Agglomeration and Comparative Advantage in Innovative Activities: the Impact of Multinationals in Europe

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Abstract

This paper argues that there are different phenomena of agglomeration explaining the pattern of spatial concentration of innovative activity, based on specialised or general technological externalities, which are specific to particular types of regions and can be used to draw a geographical hierarchy. It provides a conceptual basis for defining a hierarchy, identifying core, intermediate and lower-order locations, which is industry-specific and influenced in its dynamics by multinational corporations (MNCs). A hierarchy of German, British and Belgian regions in the chemical and pharmaceutical industry is empirically investigated, discussing the foreign-owned MNCs that they attract and their likely impact on indigenous firms and the local structure of technological activity.

Key words

Technological comparative advantage, agglomeration, multinational corporations

1. Introduction

This paper investigates the emergence and evolution of the agglomeration of technological activities in Europe and the role of multinational corporations (MNCs) in shaping it. It presents a conceptual basis for future research to guide investigation on these issues and offer some preliminary empirical evidence on the existence of technological comparative advantage and its dynamics.

This is discussed with reference to the debate on the likely evolution of the locational concentration of industrial activities in the context of globalisation and further European integration. On the one hand, European locations may maintain, develop and accumulate economic activities according to their comparative advantage. European locations would keep and build upon their significant diversity of specialisation across and within industries. From this perspective, further diversity of geographical specialisation will persist and may be reinforced by further economic integration.

On the other hand, the effect of globalisation and European integration may imply more geographical concentration of economic activities overall into only a few locations. In the international trade literature, Krugman (1991) proposed a model of regional specialisation to explain why and when manufacturing becomes concentrated in a few regions, leaving others relatively undeveloped. Enterprises concentrate because of strongly increasing returns to scale, and mobile labour moves into the region. Firms will locate more likely (other things equal) in regions with relatively large nearby demand as they are minimising transportation costs. As firms concentrate, demand will expand which will attract more firms and lead to a 'circular' process of agglomeration and regional divergence. The determination of regions in which this process starts will essentially depend on initial conditions such as the spatial distribution of the non-rural population. However, the results of the model stress the large degree of indeterminacy of the locational choice of firms. In Europe, there is still a strong prediction that the EU central locations could become the principal beneficiaries of a process of cumulative growth as capital and labour are attracted into these areas from the periphery. These locations have several advantages over those in the periphery that would induce the self-feeding process of agglomeration of firms and industries. They have a natural positional advantage of being closest to the main population centres, which may be reinforced by the fact that they contain nearly all the major urban concentrations as well as the financial and administrative capital cities. They also have better transport and telecommunications facilities as well as access to large and well qualified labour forces.

The paper focuses on the technological dimension of locations and highlights the role of MNCs in seeking to explain differing paths of localised technological development. It claims that the agglomeration patterns of technological activities, leading to either technological specialisation or more general concentration, depend on different phenomena of agglomeration that are specific to particular types of locations. These phenomena would not necessarily have a core-periphery dimension and would not easily be identified when using aggregated data.

International business studies have focused much attention on the emergence of large MNCs as key players in the dynamic mechanisms of knowledge generation and utilisation. The links between the local innovative environment and MNCs may be more complex than it is often acknowledged in the literature. In particular, the role of MNCs in the creation of international networks for technologies may increasingly be important for understanding how different types of technological activity are locationally dispersed.

Building on an evolutionary approach to technological change and innovation that emphasises the differentiation of technology across firms and locations, one of the paper's objectives is to investigate the structure, evolution and hierarchy of geographical centres in technological activity in Europe. Section 2 discusses the literature on the geography of technological activity and innovation, and suggests a conceptual basis for defining a locational hierarchy. Another objective is to analyse the impact of MNCs and their strategic interaction on the concentration and specificity of innovative capabilities across locations. An attempt is presented in section 3 to clarify the impact of MNCs on the level and structure of the technological capacity of their home and host locations. In particular, it is argued that the technological activity of MNCs has an impact on the specialisation patterns of locations and their interdependence through integrated corporate networks. This may have a particular effect on the reorganisation of the geographical and sectoral structure of the accumulation of differentiated technological competencies across national and regional boundaries in European industries. The hypotheses on the relevance and differentiation of localised technological activity and the role of regions' profile of technological activity, their position in a geographical hierarchy and how it is affected by MNCs, in germany, the UK and Belgium for the chemical and pharmaceutical industry. Finally, some conclusions are drawn in section 6.

