Corporate Diversification, Internationalisation and Location of Technological Activities by MNCs: Differences between EU and non-EU Firms in the European Regions

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ABSTRACT

Recent studies have suggested that large firms diversify their technological competencies through a cumulative learning process oriented both to augmentation in new fields as well as to exploitation in new markets, the corporate networks created for this purpose justifying the expression "globalisation of innovation". Given the international dispersion of the creation of new technology within multinational corporations (MNCs) and their consequent change of innovatory strategies, the analysis of the relationship between the diversification and internationalisation of their technological activities seems to increasingly call for a contextual account of the locational issues associated with accessing capabilities and locally specific sources of innovation external to the firm.

The purpose of this paper is thus twofold. First, it reviews the relationship between the diversification and internationalisation of technological activities by large firms historically and more recently, and to show how their closer association is bound up with the recent formation of internationally integrated networks within firms; secondly, it proceeds to investigate more thoroughly the geographical spread of such MNC networks within Europe, whether formed by European-owned or non-European-owned firms, paying particular attention as to the relative attractiveness of locations for the technological development of foreign-owned firms, at a sub-national regional level within Europe.

1. Introduction

1.1. Theoretical background

This study is concerned with the determinants of technological competence creation in firms, and in the location of such innovative development activities. As such, our work is grounded in a theoretical tradition of evolutionary economics that has emerged over the last 20 years or so, which has been concerned (among other things) to try and delve inside the black box of the firm, and to understand the workings of the firm as a social and competence-generating institution. Hence, it may be helpful to begin with some initial discussion of the theoretical premises that we rely upon, and which we have derived from this literature. Historically, with just a few notable exceptions (such as Marx, Usher and Schumpeter), most often economists have treated technological change either as an exogenous variable (like in the original neoclassical growth theories or growth accounting exercises), or alternatively as a simple response to market demand (as in Schmookler's approach) or to the availability of inventions or discoveries (like in the work of Mensch, or the conventional 'linear' model from science to commercialisation popular in public policy discussions).

Our alternative view, that technological change is an endogenous property of firms (and especially, although not exclusively, large firms) as evolutionary learning institutions, can be traced back in recent times to the pioneering contribution of Penrose (1959). In other words, the new competences a firm is able to create are a product of its prior capabilities or resources and not a simple response to external markets or discoveries. Innovative new competences (capacities to introduce new products and processes) are achieved through an internal search and problem-solving process that can only be revealed by opening up the black box of the firm (Rosenberg, 1982, 1994). It is true that interactions between the learning firm and its markets, with the science and discovery base, and with other firms (especially through cooperative relationships within the same industry, as emphasised by Richardson, 1972) all play important roles. However, technological change is essentially the outcome of continual experimentation within each firm along some path-dependent course with a certain logic of its own, which have been usefully described as technological trajectories (Dosi, 1982). Hence, the evolving profiles of technological competence of firms tend to remain stable over long periods of time and to change only gradually and incrementally, despite the much more dramatic changes in their markets or discovery base (Cantwell and Fai, 1999b).

Once the black box of the firm has been opened to examination, the organisational and social aspects of technological capability become clear; technology consists of a localised and tacit element which is context-specific, as well as potentially public knowledge (Nelson, 1992a). Nelson and Winter (1982) provided the pioneering analysis of how, when technological change is rightly understood as a path-dependent and localised process of experimental learning and search activities undertaken within firms, the fruits of innovative improvements become embodied not just in new devices, equipment or products, but also in the organisational routines of companies. Therefore, it is not surprising that the innovation systems of countries depend largely on the accumulated capabilities of large local firms, which become repositories of technological competence, even if their activities in turn depend upon the supporting structure of other institutions that characterises the local environment (Nelson, 1993).

The technological paths or trajectories that are followed by firms can also be described as a process of corporate technological diversification, which depends upon gradual changes in the degree of relatedness between competences in different technological fields. Firms can be expected to move away from combinations of technological development that have become less related, and towards new combinations of fields of activity between which there is an increase in technological complementarity. If there is a general background rise in technological interrelatedness then this will be associated with a broadening in the average degree of corporate technological diversification relative to any given extent of product or market diversification (Piscitello, 1998). However, for some very large firms that had achieved an already high degree of technological diversification, the effect may run in the opposite direction (Cantwell and Santangelo, 2000). That is, greater interrelatedness implies that each firm must utilise more carefully than in the past the most complementary combinations of technologies, which may entail a sharper focus on those combinations in an existing portfolio that are most closely complementary, partially at the expense of other lines of development which have only ever fitted moderately well. Somewhat more distant but still relevant capabilities may be better accommodated through supporting some in-house facilities as a means of monitoring and accessing developments in alliance partners or suppliers or customers, for which the fields in question are more critical and a central area of competence.

