheless, it is not always clear whether such a change is a large or small one, depending on the units used to measure x. One method is to scale by the sample mean of $x_z$, which (given the exponential mean function) is a measure of the elasticity of E[y/x] with respect to changes in the regressor $x_z$ (Elast column in Table 12). An alternative method is to consider semi-standardised coefficients that give the effect of a one-standard-deviation change in $x_z$, so use $\beta_z s_z$, where $s_z$ is the standard deviation of $x_z$ (column SSC in Table 12). Such coefficients show that variations in the independent variables related to the inter-industry spillovers (DIVERSITY) and the local market (MARKET) are the most relevant in influencing the proportionate change in the number of foreign patents in each region i and sector j.

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commerical successes (OECD, 1999).

However, in order to evaluate the marginal effect of each regressor $x_Z$ on the dependent variable (i.e. the change in the number of foreign patents due to a one-unit change in the regressors) it is worth observing that:

$\delta E[y/x]/\delta x_Z = \beta_Z \exp(x'\beta)$. [1]

Nonetheless, as calculated values differ across individuals, due to different values of x, this makes interpretation not straightforward. One of the best procedure is to aggregate over all individuals (s) and calculate the average response (column Ave in Table 12):

$(1/n)\Sigma_S \delta E[y_S/x_S]/\delta x_{SZ} = (1/n)\ \Sigma_S \beta_Z \exp(x_S'\beta)$ [2]

Due to the need for less calculation, it is otherwise common in non linear regression to report responses at the sample mean of regressors (column At Ave in Table 12). It is worth observing that the preferred Ave estimates are larger than those of the average individual, a consequence of the convexity of the exponential mean function.

Looking at the column Ave, it is possible to draw some interesting quantitative considerations. Specifically, as far as the cumulative path-dependent effect is concerned, an one-unit change in the previous stock of patents induce 0.6 more foreign patents in German region i and sector j (corresponding to a percentage change of 1.9%). The effect is similar, although at a lighter extent, in the UK (o.4 more patents and a percentage change equal to 2%) and France (0.5 and 0.7%), while such a cumulativeness effect would be definitely stronger in Italy where an existing patents by a foreign firm leads to almost 3 new foreign patents, corresponding to a proportionate change of 6.4%.

Likewise, if intra-industry spillovers undergo a one-unit increase then each German region-sector will attract 4 more foreign patents[12], 3 more in the UK case, 10 and 14 in the French and the Italian case, respectively. An one-unit change in the R&D expenditures has a greater impact in the UK than in Germany (both in absolute and in proportionate terms). The effect of an one-unit change in the market conditions is higher in France and in Germany (where the scaled effect shows a percentage change of 3.3. and 1.7 respectively).

In summary, results obtained are consistent with the view that foreign-owned subsidiaries, which play an important role in the evolution and growth of the MNC, are sensitive to agglomeration potentials. However, some differences do exist when considering different European countries, thus posing different challenges for individual Governments.

**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 (and this figure had risen to nearly 29% by the early 1990s), while the world average is

[12] The number obtained in the German case derives from a one unit increase in FORRTA (6 more

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 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 specialisation in the region, i.e. the opportunity to enjoy diversity externalities and to capture inter-industry spillovers; (iii) the presence of external sources of knowledge. 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. This is consistent with other literature

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patents) and from a simultaneous one-unit increase in DOMRTA (less 2 patents).

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 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. Additionally, factor (i) depends critically on the presence of other foreign actors while large domestically-owned firms might discourage MNCs' location. We temptatively 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. 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 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 agglomeration effect.

Future work would benefit 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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**Table 1- Patenting activity attributable to European-located foreign-owned research, across host countries, and as a proportion of all patenting from the local research of large firms 1987-95 (%)**

| | Total patents from foreign-owned facilities | | Proportion of patents from foreign-owned facilities | |
|---|---|---|---|---|
| European host country | 1987-90 | 1991-95 | 1987-90 | 1991-95 |
| Germany | 33.47 | 28.87 | 18.09 | 17.37 |
| UK | 21.00 | 21.15 | 35.44 | 45.23 |
| Italy | 5.97 | 6.46 | 43.93 | 57.50 |
| France | 14.92 | 15.60 | 27.05 | 28.94 |
| Rest of Europe | 24.64 | 27.92 | | |
| Total Europe | 100.00 | 100.00 | 24.97 | 28.63 |

Source: US patent database developed by John Cantwell at the University of Reading, with the assistance of the US Patent and Trademark Office.

