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Conference Paper

The technological relationships between indigenous firms and foreign-owned MNCs in the European regions

41st Congress of the European Regional Science Association: "European Regional Development Issues in the New Millennium and their Impact on Economic Policy", 29 August - 1 September 2001, Zagreb, Croatia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Cantwell, John; Iammarino, Simona (2001) : The technological relationships between indigenous firms and foreign-owned MNCs in the European regions, 41st Congress of the European Regional Science Association: "European Regional Development Issues in the New Millennium and their Impact on Economic Policy", 29 August - 1 September 2001, Zagreb, Croatia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

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**The Technological Relationships between Indigenous Firms and
Foreign-Owned MNCs in the European Regions**

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ABSTRACT

It has been argued that the accumulation of technological competence is a path-dependent and context-specific process, being partly firm-specific and partly location-specific. MNCs spread the competence base of the firm, and acquire new technological assets or sources of competitive advantage. For their part indigenous firms benefit from local knowledge spillovers from MNCs, given the access of the latter to complementary streams of knowledge being developed in other locations. This paper examines how the particular corporate technological trajectories of multinational corporations (MNCs) have interacted with spatially-specific resources for the creation of new competence in some leading regions in Europe.

This is all the more relevant in the presence of an in-depth process of economic integration, as is the case of the EU, which arose from the need to define the problems, and the policies aimed at solving them, in terms of geographical location and centre/periphery economic convergence.

The paper addresses some of the most relevant questions in this field of research, such as: is there a positive correlation between MNC technological profiles and regional technological specialisation? What are the main features of the nature of interactions between local and corporate knowledge? Can a hierarchy of regional centres of technological excellence be established within and across national boundaries?

The paper is divided into five sections. After the introduction, the second section addresses to the “local” and “global” dimension of innovation phenomena, providing an overview of the rising function of regional innovation systems in relation to the change of MNC innovatory strategies towards a network structure. The interaction between the “local” and the “global” is considered in section three, exploring the cumulative causation mechanisms which may arise from such an interaction and the competitive bidding that regions will have increasingly to face to cope with globalisation. Section four summarises the main findings of a comparative analysis of the locational patterns of MNC innovative activities in the regions of four of the major EU countries, namely the UK, Germany, Italy and France. Section five concludes, highlighting the more urgent questions to be addressed by the future research in this promising field of study.

THE TECHNOLOGICAL RELATIONSHIPS BETWEEN INDIGENOUS FIRMS AND FOREIGN-OWNED MNCs IN THE EUROPEAN REGIONS

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1. Introduction

The nexus between global and local processes has been investigated quite extensively by the literature of the most recent years. One crucial aspect of such a relationship lies in the creation and diffusion of innovation, which, more than other economic processes, shows rather complex patterns of distribution across space.

Indeed, as emphasised by Dicken, ““global” and “local” are not fixed scales; rather, they represent the extreme points of a dialectical continuum of complex mutual interactions” (Dicken 1994, p.103). As a consequence, neither the orthodox approach - which traditionally considers both the (multinational) firm and the local system as *black boxes* whose behaviours are determined by exogenous factors - nor an entirely endogenous perspective - which tends to explain structure and growth mechanisms as the result of purely internal forces - seem appropriate to investigate the issue ‘global versus local’. Rather, structure and behaviour of the two “extreme points” need to be considered within the context of their increasing interdependence, including both endogenous determinants and exogenous variables relevant to the analysis.

The aim of this chapter is to examine how the particular corporate technological trajectories of multinational corporations (MNCs) have interacted with spatially-specific resources for the creation of new competence in some of the leading regions in the European Union. In order to consolidate existing competencies, it is generally necessary for a firm to extend those capabilities into new related fields of production and technology, and across a variety of locations. The firm is thereby able to benefit from the dynamic economies of scope that derive from the technological complementarities between related paths of innovation or corporate learning in spatially distinct institutionally settings or environments. In this perspective, MNCs spread the competence base of the firm and acquire new technological assets, or sources of technological advantage. For their part, indigenous firms benefit from

local knowledge spillovers from MNCs, given the access of the latter to complementary streams of knowledge being developed in other regional locations.

The chapter addresses some of the most relevant questions in this field of research, such as: is there a positive correlation between MNC technological profiles and regional technological specialisation? What are the main features of the nature of interactions between local and corporate knowledge? Can a hierarchy of regional centres of technological excellence be established within and across national boundaries?

Furthermore, there is evidence which suggests that internationally integrated MNC structures for technological development are more important between the EU regions than across national boundaries anywhere else in the world, and so our empirical evidence focuses upon the European experience.

The chapter is divided into five sections. The next section addresses to the “local” and “global” dimension of innovation phenomena, providing an overview of the rising function of regional innovation systems in relation to the change of MNC innovatory strategies towards a network structure. The interaction between the “local” and the “global” is considered in section three, exploring the cumulative causation mechanisms which may arise from such an interaction and the competitive bidding that regions will have increasingly to face to cope with globalisation. Section four summarises the main findings of a comparative analysis of the locational patterns of MNC innovative activities in the regions of four of the major EU countries, namely the UK, Germany, Italy and France. Section five concludes, highlighting the more urgent questions to be addressed by the future research in this promising field of study.

2. Regional systems of innovation and the globalisation of innovative activities

The significance of the “regional dimension” of an innovative system has emerged as the logical consequence of an interactive model (Kline and Rosenberg, 1986), which puts the emphasis on the relationships with information sources external to the firm. Such relationships - between firms and science infrastructure, between producers and users at inter-firm level, between firms and the institutional environment - are strongly influenced by spatial proximity mechanisms that favour processes of polarisation and cumulativeness (Lundvall, 1988; von Hippel, 1989). Furthermore, the employment of informal channels for knowledge diffusion (the so-called tacit or uncodified knowledge) provides another argument for the tendency of innovation to be geographically confined (Hägerstrand, 1967; Lundvall,

1992). Although a break has thus occurred with the conventional economic approach¹ - in which spatial factors shaping innovation were usually considered secondary (if not thoroughly negligible) - the regional scope is still rather indeterminate with respect to the geographical location of innovatory capacity in the global economy.

A distinction is usually made between different types of agglomeration forces which shape spatial organisation, pushing related firms and industries to cluster spatially and possibly leading to patterns of uneven regional development - i.e. the emergence of centres and peripheries at the global and national level (Malmberg, Solvell and Zander, 1996). On the one hand, there are general external economies and spillover effects - so-called *urbanisation* economies - which attract all kinds of economic activities in certain areas. This provokes the emergence of regional cores with sectoral specialisations varying across different locations. On the other hand, *localisation* economies are fostered in spatial clusters of firms undertaking related or similar activities. These kinds of forces are likely to be industry-specific and to produce cumulative mechanisms which enable host locations to increase their production, technological and organisational competence over time (Richardson, 1969; Dicken and Lloyd, 1990). Agglomeration forces tend to be deeply conservative and self-reinforcing, thus leading to a strong path-dependency of regional agglomerations. In Krugman's words: "If there is one single area of economics in which path dependence is unmistakable, it is in *economic geography* - the location of production in space" (Krugman 1991b, p.80).