The other aspect of the localisation of technological change is that it tends to be not just firm-specific but also location-specific, as confirmed by the continuing significance of regional and national systems of innovation (Nelson, 1993; Archibugi, Howells and Michie, 1999), and by the tendency towards geographical proximity in the linkages between science and technology (Jaffe, Trajtenberg and Henderson, 1993; Rosenberg and Nelson, 1996). As a result, multinational corporations (MNCs) can gain competitive advantage by strategically integrating complementary streams of innovation across geographically dispersed facilities (Cantwell, 1989). By further developing the technological capacities in which a location is already specialised, such international integration of networks for innovation within MNCs may thereby have the effect of reinforcing established national and regional systems of innovation (Cantwell, 1995). In this event the closer international integration of complementary lines of technological development within the MNC also becomes bound up with the process of technological diversification at the level of the global corporate group as a whole (Cantwell and Piscitello, 2000).

Although the measures of technological diversification and product diversification may be similar, our arguments thus far suggest that the dispersion of technological competence within firms is not theoretically the same as the dispersion of their product markets, even if we would expect a correlation of the two across firms. Over time there could well be periods in which technological diversification and product diversification move in different directions on average. It has been suggested that in recent times there has been a tendency for product ranges to become more concentrated while technological capabilities have become more diversified. More substantively, cumulativeness and path-dependency apply to the process of corporate technological competence development, but not necessarily (or only to a lesser extent) to the composition of a firm’s markets.

1.2. Implications for the analysis of MNCs

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, as argued above, the analysis of technologies and product markets is different in this respect. 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 terms of product markets, diversification and internationalisation have often been considered and analysed separately as two distinct phenomena or alternative routes to growth, in the analytical framework that originated from Penrose (1959). Historically, it was usually a matter of how established competences could be more fully exploited in new markets in related industries, or in other countries. More recently, Penrose's resource-based view of the firm as a collection of productive assets has given rise to a competence-based theory of the firm (Richardson, 1972; Winter, 1988; Nelson 1991, 1992b; Loasby, 1991, 1998; Cantwell, 1991, 1994; Foss, 1993; Teece, Rumelt, Dosi and Winter, 1994; Teece, Pisano and Shuen, 1997; Hodgson, 1998; Chandler, Hagström and Sölvell, 1998), in which the firm is seen as an institution that constructs capabilities through internal learning processes in the form of evolutionary experimentation. In this event the major issue is not so much how the firm exploits a given competence, but rather how it establishes a (spatially and sectorally) diffuse system for the creation of 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. 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. In this context, recent studies have shown that firm-specific technological competence may be diversified and internationalised thus leading to the most recent emergence of corporate international networks more and more resembling heterarchies rather than hierarchies (Hedlund, 1986).

At the same time, the increasing role of MNCs in the generation of technology has been facilitated by their recent trend to “globalise” their activities; that is, to establish internal and external networks for innovation which may lead to an improvement of innovation capacity both of the MNC and of host locations (Cantwell and Iammarino, 1998; 2000). Globalisation and in particular the international integration of technological activities, is indeed a process leading to structural transformation of firms, nations and regions (Dunning, 2000), both when directed to augmenting home-based assets - often tapping into foreign research and development (R&D) - and to more effectively deploying existing technological capabilities (Kuemmerle, 1998; 1999). The growing role of the re-organisation of technological activities by MNCs as a source of competitive advantage has been indeed recently recognised to have an important impact on the shape and character of national systems of innovations and local growth prospects both for the home and host countries. The present paper focuses on the host country perspective and particularly deals with parallel, yet apparently antithetical, forces towards the geographical dispersion of asset-augmenting and asset-exploiting activities, and the concentration of such activities in a limited spatial area (Dunning, 2000) or what has been recently referred to as the paradox of "sticky places within slippery space" (Markusen, 1996).