**Table 2 - Patents granted for research in Germany in large foreign-owned and domestically-owned firms, by region, 1987-95**

| Region | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| Stuttgart | 763 | 12.74 | 2989 | 10.71 |
| Karlrushe | 369 | 6.16 | 1159 | 4.15 |
| Freiburg | 748 | 12.49 | 249 | 0.89 |
| Tubingen | 230 | 3.84 | 438 | 1.57 |
| ***Baden-Wurttemberg*** | **2110** | **35.22** | **4835** | **17.32** |
| Oberbayern | 149 | 2.49 | 3643 | 13.05 |
| Niederbayern | 47 | 0.78 | 422 | 1.51 |
| Oberpfalz | 29 | 0.48 | 260 | 0.93 |
| Oberfranken | 59 | 0.98 | 270 | 0.97 |
| Mittelfranken | 201 | 3.36 | 1298 | 4.65 |
| Unterfranken | 189 | 3.15 | 690 | 2.47 |
| Schwaben | 99 | 1.65 | 423 | 1.52 |
| ***Bayern*** | **773** | **12.90** | **7006** | **25.10** |
| ***Berlin*** | **50** | **0.83** | **635** | **2.27** |
| ***Brandenburg*** | **16** | **0.27** | **15** | **0.05** |
| ***Bremen*** | **11** | **0.18** | **14** | **0.05** |
| ***Hamburg*** | **235** | **3.92** | **102** | **0.37** |
| Darmstadt | 711 | 11.87 | 3287 | 11.77 |
| Giessen | 97 | 1.62 | 201 | 0.72 |
| Kassel | 17 | 0.28 | 61 | 0.22 |
| ***Hessen*** | **825** | **13.77** | **3549** | **12.71** |
| ***Meckelburg-Vorpommern*** | **7** | **0.12** | **30** | **0.11** |
| Braunschweig | 50 | 0.83 | 223 | 0.80 |
| Hannover | 245 | 4.09 | 304 | 1.09 |
| Luneburg | 49 | 0.82 | 216 | 0.77 |
| Weser-Ems | 25 | 0.42 | 52 | 0.19 |
| ***Niedersachsen*** | **369** | **6.16** | **795** | **2.85** |
| Dusseldorf | 298 | 4.97 | 3790 | 13.58 |
| Koln | 552 | 9.21 | 2828 | 10.13 |
| Munster | 49 | 0.82 | 584 | 2.09 |
| Detmold | 21 | 0.35 | 114 | 0.41 |
| Amsberg | 99 | 1.65 | 375 | 1.34 |
| ***Nordrhein-Westfalen*** | **1019** | **17.01** | **7691** | **27.55** |
| Koblenz | 131 | 2.19 | 208 | 0.75 |
| Trier | 34 | 0.57 | 93 | 0.33 |
| Rheinhessen-Pfalz | 186 | 3.10 | 2640 | 9.46 |
| ***Rheinland-Pfalz*** | **351** | **5.86** | **2941** | **10.54** |
| ***Saarland*** | **22** | **0.37** | **70** | **0.25** |
| ***Sachsen*** | **6** | **0.10** | **40** | **0.14** |
| Dessau | 0 | 0.00 | 4 | 0.01 |
| Halle | 0 | 0.00 | 7 | 0.03 |
| Magdeburg | 2 | 0.03 | 0 | 0.00 |
| ***Sachsen-Anhalt*** | **2** | **0.03** | **11** | **0.04** |
| ***Scheleswig-Holstein*** | **188** | **3.14** | **160** | **0.57** |
| ***Thuringen*** | **7** | **0.12** | **22** | **0.08** |
| ***Total*** | **5991** | **100.00** | **27916** | **100.00** |

**Table 3 - Patents granted for research in the UK in large foreign-owned and domestically-owned firms, by region, 1987-95**