However, both general agglomeration and industry- or sector-specific agglomeration have traditionally been considered in static terms, driven by efficiency considerations such as static economies of scale - both in production and/or in R&D -, transaction and transport costs, input-output linkages, etc.. Dynamic agglomeration economies refer rather to the occurrence of technological learning and knowledge accumulation, which are more likely to affect growth processes rather than simple unit costs of production (Harrison et al., 1991).²

¹ Among the studies in regional economics aimed at identifying the endogenous elements of "territorialised" innovative systems it is necessary to recall the approaches based on the concepts of the *milieux innovateur* (Aydalot, 1986) and the industrial district (Becattini, 1987). More recently, the attention focused on specifically defined regional systems of innovation (Saxenian, 1994; Storper, 1995; Howells, 1998). As a consequence also of the echoes of the "new economic geography" (Krugman, 1991a, b, c; Grossman and Helpman, 1991), empirical analyses have proliferated in relation to the geography of innovation, both in the US (among others, Jaffe, Trajtenberg and Henderson, 1993; Audretsch and Feldman, 1995, 1996) and in the EU (Breschi, 1997; Paci and Usai, 1998; Caniëls, 2000).

² It is worth to mention that both static and dynamic agglomeration economies were identified already by Marshall (1891) who, among the fundamental advantages of spatial agglomeration, stressed the relevance of the easy transmission of "new ideas" (i.e., knowledge and information spillovers), allowing better production functions through technical, organisational and production improvements.

The characteristics of innovation processes can provide further support to the actual importance of the local dimension in an era of increased globalisation. To summarise, the rising function of local and regional innovative contexts can be mainly explained by: a) the relations with the sources of information external to the firm, which are strongly influenced by spatial proximity; b) the use of informal channels for knowledge diffusion (tacit knowledge), which spur the tendency of innovation to be geographically polarised; c) the nature of innovative capabilities, which are highly path-dependent and geographically-specific.³ Moreover, it has been stressed that learning dynamics and exchanges of tacit knowledge are usually embedded in distinct environments of interactions among different subjects, sharing common attitudes and institutional settings towards particular types of learning (Lundvall, 1988). Therefore, “social capabilities” (Abramovitz, 1986), along with “technological congruence” (Fagerberg, Verspagen and von Tunzelman, 1994), have emerged as crucial localised factors which also determine the degree of attractiveness and the amount of spillovers that a region is able to draw. While the first refer to the overall ability of the region to engage in innovative and organisation processes, the latter points to the distance of the region from the technological frontier, or, in other words, its capacity to implement the technical properties connected to the new knowledge.

The importance of the above factors confirms the complexity of locational choices, especially in the ongoing process of globalisation. Indeed, while traditional production inputs are becoming increasingly mobile across countries, other location-specific factors remain highly concentrated in space, boosting differentiation between regions. Furthermore, the attraction of external sources of innovation and technology depends both on the strength of the regional innovative capacity and on the regional pattern of sectoral specialisation, and it is a crucial aspect of regional change in the increasingly globalised economy.

The term “globalisation” refers to a wider dimension than the one evoked by prefixes to the word national such as inter-, multi- or trans-. More specifically, by “globalisation” we

³ The notion of regional system of innovation (RSI) has emerged as a different perspective of analysis from the broader concept of national innovation system, introduced by the evolutionary theorists in the late 1980s (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Nelson and Rosenberg, 1993). Following this stream of literature, a RSI may thus be defined as ‘the *localised* network of actors and institutions in the public and private sectors whose activities and interactions generate, import, modify and diffuse new technologies’. Referring back to Howells (1999) for a comprehensive discussion on the extent of applicability of such a definition to a smaller geographical scale than the national one, the highly uneven pattern and spread of innovation in space suggests that such a phenomenon could be better depicted by assuming subnational units of analysis, which can avoid the distortions and the loss of information of hypothesising national systems as homogeneous entities. Indeed, as Carlsson and Stankiewicz accurately remarked, “high technological density and diversity are properties of regions rather than countries” (1991, p.115).

refer to a high degree of interdependency among units which constitute the MNC. In principle, therefore, we could have a higher interrelatedness among geographically dispersed units even with the same level of internationalisation of innovative activities of the MNC. The expression “globalisation of innovation” is thus used precisely to describe the recent increase in the intra-firm coordination of the innovative activities of MNCs. On the one hand, the strength that allows a firm to invest and govern its operations across national boundaries is its ability to innovate and to take advantage of such innovation in different locations through its own organisation. The authentic global generation of innovations requires, on the other hand, a wide range of skills and capabilities that only firms with specific infrastructure, organisation and management can attain (Archibugi and Iammarino, 1999). This explains why there has been a shift in attention away from the MNC as a mere vehicle of technology transfer towards the crucial role it plays as a creator of innovation and technological knowledge (Chesnais, 1988; Cantwell, 1994).

The “state of the art” on the international generation of innovation⁴ may be depicted as a trend towards increasing shares of innovation generated outside the home country and integrated within the MNC. As shown in Table 1, although the share of US patents of the world’s largest industrial firms attributable to research undertaken in foreign locations (outside the home country of the parent firm) rose only modestly in the 1969-95 period - around 10 or 11% -, there is a wide disparity between different national groups of firms. Indeed, the reason for such a moderate increase is the rising share in total corporate patenting of Japanese and, to a lesser extent, Korean firms, which as yet are on average little internationalised in their technological development, and their greater contribution to the total has acted to pull down the global average of foreign share (Cantwell and Janne, 2000). In fact, considering the total foreign share excluding Japanese firms, it rises much more strongly throughout the period, from 11.1% in 1969-77 to 16.2% in 1987-95. In the latter period, moreover, European parent firms show on average a share of patents granted for research located outside their home country of 32.5%, indicating a greater propensity to internationalise their innovatory capacity than those of US origin (whose share over the same period is 8.3%) or Japanese MNCs (1%). Whilst relatively small European countries, such as the Netherlands, Belgium, Switzerland and Sweden, have, unsurprisingly, among the highest shares of technological activity abroad, countries such as France, as well as Italy and Germany, which used to have a somewhat more centralised approach, have moved to greater

⁴ For the ongoing academic debate on the extent of the international creation of technology see, for instance, Cantwell (1995) and Patel (1995). For an interpretation of the two sets of results see Archibugi and Michie (1995).

internationalisation of technological operations in the most recent years. British firms, as well known, have been amongst the most multinational in their organisation of technology creation, with over half (53%) of their technological activity now carried out abroad.

[Table 1 here]

The traditional advantages of the centralisation of research and innovative activities - basically connected to economies of scale and scope in R&D, control on innovation and linkages with national business and non-business sectors - seem thus to be increasingly counterbalanced by those associated with decentralisation (see Pearce and Singh, 1992; Howells and Wood, 1993; Miller, 1994). From the perspective of the investor, the latter can be summarised in terms of the linkages between innovatory activity and foreign production, local markets, suppliers and clients, and the exploitation of technological fields of excellence in host countries. The latter can be aimed either at consolidating or upgrading an existing technological strength of the MNC, or at extending and diversifying its competencies into new related technological fields.

The change in MNC strategies towards a greater degree of cross-border coordination of their internationally dispersed operations requires an organisational structure that could not have been developed through purely arms-length market-based coordination between geographically separated units. As Dunning and Robson (1987) have effectively shown, transaction costs may shrink with integrated governance of units, whatever units are considered to be, either affiliates or different locations. However, the transaction costs approach, focusing basically upon benefits in terms of short-term efficiency and flexibility, fails to take into account the knowledge accumulation effects linked to the integration of innovative activities across space. Dunning and Wymbs (1997) have demonstrated that the degree of multinationality is significantly associated with the perception that firms increase their global technological advantage from foreign sources. They pursue this aim by establishing geographically dispersed networks of affiliates, as a means of building a sustainable competitive advantage based much more on capabilities and dynamic improvements than on static efficiency factors. Through such networks, technology, skills, and assets are transferred across national borders in a two-way direction - from the parent to subsidiaries and from affiliates to the parent company.