The paper is organised in the following way. The following section describes the theoretical background concerning the interlinkages between large firms' cumulative growth and internationalisation and diversification of their technological competencies. Section 3 investigates the extent and evolution of the internationalisation of technological activity at the national and industry level in the period 1969-95, by using patents granted to the largest firms in the US. Section 4 – by classifying corporate patenting by the location at the regional level of the research facility responsible for the invention - explores the locational issue at the regional level for Germany, the UK and Italy over the whole period 1969-95, and investigates whether the research activities carried out in the European regions considered follow a similar geographical profile for both domestically- and foreign-owned firms. Finally, Section 5 presents some summarising and concluding remarks, draws out one of the policy implications of our argument, and indicates an agenda for future research.

2. Largest firms' accumulation of technological competencies through the diversification and internationalisation of capabilities

Recent research applying the framework of the competence-based approach to multinational firms (Cantwell, 1989) has attempted to trace out the technological evolution of large multinational corporations over time as a path-dependent learning process following distinct corporate technological trajectories (Dosi, 1982). In the course of this process, MNCs move into new technological fields and they establish innovative activities in multiple geographical sites as a reflection of the development of the underlying capability of firms. In the internationalisation field, new theoretical and empirical models have been devised of the process by which multinational companies access locationally dispersed technological assets, through their own international operations and through alliances with other firms (Cantwell, 1989; Kogut and Chang, 1991; Dunning, 1995; Pugel, Kragas and Kimura, 1996; Almeida, 1996; Frost, 1996; Cantwell and Barrera, 1998; Kuemmerle, 1999; Cantwell and Janne, 1999; Pearce, 1999; Zander, 1999). In the diversification field, the notion of technological diversification has been conceptualised, as a means by which firms extend their technological base and capabilities. Various authors have shown that technological diversification at the firm level, defined as the process by which the breadth of corporate technology is increased over time across a wider range, was an increasing and prevailing phenomenon in Japan (Kodama, 1986), in the UK (Pavitt *et al.*, 1989), and in Sweden (Granstrand and Sjölander, 1990; Oskarsson, 1993).

Bringing together the two streams of literature, we have suggested (e.g. Cantwell and Piscitello, 2000) that the interrelationship between the two phenomena has changed historically, now becoming more often positively related parts of a common process, rather than alternative ways in which competences might be developed (as it seems that they were in general in the past), and that in the more recent internationally integrated or 'globalised' MNC, the geographical dispersion of innovation may come to facilitate the technological development of the firm, since the MNC can tap into alternative streams of innovation in different centres, and establish favourable cross-border interactions between them (Cantwell, 1995; Zander, 1997; Dunning, 1996).

As far as the evolution of the interrelationship between growth, diversification and internationalisation is concerned, our results from a dynamic cross-section econometric analysis run with reference to a large cross-firm panel of technological activity of the largest European and US industrial firms over the period 1901-1995 (Cantwell and Piscitello, 2000) confirmed the existence of three historical phases. In particular, these three stages of development are associated with three main phenomena: (i) the changes in the international environment for coordinating diverse business operations (Vernon, 1973), (ii) reasons related to the corporate life cycle, particularly the shifts in the maturity of the growth process in large firms (Chandler, 1990), and in the maturity of internationalisation strategies in large multinational companies (Dunning, 1992), and (iii) an historical shift in what has been termed the techno-socio-economic paradigm (Freeman and Perez, 1988), from technological diversification linked to economies of scale and increasing size (Chandler, 1990) to technological diversification based on interrelatedness and new combinations (Cantwell and Fai, 1999a).

In the earlier stages of development of large firms in the interwar and early post-war periods, it is reasonable to depict diversification and internationalisation of markets as two alternative strategies for corporate growth, as suggested by Penrose (1959). However, in this phase while large firms were commonly diversifying their technological competence in the normal course of growth (as shown by Chandler, 1990, and in company case studies by those such as Hounshell and Smith, 1988 and Warner, 1978), their internationalisation of R&D was aimed at the wider exploitation of the basic competence they had already established at home rather than at extending that competence into new fields or ‘sourcing’ technology abroad. Affiliate R&D concentrated upon the adaptation of products to local tastes, and the adaptation of processes to local resource availabilities and production conditions (Cantwell, 1995). Thus, in the early stages, although the internationalisation of corporate technology should not be underestimated (a criticism of some recent literature advanced by Cantwell, 1995), it was motivated mainly by the extent of dissimilarity between home and foreign markets rather than by the rationale of the process of further competence accumulation.