| Region | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| Cleveland, Durham | 54 | 1.33 | 226 | 3.73 |
| Cumbria | 4 | 0.10 | 45 | 0.74 |
| Northumberland, Tyne and Wear | 34 | 0.83 | 41 | 0.68 |
| ***North*** | **92** | **2.26** | **312** | **5.15** |
| Humberside | 14 | 0.34 | 96 | 1.58 |
| North Yorkshire | 33 | 0.81 | 64 | 1.06 |
| South Yorkshire | 41 | 1.01 | 40 | 0.66 |
| West Yorkshire | 55 | 1.35 | 59 | 0.97 |
| ***Yorkshire and Humberside*** | **143** | **3.51** | **259** | **4.27** |
| Derbyshire, Nottinghamshire | 50 | 1.23 | 239 | 3.94 |
| Leics., Northamptonshire | 95 | 2.33 | 207 | 3.41 |
| Lincolnshire | 14 | 0.34 | 19 | 0.31 |
| ***East Midlands*** | **159** | **3.90** | **465** | **7.67** |
| ***East Anglia*** | **289** | **7.10** | **108** | **1.78** |
| Bedfordshire, Hertfordshire | 420 | 10.31 | 427 | 7.04 |
| Berks., Bucks., Oxfordshire | 457 | 11.22 | 567 | 9.35 |
| Surrey, East-West Sussex | 486 | 11.93 | 472 | 7.78 |
| Essex | 213 | 5.23 | 368 | 6.07 |
| Greater London | 324 | 7.95 | 486 | 8.02 |
| Hampshire, Isle of Wight | 295 | 7.24 | 155 | 2.56 |
| Kent | 161 | 3.95 | 189 | 3.12 |
| ***South East*** | **2356** | **57.84** | **2664** | **43.94** |
| Avon, Gloucs., Wiltshire | 173 | 4.25 | 322 | 5.31 |
| Cornwall, Devon | 19 | 0.47 | 23 | 0.38 |
| Dorset, Somerset | 30 | 0.74 | 57 | 0.94 |
| ***South West*** | **222** | **5.45** | **402** | **6.63** |
| Hereford-Worcs., Warwicks. | 52 | 1.28 | 228 | 3.76 |
| Shropshire, Staffordshire | 27 | 0.66 | 89 | 1.47 |
| West Midlands | 54 | 1.33 | 309 | 5.10 |
| ***West Midlands*** | **133** | **3.27** | **626** | **10.32** |
| Cheshire | 93 | 2.28 | 441 | 7.27 |
| Greater Manchester | 135 | 3.31 | 272 | 4.49 |
| Lancashire | 41 | 1.01 | 111 | 1.83 |
| Merseyside | 69 | 1.69 | 142 | 2.34 |
| ***North West*** | **338** | **8.30** | **966** | **15.93** |
| Clwyd, Dyfed, Gwynedd, Powys | 10 | 0.25 | 54 | 0.89 |
| Gwent, Mid-S-W Glamorgan | 133 | 3.27 | 71 | 1.17 |
| ***Wales*** | **143** | **3.51** | **125** | **2.06** |
| Bord.-Centr.-Fife-Loth-Tayside | 88 | 2.16 | 55 | 0.91 |
| Dumfr.-Galloway, Strathclyde | 76 | 1.87 | 53 | 0.87 |
| Highlands, Islands | 2 | 0.05 | 1 | 0.02 |
| Grampian | 27 | 0.66 | 25 | 0.41 |
| ***Scotland*** | **193** | **4.74** | **134** | **2.21** |
| ***Northern Ireland*** | **5** | **0.12** | **2** | **0.03** |
| ***Total*** | **4073** | **100.00** | **6063** | **100.00** |

**Table 4 - Patents granted for research in France in large foreign-owned and domestically-owned firms, by region, 1987-95**

| Region | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| ***Ile-de-France*** | **1462** | **49.43** | **4001** | **52.72** |
| Champagne-Ardenne | 48 | 1.62 | 44 | 0.58 |
| Picardie | 44 | 1.49 | 240 | 3.16 |
| Haute-Normandie | 102 | 3.45 | 299 | 3.94 |
| Centre | 86 | 2.91 | 123 | 1.62 |
| Basse-Normadie | 62 | 2.10 | 27 | 0.36 |
| Bourgogne | 71 | 2.40 | 66 | 0.87 |
| ***Bassin parisien*** | **413** | **13.96** | **799** | **10.53** |
| ***Nord-Pas-de-Calais*** | **21** | 0.71 | **86** | 1.13 |
| Lorraine | 53 | 1.79 | 97 | 1.28 |
| Alsace | 192 | 6.49 | 90 | 1.19 |
| Franche-Comté | 17 | 0.57 | 74 | 0.98 |
| ***Est*** | **262** | **8.86** | **261** | **3.44** |
| Pays de la Loire | 8 | 0.27 | 64 | 0.84 |
| Bretagne | 17 | 0.57 | 88 | 1.16 |
| Poitou-Charentes | 25 | 0.85 | 49 | 0.65 |
| ***Ouest*** | **50** | **1.69** | **201** | **2.65** |
| Aquitaine | 21 | 0.71 | 313 | 4.12 |
| Midi-Pyrénées | 49 | 1.66 | 138 | 1.82 |
| Limousin | 22 | 0.74 | 2 | 0.03 |
| ***Sud-Ouest*** | **92** | **3.11** | **453** | **5.97** |
| Rhone-Alpes | 290 | 9.80 | 1208 | 15.92 |
| Auvergne | 20 | 0.68 | 95 | 1.25 |
| ***Centre-Est*** | **310** | **10.48** | **1303** | **17.17** |
| Languedoc-Roussillon | 20 | 0.68 | 122 | 1.61 |
| Provence-Alpes-Coted'Azur | 328 | 11.09 | 362 | 4.77 |
| Corse | 0 | 0.00 | 1 | 0.01 |
| ***Méditerranée*** | **348** | **11.76** | **485** | **6.39** |
| ***Total*** | **2958** | **100.00** | **7589** | **100.00** |