Such networks, however, take a rather complex configuration precisely because of the different types of agglomeration forces which shape spatial organisation. On the one hand, as seen above, there are urbanisation economies and general spillover effects which attract all kinds of innovative activities in certain regions and determine, in the case of corporate

integration, the localisation of new research units. These centripetal forces strengthen the inter-border intra-firm integration and the feedback of knowledge, expertise and information which occurs within networks of affiliates. On the other hand, sector-specific localisation economies intensify intra-border sectoral integration, implying local external networks between affiliates, indigenous firms and local non-market institutions. In both cases, by tapping into local knowledge and expertise, foreign affiliates gain a competitive advantage which can be exploited locally and/or transferred back to the parent company, enhancing its global technological competence. However, a geographical hierarchy of regional centres can be hypothesised, as a consequence of the type of interaction of agglomeration forces, which in turn depend upon the structural features of the regional system considered.

3. Local *versus* global: the regional hierarchy

The international dispersion of the creation of new technology and the change of innovatory strategies of MNCs make it all the more important to take into account the geographical concentration of MNC technological operations at a subnational level. From this perspective, it makes sense to assume that globalisation implies that location matters even more than in the past. The significance of the tendency of industrial innovation to agglomerate in certain regions on one side, and the emergence of a “performance” type of MNC - identified by “heterarchical” internal structures and innovation-based competitiveness (Dunning, 1993; Cantwell, 1992a, 1994; Amin and Tomaney, 1995) - on the other, tend to make the geographical polarization of innovative activities stable and self-organising. Hence, as both globalisation and economic integration processes are likely to interact with the change of the MNCs organisation of innovative activities - spurring the rising function of local innovative contexts - we could argue that MNCs are to be considered as the key-ring of the chain from global to local.

As argued above, a crucial element in the model of local accumulation of knowledge involves the attraction of outside resources, which may set off a strong cumulative process. The inflow of knowledge is driven both by actors from the outside attracted into the region and by local actors which try and tap into outside knowledge. Cumulative causation mechanisms might thus be reinforced, giving rise to vicious and virtuous circles which strictly depend upon the sectoral points of strength and weakness of both the MNC and the

regional innovation system.⁵ The pertinent issue for the host economy in attempting to entice such high value added operations is to understand what renders a location attractive or “sticky in such slippery space” (Markusen, 1996). Once the knowledge-seeking activity is located in the regional economy, “each region finds itself increasingly integrated into an international division of labour for the development of new technological systems” (Cantwell and Piscitello, 1999, p. 19).

The “competitive bidding” between European regional systems - in order to attract MNCs research and innovation activities - seems to have become increasingly tougher. In fact, the benefits of the global generation of innovation are not likely to be evenly spread between regional centres of technological excellence. Furthermore, the risk of regional inequalities within national boundaries might also increase as a consequence of the fact that strong regional systems of innovation would become more and more attractive, while backward regions would be further undermined by the strategies of MNCs.

As far as the latter point is concerned, we have stated above that location exerts a strong centripetal pull on the innovative activities of MNCs. However, the centrifugal forces which might offset the advantages of agglomerating in particular regions - such as rising prices of locally available resources or congestion effects - do not seem to have a large influence on location decisions of this kind. The typical arguments for convergence - based on assumptions such as the price-cost equalisation mechanism, homogeneity of firms and sectors, positive incentives to locate in the periphery, etc. - are not always applicable and it is hardly plausible that self-reinforcing regional growth (or decline) may be easily reversed by centrifugal forces stemming from conventional market mechanisms. Technologically declining regions, therefore, are not eligible as attractive locations for quality-seeking inward investment, although, if the latter occurs, there may be some benefits in terms of the revitalisation of past innovation capabilities through positive spillover effects (Cantwell, 1992a).

On the other hand, following the rationalisation of MNC innovation activity, a stronger competition is likely to occur between technologically advanced locations, especially within an economically integrated area such as the European Union. The relationship between the internationalisation of innovation and the competitiveness of local systems follows a circular

⁵ The idea that cumulative causation may give rise to a widening of regional inequalities is not a new one: it goes back to Young (1928), Perroux (1950), Myrdal (1957) and Kaldor (1970, 1981), in its broader formulation within development economics. Only more recently, however, it has received renewed attention by some scholars interested in giving a fuller account of its interdependence with the process of economic integration and the dynamics of technological globalisation (see, among others, Cantwell, 1987, 1989; Cantwell and Dunning, 1991).

pattern which - in the case of a virtuous circle - goes from the upgrading of local innovatory capacity to the increase of the share of research-related production, and from it to the improvement of competitive performances, setting in motion a positive interaction between foreign and indigenous research and production activity (Cantwell, 1992b).

The role of MNC networks for innovation turns out to be a function of the geographical hierarchy of regional centres - i.e. of the strategic importance of the host region and of the innovative dynamism of local competitors, suppliers, customers and institutions. The sectoral composition of technological strengths, in fact, differs across regional centres, while the technological specialisation of foreign subsidiaries depends upon the rank of the regional location in a geographical hierarchy and its gradual change over time.

Arising from the above mentioned differentiation of agglomeration economies, it has become possible to distinguish between *higher order* and *intermediate* regional centres.⁶ Such centres, indeed, arise “as a consequence of the interaction and the intensity of general external economies and localisation economies, which in turn depend upon the characteristics of the regional system considered” (Cantwell and Iammarino, 1998, p. 387). This differentiation has enabled us to distinguish between the form of potential knowledge spillovers and technological networks in operation between foreign-owned firms and their indigenous counterparts in different regions in Europe.

These interactions are more likely to further upgrade *higher order* regional locations, in which the strategy of subsidiaries, and their capacity to incorporate backward and forward linkages in their external networks for innovation, aim at exploring local knowledge and expertise, which will then be integrated to widen technological competence at the corporate level through the intra-firm network. Indeed, when foreign research has a more pronounced exploratory nature, it is likely to be attracted by *higher order* cores, treating them as a source of general expertise and skills (Cantwell and Janne, 1999). On the other hand, *intermediate* locations, with a narrower scope of technological advantages, are seen as sources of specific capabilities in some particular field. Thus, they might be relatively more exposed to the risk of being negatively affected, due to the strategy of foreign affiliates which follows a logic of exploitation of indigenous expertise, with the possible aim of out-competing local rivals. In other terms, as the position of the region in the hierarchy falls, so the profile of technological specialisation of foreign-owned firms in that region becomes more closely related to the equivalent pattern of specialisation of indigenous firms in the same region. Conversely, a

⁶ The other extreme is that of *lower order* regions, i.e. technologically weak and backward regions that have an inadequate innovative base in order to compete with other locations and to be attractive for external flows of knowledge and technology.

centre at the top of the hierarchy is more likely to attract a broad range of foreign innovative activities, as MNCs will generally try to extend their established lines of specialisation through corporate networks. Therefore, *higher order* locations should attract foreign research for their general reservoir of skills and resources, while centres further down are attractive more for their limited range of specialised expertise, thus bringing foreign and local technological profiles closer together.

Moreover, it has been pointed out that, by specialising according to the local strength in each location, MNCs technological activity is broadened (Cantwell, 1992b). Instead, in the case of *higher order* regions, it has been shown that the broadening of specialisation is one of the possible forms of incremental change in the composition of local innovation, since regional profiles may, in other cases, be reinforced and concentrated in their established areas of technological expertise (Cantwell and Iammarino, 2001). In other words, only some *higher order* cores are able to adjust their profiles of specialisation to the highest technological opportunities over time, whilst others - which experience a slower process of convergence between old and new technologies - may end up by losing gradually their competitiveness. The location-specific and incremental nature of technological change might thus eventually imply the rise and the decline of technological poles within Europe.