In the second phase, by around the mid-1970s, the old technology paradigm ran into difficulties (Freeman and Perez, 1988), as the opportunities for integrating diverse technologies in large scale plants had been gradually exhausted. Thus, at around this time the relationship between the accumulation and diversification of competence broke down. Technological diversification was now increasingly based instead on the growing interrelatedness between formerly separate technologies (Kodama, 1986), but like with the formation of corporate international networks, the new opportunities for innovative development were still at an early stage in the 1970s. Even in this second phase, after the early post-war period, there seems to have been a general widening of the internationalisation and diversification of technology across a wider range of firms (Cantwell, 1995). The most common explanation is that lower transport and communication costs contributed to a general expansion across large firms in the internationalisation of technological activity (Vernon, 1973), while an increase in technological interrelatedness prompted a broader cross-section of firms into technological diversification[1] (Pavitt, Robson and Townsend, 1989; Patel and Pavitt, 1997, 1998).

More recently, however, the nature of the competence creation process seems to have entered a third phase in the technologically leading firms (Cantwell, 1995). What previously had been a dispersed set of loosely connected efforts for the consolidation and adaptation of competence within the firm (achieved through some combination of diversification and internationalisation), has been transformed in some companies into a more complex integrated and interactive network for the generation of new competence (Pearce, 1999; Zander, 1999). This new system for corporate development relies on the interrelatedness between specialised activities conducted in particular locations, each of which takes advantage of spatially-specific resources or capabilities. In this event internationalisation, diversification and competence creation become for the first time necessarily interconnected and thus mutually positively related parts of a common process. The wider picture of

[1] Another aspect which has recently entered into the discussion is the changing nature of technological knowledge itself (Nelson and Thomson, 1997), that with the development of scientific and engineering communities became more susceptible to transmission between fields of activity and between countries.

which this is part is one which formerly local market oriented affiliates have been increasingly integrated into international networks within their respective multinational companies, such networks coming to resemble 'heterarchies' more than hierarchies (Hedlund, 1986; Doz, 1986; Porter, 1986; Bartlett and Ghoshal, 1989; Dunning, 1992), and affiliates have increasingly pursued ‘asset-seeking’ motives (Dunning, 1995). The co-evolution of international corporate networks for the accumulation of technological competence and the organisational capability to manage such complex heterarchical structures is a special case of the co-evolution of technological and organisational innovation (Coriat and Dosi, 1998).

Beyond the emergence of a new interrelationship between the accumulation, diversification and internationalisation of corporate technological competence, the third phase is distinctive in changes in the cross-firm pattern of activity in another respect too. Given that the internationally dispersed development of technology is now a source of competitive advantage, two different types of firm behaviour can be observed, depending upon whether a firm that begins with relatively little international activity needs to ‘catch-up’ (Cantwell and Sanna-Randaccio, 1990), or an established multinational reorganises its existing international network to better exploit the respective comparative advantages in innovation of the locations in which it operates (Cantwell and Sanna-Randaccio, 1993). In an integrated multinational company network each affiliate specialises in accordance with the specific characteristics of local production conditions, technological capabilities and user requirements. The network benefits from economies of scale through the local concentration of particular lines of activity (increasing returns from local research in a specialised field as opposed to research in general), economies of locational agglomeration through an interchange with others operating in the same vicinity in technologically allied fields, and economies of scope through the international intra-firm coordination of related but geographically separated activities. The experience acquired in a specialised activity in one location creates technological spillovers that can be passed on to other parts of the multinational company network elsewhere[2].

Other recent evidence suggests that this type of internationally integrated or globalised strategy for innovation is particularly characteristic of corporate technology leaders today (Cantwell, 1995). The extent to which the affiliates of MNCs specialise within their industry across national boundaries in accordance with the comparative advantage of local expertise tends to rise as the technological strength of MNCs increases, and in particular tends to be greater for the leading MNCs that originate from the major locational centres of excellence for their industry (Cantwell and Sanna-Randaccio, 1992; Cantwell and Janne, 1999; 2000). The particular role of the largest and best known MNCs in the formation of internationally integrated networks for technological

[2] It has been shown that in recent times, in industries in which such net advantages to multinational integration were available, multinationality has been a source of competitive success and faster growth (Cantwell and Sanna-Randaccio, 1993).

development is attributable partly to their capability to devote the resources needed to organise a complex organisational network, and partly due to their having a wide enough range of existing absorptive capacity (an established diversity of competences) to be able to effectively utilise and bring together a variety of new streams of innovation, each to some extent specific to their own particular local institutional setting or environment.