**Table 5 - Patents granted for research in Italy in large foreign-owned and domestically-owned firms, by region, 1987-95**

| Region | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| Piemonte | 106 | 8.94 | 418 | 35.64 |
| Valle d'Aosta | 0 | 0.00 | 0 | 0.00 |
| Liguria | 89 | 7.50 | 4 | 0.34 |
| ***North West*** | **195** | **16.44** | **422** | **35.98** |
| Milano | 462 | 38.95 | 494 | 42.11 |
| Lombardia (excluding Milano) | 195 | 16.44 | 87 | 7.42 |
| ***Lombardia*** | **657** | **55.40** | **581** | **49.53** |
| Trentino Alto Adige | 0 | 0.00 | 0 | 0.00 |
| Veneto | 29 | 2.45 | 36 | 3.07 |
| Friuli Venezia Giulia | 6 | 0.51 | 17 | 1.45 |
| ***North East*** | **35** | **2.95** | **53** | **4.52** |
| ***Emilia Romagna*** | **75** | **6.32** | **33** | **2.81** |
| Toscana | 10 | 0.84 | 24 | 2.05 |
| Umbria | 2 | 0.17 | 5 | 0.43 |
| Marche | 3 | 0.25 | 4 | 0.34 |
| ***Centre*** | **15** | **1.26** | **33** | **2.81** |
| ***Lazio*** | **110** | **9.27** | **25** | **2.13** |
| Abruzzo | 2 | 0.17 | 20 | 1.71 |
| Molise | 0 | 0.00 | 0 | 0.00 |
| ***Abruzzo-Molise*** | **2** | **0.17** | **20** | **1.71** |
| ***Campania*** | **24** | **2.02** | **3** | **0.26** |
| Puglia | 29 | 2.45 | 2 | 0.17 |
| Basilicata | 0 | 0.00 | 0 | 0.00 |
| Calabria | 2 | 0.17 | 0 | 0.00 |
| ***South*** | **31** | **2.61** | **2** | **0.17** |
| ***Sicilia*** | **42** | **3.54** | **1** | **0.09** |
| ***Sardegna*** | **0** | **0.00** | **0** | **0.00** |
| ***Total*** | **1186** | **100.00** | **1173** | **100.00** |

**Table 6 - Patents granted for research in Germany in large foreign-owned and domestically-owned firms, by industry, 1987-95**

| Industry | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| Food, drink, tobacco and allied products | 97 | 1.62 | 0 | 0.00 |
| Chemicals | 914 | 15.26 | 12439 | 44.56 |
| Pharmaceuticals | 225 | 3.76 | 2134 | 7.64 |
| Metals | 375 | 6.26 | 2002 | 7.17 |
| Mechanical engineering | 488 | 8.15 | 1442 | 5.17 |
| Electrical equipment | 2300 | 38.39 | 4643 | 16.63 |
| Office equipment | 339 | 5.66 | 51 | 0.18 |
| Motor vehicles | 379 | 6.33 | 4075 | 14.60 |
| Aircraft | 112 | 1.87 | 381 | 1.36 |
| Other transport equipment | 1 | 0.02 | 0 | 0.00 |
| Textiles | 0 | 0.00 | 5 | 0.02 |
| Paper, printing and publishing | 34 | 0.57 | 0 | 0.00 |
| Rubber products | 19 | 0.32 | 37 | 0.13 |
| Non-metallic mineral products | 362 | 6.04 | 0 | 0.00 |
| Coal and petroleum products | 125 | 2.09 | 48 | 0.17 |
| Professional and scientific instruments | 193 | 3.22 | 449 | 1.61 |
| Other manufacturing | 28 | 0.47 | 210 | 0.75 |
| ***Total*** | **5991** | **100.00** | **27916** | **100.00** |

**Table 7 - Patents granted for research in the UK in large foreign-owned and domestically-owned firms, by industry, 1987-95**

| Industry | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| Food, drink, tobacco and allied products | 76 | 1.87 | 346 | 5.71 |
| Chemicals | 775 | 19.03 | 1405 | 23.17 |
| Pharmaceuticals | 760 | 18.66 | 636 | 10.49 |
| Metals | 186 | 4.57 | 176 | 2.90 |
| Mechanical engineering | 285 | 7.00 | 146 | 2.41 |
| Electrical equipment | 870 | 21.36 | 1210 | 19.96 |
| Office equipment | 418 | 10.26 | 83 | 1.37 |
| Motor vehicles | 201 | 4.93 | 612 | 10.09 |
| Aircraft | 29 | 0.71 | 690 | 11.38 |
| Other transport equipment | 1 | 0.02 | 16 | 0.26 |
| Textiles | 0 | 0.00 | 46 | 0.76 |
| Paper, printing and publishing | 42 | 1.03 | 20 | 0.33 |
| Rubber products | 17 | 0.42 | 53 | 0.87 |
| Non-metallic mineral products | 71 | 1.74 | 72 | 1.19 |
| Coal and petroleum products | 93 | 2.28 | 505 | 8.33 |
| Professional and scientific instruments | 197 | 4.84 | 0 | 0.00 |
| Other manufacturing | 52 | 1.28 | 47 | 0.78 |
| **Total** | **4073** | **100.00** | **6063** | **100.00** |