Indeed, knowledge spillovers in *higher order* regions seem to operate mainly through exchanges in and around core technological systems, creating linkages between actors in quite separate alternative fields of specialisation. Such core systems appear to be rooted in the 'general purpose' technologies (GPTs) - such as background engineering, mechanical methods, electronics and Information and Communication Technologies (ICTs) - in which foreign-owned and indigenous firm's technological advantages appear to overlap in these *higher order* centres. Empirical studies have demonstrated that MNC foreign affiliates account for an increasing share of all new technologies that are introduced in the multinational networks and that they are associated with a significantly higher probability of entry into new and more distantly related fields of technology, creating a long-term drift into new technological competence (Zander, 1997). These findings are consistent with the evolutionary view of the MNC, involving a gradual shift into new technological systems thorough the consolidation of international operations and the establishment of a network structure. When the latter occurs, international growth through time allows the MNC to leverage its accumulated experience and to smooth out the transition between major technological breakthroughs (Zander, 1997).

To summarise, the interaction between local and global processes of knowledge creation may spur regional gaps within a country - with agglomeration in centres of excellence (either *higher order* or *intermediate*) being strengthened and backward regions experiencing further marginalisation - as well as it is likely to entail a tougher competition between core regional systems across countries, to grasp the best growth opportunities offered by GPTs and innovation networks.

4. Technological profiles and the regional hierarchy in the EU

Evidence of tighter cross-border corporate integration of innovation coupled with heightened intra-border/inter-company exchange of knowledge renders it increasingly pertinent to investigate the precise nature and location of MNC technological activities. As argued above, whilst such new structures for innovation are a natural consequence of the globalisation process, certain shocks have served to accentuate this process. As a result of closer European integration, greater interdependency among MNC units in the EU has provided us with a unique testing ground for analysing such phenomena. Here we present a comparative view of such issues by drawing together the findings of four recent country-studies in this area, which focus upon regional innovation patterns in the UK, Italy, France (Cantwell and Iammarino, 1998, 2000, 2001b) and Germany (Cantwell and Noonan, 1999).

The basic premise of the existence of a hierarchy of research centres has been explored by examining the precise technological profile of foreign-owned firms located within regional centres of excellence. Patent data are used to analyse the location of research activity across space. The data were obtained from the United States Patent and Trademark Office (USPTO) and cover all patents granted to large firms (both national and foreign) located in the UK, Italy, France and Germany over the 1969-95 period. Each patent was classified into one of 56 technological sectors derived by mapping from the primary classification of the USPTO and organising patents into common groups (see Appendix for the resulting 56 sectors). To facilitate a sub-national analysis of location, the data were also regionalised according to the residence of the first-named inventor (research facility responsible). This was achieved by attributing the location of the principal facility

responsible for the innovation to an area code obtained from Eurostat Nomenclature of Territorial Units for Statistics (NUTS).⁷

The use of patents as an indicator of advanced technological capacity and ability to develop innovation is one of the most established and reliable methods of estimating innovative activities. The advantages and disadvantages of using patent statistics are well known in the literature (see, among others, Pavitt, 1988; Griliches, 1990; Archibugi, 1992) and will not be rehearsed here. For our purpose, it is useful to remind that the use of patent records provides information on the address of both the inventor and the owner of the invention (from which we have derived the country of location of the parent firm through a consolidation of patents at the level of international corporate group). Furthermore, 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 over time the patenting of inventions that have a significant commercial importance, as well as allowing for a meaningful analysis - based on common legal and institutional standard for comparison - of the territorial distribution of the technological operations of MNCs in the European Union.

4.1 Country characteristics

It is generally acknowledged that wide disparities in technological competencies exist across the economies of Europe (Paci and Usai, 1998; Verspagen, 1997; Caniëls, 2000). Table 2 reports on the distribution and penetration of foreign-owned innovative activity across the four economies under study. Whilst the distribution figures (D) highlight the attractiveness of the various locations against one another, the penetration statistics (P) indicate the degree to which foreign-owned activity has infiltrated the aggregate local innovative activity within each of these economies.

[Table 2 here]

In terms of distribution, the UK was the main host in Europe of foreign-owned patenting activity in the early years, whilst since the 1970s Germany has been the most attractive location. Italy is further behind, although recording an increase in the proportion of foreign activity carried out in the country since the mid-1980s, whilst France displays an intermediate position, with a rather stable share of foreign-owned patenting through time, increasing particularly since the beginning of the 1990s. In terms of penetration – i.e. percentage of foreign patenting on total national patenting – the overall proportion of

⁷ For further discussion of the data see Cantwell and Iammarino (1998, 2000, 2001) and Cantwell and Noonan (1999).

foreign-owned research located in Europe has on average increased over this time period with a most noticeable rise in recent years (almost 29% in 1991-95). Whilst in the UK and Italy foreign-owned firms constitute a substantial and rising proportion of aggregate activity (with shares of 45.2% and 57.5% respectively in 1991-95), the same share in Germany is approximately 17% at the end of the period considered. In France the share of foreign-owned firms on the overall total is 25.6% for the 27 years: this is consistent with other studies on the economic role of foreign affiliates, which in fact place France in an intermediate position between the highly globalised character of the research carried in the UK and the historically endogenously-based strength of the German technological competence.⁸

In terms of absolute size of large firms' patenting activity in the period 1969-95 as a whole (see Table 3 below), Germany, with 92,058 patents, has consistently accounted for the highest proportion (approximately 40%) of patents granted by the USPTO to firms located in the European Union, albeit declining since the mid-1980s. France, showing 28,106 patents, represents less than one third of the overall activity carried out in Germany, lags well behind the UK, with 35,219 patents, but is far above Italy, with only 7,040.

Such observations generally support the presence of a ranking among European national innovation systems, reflecting their evolution over time and the different degree of openness of the national knowledge bases.

4.2 Geographical concentration at the subnational level

Considerable sub-national differences exist across the four EU economies. Table 3 records the regional distribution of patenting activity by large firms located in each country over the 1969-95 period.

[Table 3 here]

In further support of the regional disparities and commensurate with the clustering activity thesis outlined above, very strong geographical agglomeration of patenting from innovative activity is found in three out of four economies. In the case of both the UK and Italy, a very strong concentration of the overall technological activity carried out by large firms (both indigenous and foreign-owned) in the period 1969-95 is found in just a few regions. In the former country, the South East accounts for 47% of the total, whilst large firms located in the North West and West Midlands represent an additional 26%; in the latter

⁸ Germany hosts the largest absolute number of patent grants but records a significant imbalance between those attributed to foreign-owned versus indigenous research. As highlighted, whilst foreign-owned firms share of patents has been increasing over time in both the UK and Italy - it averages approximately half in the 1991-95 period - and has been raising in the most recent years in France (slightly less than 30% in 1991-95), such a figure is substantially lower in Germany throughout the three decades under observation.

economy, Lombardia accounts for 53% of total patenting activity in Italy, with Piemonte providing a further 25%. Geographical agglomeration turns out to be outstanding also in the French case: with reference to the main regional core, actually, it is the most pronounced in comparison with the other two countries. In fact, more than 58% of the overall patenting activity (in both foreign- and nationally-owned cases) is concentrated in Île de France, followed by the Centre-Est, with almost 15%, and Bassin Parisien, with slightly less than 10%. On the contrary, in the German case, although agglomeration of innovation is also recorded, it is spread across a greater number of regions. Concentration is relatively strong in the regions of Nordrhein Westfalen and Bayern, which together host 50% of total large firm patenting over this period. Coupled with these regions in Germany, substantial agglomeration of innovative activity is also recorded in Baden Wuerttemberg and Hessen: the four regions together record over 80% of total MNC research in Germany.⁹