The empirical evidence, based on the technological activity of world's largest firms, supports the notion that largest and technologically leading firms have witnessed the emergence of corporate international networks for the accumulation of both geographically and sectorally dispersed technological competencies (Cantwell and Piscitello, 1999), and highlights the need to examine where and how innovative activity by MNCs is internationally dispersed and regionally concentrated.

3. 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. The regionalisation of the 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). 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). This is particularly appropriate here since our indicator of the degree of foreign participation across regions relative to the locational distribution of indigenous firms requires us to take into account the sectoral specialisation of domestic firms in each region as compared to the pattern of technological specialisation of foreign investors. Finally, the choice of US patenting is convenient, since large firms are especially prone to patent their best quality inventions in the US market, the largest and the most technologically advanced. It is therefore likely that our data reflect the patenting of inventions that have a significant commercial importance, as well as allowing for a meaningful analysis of the territorial distribution of the technological activities of MNCs in the EU.

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.

For some time, European firms have made much greater use of international research strategies than their counterparts from the US and Japan, although more recently US and Japanese MNCs have increasingly used foreign research facilities. European MNCs still rely to a greater extent on foreign-based research than do others. The total foreign share of the largest European firms increased from 28% to 35% over the whole period 1969-95. The share of technological activity carried out abroad by European firms increased in the early 1970s, then there was a temporary decrease during the late 1970s, followed by a recovery of the upward trend in the 1980s and early 1990s. Unsurprisingly, relatively small European countries, such as the Netherlands, Belgium, Switzerland and Sweden, have among the highest shares of technological activities abroad. In contrast, firms from larger countries with a strong domestic technological base - Japan and the US - have had a much weaker propensity to undertake their technological activity abroad; even though they have all showed and increase in the internationalisation in the early 1990s. France, as well as Germany and Italy, used to be in an unusual position among the European countries in the sense that the technological activity of its largest firms had remained relatively centralised until recently, but it is not longer true in the 1990s. However, British firms have a long international tradition, and have been amongst the most multinational in their organisation of technological activity with now well over half of their technological activity (56%) being carried out abroad.

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. It is also worth noting that European-owned firms have also a relatively small and only very slowly increasing share of their research located in the Rest of the World, rising from 6.3% in 1969-72 to 6.5% in 1991-95.

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). Just as UK-owned firms have long been among the most internationalised in their technological efforts, so now the UK as a country has become highly dependent on the research of foreign-owned firms, which accounts for 45.2% of the UK-located research of the largest firms in 1991-95. The share of foreign-owned firms in local technology creation is also very high in Italy, but this is because there are so few Italian firms in the world's largest (11 out of 784). By contrast, in Germany and France foreign penetration into local R&D has risen much less (from 16.3% to 17.4% and from 24.2% to 28.9% respectively) than has the technological effort of indigenous firms abroad (with reference back to Table 1).

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. 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.

4. The 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, 1998; Scott, 1998), 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 that give rise to geographical agglomeration, we examined three of the largest European countries involved in the globalisation process (namely Germany, the UK and Italy) at a more detailed geographical unit of analysis. In particular, we analyse the locational pattern of MNCs' technological activities within and across the countries and investigate whether locational preferences differ between foreign-owned and domestically-owned firms, and amongst the former between European- and US-owned firms.

4.1. *Methodological Issues*

In order to understand the geographical pattern of innovation in Europe, we referred to 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

[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 (1998a, b) consider NUTS 1 for UK and NUTS 2 for Italy.

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.

4.2. The Location of MNC Technological Activities in the European Regions by Foreign-Owned and Indigenous Firms

The regionalisation of the University of Reading patent database has been extended to cover Germany, the UK and Italy. The three host countries substantially differ each other in terms of the magnitude of the phenomenon under investigation. Indeed, 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)[4].

