AGGLOMERATION IN THE TECHNOLOGICAL ACTIVITIES OF MNCs IN EUROPE: THE ROLE OF SPILLOVERS AND OTHER TERRITORIAL EXTERNALITIES

John Cantwell
University of Reading
Lucia Piscitello
Politecnico di Milano

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ABSTRACT
This paper examines the relative attractiveness of the Italian, German and UK regions for the siting of foreign-owned corporate technological development, controlling for the geographical distribution of the equivalent innovative efforts of established indigenous firms in each country. The data used are patents granted in the US to the world's largest firms from 1969-95, identifying the ultimate nationality of ownership and the location of the research facility responsible for each patent. It is shown that the relative attraction of a location for foreign-owned research depends positively upon the local scientific and educational infrastructure, the potential for cluster-specific spillovers, and the potential for spillovers of general purpose technologies.

1. Introduction

The existing knowledge base of a region plays an important role in the decisions of the largest foreign-owned firms as to where to locate technological activities (Cantwell and Iammarino, 1998, 2000; Cantwell and Noonan, 2001). Thus, in each country the local technological efforts of foreign-owned firms tend to be strongly agglomerated at a sub-national and regional level. The present paper analyses whether this agglomeration effect (Braunerhjelm and Svensson, 1998; Barrel and Pain, 1999) depends linearly on the cross-regional distribution and the regional specialisation of technological activities in indigenous firms, or whether foreign-owned firms are instead also attracted to certain places by other location-specific variables and territorial externalities. Specifically, the purpose of this paper is twofold: (i) to analyse the regional distribution of technological activities carried out by large multinational corporations (MNCs) in Europe over the last 30 years; (ii) to explain the locational preferences of foreign-owned firms across the European regions allowing for a linear sector-specific agglomeration effect and territorial externalities.

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 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 indigenous and foreign-owned firms is then compared using a methodology developed by Mariotti and Piscitello (1995), which establishes departures from a linear proportionality between the locational distributions of different sets of firms, controlling for the degree of correlation between the profiles of technological specialisation of each set, since co-specialised firms are more likely to be co-located. We find that there are significant differences in the cross-regional distribution of technological development between locally-owned and foreign-owned firms[1]. We discuss some explanations for these differences (which are associated with the co-evolution of alternative corporate technological trajectories and local innovation systems), and propose an econometric model in order to explain these locational preferences of MNCs across the European regions.

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 at the national and industry level in the period 1969-95. Section 4 explores in greater depth the regional location of technological development in the German, UK and Italian regions over the whole period 1969-95, and investigates whether the research activities carried out in these regions follow a similar geographical profile for both domestically- and foreign-owned firms. Section 5 reports the econometric model, the variables and the results obtained. Finally, Section 6 presents some summarising and concluding remarks, draws out one of the policy implications of our argument, and indicates an agenda for future research.

2. Distinguishing types of locational spillover potential: 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

[1] For a similar result in the UK, see also Cantwell and Iammarino (2000).

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[2].

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 the location which hosts them. Thus, 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. The choice clearly depends upon: (i) the strategy followed by the MNC (the extent to which it has evolved an internationally integrated network); and the (ii) 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***

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

[2] 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).

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). By contrast, where the technological capacity of a host country is weak in the sector concerned, the investments of MNEs may drive out local competition and reduce local technological capability still further (Cantwell, 1987). 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 MNE as a whole.

(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). 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. 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).

(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 large number of technologically active firms in the same region, as measured by their patenting of inventions due to local research facilities;

ii. Sector-specific spillovers, associated with the particular focus of specialisation in a region, i.e. the existence of firms working in closely related fields of research, thus sharing complementary competencies, abilities and experiences;

iii. General purpose spillovers, entailing inter-industry spillovers in general purpose technologies which are relevant to most industries - such as mechanical equipment, electrical communication and computing, instruments or new materials. 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 MNCs, as the attraction is related to spillovers in core technological sectors which are of an inter-industry kind. In comparison, more specialised regional centres are attractive mainly as a location for the affiliate R&D within the industries for which the local region is best known (Cantwell and Iammarino, 1998) - and so for the second kind of spillover rather than the third.

All these factors suggest that innovative activities tend in general to agglomerate within specific locations. Nonetheless, we claim that foreign-owned firms tend to be more able than indigenous companies to respond to these incentives. This is because indigenous firms have normally grown up concentrated in their region of origin, and this path-dependent growth of the firm has left it less likely to respond fully to other locational pulls or pushes in its own national environment. In contrast, foreign-owned firms have come in from the outside, and often entered relatively recently, so they are much more mobile within the host country in terms of their choice of location. Hence they are better equipped to respond to these regional differences. Therefore, we expect the locational choices of foreign-owned firms to be more strongly influenced by the attraction of these potential spillover benefits, as far as their technological activities are concerned.

3. Evidence on the globalisation of corporate technology

3.1. The globalisation of corporate technology at the national 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. Moreover, patents can be classified by detailed technological fields (grouped into 56 sectors in the database, see the Appendix), which would not be possible otherwise by using indicators such as for example, R&D expenditure (Zander, 1997).

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 the Fortune 500 listings (Dunning and Pearce, 1985). Of these 792 companies 730 had an active patenting presence during the period 1969-1995. Another 54 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 examines the share of US patents of the world's largest firms attributable to overseas research in terms of the nationality of the parent company. The general trend is upwards – from a foreign research share of 10.5% in 1969-72 to 16.5% in 1991-95, excluding Japanese firms – although this is disguised in the overall global average foreign share owing to the sharply rising contribution to total corporate patenting of Japanese companies, whose research has been little internationalised. The most significant increase in internationalisation is found in the two most recent periods. While a significant increase in foreign technological development already started for most of the national groups of companies in 1987-90, all the groups moved to a greater internationalisation of technological activity in the early 1990s; even those which have had in the past a somewhat more centralised approach to their research strategy, such as the Japanese and, more relevantly for the present study, the Italian. Furthermore, the trend increase in the internationalisation of research has been most stable and marked in US and Swedish companies since 1969, and in German and French firms since 1983.