Further differences are found when looking at the degree of geographical concentration of innovation by ownership. Yet, although innovative activities show a strong tendency to cluster in space, the extent of such a tendency may vary significantly and is rather context-specific. Whilst both foreign-owned and indigenous firms concentrate their research in the same region in the UK (the South East), in France (Île de France) and in Italy (Lombardia), the same does not hold for Germany, where Nordrhein Westfalen hosts the highest share of indigenous activity (29%), but only represents the second most popular location for foreign-owned research after Baden Wuerttemberg. This differing pattern for Germany can be explained by considering the type of technological activity associated with Nordrhein Westfalen. This region is the traditional home of the German chemical/pharmaceutical industry and continues to record substantial technological advantage for indigenous firms that base their research there, which is reflected also in the research profiles of the universities and research institutes located in the region (Blind and Grupp, 1999, p. 461). As elsewhere suggested, this might be due to the fact that foreign-owned chemical firms may experience difficulty in trying to access the deeply entrenched technology networks and communication channels that have evolved through time. Thus, they disperse their research more widely, and account for a relatively low share of total German research in chemicals (Cantwell and Noonan, 1999). This contrasts quite significantly with the pharmaceutical industry in the UK where, despite historical strength in these technologies, high foreign penetration characterises this sector (Cantwell and Piscitello, 1999).

⁹ The regions of Rheinland Pfalz and Niedersachsen were also included in the analysis of the German case because of the relatively high absolute number of patents granted to firms located there.

More marked interregional differences are found in the case of France, at least with respect to the UK and Italy: whilst Bassin Parisien is the second most popular location for foreign research carried out in the country (14%), the Centre-Est ranks fifth in order of importance, accounting for only 6.9% of foreign-owned France-based patenting, in spite of its second largest share of indigenous research (17.4%).

The four economies are similar in that, even allowing for potential population and economic size effects, all record relatively high concentrations of innovative activity within their borders, which allows for a generic classification of ‘core’ regions (that is, those which host the highest proportions of patenting activity over time within each country). In the more detailed sectoral analysis, therefore, we have restricted our study to these regional centres of excellence.¹⁰ It is interesting to note that, in all four countries, foreign-owned research appears to be relatively more dispersed outside the regional cores than that undertaken by their indigenous counterparts. In this respect, the most striking evidence is that of Italy: foreign-owned firms locate approximately 68% of their R&D in the two core regions of Lombardia and Piemonte, whilst 82% of patenting by indigenous firms is located there.

It is necessary to bear in mind, however, the differences in the degree of attractiveness of external resources that mark out the regional systems considered, which per se lend support, at least at first glance, to our hypothesis of the existence of a geographical hierarchy within the national boundaries.

4.3 Sectoral features and the country rank

Table 4 records the contribution of foreign-owned innovation to total regional activity by technological macro-sector over the period 1969-95. As expected, the highest contribution of foreign-owned activity to the regional totals occurs in the South East region of the UK (43.3%), Lombardia in Italy (39.1%) and Baden Wuerttemberg in Germany (28.2%): in all cases these contributions are well above the national average (33.5% in the UK, 36.1% in Italy and 16.7% in Germany). France differs insofar as the highest contribution of foreign research is recorded in Bassin Passin (36.5%), which is much above that observed for the main core of Île de France (25.6%, as the national average).

[Table 4 here]

Whilst in the South East foreign-owned firms record a significant presence in metals, chemicals and, even to a greater extent, electrical technologies (52% of the regional total

¹⁰ As highlighted in the country-studies, the fact that a number of regions were dropped from the analysis due to having inadequate numbers for statistical purposes in itself supports the hypothesis that internal geographical hierarchies exist in these economies.

research in the macro-sector), in Lombardia their contribution is even higher within this technological field (76.2%) - with a commanding foreign presence particularly noticeable in photographic processes - and is also substantial in metals and mechanical sectors. West Midlands and the North West show a relatively high foreign presence in the more sectorally-focused chemical technologies, while Piemonte, as expected, is particularly attractive in the mechanical field, where the region shows also a very strong specialisation of production. In Île de France only electrical technologies show a contribution higher than the regional average. In fact, both Île de France and Bassin Parisien receive relatively high supplements from foreign research in the ICT sectors (telecommunications, other electrical communication systems, semiconductors and office equipment and data processing), where the foreign contribution is remarkable also at the national level. Foreign-owned research located in Baden Wuerttemberg is also quite pronounced in the electrical macro-sector, as well as in the mechanical sector (40.7%, most noticeably in the textile and clothing machinery). Interestingly, the contribution of foreign-owned research to the regional total is also above the national average in the Niedersachsen (particularly in chemical technologies, despite the fact that aggregate foreign-owned activity is low in this technology, and mechanical) and Hessen (especially in transport, metals and mechanical technologies).

As highlighted elsewhere, one of the main drawbacks of using absolute numbers of patents is the difficulty associated with then making comparisons between the activity of heterogeneous areas of technological endeavour. Since the propensity to patent is higher in certain fields of activity (for example, pharmaceuticals), this poses potential problems when undertaking comparative analyses. This can be circumvented however, by employing the Revealed Technological Advantage (RTA) index, a technique first applied by Soete (1987) and subsequently developed by Cantwell (1989, 1993).¹¹

What generally emerges from the analysis of the technological specialisation across the economies is a kind of rank within the EU area, first of all at the level of national systems of innovation.

Looking at the sectoral dispersion of activity at the country level, as measured by the standard deviation of the RTA index across the 56 fields of activity (Table 5), it appears that

¹¹ The RTA is a proxy for technological specialisation and is calculated in the following way:

$$RTA_{ij} = \frac{(P_{ij} / P_{wi})}{(\sum_i P_{ij} / \sum_i P_{wi})}$$

where: P_{ij} = number of patents granted to technology i in region j

P_{wi} = number of world patents granted in technology i .

The RTA for a given region in a specified technology will vary around unity. An index greater than one indicates a relative advantage (or specialisation) in this technology whereas an index less than one points to a relative disadvantage.

the technological advantage of firms (both foreign-owned and indigenous) located in the UK is by far the most widely dispersed at sectoral level with respect to their counterparts located in the other three countries. However, while the cross-sectoral variance of the RTA index for Germany and France does not diverge much from that observed in the UK, the Italian figures, albeit somewhat lower for the activity of foreign-owned firms located there, are in aggregate substantially higher relative to the other three EU economies. This confirms that, while the overall Italian pattern displays the characteristics of a ‘medium’ research system (since both foreign-owned and indigenous firms are highly concentrated in their technological activities), the aggregate UK, German and French models correspond to ‘advanced’ national research locations. The main explanation for this result is the smaller size of large firms’ technological activity in Italy, given that there tends to be a good inverse relationship between technological size and the degree of technological specialisation (Archibugi and Pianta, 1992; Cantwell and Santangelo, 2000).

[Table 5 here]

This is further endorsed by the results of the regression analysis carried out at both regional and national level. First, we have regressed the sectoral specialisation profiles (as proxied by the RTA index) of foreign-owned firms between 1969-95 on that of indigenous firms across the 56 technological sectors. In addition, by dividing our data into two separate time periods (1969-82 and 1983-95), we have analysed the nature of this relationship over time. Specifically, we have examined the degree to which our data lend support to the thesis that the innovative activity of multinational corporations is path dependent in nature i.e., that technological specialisation of foreign-owned firms in period t is highly correlated to that of nationally-owned firms in period $t-1$ (see Cantwell and Iammarino, 1998, 2000 and Cantwell and Noonan, 1999 for a more detailed discussion of the methodology employed).