Tables 7a-7c report the total number and the percentage share of patents granted to domestically-owned firms and to foreign-owned firms in each region considered[5]. 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.

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[4] It is worth observing that this is partly due to the very different policy approaches adopted in the three countries (see Cantwell and Iammarino, 1998b).

[5] The regions considered meet a size restriction which we had to impose in order to avoid small number problems. 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).

4.3. The Asymmetry in the Geographical Distribution of Foreign-Owned MNC vs. Domestically-Owned Corporate Technological Activities

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 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.

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[6]). Let N_{jm} be the total number of patents granted to foreign firms in each sector j in country m. 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_{jm} patents would be distributed in each region i of country m, in proportion to the total number of patents granted in the same region to domestic firms in sector j. Therefore:

let n_{ijm} be the total number of patents granted to domestic firms in region i, sector j and country m 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:

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

Assuming that foreign firms follow a random process in the location of their technological activities, the expected number of patents $\tilde{n}_{ijm}$ granted to foreign firms in region i, sector j and country m is:

$\tilde{n}_{ijm} = \alpha_{ij} * N_{jm}$

Consequently, the expected total number $\tilde{N}_{im}$ of patents granted to foreign firms in each region i in country m is:

$\tilde{N}_{im} = \Sigma_j \tilde{n}_{ijm} = \Sigma_j \alpha_{ij} * N_{jm}$

where:

m = Germany, UK, Italy;

i = 1, …, 77;

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

$j = 1, \ldots, 56$

Therefore, it is possible to compare the distribution of the expected values $\tilde{N}_{im}$ with the number of patents actually granted to the foreign firms in each region of the country, N_{im}, during the period considered. The statistically significant equality of the two distributions would imply that the activity of domestic firms, that is the existing knowledge base in each region, explains almost perfectly the locational choices of technological activities by foreign firms in that country.

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 within each country considered 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 linear agglomeration effect hypothesis can be significantly rejected.

To provide an appropriate measure of such a discrepancy between foreign and domestic locational behaviour in the three countries considered, we built a variable based on the difference between the two profiles obtained (that is N_{im} and $\tilde{N}_{im}$). 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 in the country m, while controlling for (iii) general sector-specific differences in the propensity to patent. Therefore, the absolute difference between N_{im} and $\tilde{N}_{im}$ should be corrected through a normalisation factor taking into account the three effects just mentioned, which is given by the following:

$I_{im} = (n_{im}/s)*\Sigma_j rta_{ijm}*RTA_j$

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);

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

$rta_{ijm} = (n_{ijm}/n_{im})/(w_j/w)$ 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 $PREFERENCE_{im}$, which measures the attractiveness of the individual region i in country m for foreign investors, is defined as:

$$PREFERENCE_{im} = (N_{im} - \tilde{N}_{im})/I_{im}$$

In order to model the differences between different home countries, the variable considered becomes:

$$PREFERENCE_{imk} = (N_{imk} - \tilde{N}_{imk})/I_{imk}$$

where k in our case can assume two different values referring either to European-owned firms or US-owned firms[7].

This index might vary theoretically between -∞ and +∞, in proportion to the attractivness 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.

4.4. Favoured Locational Patterns of Foreign-Owned Firms Across the Regions within each European Country and across European Regions

In order to analyse whether the locational behaviour adopted by foreign European- and US-owned firms follow similar patterns, Table 8 shows the correlation coefficients for the locational preferences of the two sets of foreign-owned firms (European or US, with each other and with the whole set of foreign-owned firms combined) across German, UK and Italian regions respectively. Interestingly, the locational pattern of foreign-owned technological activities as a whole in Germany seems to be led more by other European than by US firms (the correlation coefficients are 0.862 and 0.608, respectively), while there is no correlation between the two individually. Conversely US firms' locational behaviour (likewise uncorrelated with the European) seems to drive the spatial distribution of technological activities in Britain (the coefficient is 0.892, while that for European-owned firms is 0.585); while for Italy, perhaps partly because of the small numbers involved, European- and US-owned firms similarly contribute (the correlation coefficient is 0.788) to the distribution of technological activities across regions.