Looking at the locational issue from the parent's company viewpoint, Table 2 shows that the R&D activities of European companies abroad are concentrated in the US (over 50% on average) and elsewhere in Europe (about 40% in average). In particular, the share of US patents of European-owned companies attributable to foreign-located research undertaken within Europe has risen from 30.2% in 1969-72 to 40.4% in 1991-95, although this trend seems to have been partially reversed in the early 1990s. The US is the most important location for German- and British-owned research abroad, with more than half of their total foreign research accounted for by that location, indicating a reliance upon more widely "globalised" technological strategies encompassing facilities outside Europe. French firms have also a significant part of their technological activity abroad in the US, while Italian companies recently showed a sharp increase in their preference for other European locations.

Concerning the dispersion of foreign-owned research activities across the European economy, Table 3 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 4 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 the major firms displayed in Table 1 (from a foreign share of 10.5% to one of 16.5%, excluding Japanese companies).

The sectoral forms of foreign penetration in the major European countries is shown in Tables 5 and 6, which examine the contribution to local research of foreign-owned firms by industry (Table 5) and by the field of technological activity derived from the US patent class system (Table 6). Looking first at Table 5, in the world as a whole foreign penetration is highest in the chemicals, pharmaceuticals, oil and food product industries. In Europe instead, while the same applies in oil and food products, the foreign-owned share of local development is below average in chemicals (15.6% as against 24.0%), and only slightly above average (at 27.4%) in pharmaceuticals. This is because of the strength of indigenous companies in the European chemicals and pharmaceuticals industries. In contrast, foreign penetration is above average in Europe in the group of electrical equipment, professional and scientific instruments, and especially in office and computing equipment. These are the industries in which European-owned firms are technologically weakest vis-à-vis their US and Japanese rivals, and so the European economies have become relatively more dependent on the locally conducted research of foreign-owned firms. Similar explanations can be applied to the variations across individual host countries (see Cantwell and Kosmopoulou, 2000). Foreign penetration is not especially high in food products in the UK, in oil in the UK, Italy or France, in electrical equipment in France, or in office and computing equipment in Italy. In each of these cases large indigenous companies have a comparative technological advantage. The one interesting exception to this argument is the high foreign penetration into UK research in pharmaceuticals, an industry in which the UK is a centre of technological excellence. In this instance, the interaction between the innovation of indigenous and foreign-owned companies has taken the form of a virtuous circle of increased activity on both sides (Cantwell, 1987, 1989).

Turning to the equivalent disaggregation of foreign penetration in European development by the type of technological activity (Table 6), the general world background reveals two apparent differences from the industry-based picture. Foreign penetration is relatively low in oil-related chemicals, but above average in mechanical engineering. This suggests that the oil companies are using their high foreign-located development more in relation to mining and mechanical technologies rather than for innovation in petrochemicals, and indeed a similar pattern may apply to a lesser extent to firms in other industries. In Europe, again, foreign penetration is relatively low (unlike in the rest of the world) in the development of chemical and pharmaceutical technologies, but relatively high in the electrical equipment, office and computing equipment, and instruments group, and also in metals and machinery. Conversely again, foreign penetration in pharmaceutical development in the UK is higher than its status as a centre of excellence might suggest, but owes to the positive interaction between UK-owned and the best foreign-owned companies. Foreign participation in new drug development is also high in France, but this is probably attributable to the local regulatory regime, which has insisted on the presence of local research facilities as a condition of local medical sales.

3.2. The globalisation of corporate technology at a European regional level

From the above discussion, it becomes quite clear that foreign investment in innovation has 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). Although some authors have recently suggested that regions are increasingly becoming important *milieux* for 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), the empirical research on the locational issue is still quite scant.

In order to throw some light on the circumstances that lead to the geographical dispersion of technological activities and give rise to geographical agglomeration, we examined three of the largest European countries (Germany, the UK and Italy) at a more detailed level of analysis. 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 spillover hypotheses outlined above. We have used 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.

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[3], 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 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). 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 (106,383) is more than twice that registered for the UK (46,253), which in turn is more than five times that registered for Italy (8,756).

[3] 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) consider NUTS 1 for the UK and NUTS 2 for Italy.

Tables 7a-7c report the total number and the percentage share of patents granted to the domestic firms and to foreign-owned firms in each region considered[4]. Concerning Germany (see Table 7a) it is worth noting that the number of patents granted to domestic firms is more than twice that for foreign-owned firms, while for both the UK and Italy the efforts of indigenous and foreign-owned firms are of similar magnitude. As explained already, 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. It is interesting to observe that while the pattern of regional concentration of the local technological efforts of indigenous and foreign-owned firms is similar in the UK (in London and South East England) and in Italy (in Milano), there is a significant difference in Germany. The leading centre for domestically-owned innovation in Germany is Oberbayern, but foreign-owned development is concentrated instead mainly in Stuttgart and Darmstadt.

4. Does foreign MNC location just follow the established geographical pattern of indigenous company activity?

Having illustrated the geographical distribution of the technological activity carried out by domestic and foreign-owned firms across the European regions of the largest economies, the main issue is whether our observation of the similarity (in the UK and Italy) or the difference (in Germany) between indigenous and foreign-owned firms with respect to the single major centre of activity can be extended to an analysis of the regional distribution of activity as a whole. That is, are there significant asymmetries between the geographical distribution of foreign-owned firm activity compared to that of domestically-owned firms? In particular, we investigate whether a linear proportionality 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 territorial and region-specific externalities.

[4] The regions considered meet a size restriction which we had to impose in order to avoid small number problems. Specifically, the cut off point has been imposed on the domestic side, that is we excluded all the regions which did not account more than 25 patents granted to indigenous firms in the whole period considered. Such a cut off point left us with 35 regions for Germany (out of the original 38), 33 for the UK (from 35) and 9 in the case of Italy (out of 20).

The problem has been tackled as follows (for a similar technical approach applied to the manufacturing foreign direct investment [FDI] in Italy and in USA see Mariotti and Piscitello, 1995, and Shaver, 1998, respectively[5]). Let N_{jm} be the total number of patents granted to foreign-owned firms in each sector j. It is worth observing that to avoid problems related to the mixed presence of German and British firms abroad within the set of the European foreign-owned firms, we restricted this part of our analysis to US-owned firms alone[6]. Therefore, we considered the distribution of the total number of patents granted to the US firms in the period 1969-1995 over the 77 regions considered.