The overall UK, German and French models, unlike the Italian case, suggest a kind of attractiveness towards foreign resources based on general technological competencies, spillovers and institutional and infrastructural supports offered by the economic environments as a whole. In fact, the specialisation of foreign-owned firms does not depend on the technological advantage of indigenous firms in none of these three countries. In contrast, the specialisation profile of the foreign and Italian firms matches for the overall period and even more through time, confirming that the Italian model is rather configurable as a medium technological location, attracting foreign-owned research over a narrower range on a more sector-specific basis.

4.4 Regional hierarchies

Turning to the technological specialisation across the subnational economies,¹² a very clear dichotomy between *higher order* and *intermediate* research locations do emerge. Such a dichotomy, however, turns out to be less clear-cut in the case of the French regional cores, where the geographical concentration is anyway confirmed, but the overall regional profiles of technological specialisation seem to be relatively more influenced by the local expertise in particular leading technologies, which is, ultimately, the reflection of the highly centralized structure of the French national innovation system and of the pervasive State involvement in technology creation (see, among others, Chesnais,1993).

[Table 6 here]

As shown in Table 6, in the South East region of the UK, Lombardia in Italy, Bassin Parisien in France and all six German regions, statistical support was found for the thesis that these regions attract foreign-owned firms not because of the existing indigenous technological specialisation. Foreign firms are there attracted because of the wider technological competencies and infrastructural supports available (i.e., banking, finance, insurance and business services, degree of openness to foreign-owned investors, business climate, corporate and enterprise culture, etc.). Technological activity of foreign-owned and indigenous firms in these regions is typically broad ranging in nature and extends across a spectrum of technologies: thus, they can be labeled *higher order* centres.

In the case of Île de France, instead, which emerged as the main technological core of France both for foreign and indigenous research, the aggregate patenting activity of foreign firms located in the region is dependent upon the technological specialisation of indigenous firms (the coefficient is significant at 5%): this is even more true when looking at the regression over time (1% level of significance). Yet, these results are puzzling only at a first glance. As already pointed out, technological spillovers in *higher order* regions operate mostly through exchanges in and around core technological systems. Relationships then form between actors in otherwise quite separate fields of specialisation. In the case of Île de France the regional comparative advantages lie, in the main, right in leading GPTs. This is in line with what has been shown by Cantwell and Iammarino (2001) - carrying out a more in-depth inspection of change, stability and strengthening of technological comparative advantages across a wider number of European regions over time - where the French capital region records one of the strongest concentration in terms of number of sectors showing a consolidation of technological specialisation; such a process appears indeed to have occurred

¹² In the regional regressions, a logarithmic transformation of the index (or its adjusted version) was used, since the distribution of the RTA index in each regional case is skewed because of the smaller numbers of patents at

particularly in GPTs technologies and core technological systems. This suggests that foreign-owned firms from a wider range of industries than locally are attracted into the region, but their technological focus is then similar to the local structure of comparative advantages - i.e. overlapping in ICT (telecommunications and radio systems, a traditional French strength, included in the electrical macro-sector), metalworking (metals), general machinery and general instruments (mechanical), all of which are leading GPTs. Therefore, it is possible to conclude that Île de France is clearly a *higher order* core, insofar as the similarity of the indigenous and foreign technological profiles can be viewed as a coincidental consequence of the regional pattern of specialisation (Cantwell and Iammarino, 2001b).

Results for the other Italian and British regions suggest the presence of *intermediate* research locations. Technological specialisation profiles of foreign-owned firms were found to be closely correlated with those of indigenous technological expertise (also in the regressions over time) so that knowledge spillovers are likely to be intra-sectoral in nature. This is consistent with the hypothesis that *intermediate* regions attract the innovative activities of foreign-owned MNCs because of a very particular set of sectorally-specific expertise on offer in that region. By basing research facilities in such locations, foreign-owned MNCs may be able to upgrade their own technological capabilities in particular technological fields which may be sub-sets of their own major areas of technological interest (Cantwell, Iammarino and Noonan, 2000).

The case of Centre-Est is again, at a first glance, more blurred: the results obtained seem to indicate a relative degree of overlapping in the technological profiles of foreign-owned patenting in the second period (t) and French-owned patenting in the first time period ($t-1$) (the coefficient is significant at 10%), whilst the correlation is not significant for the overall period 1969-95. However, it has been shown (Cantwell and Iammarino, 2001b) that Centre-Est should be definitely categorised as a *intermediate* regional location. The main argument is that foreign-owned firms are here attracted in sectors in which there is indeed a strength owing to local firms but, given that the foreign entrants are often classified in different or related industrial sectors, they locate allied research also into what (for them) is the related technological field (which is not a local specialisation).

Furthermore, the empirical analysis of the evolution over time of both technological capacity and sectoral specialisation of different EU regional centres has provided support for our hypothesis that a geographical hierarchy of regional locations can be established also

the regional level, creating a pattern closer to lognormality than to normality, unlike for the overall national countries.

across national boundaries in the European Union area (Cantwell and Iammarino, 2001b). Multinational firms may fit into regional profiles of specialisation, thus supporting the process of local technological concentration. In contrast, depending upon the initial pattern of regional specialisation, MNCs may spur the diversification of the regional profile towards areas of interrelated technological competence. As an example, the recent information technology revolution has caused a great increase of research in some closely related electrical/electronic technologies: such interrelatedness might therefore have pushed the broadening of technological specialisation in those regional cores which show greater expertise in information and communications technologies (because of more complementary activities and higher potential spillover effects).

Our empirical findings have shown that in the European area, which has been influenced by a process of strong economic restructuring as a consequence of integration processes, two different paths may be observed over the last decades. On the one hand, core regions, especially those characterised by more mature clusters of activity (such as, for instance, the South East in the UK or the Basel region in Switzerland), which have become more narrowly specialised in their technological activities, might experience a slower process of convergence between old and new technologies because of a lock-in trend due to both the initial pattern of specialisation and the institutional environment. On the other hand, some other regional cores, especially those in which geographical agglomeration of general economic activity has been strongly affected by EU integration, being also closer to the EU institutional core (such as are Flanders-Brussels, South Netherlands and also Baden Wuerttemberg.), which have broadened their specialisation, might experience a faster process of convergence between old and new technologies, reaching a potentially greater competitiveness. This seems to comfort the idea that European clusters entering in the maturity phase might be more liable to decline, and their possible resurgence, more than to the traditional price mechanism (in the declining cluster costs fall, but so also do benefits), is due to the convergence between old and new technologies: if they do converge, spillovers generated even in an old specialised region may attract entry in newer and fast-growing sectors, causing a shift in the core specialisation and eventually its recovery (Swann, 1997; see also Brezis and Krugman, 1993).

5. Concluding remarks and open questions

Our EU case-studies have provided support to the hypothesis that the pattern of MNC networks for innovation conforms to an internal (*within* national boundaries) hierarchy of regional centres, as large firms appear extremely sensitive to the characteristics of regional systems. Furthermore, we have also shown that a geographical hierarchy of regional locations can be established as well *across* national boundaries in the European area. In such a context, it becomes clear that, if for the MNC the imperative to create global R&D networks has grown all the more pressing, the ability of regions to reap the best technological opportunities will be increasingly crucial to meet the challenges of the new dynamic.