Furthermore, to reveal at a deeper level of detail MNCs' regional locational preferences in the three European countries considered, Tables 9a-9c report the values of the index PREFERENCE for the regions within each country for the whole set of foreign-owned firms as well as for European- and the US-owned firms respectively. Likewise, Tables 10a-10c report the corresponding ranking of the regions themselves. The differences in locational distribution between foreign European-owned and US-owned corporate technological development is also illustrated in Figures 1a-1c.

The geographical patterns shown by Tables 9, 10 and Figure 1 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

[7] It is worth noting that i = 1,.., 35 when k = Germany; i = 1,…, 33 when k = UK and i = 1,…9 in the Italian case.

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. For US-owned firms this is almost exactly the pattern observed in Tables 9a and 10a, and Figure 1a, and for foreign European-owned firms it is more or less accurate as well. The value of our indicator of relative locational attractiveness is negative for US firms for all the regions of Nordrhein Westfalen (Arnsberg, Köln, Detmold, Dusseldorf and Munster) and their rankings lie between 22 and 30 (out of 34); while for foreign European-owned firms the same is true for Detmold, Dusseldorf and Munster (with rankings between 25 and 29), but the indicator is just positive for Arnsberg (ranked 15), and Köln (ranked 12) is a partial exception. On the other hand, foreign-owned firms are not especially attracted either to the regions of Bayern, which is the least distinctive of the German macro(NUTS1)-regions, in that the technological specialisation of domestically-owned firms located there is very broadly dispersed (Cantwell and Noonan, 1999). Here the picture is clearest for foreign European-owned companies, for which Niederbayern, Mittelfranken, Oberfranken and Oberbayern are all negative and lowly ranked (between 28 and 32), and Oberpfalz ranks lowest of all. However, for US-owned firms Oberfranken and Niederbayern rank slightly higher (at 18 and 19 out of 34), while Oberpfalz is a clear exception, being the most highly ranked region in terms of relative attractiveness for US-owned affiliate development.

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 engineering (Cantwell and Noonan, 1999). 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. For both foreign European-owned and US-owned firms these regions in ascending order of attractiveness are Stuttgart, Tübingen (ranked 10th for both), Karlsruhe (ranked 7th for both) and Freiburg (which has the 2nd highest ranking in both cases).

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.

Tables 9b, 10b and Figure 1b help to provide more detailed evidence. In the South East, Hampshire and the Isle of Wight are highly relatively attractive both for foreign European-owned firms (ranked 4 out of 33) and US-owned firms (ranked 2nd). Yet while the research of foreign European-owned companies is relatively oriented to Greater London (ranked 8) and Surrey and Sussex (ranked 2), US-owned firms are relatively more drawn to Kent (ranked 12) and the Thames Valley (ranked 9); while Essex is moderately ranked (at 14) by both groups. Conversely, neither foreign European-owned nor US-owned firms are relatively attracted to West Midlands county or to Hereford, Worcestershire and Warwickshire (in the West Midlands), or to Merseyside, Lancashire or Cheshire (in the North West). The one exception is Greater Manchester, which is highly ranked (at 5) for other European-owned firms, but not for US-owned companies (ranked 30). It may be that other European-owned, and particularly German-owned firms are especially attracted by the local expertise in chemicals available in the Manchester area, given that this is the major field of German technological strength and hence outward asset-seeking investment.

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, Tables 9c, 10c and Figure 1c reveal 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 US-owned firms, and actually has a negative indicator value for foreign European-owned companies. 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.

Looking more widely at an inter-country perspective on 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 adapt the model thus far employed at the single country level to the situation in which foreign activities could in principle spread over the whole set of the European regions considered. In particular, in order to avoid problems related to the mixed presence of German and British foreign firms within the set of the European foreign-owned firms, we restricted this part of our analysis to US-owned firms alone[8]. 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. The results are shown in Table 11, in which the rankings are compared as between the cross-country and within country perspectives.

The effects of this comparison are quite interesting. As might be expected given the historical orientation of US FDI in Europe towards the UK, once we allow for locational competition between regions across national borders rather than just within them, the British regions tend the rank more highly and the German regions lower in their relative attractiveness to US-owned MNCs. Yet it is the regions of South East England that seem to benefit most from the cross-country regional perspective (notably Hampshire and the Isle of Wight, and Kent), as well as a couple of Scottish regions (Borders and Grampian) which are less important in terms of overall activity (Table 7b). On the German side the anomaly posed by Oberpfalz looks much less stark in the cross-border setting, as its ranking drops from 4 to 19. For the Italian regions the effect of the wider international comparison is to increase the variance of the cross-regional rankings. Milano and the rest of Lombardia are ranked more highly (although Veneto, Lazio and Toscana fall a bit), while Piemonte and Friuli Venezia Giulia are ranked lower in the wider cross-country context.