2. Technological Agglomeration and Comparative Advantage: a Locational Hierarchy

Agglomeration and Comparative Advantage

Studies on the spatial dimension of innovation and learning have emphasised the heterogeneity of the sectoral structure of technological activities and the process of specialisation at the national level (Archibugi and Pianta 1992, Padoan 1997). Interregional disparities in technological development are even more contrasted as demonstrated by the more recent studies on the geography of innovation in Europe (Caniëls 1999, Cantwell and Iammarino 1998, 2000, Cantwell and Noonan 2001). The spatial pattern of innovation in any industry would be more concentrated the more tacit and complex the relevant knowledge for that industry, and so particularly for the chemical, pharmaceutical, electrical and electronic industrial sectors (Breschi 1997, Audretsch and Feldman 1996).

Technological spillovers and other externalities are central to the argument for the geographical clustering of innovation. Some of the major factors identified as increasing innovative activity are those of spillovers across industries, spillovers of university research, the presence of related industries and specialised business services (Feldman 1994, Jaffe et al. 1993, Jaffe 1986, Baptista and Swann 1998, Swann and Prevezer 1996). The spatial concentration of innovative activity is argued to be attributable to factors related to technological external economies, as separated from factors leading to the concentration of production (Audretsch and Feldman 1996, Mariani 1999). In addition, geography matters because of the interactive nature of the innovation process, when increasing reliance on external knowledge and technology sources implicitly suggests strong links to geography. Knowledge-creating systems contribute to the differentiation of national or regional space in which firms are rooted (Maskell and Malmberg 1999). With a systemic approach to innovation, the concepts of national or regional systems of innovation put major emphasis on the importance of localised institutions, culture and history in the innovation and diffusion processes (Freeman 1995, Patel and Pavitt 1994b, Nelson 1996).

The concept of the 'learning' or 'knowledge-creating' region within which firms operate has been defined by extending the competence perspective from the analysis of the firm to that of the region (Enright 1998, Lawson 1999, Maskell and Malmberg 1999). The region's learning process is seen as sector-specific and path-dependent, grounded in the local specific institutional context. States or regions that contain concentrations of innovative inputs in some fields of production will develop a comparative advantage in the fields in question. Since the path-dependent nature of technology, geographical areas exhibit a sector-specific character, which is rooted in their history (Arthur 1989, 1990). Knowledge accumulation mechanisms in turn lead to further geographical concentration and industrial specialisation, and consequently persistent differences in innovation and growth among locations. The dynamics may nevertheless imply geographical areas being 'locked in' into a particular pattern of technological specialisation, and the emergence of a phenomenon of inertia. As a consequence, locations would be constrained in their technological development by their own prior accumulation of competencies, which tends to be sector-specific and persist over time.

Although significant spatial clustering of industrial activity (innovative and economic) is observed, the sources and dynamics of these externalities, external economies or 'agglomeration economies' vary across locations and are difficult to isolate empirically (Almeida and Kogut 1999, Appleyard 1996, McCann 1995, Gordon and McCann 2000). Agglomeration economies stimulate innovation, productivity and growth in the geographical area, as well as attract new firms to the area. The economic benefits of local external economies are traditionally described in terms of economies of scale in transaction costs achieved by firms through labour pooling (e.g. reduced search costs) and sharing of tangible and intangible assets (e.g. more accessible and efficient local services, more rapid supplier-firm communication). These supply-side externalities may be supplemented by demand-side ones, that is effects from proximity of local demand, inter-firm rivalry on market shares and lower search costs for customers (Swann 1998). As already discussed, agglomeration benefits in the innovation literature are increasingly shown to include dynamic knowledge accumulation effects, spillovers and information flows of a more complex and social nature than the traditional ones, enhancing the local innovative and learning capabilities (Malmberg et al. 1996, Maskell and Malmberg 1999). However, spatial clusters may also experience negative externalities or congestion effects as they mature, and/or may be locked in outdated technological trajectories (Audretsch and Feldman 1995, Swann 1998, Baptista and Swann 1998).