If the location of technological activities by foreign firms were exclusively related to the technological activities and to technological specialisation of domestic firms, then the N_j patents would be distributed in each region i, in proportion to the total number of patents granted in the same region to domestic firms in sector j. Therefore:

let n_{ij} be the total number of patents granted to domestic firms in region i and sector j in the period considered. For each sector, the share of patents granted to domestic firms in region i with respect to the national average is:

$\alpha_{ij} = n_{ij}/\Sigma_i n_{ij}$

Assuming that foreign firms follow a random process (related only to the indigenous firms' activities) in the location of their technological activities, the expected number of patents $\tilde{n}_{ij}$ granted to foreign-owned firms in region i, sector j is:

$\tilde{n}_{ij} = \alpha_{ij} * N_j$

Consequently, the expected total number $\tilde{N}_i$ of patents granted to foreign-owned firms in each region i is:

$\tilde{N}_i = \Sigma_j \tilde{n}_{ij} = \Sigma_j \alpha_{ij} * N_j$

where:

$i = 1, \ldots, 77;$

$j = 1, \ldots, 56$

Therefore, it is possible to compare the distribution of the expected values $\tilde{N}_i$ with the number of patents actually granted to foreign-owned firms in each European region, N_i, during the period considered. The statistically significant equality of the two

[5] Another approach to the evaluation of firms' location tendencies in Europe is Mur and Trivez (1998).

[6] Not only are US firms easily the major national group developing technology in Europe without a local home base there, but of patents due to inventions from foreign-owned facilities in Germany, Italy and the UK, the number granted to US-owned firms is larger than that due to all other foreign-owned companies taken together, and so US firms are likely to lead overall foreign behaviour.

distributions would imply that the activity of domestic firms, that is the existing knowledge and competence base in each region, explains almost perfectly the locational choices of technological activities by foreign firms in Europe.

In order to compare the two distributions, a chi-square test has been carried out. Since the equality between the expected and actual distributions is significantly rejected ($p < .01$) for all the cases considered, this means that foreign technological activities are distributed dissimilarly across the regions compared to the existing patterns of technological activities carried out by domestic firms (which confirms previous results by Cantwell and Iammarino 1998; 2000) and that therefore the hypothesis of a linear agglomeration effect can be significantly rejected.

5. The econometric model and specification of the variables used

5.1. The dependent variable

As the phenomenon under study is the locational preference of foreign-owned firms as between the regions of alternative European countries once companies have decided to locate their technological activities in Europe, we consider the situation in which foreign activities could in principle spread over the whole set of the European regions considered.

In order to measure the discrepancy between foreign and domestic locational preferences across the regions, we built a variable based on the difference between the two profiles obtained (that is N_i and $\tilde{N}_i$). In particular, a proper measure of such a difference should take into account (i) the regional size, and (ii) the degree of co-specialisation between indigenous firms in region i and foreign-owned firms, while controlling for (iii) general sector-specific differences in the propensity to patent. Therefore, the absolute difference between N_i and $\tilde{N}_i$ should be corrected through a normalisation factor taking into account the three effects just mentioned, which is given by the following:

$I_i = (n_i/s)*\Sigma_j rta_{ij}*RTA_j$

where

n_i is the measure of the regional size (that is the number of patents granted to the domestic firms);

s is the number of technological sectors considered (s = 56 in our study);

$\Sigma_j rta_{ij}*RTA_j$ measures the extent of technological co-specialisation between domestic and foreign-owned firms. In particular:

$rta_{ij} = (n_{ij}/n_i)/(w_j/w)$ and $RTA_j = (N_j/N)/(w_j/w)$

where w denotes the total world patenting (i.e. of large firms in the US from facilities anywhere in the world).

Finally, the variable $PREFERENCE_i$, which measures the attractiveness of the individual region i for foreign investors, is defined as:

$$PREFERENCE_i = (N_i - \tilde{N}_i)/I_i$$

This index might vary theoretically between -∞ and +∞, in proportion to the attractiveness of the i-th region, by virtue of its endowment of location factors. *Ceteris paribus*, when the value of the variable is positive (negative), it means that foreign firms have been granted there more (less) patents than expected under the hypothesis of a perfect proportionality with the patents granted to the domestic firms.

Table 8 reports PREFERENCE_i calculated at the region level. The British regions, notably the regions of South East England (Hampshire and the Isle of Wight, and Kent), as well as a couple of Scottish regions (Borders and Grampian) rank most highly[7]. On the other hand, foreign-owned firms are not especially attracted either to the regions of Bayern, (Niederbayern, Mittelfranken, Oberfranken and Oberbayern are all negative) in that the technological specialisation of domestically-owned firms located there is very broadly dispersed (Cantwell and Noonan, 2001). Indeed, that may be related to our earlier discussion of the sectoral patterns of foreign penetration of the national research base in each of the host countries in question in Tables 5 and 6. Thus, we saw earlier for example, that in Germany foreign-owned firms contribute relatively much in electrical and computing equipment and in general engineering, but relatively little in chemicals, the area of greatest indigenous strength. This suggests that foreign-owned firms may be less attracted to the main centres for chemical research in Germany (in Nordrhein Westfalen), but disperse their technological efforts more widely across other areas. The most attractive macro-region for foreign-owned R&D is Baden-Würtemburg, that as a centre of engineering excellence in the motor vehicle industry (in which sphere of technology creation it is very highly specialised) has proved a magnet for foreign-owned development efforts in the areas of electrical and computing equipment, and general

[7] It is worth observing that that is partly due to the historical orientation of US FDI in Europe towards the UK.

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, let us recall from Table 5 that foreign-owned firms contribute most to the UK research base again in mechanical engineering, electrical and computing equipment and instruments; they have also participated well in the British success in pharmaceuticals research, and they have made a roughly average contribution in chemicals. 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 (Table 7b), 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 lower order 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, electrical equipment (other than computing equipment) and in pharmaceuticals (Table 5). 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 (Cantwell and Iammarino, 1998). However, Table 8 reveals an interesting twist to this story. 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.

5.2. The independent variables

According to the conceptual model developed in section 2, the independent variables relate to (i) the local knowledge externalities (external sources of knowledge); and to (ii) the localised inter-company spillovers related to the context-specific character of technical change. Additionally, we considered the Knickerbocker effect, which suggests that foreign-owned firms 'follow the leader'. Finally, we added some control variables related to the basic location factors have been included in the model.