**Table 8 - Patents granted for research in France in large foreign-owned and domestically-owned firms, by industry, 1987-95**

| Industry | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| Food, drink, tobacco and allied products | 17 | 0.57 | 35 | 0.46 |
| Chemicals | 667 | 22.55 | 1291 | 17.01 |
| Pharmaceuticals | 148 | 5.00 | 688 | 9.07 |
| Metals | 42 | 1.42 | 247 | 3.25 |
| Mechanical engineering | 136 | 4.60 | 170 | 2.24 |
| Electrical equipment | 935 | 31.61 | 1850 | 24.38 |
| Office equipment | 231 | 7.81 | 176 | 2.32 |
| Motor vehicles | 297 | 10.04 | 494 | 6.51 |
| Aircraft | 22 | 0.74 | 881 | 11.61 |
| Other transport equipment | 0 | 0.00 | 0 | 0.00 |
| Textiles | 27 | 0.91 | 4 | 0.05 |
| Paper, printing and publishing | 30 | 1.01 | 0 | 0.00 |
| Rubber products | 18 | 0.61 | 97 | 1.28 |
| Non-metallic mineral products | 64 | 2.16 | 306 | 4.03 |
| Coal and petroleum products | 142 | 4.80 | 1350 | 17.79 |
| Professional and scientific instruments | 59 | 1.99 | 0 | 0.00 |
| Other manufacturing | 123 | 4.16 | 0 | 0.00 |
| ***Total*** | ***2958*** | ***100.00*** | ***7589*** | ***100.00*** |

**Table 9 - Patents granted for research in Italy in large foreign-owned and domestically-owned firms, by industry, 1987-95**

| Industry | No. foreign-owned patents | % | No. domestically-owned patents | % |
|---|---|---|---|---|
| Food, drink, tobacco and allied products | 23 | 1.94 | 0 | 0.00 |
| Chemicals | 314 | 26.48 | 488 | 41.60 |
| Pharmaceuticals | 76 | 6.41 | 0 | 0.00 |
| Metals | 33 | 2.78 | 2 | 0.17 |
| Mechanical engineering | 64 | 5.40 | 0 | 0.00 |
| Electrical equipment | 461 | 38.87 | 19 | 1.62 |
| Office equipment | 67 | 5.65 | 95 | 8.10 |
| Motor vehicles | 33 | 2.78 | 323 | 27.54 |
| Aircraft | 21 | 1.77 | 0 | 0.00 |
| Other transport equipment | 0 | 0.00 | 0 | 0.00 |
| Textiles | 0 | 0.00 | 1 | 0.09 |
| Paper, printing and publishing | 0 | 0.00 | 0 | 0.00 |
| Rubber products | 32 | 2.70 | 150 | 12.79 |
| Non-metallic mineral products | 24 | 2.02 | 0 | 0.00 |
| Coal and petroleum products | 29 | 2.45 | 95 | 8.10 |
| Professional and scientific instruments | 0 | 0.00 | 0 | 0.00 |
| Other manufacturing | 9 | 0.76 | 0 | 0.00 |
| ***Total*** | **1186** | **100.00** | **1173** | **100.00** |