As different sources of agglomeration forces have been identified, agglomeration economies may also be classified according to whether they derive from externalities within similar or related industries, or more general economies of the local environment (Malmberg et al. 1996, Porter and Sölvell 1998). On the one hand, agglomeration economies may derive from the geographical concentration of firms engaged in similar activities or within an industry, leading to further local clustering of related firms and accumulation of knowledge. Spatial clusters benefiting from these 'localisation economies' may develop a cumulative comparative advantage, attracting outside resources in similar or related activities, which may in turn enhance the knowledge accumulation mechanism into specific fields. In this sense, as regards to technological externalities, the concept of technological comparative advantage remains relevant for explaining the geographical spread of innovative activity among European countries and regions, which is associated with the scale and strength of activity in a particular industry. The implication in terms of geographical distribution of activity is that particular industries agglomerate in particular locations.

On the other hand, more general agglomeration economies may arise from the diversity and scale of the local environment as a whole, favouring the emergence of core regional centres[1] because of the presence of multiple sources of externalities and knowledge spillovers across all types of industrial activities into the location. In this sense, as regards to technological externalities, these external economies relate more generally to the overall scale of innovative activity in the area, associated with the size and strength of the geographical concentration as a whole. The implication in terms of geographical distribution of activity is that most innovative activity would be concentrated in the largest centres. The two types of externalities may play an important role into the creation and diffusion of technological knowledge and affect differently the strength of the local growth (Cantwell and Iammarino 1998).

There is some evidence relating to cities in the US that diversity across industries may promote innovation and knowledge spillovers better, and prevail in the core, metropolitan areas (Feldman and Audretsch 1999). In high technology industries such as computing and biotechnology, a mix of industrial sectors and a strong science base would provide more opportunities for the creation of new firms, while incumbent firms would benefit more from clusters which are strong in their own industrial sector (Swann, Prevezer and Stout 1998). Core clusters with industry variety may be better disposed to generate higher innovative activity and attract new firms compared with smaller and more specialised clusters, although they may become congested.

At the level of specific technologies, multi-technology clusters, similarly to multi-technology firms, are argued to be fitter to survive and adapt to an increasingly turbulent technological environment. The argument was discussed at the firm level from the observation that large firms are typically active in a wide range of technologies and more diversified in their technologies than in their product range (Patel and Pavitt 1994a, 1998). This emphasised that most technologies would reflect the need for broader or 'background' competencies to enable the firm to benefit from external knowledge, which is especially useful in industries with complex products or production processes and to survive technological radical breakthroughs. Similarly, a location's ability to monitor and take advantage of advances in outside technological and scientific knowledge or capture knowledge 'spillovers' has a significant role in the generation of technology. From a competence-based and evolutionary approach, nations or regions need to develop innovative and learning capabilities in order to innovate, but also imitate or absorb outside innovations. A wider range of technologies may reflect a stronger accumulated knowledge base and support the

[1] A 'centre' is here broadly defined as a set of firms and/or activities that exist in the same local

development of agglomeration economies whether across or within industries. Specialisation of innovative activity into one industry may be a rewarding strategy for a location's development providing its indigenous ability to develop and exploit a relatively wide range of technological competencies in that industry.

A locational hierarchy

Firstly, the paper argues that a geographical hierarchy of locations can be established for every industry according to the strength of their technological specialisation in that industry, and referring to the corresponding characteristics of each local innovation systems that are built on unique historical conditions. Therefore, an industry-specific hierarchy of geographical locations may be drawn that refers to considerations on the sources and development of national (or regional) comparative advantage.

Secondly, general agglomeration forces would also play an important role in explaining the geographical concentration of innovative activity that pushes to the emergence of a core-periphery structure across locations over time. The paper argues that core-periphery and industry-specific hierarchies are not necessarily equivalent, and comparative advantages still matter. It suggests that locations evolve differently according to their position in a more broadly defined hierarchy and, in particular, that it affects their performance and the technological specialisation of their domestic firms and foreign-owned affiliates across and within industries.

A higher order centre is defined as one location that has accumulated relatively high levels of innovative activities, tends to have the greater indigenous capability and a relatively broad profile of technological specialisation. What matters more is the locally accumulated stock of knowledge. A lower order centre is an area that has developed lesser innovative and learning capabilities, and demonstrates relatively small accumulation of knowledge. It tends to be more narrowly specialised in few technological fields.