(i) In order to capture the complex character of local knowledge externalities, we considered the following proxies for external sources of knowledge. *Innovative inputs*: The proxies used are total local R&D expenditures and the number of employees in R&D for all sectors (RDEXP_T, RDEMP_T), for the business sector (RDEXP_B, RDEMP_B), for the Government sector (RDEXP_G, RDEMP_G), and for the higher education sectors (RDEXP_H, RDEMP_H). Other proxies relate to the expenditures and to the employees in R&D in the private- and in the state-owned institutions (RDEXP_PRIV, RDEXP_STAT, RDEMP_STAT). *The education level*: The proxy is the total number of students in full-time education (EDUCATION).

(ii) To capture localised spillovers related to the context-specific character of technology, we use the following proxies: CLUSTER, which is measured by the inverse of the cross-firm concentration of activity in a region, is a proxy for cluster-based spillovers due to a widespread inter-company technological presence. In particular, the variable is the inverse of the coefficient of variation across firm shares of patenting. SPECIALISATION, measured by the degree of focus of technological specialisation of the region, is a proxy for sector-specific spillovers. The variable has been constructed as the coefficient of variation across the 56 sectoral RTA values for each region. Finally, we proxied the potential for general purpose spillovers through a series of dummies set equal to one (rather than zero) when the region is specialised in each of a selection of general purpose technological fields, considered in turn. Specifically, the dummy MECHANICAL shows whether the region is specialised in all the fields 14, 18 and 25 (see Appendix 1); the dummy ELECT_COMM shows if the region is specialised in any 3 of fields 33, 34, 35 and 38; INSTRUMENTS shows if the region is specialised in field 53; SYNTH_MAT shows if the region is specialised in both fields 9 and 49; and OTH_MAT shows if the region is specialised in field 48.

(iii) The Knickerbocker agglomeration effect has been proxied by the variable FOREIGN, which measures simply the cumulative absolute number of foreign-owned firms that are technologically active in each region.

(iv) As other control variables to depict the influence of basic location factors[8], we considered variables related to the regional level of development (the *pro capita* gross domestic product, GDP_P; the gross value added in manufacturing and in the whole set of sectors, GVA_MNF, GVA_TOT). In particular, in order to take into account a possible congestion effect in highest income regions, we also adopted the GDP_P squared which we called CONGESTION. Finally, we added some variables related to the local presence of transport infrastructures: road (MOTORWAY, OTH_ROAD, TOT_ROAD), rail (RAIL), and waterway networks (CANAL, RIVER).

5.3. Empirical findings of the model

Empirical findings, obtained through an OLS regression, are reported in Table 9. 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. All the estimated equations in Table 9 confirm the positive impact of local external sources of knowledge. Specifically, a proper education base is attractive to the location of foreign-owned research (EDUCATION is significant at $p<.01$ both in Models 1 and 3) as are region-specific public science externalities. Indeed, the positive and highly significant signs for RD_EXPSTAT (at $p<.01$ in both Models 2 and 4) bears testament to the role played by the governments in strengthening the regional science base by providing the core general funding. These results confirm that lower-order regions can be highly relatively attractive where they have a good local science base (Cantwell and Iammarino, 2000). They also confirm the importance in Europe of co-location for science-technology linkages, as demonstrated previously from US evidence (Jaffe et al., 1993).

Additionally, the estimated coefficients reveal the importance of localised spillovers in the locational choices of foreign-owned technological activities. In particular, the coefficient of CLUSTER is positive and highly significant in all of the four models reported in Table 9, thus showing the relevance of cluster-specific spillovers related to a general agglomeration effect associated with the widespread dispersion of patenting firms in the region. Similarly, the presence of general purpose spillovers (namely, those related to MECHANICAL and ELECT_COMM) show a significantly positive coefficient in the models considered. Specifically, it emerges that the region's specialisation in metal and material-handling equipment is particularly relevant in attracting foreign-owned technological activities (MECHANICAL is indeed significant at p<.01 in all the models), but ELECT_COMM disappears in the best specification of the models. However, the coefficient of the proxy used for sector-specific spillovers (SPECIALISATION) shows a positive, although not highly significant coefficient (only at p<.20 in Models 1 and 2), while it is not included in the best specifications.

Some evidence is also provided about the relevance of the cumulative 'follow the leader' Knickerbocker effect, and it appears not to have any distinctive additional impact. Indeed, the variable FOREIGN presents a rather weak influence on the dependent variable: while it is positive and significant in Model 1 (at p<.01), it disappears both when using RD_EXPSTAT instead of EDUCATION (Model 2), and in the best specifications (Models 3 and 4)[9].

Finally, it is worth observing that the lack of significance of the variables linked to the basic locational factors, such as the availability of infrastructures, services and intangible assets is a surprise. Nonetheless, this effect could be due to the poor definition and unsuitability of the proxies used in the model and therefore requires further study.

The values of the adjusted R^2 (0.26 in the best specification) are also worthy of note. This is a satisfactory result if we consider the role played in the decision of undertaking R&D locally, by home firm-specific factors which were intentionally omitted and the fact that the dependent variable corresponds to variations in "flow" and not in "stock", and is therefore more affected by random errors.

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

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[8] All these variables come from the database REGIO (Eurostat).

[9] The variable FOREIGN deserves some caution. In fact, a persistent high significance when considered alone should be evaluated taking into account that it could embody some omitted variables. Therefore, its weak significance in most of the specifications obtained at least suggests that possible omissions of variables are not too serious.

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. However, as we have seen above, the form of potential which is accessed in alternative regional centres varies. In lower order locations like North West England foreign-owned firms focus upon access to specific expertise deriving from the local strength in chemicals (Cantwell and Iammarino, 2000). More precisely, it seems that German-owned MNCs in the chemical industry have been attracted by the technological resources of Greater Manchester, wishing to incorporate the local chemical capabilities from that area into their corporate networks. Conversely, in parts of South East England, or in Lombardia outside Milano, and in certain German regions, foreign-owned MNCs are attracted to extend their attempts at competence creation by a broader range of technological expertise and engineering skills, and by local infrastructure. Yet within these latter regions at a more detailed geographical level we have also found some further locational specificities in terms of the types of competence development that are most likely to be established locally.