## Table 10 – Correlation and characteristics of the variables

**Germany**

| | *mean* | *Std Dev* | *min* | *max* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1* $FORPAT_t$ | 9.27 | 32.46 | 0.00 | 341.00 | 1.000 | 0.212 | 0.060 | 0.051 | 0.033 | 0.854 | 0.163 | 0.155 |
| *2* GDP_PC_92 | 110.95 | 45.01 | 15.00 | 215.00 | 0.212 | 1.000 | -0.006 | -0.229 | -0.132 | 0.232 | -0.089 | 0.356 |
| *3* RDEXP_G | 162.83 | 135.18 | 29.83 | 795.05 | 0.060 | -0.006 | 1.000 | 0.642 | 0.025 | 0.052 | -0.088 | 0.027 |
| *4* EDUC_TOT | 358.50 | 160.30 | 122.00 | 792.00 | 0.051 | -0.229 | 0.642 | 1.000 | 0.040 | 0.087 | -0.066 | 0.178 |
| *5* $DOMRTA_{t-1}$ | 0.74 | 1.86 | 0.00 | 15.78 | 0.033 | -0.132 | 0.025 | 0.040 | 1.000 | 0.048 | -0.033 | -0.030 |
| *6* $FORPAT_{t-1}$ | 8.04 | 27.16 | 0.00 | 246.00 | 0.854 | 0.232 | 0.052 | 0.087 | 0.048 | 1.000 | 0.249 | 0.175 |
| *7* $FORRTA_{t-1}$ | 0.92 | 2.60 | 0.00 | 30.93 | 0.163 | -0.089 | -0.088 | -0.066 | -0.033 | 0.249 | 1.000 | -0.105 |
| *8* $DIVERSITY_{t-1}$ | 0.01 | 0.00 | 0.00 | 0.01 | 0.155 | 0.356 | 0.027 | 0.178 | -0.030 | 0.175 | -0.105 | 1.000 |

**UK**

| | *mean* | *Std Dev* | *min* | *max* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1* $FORPAT_t$ | 6.85 | 22.17 | 0.00 | 322.00 | 1.000 | 0.126 | 0.298 | 0.318 | -0.045 | 0.872 | 0.237 | 0.251 |
| *2* GDP_PC_92 | 84.00 | 12.68 | 65.00 | 128.00 | 0.126 | 1.000 | 0.404 | 0.416 | -0.021 | 0.118 | -0.070 | 0.634 |
| *3* RDEXP_G | 73.05 | 78.24 | 3.05 | 237.53 | 0.298 | 0.404 | 1.000 | 0.833 | -0.085 | 0.295 | -0.121 | 0.682 |
| *4* EDUC_TOT | 364.03 | 101.31 | 226.33 | 533.43 | 0.318 | 0.416 | 0.833 | 1.000 | -0.118 | 0.330 | -0.119 | 0.712 |
| *5* $DOMRTA_{t-1}$ | 1.42 | 4.35 | 0.00 | 77.46 | -0.045 | -0.021 | -0.085 | -0.118 | 1.000 | -0.035 | 0.067 | -0.072 |
| *6* $FORPAT_{t-1}$ | 6.17 | 20.43 | 0.00 | 221.00 | 0.872 | 0.118 | 0.295 | 0.330 | -0.035 | 1.000 | 0.294 | 0.250 |
| *7* $FORRTA_{t-1}$ | 1.05 | 8.34 | 0.00 | 49.44 | 0.237 | -0.070 | -0.121 | -0.119 | 0.067 | 0.294 | 1.000 | -0.151 |
| *8* $DIVERSITY_{t-1}$ | 0.01 | 0.00 | 0.00 | 0.01 | 0.251 | 0.634 | 0.682 | 0.712 | -0.072 | 0.250 | -0.151 | 1.000 |

**Italy**

| | *mean* | *Std Dev* | *min* | *max* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *1* $FORPAT_t$ | 3.67 | 15.91 | 0.00 | 192.00 | 1.000 | -0.202 | -0.033 | -0.028 | -0.037 | 0.564 | 0.059 | 0.313 |
| *2* GDP_PC_92 | 80.15 | 43.08 | 13.10 | 127.00 | -0.202 | 1.000 | 0.277 | 0.281 | 0.064 | -0.244 | 0.201 | -0.214 |
| *3* RDEXP_G | 115.30 | 233.59 | 0.00 | 1125.70 | -0.033 | 0.277 | 1.000 | 0.441 | -0.154 | -0.148 | 0.196 | 0.334 |
| *4* EDUC_TOT | 302.53 | 312.52 | 4.00 | 1156.24 | -0.028 | 0.281 | 0.441 | 1.000 | -0.029 | -0.013 | 0.175 | 0.084 |
| *5* $DOMRTA_{t-1}$ | 0.79 | 2.79 | 0.00 | 25.13 | -0.037 | 0.064 | -0.154 | -0.029 | 1.000 | 0.097 | -0.052 | -0.054 |
| *6* $FORPAT_{t-1}$ | 2.11 | 8.30 | 0.00 | 103.00 | 0.564 | -0.244 | -0.148 | -0.013 | 0.097 | 1.000 | 0.309 | 0.265 |
| *7* $FORRTA_{t-1}$ | 0.64 | 2.19 | 0.00 | 17.35 | 0.059 | 0.201 | 0.196 | 0.175 | -0.052 | 0.309 | 1.000 | 0.072 |
| *8* $DIVERSITY_{t-1}$ | 0.00 | 0.00 | 0.00 | 0.01 | 0.313 | -0.214 | 0.334 | 0.084 | -0.054 | 0.265 | 0.072 | 1.000 |