5. Summary and Conclusions

Since the late 1970s (Cantwell and Piscitello, 2000), large MNCs have increasingly extended or diversified their fields of technological competence through their use of internationally integrated networks for technological development. In each location in such a network MNCs tap into specialised sources of local expertise, and so differentiate their technological capability, by exploiting geographically separate and hence distinct streams of innovative potential. 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

[8] 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.

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. While Hampshire, Lombardia and Freiburg seem generally attractive to firms of most national backgrounds, Kent, Berkshire and Oberpfalz appeal mainly to US-owned firms, while Surrey, Sussex, Greater London and Köln are relatively more attractive for the siting of the development efforts of other European-owned MNCs.

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, (ii) the degree (breadth) of local technological specialisation in the region, and (iii) whether the composition of local specialisation includes a focus on mechanical technologies and engineering skills (and perhaps also in electrical engineering and computing) which provide a linkage between technological development in a wide variety of areas. Our results are broadly consistent with these three propositions. However, it remains to explore them more fully statisically in future research, while allowing for the possible role of other regional effects, such as the extent and composition of the local science base, which may influence the level of corporate technological development efforts sited in each region by each substantial group of foreign-owned companies.

5.1. Implications for European firms and regions

Summarising the implications for European firms and regions, these depend upon the category into which firms and regions fall. We can distinguish between technologically leading larger MNCs normally originating from a major centre for their industry, other large MNCs typically from other centres, and smaller companies whose activities may be localised or at least heavily concentrated in just one or two regions in the same country; and we distinguish as well between higher order and lower order regions according to the differing scale and breadth of innovative activity located in each. On the one hand, European firms originating from the major centres for their industry (such as the leading German chemical companies) are able to create cross-border European networks to diversify their corporate technology base, and while continuing to develop the principal technologies for their industry mainly at home, they can source related technologies in the appropriately specialised regions. As a result of such strategies of corporate European integration by the leading European MNCs, lower order regions are able to deepen their established patterns of technological specialisation, since the new research facilities of capable foreign-owned MNCs not only access the region’s existing local skills and expertise, but locally build upon them and enhance them. On the other hand, European MNCs from other centres are more likely to extend their already established lines of development in European locations outside their home countries, so that their international networks generate only a lesser degree of corporate technological diversification, but still facilitate access to the wider range of infrastructure and skills which are found in higher order regions elsewhere. Since higher order regions attract a greater diversity of foreign-owned MNCs, the impact of MNC technological development within these regions is to widen their pattern of technological specialisation, and to reinforce the general tendency for technological activity to geographically agglomerate in these areas.

A further implication, which brings into consideration the effects of cross-border MNC development on smaller and more localised (non-multinational) European firms, is that the kinds of technology spillovers which occur between firms within regions are likely to differ between lower order and higher order regions. In lower order regions spillovers are typically intra-industry or at least involve a common set of broad technological fields, and hence reinforce the established pattern of specialisation (such as within motor vehicle and related engineering in the West Midlands or Piemonte, or within chemicals in the North West). Conversely, in higher order regions spillovers occur much more in fields of technology that are common to many industries, such as in general mechanical processes, information and communication technologies, or new materials, and the existence of these kinds of localised network externalities increases the attractiveness of such regions for foreign-owned corporate technological development in general. The availability of localised technology spillovers within regions in turn increases the potential for foreign-owned affiliates to acquire an independently technologically creative role within their international corporate groups, to which they are connected (among other things) by means of cross-border knowledge flows. For all the European regions in which some significant MNC research activity is located, MNC international networks provide a linkage mechanism for all local companies (through their cooperation with local MNC affiliates) to innovation in other European regions, which allows each region to become more specialised in the fields of its own greatest potential, while better appreciating and responding to complementary technological development elsewhere in Europe. Hence, the growing intensity of knowledge flows in the European economy helps to promote and not to hinder innovative efforts, with respect to both flows between firms (often within regions) and between regions (often within MNCs).

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