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). However, it is important to understand that these intra-European networks have significant links with US technology creation as well. The international networks of British-owned and German-owned MNCs are largely US-oriented, while US-owned MNCs remain European-oriented in their foreign location of R&D, despite the lower degree of internationalisation of competence creation in US firms and some fall in their share of foreign activity located in Europe (since their share in Europe still remains at over one-half).

As a consequence of the establishment of these international corporate networks for the diversification of technological competence, in many European regions in particular both inward and outward direct investment (FDI) have become important as a facilitator of local technological specialisation, in a supporting framework that includes cross-border knowledge flows within MNCs between selected regional centres of excellence. Given the complexity and interdependence of modern technological systems the most dynamic centres of innovation require an ever-increasing intensity of such knowledge flows, which should therefore be encouraged as a matter of policy. This policy conclusion is worth emphasising, since it is the reverse of the central thrust of the conventional outlook upon technology policy, the major concern of which has been to counteract problems associated with a lack of appropriability of returns on investment in new knowledge creation if knowledge 'leaks out' too freely to those that did not fund its development (Cantwell, 1999). Instead, in inter-linked networks innovation rises with the intensity of knowledge flows between complementary branches of technological development, since outward and inward knowledge flows become part of a mutual structure that feeds into the local learning that generates corporate technological capabilities, and it is these capabilities that typically earn a return rather than the individual knowledge inputs into learning. Each participating region finds itself increasingly integrated into an international division of labour for the development of new technological systems.

For the leading or higher order regional centres this provides an opportunity for them to widen their technology base as they play host to MNC networks across a broader range of fields of competence development, and become engaged in a broader set of knowledge flows with other centres. In lower order or more narrowly technologically specialised regions foreign-owned MNCs are more often attracted by their fairly specific fields of local innovative potential. So in this second category of regions MNC networks create opportunities to deepen specialised regional technological excellence, to further differentiate their capabilities in what has become their focal area of expertise, and to gain access to complementary resources and related knowledge in the major centres elsewhere.

Thus, the presence of technological development in foreign-owned firms tends to compensate for weaknesses in the indigenous research base of the European economies, partly through the higher shares of foreign-owned MNCs in local technology creation that are typically associated with industries and fields in which indigenous firms are weaker, but also because of the international linkages MNCs provide in support of the activities in which indigenous firms are stronger. In addition, the cross-border networks of MNCs coordinate mutual innovative strengths between the leading centres of excellence across countries (as in the case of the outward and inward investment associated with the UK pharmaceutical industry). As a result, MNC asset-seeking investment is attracted to the major regions for technological development by the generic skills and infrastructure that can be found locally. In the UK and Italy the attractiveness of the leading centres is linked as well to specific skills in the main fields of innovation of indigenous firms – such as pharmaceuticals in the UK and the South East region, and specialised machinery in Italy and Lombardia. Instead in Germany indigenous firms are themselves much more highly regionally differentiated, so that the leading region for chemical development is not also the most generally attractive to the broader range of foreign-owned company development. For this reason foreign-owned development has tended to be dispersed more widely (as foreign-owned specialisation does not match the indigenous profile), and has been attracted most to Baden Würtemburg, with the greatest background engineering skills and which offers innovative linkages to SMEs.

We have suggested that foreign-owned firms establish facilities for competence creation in regions either because of their general expertise, engineering skills and infrastructure, or as a means of accessing more specialised capabilities, and that the relative significance of these motives varies between regions. In particular, the former are more significant in higher order centres with substantial levels of development. Yet, as the German experience shows, not all higher order centres are automatically attractive for this reason; some such centres may remain fairly narrowly focused in their innovative efforts even though their overall level of development is high, and this may not be attractive to firms outside the industry of excellence. This suggests that the relative attractiveness of regions to the technological efforts of foreign-owned MNCs depends upon (i) the regional level of development, and especially the presence of external sources of knowledge; (ii) the presence of cluster-based spillovers; (iii) the degree (breadth) of local technological specialisation in the region, and (iv) whether the composition of local specialisation includes a focus on mechanical and electrical communication technologies which provide a linkage between technological development in a wide variety of areas. Our results are broadly consistent with these propositions.

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Table 1 - Share of US patents of the world's largest firms attributable to research in foreign locations, organised by the nationality of the parent firms, 1969-95 (%)

Nationality of the parent firm	1969-72	1973-77	1978-82	1983-86	1987-90	1991-95
US	4.96	5.89	6.40	7.53	7.91	8.62
Germany	12.77	11.05	12.07	14.47	17.05	20.72
UK	43.08	41.24	40.47	47.09	50.42	55.79
Italy	13.39	16.03	13.85	12.59	11.14	16.47
France	8.16	7.74	7.17	9.19	18.17	33.17
Japan	2.63	1.88	1.22	1.26	0.92	1.08
Netherlands	50.40	47.37	47.65	53.99	53.96	55.69
Belgium-Lux	50.36	51.11	49.28	58.15	47.53	53.25
Switzerland	44.36	43.63	43.78	41.59	42.99	52.47
Sweden	17.82	19.90	26.20	28.94	30.60	42.42
Austria*	5.06	16.76	19.84	11.82	8.00	0.00
Norway*	20.00	1.67	12.31	32.50	37.14	20.22
Finland*	18.87	27.11	26.89	18.67	27.94	39.49
Canada	41.19	39.30	39.49	35.82	40.12	43.96
Others	28.21	22.22	26.37	30.34	7.54	3.94
Total	10.04	10.53	10.50	10.95	11.28	11.27
excluding Japan	10.52	11.59	12.25	13.87	15.76	16.53
European countries**	28.01	25.19	24.52	26.95	29.99	34.78

Source: US patent database developed by John Cantwell at the University of Reading, with the assistance of the US Patent and Trademark Office.
* Number of patents less than 50 for several periods.
** Including: Germany, UK, Italy, France, Netherlands, Belgium-Lux, Switzerland, Sweden, Denmark, Ireland, Spain, Portugal, Greece, Austria, Norway and Finland.