**France**

| | *mean* | *Std.Dev* | *min* | *max* | *1* | *2* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *1* $FORPAT_t$ | 7.91 | 38.72 | 0.00 | 597.00 | 1.000 | 0.425 | 0.434 | -0.004 | 0.854 | 0.072 | 0.333 |
| *2* GDP_PC_92 | 101.27 | 17.23 | 80.00 | 170.00 | 0.425 | 1.000 | 0.848 | -0.025 | 0.478 | -0.020 | 0.730 |
| *4* EDUC_TOT | 88.73 | 106.98 | 4.00 | 536.00 | 0.434 | 0.848 | 1.000 | -0.032 | 0.481 | 0.007 | 0.785 |
| *5* $DOMRTA_{t-1}$ | 1.03 | 4.28 | 0.00 | 68.84 | -0.004 | -0.025 | -0.032 | 1.000 | -0.002 | 0.395 | -0.045 |
| *6* $FORPAT_{t-1}$ | 5.92 | 30.87 | 0.00 | 442.00 | 0.854 | 0.478 | 0.481 | -0.002 | 1.000 | 0.111 | 0.360 |
| *7* $FORRTA_{t-1}$ | 1.08 | 2.83 | 0.00 | 27.47 | 0.072 | -0.020 | 0.007 | 0.395 | 0.111 | 1.000 | 0.036 |
| *8* $DIVERSITY_{t-1}$ | 0.00 | 0.00 | 0.00 | 0.01 | 0.333 | 0.730 | 0.785 | -0.045 | 0.360 | 0.036 | 1.000 |

**Table 11 - Estimation results (dependent variable FORPATt)**

| | Germany | | UK | | France | | Italy | |
|---|---|---|---|---|---|---|---|---|
| $FORPAT_{t\_1}$ | 0.019 *** | (5.742) | 0.021 *** | (4.382) | 0.007 *** | (2.940) | 0.064 *** | (3.333) |
| $FORRTA_{t\_1}$ | 0.209 *** | (6.044) | 0.138 *** | (4.673) | 0.266 *** | (5.822) | 0.311 *** | (3.868) |
| $DOMRTA_{t\_1}$ | -0.066 | (-1.465) | 0.025 | (0.974) | -0.113 * | (-1.956) | 0.030 | (0.428) |
| $DIVERSITY_{t\_1}$ | 221.07 *** | (5.245) | 293.74 *** | (6.227) | 190.45 *** | (3.242) | 572.52 *** | (5.238) |
| EDUC_TOTOT | | | | | 0.0004 | (0.216) | 0.001 *** | (2.101) |
| RDEXP_G | 0.001 ** | (2.393) | 0.002 * | (1.748) | | | | |
| MARKET | 0.015 *** | (6.314) | 0.003 | (0.564) | 0.033 *** | (2.784) | -0.007 ** | (-2.077) |
| Food, drink, tobacco | 1.423 *** | (3.468) | 0.128 | (0.351) | -1.420 ** | (-2.168) | 1.515 *** | (2.140) |
| Chemicals | 3.085 *** | (7.456) | 2.162 *** | (6.060) | 2.691 *** | (5.544) | 2.512 *** | (3.518) |
| Pharmaceuticals | 1.843 *** | (4.536) | 1.901 *** | (5.437) | 0.784 | (1.624) | 2.105 *** | (2.995) |
| Metals | 2.305 *** | (5.637) | 0.972 *** | (2.771) | 0.049 | (0.091) | 1.289 * | (1.776) |
| Mechanical engineering | 2.177 *** | (5.439) | 1.348 *** | (3.826) | 1.239 ** | (2.576) | 1.577 ** | (2.087) |
| Electrical equipment | 3.434 *** | (8.333) | 1.544 *** | (4.239) | 2.689 *** | (5.668) | 3.930 *** | (5.526) |
| Office equipment | 1.707 *** | (4.172) | 1.420 *** | (4.017) | 0.560 | (1.118) | 1.227 * | (1.663) |
| Motor vehicles | 1.978 *** | (4.840) | 1.270 *** | (3.603) | 1.388 *** | (2.896) | 0.988 | (1.318) |
| Aircraft | 1.740 *** | (4.228) | -0.456 | (-1.129) | -0.777 | (-1.323) | -0.646 | (-0.706) |
| Other transport equipment | -2.825 *** | (-2.571) | -3.772 *** | (-3.495) | -32.362 | (0.000) | -33.740 | (0.000) |
| Textiles | -31.514 | (0.000) | -33.440 | (0.000) | -1.899 *** | (-2.765) | -34.063 | (0.000) |
| Paper, printing, publishing | -0.116 | (-0.255) | -0.070 | (-0.181) | -1.516 ** | (-2.397) | -36.988 | (0.000) |
| Rubber products | -0.401 | (-0.833) | -1.117 *** | (-2.586) | -2.117 *** | (-3.027) | -1.689 | (-1.566) |
| Non-metallic mineral prods. | 1.350 *** | (3.395) | -0.658 | (-1.627) | 0.469 | (0.854) | 0.629 | (0.859) |
| Coal and petroleum prods. | 1.792 *** | (4.386) | 0.288 | (0.785) | 1.756 *** | (3.544) | 1.093 | (1.453) |
| Prof. and scientific insts. | 1.844 *** | (4.512) | 0.462 | (1.281) | 0.786 | (1.578) | -33.758 | (0.000) |
| Constant | -4.212 *** | (-8.558) | -2.136 *** | (-3.900) | -4.493 *** | (-3.992) | -3.429 *** | (-4.554) |
| Included observations | 595 | | 578 | | 357 | | 289 | |
| Log likelihood | -1178.23 | | -1095.88 | | -626.10 | | -327.26 | |
| LR statistic | 21435.7 *** | | 13109.1 *** | | 12506.2 *** | | 5046.42 *** | |
| LR index (Pseudo-R2) | 0.900 | | 0.856 | | 0.909 | | 0.885 | |