On the other hand, it has been shown that the regional hierarchy is far from being a clear-cut and rigid classification of local contexts within and across EU national borders. A categorisation without distinctions would have implied an oversimplification of the complex interactions between the global and the local dimensions of the generation of new technology and, particularly, the oversight of the role of the State as the intermediary between the ‘extreme points of such a dialectical continuum’.

Yet, the limited attention paid to the role of MNC innovation networks for regional development in industrialised economies need to be overcome by future research efforts. There are a number of issues in this area which should be urgently addressed and it would be impossible here to recall all of them. We will then just mention those more closely related to the research presented in this chapter, which will represent guidelines for our ongoing work.

The first issue, rather conceptual in nature, has to do with the definition of regional innovation system. Any step in the direction of accomplishing a more suitable notional depiction of RSI, however, has to take into account two major problems. The national innovation system, in fact, has been conceptualised and operationalized looking at actors, institutions and linkages which operate and are governed mainly on a national scale (i.e. R&D system and infrastructure, S&T policy making process, educational structures, etc.). This sort of “national bias” calls for a substantial rethinking of which are the relevant actors, institutions and relationships handling at regional level and how this regional dimension could be picked up. The second problem, a rather general one in regional economics, has to do with the scarcity of data at a sub-national scale. The availability of figures on the role and performance not only of firms, but of the multitude of actors and institutions which shape an innovation system, is even more severe than at the national level. The methodology of data and information collection for R&D and innovative activities is, in practice, still heavily dependent on the custom of the “territorialisation” of

national data and this has so far constrained the possibility of exploring the existence and nature of regional systems of innovation on the basis of statistically robust evidence.

The second issue, related to the previous one, is that too little is still known on the linkages between the global and the local. Much of the literature on local systems as centres for innovation suffers from the defect that it focuses almost entirely on the interchanges that occur within such areas between small and medium-sized enterprises (SMEs). This literature has rarely paid much attention to the role of larger leader companies within such localities, or to the connections with complementary innovation in other distant sites that is provided when these larger firms are part of a multinational corporation. The need to redress the balance by considering MNC role shares the perspective that both localised and international knowledge exchanges are important and that the coevolution of interactions between local systems of SMEs (with their tacit and contextual knowledge) and the codified knowledge generated at the global level is a crucial factor for future competitiveness.

Another crucial question seems to arise from the above prospect. The work here presented constitutes a contribution to the analysis of subnational innovative activity within the EU area and represents a vital component in the formulation of the future technological and industrial policy of the Union, which aims to sustain the development of the “Europe of regions”. The ability of the region to attract foreign high-value added resources and R&D commitments depends first and foremost upon the existing absorptive capacity of the location. As large differences in terms of absorptive capacity give rise to a considerable degree of geographical agglomeration, knowledge will flow more easily and economic activity in general will be more spread if high absorptive capacity exists across space. Moreover, the trend in the most industrialised economies with respect to FDI is one of a progressive convergence between FDI policies and development policies, by acting through both normative instruments and ad hoc institutional structures for the promotion of innovation. Nevertheless, how to attract asset-seeking FDI in R&D or how to promote a research-conducive environments, is something much less clear than with respect to FDI in production.

These considerations are all the more important as structural upgrading has clearly dynamic consequences, as do the spillovers of MNC operations but, rather surprisingly, there is not yet even a comprehensive theory of MNC and economic growth. More conceptual work is needed especially to investigate the most recent, innovation-driven stage of MNC-facilitated growth, particularly in regional economics. As emphasised by many, the literature on regional development suggests some possible routes through which the MNC may act as

an “engine of growth”. This is consistent also with the insights gathered from the *new growth theory*, although we believe that, in this respect, factors underlying growth such as business organisation, the role of institutions and government intervention, come out as essential. Theoretical and conceptual work in this direction is still today rather undeveloped.

Besides, there is some empirical evidence pointing out differences in the quality of foreign investment not only between core and backward regions, but also among the latter group itself. On the one hand, for example, the lack of the prerequisite - i.e. the “necessary condition” of possessing a minimum threshold stock of technological competence or “critical mass” - to become part of a global network for innovation, is one of the explanations underlying the *lagging behind* of some backward regions (i.e. the Italian Mezzogiorno) and the substantial absence of much foreign-owned technological activity even at the country level. On the contrary, some peripheral regions - such as those of the UK outside England, namely Wales, Scotland and, although to a lesser extent, Northern Ireland - have recorded substantial benefits in terms of employment, productivity levels, innovation rates and, ultimately, economic growth, which reflect the observed increase in both the magnitude and the quality of FDI attracted. What is and how to build a “critical mass” needs to be explored more in depth, given its relevance for the overall social and economic cohesion of the European Union.

As far as the empirical exercise here retrieved is concerned, the aim is to proceed in the direction of further improving our understanding of some aspects of the effects of innovation and globalisation on firms and regions - i.e. technological spillovers - by examining more in detail the patterns of technological (by technological field of the largest firms) and production (by industry of the output of the largest firms) specialisation in each region. As also emerged in the case of the French regions, differences between the two specialisation profiles may be indicative of technological diversification by industry, and hence potential technological overlaps between industries. Furthermore, the patterns of technological diversification of industries should be further explored by looking at which firms are responsible for a positive technological specialisation in the case of a region that lacks specialisation in the equivalent industrial category, and how this fits into the overall pattern of technological diversification of the firms in question. We believe that this integrated view of production and innovation would add a substantial insight to our knowledge of local *versus* global processes of knowledge creation.

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Appendix: The 56 fields of technological activity.

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

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 firm, 1969-95 (%)

Nationality	1969-1977	1978-1986	1987-1995
US	5,4	6,9	8,3
Japan	2,1	1,2	1,0
Germany	11,7	13,2	19,0
UK	42,1	43,4	53,0
Italy	14,9	13,3	13,5
France	7,9	8,1	26,9
Netherlands	48,6	50,8	54,8
Belgium-Lux.	50,9	53,8	50,2
Switzerland	43,9	42,9	47,7
Sweden	19,1	27,5	36,5
Total European countries*	26,3	25,6	32,5
Total all countries**	10,3	10,7	11,3
Total excluding Japan	11,1	13,0	16,2

* Germany, UK, Italy, France, Netherlands, Belgium-Lux., Switzerland, Sweden, Denmark, Ireland, Spain, Portugal, Greece, Austria, Norway, Finland

** Total includes all the world's largest firms, some not presented separately in this table

Source: Cantwell and Janne (2000)

Table 2 - Distribution (D) and penetration (P) of foreign-owned patenting activity by location, 1969-95

HOST	1969-72		1973-77		1978-82		1983-86		1987-90		1991-95	
	D	P	D	P	D	P	D	P	D	P	D	P
	<i>Percentage (%)</i>											
UK	29,3	27,7	26,8	30,8	25,0	31,3	22,6	36,0	21,0	35,4	21,2	45,2
ITALY	4,3	27,3	4,9	31,1	4,4	26,5	4,5	32,9	6,0	43,9	6,5	57,5
GERMANY	27,0	16,3	30,2	15,6	31,8	15,2	35,6	18,8	33,5	18,1	28,9	17,4
FRANCE	13,2	24,2	14,9	24,7	14,5	24,0	14,2	25,1	14,9	27,1	15,6	28,9
<i>EUROPE</i>	<i>100,0</i>	<i>22,7</i>	<i>100,0</i>	<i>21,6</i>	<i>100,0</i>	<i>21,4</i>	<i>100,0</i>	<i>24,4</i>	<i>100,0</i>	<i>25,0</i>	<i>100,0</i>	<i>28,6</i>

Source: Cantwell and Piscitello (1999).