Table 2 - Patenting activity attributable to foreign-located research , by host country and nationality of the parent firms, 1969-95 (%)

	Europe					
Nationality of the parent firm	1969-72	1973-77	1978-82	1983-86	1987-90	1991-95
Germany	42.66	49.22	31.40	25.09	22.04	26.92
UK	15.44	18.16	22.40	23.99	24.91	27.17
Italy	33.94	25.54	25.49	48.51	53.57	81.00
France	43.56	59.52	51.80	55.66	68.07	45.69
Total European countries	30.16	37.29	39.53	41.34	41.84	40.39
US	74.20	73.69	73.91	73.27	68.36	57.06
Japan	51.43	26.24	11.27	16.33	19.68	18.94

	USA					
Nationality of the parent firm	1969-72	1973-77	1978-82	1983-86	1987-90	1991-95
Germany	51.53	38.29	60.30	60.13	62.59	64.16
UK	76.87	72.77	68.56	66.04	66.21	66.10
Italy	59.63	72.83	73.20	50.50	42.86	18.00
France	51.11	33.04	42.81	31.50	29.13	49.95
Total European countries	63.55	55.76	54.44	50.25	50.19	53.12
Japan	43.33	67.93	84.86	83.42	77.15	74.45

	Rest of the World					
Nationality of the parent firm	1969-72	1973-77	1978-82	1983-86	1987-90	1991-95
Germany	5.81	12.49	8.30	14.78	15.37	8.92
UK	7.69	9.07	9.04	9.97	8.88	6.73
Italy	6.43	1.63	1.31	0.99	3.57	1.00
France	5.33	7.44	5.39	12.84	2.80	4.36
Total European countries	6.29	6.95	6.03	8.41	7.97	6.49
US	25.80	26.31	26.09	26.73	31.64	42.94
Japan	5.24	5.83	3.87	0.25	3.17	6.61

Source: As for Table 1.

Table 3 - Patenting activity attributable to European-located foreign-owned research, across host countries, 1969-95 (%)

	Total patents from foreign-owned facilities					
European host country	1969-72	1973-77	1978-82	1983-86	1987-90	1991-95
Germany	27.03	30.23	31.81	35.63	33.47	28.87
UK	29.34	26.78	25.03	22.63	21.00	21.15
Italy	4.34	4.94	4.37	4.50	5.97	6.46
France	13.21	14.95	14.52	14.21	14.92	15.60
Rest of Europe	26.08	23.10	24.27	23.03	24.64	27.92
Total Europe	100.00	100.00	100.00	100.00	100.00	100.00

Source: As for Table 1.

Table 4 - Patenting activity attributable to foreign-owned research, as a proportion of all patenting from the local research of large firms, by European host country, 1969-95 (%)

	Proportion of patents from foreign-owned facilities					
European host country	1969-72	1973-77	1978-82	1983-86	1987-90	1991-95
Germany	16.32	15.57	15.16	18.77	18.09	17.37
UK	27.66	30.80	31.30	36.00	35.44	45.23
Italy	27.32	31.09	26.49	32.85	43.93	57.50
France	24.17	24.73	24.04	25.13	27.05	28.94
Total Europe	22.70	21.63	21.43	24.40	24.97	28.63

Source: As for Table 1.

Table 5 - US patents from corporate research located in each host country due to foreign-owned firms, by the industrial group of the parent company, 1969-95 (%)

Sector	Germany	UK	Italy	France	Europe	World
Food, Drink, and Tobacco	99.64	15.45	100.00	55.25	44.55	22.24
Chemicals	6.49	29.55	31.97	33.31	15.57	14.21
Pharmaceuticals	13.91	50.34	100.00	19.34	27.37	16.16
Metals	9.87	29.62	63.87	11.20	13.25	10.32
Mechanical Engineering	25.84	47.16	100.00	52.00	26.93	12.47
Electrical Equipment	30.01	43.48	91.32	27.85	30.48	9.74
Office Equipment	86.34	76.71	21.87	56.76	67.36	10.34
Motor Vehicles	8.35	13.18	7.67	21.83	12.28	5.68
Aircraft and Aerospace	15.18	10.54	100.00	2.85	13.00	2.39
Coal and Petroleum Products	80.47	19.43	12.07	10.31	39.25	15.08
Professional Instruments	29.90	97.79	100.00	100.00	45.62	3.37
Other Manufacturing	56.64	26.71	26.13	30.66	35.16	10.39
Total	16.87	33.73	36.60	25.86	23.97	10.81

Source: As for Table 1.

Table 6 - US patents from corporate research located in each host country due to foreign-owned firms, by the type of technological activity, 1969-95 (%)

Sector	Germany	UK	Italy	France	Europe	World
Food, Drink, and Tobacco	30.85	20.73	61.11	45.71	34.76	13.62
Chemicals	8.09	35.54	31.58	21.19	18.40	12.49
Pharmaceuticals	8.05	41.55	38.57	37.61	23.40	18.79
Metals	28.78	34.86	43.27	20.37	27.97	10.41
Mechanical Engineering	25.73	28.35	40.56	26.58	27.26	12.14
Electrical Equipment	25.13	39.45	60.08	28.66	28.81	9.36
Office Equipment	29.37	50.53	34.40	40.46	34.74	7.84
Motor Vehicles	7.01	20.79	10.14	21.62	11.33	5.57
Aircraft and Aerospace	9.09	0.87	33.33	4.76	5.40	2.58
Coal and Petroleum Products	14.14	18.32	10.34	9.09	25.84	8.62
Professional Instruments	20.63	37.05	23.65	30.58	27.32	8.77
Other Manufacturing	16.33	19.75	19.49	16.06	20.86	9.33
Total	16.87	33.73	36.60	25.86	23.97	10.81

Source: As for Table 1.