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

**Table 12 – Estimated coefficients, mean effects and scaled coefficients**

**Germany**
[646]

| | | Mean effect | | Scaled coefficients | |
|---|---|---|---|---|---|
| | Coefficient | Ave | At Ave | Elast | SSC |
| FORPAT$_{t_1}$ | 0.019 | 0.579 | 0.004 | 0.153 | 0.516 |
| FORRTA$_{t_1}$ | 0.209 | 6.367 | 0.045 | 0.192 | 0.544 |
| DOMRTA$_{t_1}$ | -0.066 | -2.011 | -0.014 | -0.049 | -0.123 |
| DIVERSITY$_{t_1}$ | 221.07 | 6734.986 | 47.466 | 1.149 | 0.459 |
| RDEXP_G | 0.001 | 0.030 | 0.000 | 0.163 | 0.135 |
| MKT_SIZE | 0.015 | 0.457 | 0.003 | 1.664 | 0.675 |

**UK**
[595]

| | | Mean effect | | Scaled coefficients | |
|---|---|---|---|---|---|
| | Coefficient | Ave | At Ave | Elast | SSC |
| FORPAT$_{t_1}$ | 0.021 | 0.442 | 0.005 | 0.130 | 0.429 |
| FORRTA$_{t_1}$ | 0.138 | 2.905 | 0.030 | 0.145 | 0.438 |
| DOMRTA$_{t_1}$ | 0.025 | 0.526 | 0.005 | 0.036 | 0.109 |
| DIVERSITY$_{t_1}$ | 293.74 | 6183.823 | 63.506 | 1.545 | 0.619 |
| RDEXP_G | 0.002 | 0.042 | 0.000 | 0.146 | 0.156 |
| MKT_SIZE | 0.003 | 0.063 | 0.001 | 0.252 | 0.038 |

**France**
[374]

| | | Mean effect | | Scaled coefficients | |
|---|---|---|---|---|---|
| | Coefficient | Ave | At Ave | Elast | SSC |
| FORPAT$_{t_1}$ | 0.007 | 0.498 | 0.001 | 0.041 | 0.216 |
| FORRTA$_{t_1}$ | 0.266 | 18.910 | 0.021 | 0.287 | 0.752 |
| DOMRTA$_{t_1}$ | -0.113 | -8.033 | -0.009 | -0.116 | -0.484 |
| DIVERSITY$_{t_1}$ | 190.45 | 13538.88 | 15.149 | 0.931 | 0.453 |
| EDUC_T | 0.0004 | 2.346 | 0.003 | 0.035 | 0.043 |
| MKT_SIZE | 0.033 | 0.028 | 0.000 | 3.342 | 0.569 |

**Italy**
[357]

| | | Mean effect | | Scaled coefficients | |
|---|---|---|---|---|---|
| | Coefficient | Ave | At Ave | Elast | SSC |
| FORPAT$_{t_1}$ | 0.064 | 2.856 | 0.000 | 0.135 | 0.009 |
| FORRTA$_{t_1}$ | 0.311 | 13.881 | 0.000 | 0.199 | 0.235 |
| DOMRTA$_{t_1}$ | 0.030 | 1.339 | 0.000 | 0.024 | 0.030 |
| DIVERSITY$_{t_1}$ | 572.52 | 25552.95 | 0.064 | 1.712 | 0.000 |
| EDUC_T | 0.001 | 0.045 | | 0.303 | 0.047 |
| MKT_SIZE | -0.007 | -0.312 | 0.000 | -0.561 | -0.008 |