Table 3 - Regional breakdown of US patent grants to large firms, 1969-95 (% of each group's total grants); population and GDP by region (1995)

	<i>Percentage (%)</i>				
	Indigenous	Foreign	Total	% Pop.*	% Output**
UK					
South East	40,2	60,8	47,1	30,6	35,7
West Midlands	16,4	3,6	12,1	9,1	8,1
North West	17,0	7,8	13,9	10,9	9,7
Others	26,4	27,8	26,9	49,4	46,4
Total UK	100,0	100,0	100,0	100,0	100,0
Total (absolute nos.)	23404	11815	35219	58,4	785697
ITALY					
Lombardia	50,3	57,1	52,8	15,6	20,0
Piemonte	31,8	11,3	24,4	7,5	8,5
Others	17,9	31,6	22,8	76,9	71,5
Total Italy	100,0	100,0	100,0	100,0	100,0
Total (absolute nos.)	4490	2540	7040	57,2	810036
GERMANY					
Nordrhein Westfalen	29,0	19,0	27,0	22,0	22,5
Bayern	25,0	14,0	23,0	15,0	18,8
Baden Wuerttemberg	16,0	31,0	19,0	13,0	16,2
Hessen	13,0	14,0	13,0	7,0	11,2
Niedersachsen	3,0	5,0	4,0	10,0	10,1
Rheinland Pfalz	9,0	5,0	9,0	5,0	4,9
Others	5,0	12,0	5,0	28,0	16,3
Total Germany	100,0	100,0	100,0	100,0	100,0
Total (absolute nos.)	76535	15523	92058	81,5	1420439
FRANCE					
Île de France	58,3	58,2	58,3	18,9	28,4
Bassin Parisien	8,4	14,0	9,8	18,0	16,4
Centre Est	17,4	6,9	14,7	11,9	11,2
Others	15,9	20,9	17,2	51,2	44,0
Total France	100,0	100,0	100,0	100,0	100,0
Total (absolute nos.)	20902	7204	28106	57,9	936874

* Total population (millions)

** Gross value added (Mio. Ecu)

Source: Cantwell and Iammarino (1998, 2000, 2001b); and Cantwell and Noonan (1999).

Table 4 - Average foreign-owned shares of US patents by technological macro-sector and region, 1969-95

REGION	MACRO SECTOR						Total 56*
	Chemicals	Metals	Mechanical	Electrical	Transport	Other	
South East	43,7	48,7	38,4	52,0	21,0	44,5	43,3
West Midlands	21,2	20,9	13,5	10,5	4,2	2,6	10,0
North West	24,5	16,9	23,3	20,8	19,9	8,1	18,8
Total UK	37,0	34,3	32,5	43,1	16,7	28,4	33,5
Lombardia	32,6	48,8	43,1	76,2	4,0	5,6	39,1
Piemonte	18,8	19,6	25,8	13,9	16,2	0,0	16,7
Total Italy	37,3	43,3	40,4	50,1	11,1	7,9	36,1
Nordrhein Westfalen	4,7	33,5	37,0	42,3	20,7	37,7	11,9
Bayern	9,5	15,0	15,0	8,9	5,6	6,0	10,2
Baden Wuerttemberg	32,1	30,7	40,7	38,9	33,2	36,1	28,2
Hessen	7,0	41,8	39,1	30,1	42,3	28,9	18,1
Niedersachsen	31,9	15,0	28,5	19,7	6,9	11,0	23,7
Rheinland Pfalz	2,1	37,9	29,5	35,2	22,9	42,4	9,6
Total Germany	8,7	28,3	30,0	25,8	12,9	20,0	16,7
Île de France	17,5	20,5	21,2	26,6	11,8	16,1	25,6
Bassin Parisien	25,5	37,5	31,6	58,5	48,3	9,8	36,5
Centre Est	7,6	16,0	23,9	13,6	31,8	22,7	12,0
Total France	19,2	19,3	22,6	30,5	18,9	16,2	25,6

*Note this is the average across the total of all 56 sectors, as opposed to the more restricted number of technologies developed at a regional level.

Source: Cantwell and Iammarino (1998, 2000, 2001b); and Cantwell and Noonan (1999).

Table 5 - Regional dispersion of technological specialisation, 1969-95

REGION	Indigenous	Foreign
South East	0,81	0,69
West Midlands	1,08	0,97
North West	0,87	1,08
Total UK	0,47	0,49
Lombardia	1,10	2,10
Piemonte	6,40	1,60
Total Italy	2,10	1,20
Nordrhein Westfalen	0,99	0,97
Bayern	0,62	0,98
Baden Wuerttemberg	1,98	0,75
Hessen	1,60	1,28
Niedersachsen	1,09	0,98
Rheinland Pfalz	1,42	1,32
Total Germany	0,60	0,66
Île de France	1,1	0,75
Bassin Parisien	0,79	0,77
Centre Est	1,0	0,75
Total France	0,64	0,56

Table 6 - Summary of Regional Regression Results

$$RTAFOR_{ij} = \alpha + \beta RTAINDIG_{ij} + e_{ij} \quad (RTA = \text{either } \ln RTA \text{ or } adjRTA)$$

where i = regions; j = technological sectors

		Coefficient	Stn. Error	T-Ratio	Prob.
UK					
South East	Slope	0,154	0,101	1,517	[0.135]
	Intercept	-0,524	0,203	-2,589	[0.012]
West Midlands	Slope	0,447	0,203	2,200	[0.032]
	Intercept	-2,125	0,604	-3,520	[0.001]
North West	Slope	0,791	0,156	5,061	[0.000]
	Intercept	-1,239	0,468	-2,646	[0.011]
ITALY					
Lombardia	Slope	0,111	0,159	0,703	[0.484]
	Intercept	0,429	0,106	4,058	[0.000]
Piemonte	Slope	0,541	0,109	4,950	[0.000]
	Intercept	0,150	0,091	1,645	[0.105]
GERMANY					
Nordrhein Westfalen	Slope	-5,870	0,167	-0,351	[0.728]
	Intercept	0,685	0,120	5,710	[0.000]
Bayern	Slope	-0,134	0,243	-0,553	[0.584]
	Intercept	0,672	0,174	3,852	[0.001]
Baden Wuerttemberg	Slope	-8,960	0,107	-0,838	[0.408]
	Intercept	0,749	0,087	8,648	[0.000]
Hessen	Slope	-0,169	0,155	-1,079	[0.288]
	Intercept	0,809	0,119	6,773	[0.000]
Niedersachsen	Slope	0,173	0,184	0,943	[0.352]
	Intercept	0,522	0,130	4,019	[0.000]
Rheinland Pfalz	Slope	-0,131	0,162	-0,806	[0.426]
	Intercept	0,704	0,118	5,988	[0.000]
FRANCE					
Île de France	Slope	0,228	0,112	2,039	[0.046]
	Intercept	-0,189	0,049	-3,831	[0.000]
Bassin Parisien	Slope	-0,045	0,139	-0,327	[0.745]
	Intercept	-0,211	0,072	-2,921	[0.005]
Centre Est	Slope	0,139	0,165	0,842	[0.403]
	Intercept	-0,335	0,091	-3,692	[0.001]

No. of observation: 56. Test 1 = Serial Correlation (Lagrange) Test 2 = Normality (Jarque-Bera)

Test 3 = Heteroscedasticity (regression of squared residuals on squared fitted values)

Source: Cantwell and Iammarino (1998, 2000, 2001b); and Cantwell and Noonan (1999).