Table 7a - Number (and share) of patents granted to domestic, EU, US and total foreign-owned firms in the German regions

	Domestic firms		European firms		US firms		total foreign firms	
Regions	N.	%	N.	%	N.	%	N.	%
Stuttgart	7768	10.20	422	5.25	1427	20.34	1851	12.17
Karlsruhe	2755	3.62	519	6.46	473	6.74	992	6.52
Freiburg	808	1.06	885	11.02	455	6.49	1342	8.82
Tubingen	1089	1.43	281	3.50	317	4.52	599	3.94
Oberbayern	10785	14.16	120	1.49	244	3.48	381	2.51
Niederbayern	819	1.08	32	0.40	58	0.83	90	0.59
Oberpfalz	559	0.73	17	0.21	264	3.76	283	1.86
Oberfranken	533	0.70	22	0.27	67	0.96	89	0.59
Mittelfranken	3806	5.00	318	3.96	93	1.33	422	2.77
Unterfranken	1238	1.63	554	6.90	39	0.56	593	3.90
Schwaben	1101	1.45	97	1.21	165	2.35	284	1.87
Berlin	1875	2.46	51	0.63	88	1.25	141	0.93
Brandenburg	56	0.07	12	0.15	12	0.17	24	0.16
Bremen	128	0.17	28	0.35	19	0.27	47	0.31
Hamburg	315	0.41	648	8.07	105	1.50	754	4.96
Darmstadt	9195	12.07	708	8.81	1236	17.62	1959	12.88
Giessen	650	0.85	112	1.39	56	0.80	191	1.26
Kassel	174	0.23	24	0.30	11	0.16	47	0.31
Meckelenburg-Vorpommern	94	0.12	19	0.24	4	0.06	24	0.16
Braunschweig	913	1.20	50	0.62	52	0.74	110	0.72
Hannover	1048	1.38	274	3.41	215	3.06	495	3.25
Luneburg	349	0.46	51	0.63	95	1.35	147	0.97
Weser-Ems	280	0.37	19	0.24	21	0.30	41	0.27
Dusseldorf	9444	12.40	613	7.63	335	4.78	951	6.25
Koeln	9586	12.59	1052	13.10	428	6.10	1484	9.76
Munster	1345	1.77	100	1.24	34	0.48	135	0.89
Detmold	300	0.39	17	0.21	27	0.38	44	0.29
Arnsberg	1268	1.66	170	2.12	107	1.53	282	1.85
Koblenz	585	0.77	246	3.06	99	1.41	351	2.31
Trier	253	0.33	27	0.34	59	0.84	86	0.57
Rheinhessen-Pfalz	6212	8.16	105	1.31	206	2.94	322	2.12
Saarland	137	0.18	31	0.39	31	0.44	62	0.41
Sachsen	112	0.15	13	0.16	19	0.27	33	0.22
Schleswig-Holstein	511	0.67	384	4.78	144	2.05	530	3.49
Thuringen	66	0.09	12	0.15	10	0.14	22	0.14
Total	*76157*	*100.00*	*8033*	*100.00*	*7015*	*100.00*	*15208*	*100.00*

Table 7b - Number (and share) of patents granted to domestic, EU, US and total foreign-owned firms in the British regions

	Domestic firms		European firms		US firms		total foreign firms	
Regions	N.	%	N.	%	N.	%	N.	%
Cleveland, Durham	629	2.70	23	0.72	57	0.72	82	0.70
Cumbria	136	0.58	0	0.00	19	0.24	19	0.16
Northumberland, Tyne and Wear	166	0.71	20	0.63	142	1.78	164	1.40
Humberside	213	0.91	30	0.94	35	0.44	66	0.56
North Yorkshire	362	1.55	15	0.47	89	1.12	107	0.91
South Yorkshire	199	0.85	22	0.69	111	1.39	133	1.13
West Yorkshire	255	1.09	55	1.72	97	1.22	157	1.34
Derbyshire, Nottinghamshire	921	3.95	32	1.00	103	1.29	143	1.22
Leicestershire, Northamptonshire	503	2.16	19	0.60	277	3.48	319	2.71
Lincolnshire	61	0.26	3	0.09	66	0.83	71	0.60
East Anglia	342	1.47	312	9.78	273	3.43	621	5.28
Bedfordshire, Hertfordshire	1528	6.55	238	7.46	1093	13.72	1353	11.51
Berks, Buckshire, Oxon	1669	7.15	133	4.17	1017	12.77	1231	10.47
Surrey, Sussex	1703	7.30	732	22.95	477	5.99	1250	10.64
Essex	991	4.25	199	6.24	596	7.48	815	6.93
Greater London	2487	10.66	389	12.20	839	10.53	1300	11.06
Hampshire, Isle of Wight	463	1.98	133	4.17	574	7.21	801	6.82
Kent	574	2.46	19	0.60	405	5.08	432	3.68
Avon, Gloucestershire, Wiltshire	1103	4.73	87	2.73	255	3.20	370	3.15
Cornwall, Devon	64	0.27	9	0.28	52	0.65	62	0.53
Dorset, Somerset	166	0.71	33	1.03	28	0.35	65	0.55
Hereford&Worcester, Warwickshire	983	4.21	10	0.31	95	1.19	135	1.15
Shropshire, Staffordhire	620	2.66	22	0.69	60	0.75	90	0.77
West Midlands	2200	9.43	12	0.38	131	1.64	187	1.59
Cheshire	1161	4.98	138	4.33	94	1.18	235	2.00
Greater Manchester	1202	5.15	285	8.94	129	1.62	455	3.87
Lancashire	516	2.21	21	0.66	74	0.93	98	0.83
Merseyside	1100	4.71	33	1.03	97	1.22	132	1.12
Clwyd, Dyfed, Gwynedd, Powys	153	0.66	3	0.09	62	0.78	66	0.56
Gwent, Mid-South-West Glamorgan	398	1.71	19	0.60	296	3.72	323	2.75
Borders-Central-Fife-Lothian-Tayside	175	0.75	16	0.50	166	2.08	187	1.59
Dumfries&Galloway, Strathclyde	251	1.08	127	3.98	103	1.29	231	1.97
Grampian	42	0.18	0	0.00	53	0.67	53	0.45
Total	*23336*	*100.00*	*3189*	*100.00*	*7965*	*100.00*	*11753*	*100.00*

Table 7c - Number (and share) of patents granted to domestic, EU, US and total foreign-owned firms in the Italian regions

	Domestic firms		European firms		US firms		total foreign firms	
Regions	N.	%	N.	%	N.	%	N.	%
Piemonte	1430	32.52	168	16.18	119	10.43	287	12.84
Milano	1986	45.17	397	38.25	613	53.72	1020	45.62
Lombardia	274	6.23	207	19.94	211	18.49	431	19.28
Veneto	127	2.89	61	5.88	25	2.19	86	3.85
Friuli Venezia Giulia	87	1.98	12	1.16	4	0.35	16	0.72
Emilia Romagna	186	4.23	102	9.83	64	5.61	169	7.56
Toscana	107	2.43	24	2.31	12	1.05	36	1.61
Umbria	52	1.18	2	0.19	1	0.09	3	0.13
Lazio	148	3.37	65	6.26	92	8.06	188	8.41
Total	*4397*	*100.00*	*1038*	*100.00*	*1141*	*100.00*	*2236*	*100.00*

Source: As for Table 1.

Table 8 - The dependent variable (PREFERENCE)

Regions	PREFERENCE		PREFERENCE
Hampshire, Isle of Wight	58.32	Stuttgart	0.73
Borders-Central-Fife-Lothian-Tayside	51.83	Hannover	0.61
Grampian	50.23	Darmstadt	0.25
Lincolnshire	47.96	Schwaben	0.13
Northumberland, Tyne and Wear	34.50	Cumbria	-0.90
East Anglia	33.96	Thuringen	-1.55
Lombardia	33.44	Greater Manchester	-1.67
Bedfordshire, Hertfordshire	28.38	Cleveland, Durham	-1.79
Kent	26.26	Lancashire	-1.98
Gwent, Mid-South-West Glamorgan	25.05	Merseyside	-2.47
Cornwall, Devon	23.70	Oberfranken	-2.86
Berkshire, Buckinghamshire, Oxfordshire	23.20	Cheshire	-3.09
Lazio	22.22	Derbyshire, Nottinghamshire	-3.50
Essex	19.09	Arnsberg	-3.70
South Yorkshire	19.06	Dorset, Somerset	-3.77
Freiburg	17.67	Hereford&Worcester, Warwickshire	-3.79
Leicestershire, Northamptonshire	17.60	Niedarbayern	-3.90
Dumfries&Galloway, Strathclyde	15.58	Bremen	-4.03
Oberpfalz	15.57	Toscana	-4.05
Emilia Romagna	14.69	GieBsen	-4.07
Clwyd, Dyfed, Gwynedd, Powys	12.05	Koln	-4.29
Hamburg	10.52	Rheinhessen-Pfalz	-4.54
West Yorkshire	10.27	Dusseldorf	-4.86
Luneburg	8.80	Piemonte	-5.18
Milano	8.78	Weser-Ems	-5.22
Greater London	7.92	Detmold	-5.80
Surrey, East_West Sussex	5.60	West Midlands	-5.95
Tubingen	5.56	Kassel	-5.95
Trier	4.61	Berlin	-5.99
Schleswig-Holstein	4.38	Umbria	-6.00
Saarland	3.78	Braunschweig	-6.30
Brandenburg	3.70	Munster	-6.38
North Yorkshire	3.42	Unterfranken	-6.62
Avon, Gloucestershire, Wiltshire	2.86	Shropshire, Staffordhire	-6.98
Koblenz	1.22	Friuli Venezia Giulia	-7.40
Veneto	1.21	Meckelenburg-Vorpommern	-8.15
Karlsruhe	1.04	Mittelfranken	-8.99
Humberside	1.02	Oberbayern	-9.76
Sachsen	0.80		

Source: As for Table 1.

Table 9 - Results of the econometric analysis - OLS estimation (dependent variable = PREFERENCE)

	Model #1		Model #2		Model #3		Model #4	
INTERCEPT	-25.451	***	-17.053	**	-12.441	**	-9.797	**
	(-3.084)		-(2.239)		-(2.588)		-(2.632)	
RD_EXPSTAT			0.017	***			0.019	***
			(4.248)				(5.586)	
EDUCATION	0.021	***			0.025	***		
	(2.763)				(3.273)			
CLUSTER	21.882	**	20.403	**	14.606	*	17.968	**
	(2.417)		(2.404)		(1.772)		(2.381)	
SPECIALISATION	0.031		0.024					
	(1.287)		(1.047)					
MECHANICAL	16.349	***	14.881	***	16.096	***	15.592	***
	(2.782)		(2.703)		(2.726)		(2.886)	
ELECT_COMM	8.545	*	4.629		10.790	**		
	(1.792)		(1.024)		(2.335)			
FOREIGN	0.144	***	0.051					
	(2.020)		(0.688)					
No. Observations	77		77		77		77	
R2 adj	0.264		0.351		0.241		0.357	
F	5.544	***	7.852	***	7.023	***	8.054	***

Notes: Number in brackets are t-ratios. Two tail probabilities are reported for t-test

*** significant at p<.01; ** significant at p<.05; * significant at p<.10

Appendix - Sectoral groups

1	Food and tobacco products
2	Distillation processes
3	Inorganic chemicals
4	Agricultural chemicals
5	Chemical processes
6	Photographic chemistry
7	Cleaning agents and other compositions
8	Disinfecting and preserving
9	Synthetic resins and fibres
10	Bleaching and dyeing
11	Other organic compounds
12	Pharmaceuticals and biotechnology
13	Metallurgical processes
14	Miscellaneous metal products
15	Food, drink and tobacco equipment
16	Chemical and allied equipment
17	Metal working equipment
18	Paper making apparatus
19	Building material processing equipment
20	Assembly and material handling equipment
21	Agricultural equipment
22	Other construction and excavating equipment
23	Mining equipment
24	Electrical lamp manufacturing
25	Textile and clothing machinery
26	Printing and publishing machinery
27	Woodworking tools and machinery
28	Other specialised machinery
29	Other general industrial equipment
30	Mechanical calculators and typewriters
31	Power plants
32	Nuclear reactors
33	Telecommunications
34	Other electrical communication systems
35	Special radio systems
36	Image and sound equipment
37	Illumination devices
38	Electrical devices and systems
39	Other general electrical equipment
40	Semiconductors
41	Office equipment and data processing systems
42	Internal combustion engines
43	Motor vehicles
44	Aircraft
45	Ships and marine propulsion
46	Railways and railway equipment
47	Other transport equipment
48	Textiles, clothing and leather
49	Rubber and plastic products
50	Non-metallic mineral products
51	Coal and petroleum products
52	Photographic equipment
53	Other instruments and controls
54	Wood products
55	Explosive compositions and charges
56	Other manufacturing and non-industrial