This paper suggests that three broadly defined types of locations may be identified:

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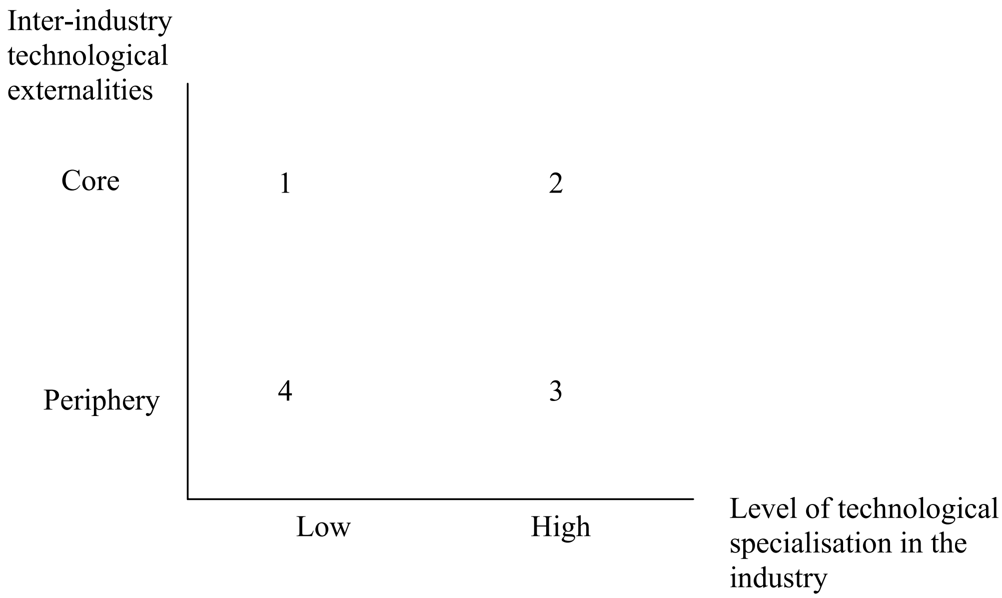
environment, defined as to incorporate economic, social, cultural and institutional factors.

- ‘Core’ regions or nations are higher-order locations that, although characterised by their own industrial specificity, accumulate a wide range of technological competencies and develop inter-industry spillovers in pervasive or ‘general purpose’ technologies (e.g. information technology and mechanical technologies) (Bresnahan and Trajtenberg 1995). Their broad technological competencies may also allow for a more efficient identification and integration of opportunities arising from the new pervasive technologies such as information technology, new material and biotechnology. These locations are closer to the central and most prosperous locations of the EU (e.g. Greater London in Britain, Ile de France in France, central Germany and Northeast Italy). They may experience both localisation and more general agglomeration economies.
- ‘Intermediate’ regions or nations are higher-order locations within a specific industry. These locations are more specialised and have a strong indigenous base into a particular industrial sector. They accumulate a wide range of technological competencies particular to that industry that may provide opportunities for further technological development. These locations are more prone to develop intra-industry spillovers in specialised technological fields.
- ‘Lower-order’ locations are at the bottom of the hierarchy and demonstrate only weak indigenous competencies in any industry. These locations are more narrowly specialised at the industry and technological levels, and more likely to be found at the periphery of the EU. These locations may generate some localisation economies, mostly achieved on the basis of more traditional economies of scale.

A ranking of locations defines ‘higher’ to ‘lower order’ centres, representing the two extreme ends of a spectrum of possible positions in which a location may be classified. Furthermore, locations may evolve in one or the other direction over time, upgrading and further accumulating knowledge or declining, depending on their prior level of indigenous innovative capabilities. The most dynamic externalities in the indigenous environment, including technological spillovers and localised knowledge flows, would be more likely to promote sustained performance and upgrading mechanisms (Malmberg et al 1999). Congestion, lock-in and inertia phenomenon would be more likely to contribute to a decline of the centre. Because of the dynamic nature of the learning mechanisms involved it is difficult to estimate the precise magnitude and significance of the hierarchy produced.

Figure 1 suggests a conceptual basis for defining a hierarchy in a particular industry. The identity of location and the extent to which technological activity becomes geographically dispersed is expected to vary for every industry. The vertical and horizontal axes reflect differences in the ranking of locations according to the type of externalities generated, operating respectively at (1) the general level and (2) the level of similar or related industries, approximated by the location's degree of specialisation in the particular industry.

Figure 1: broad typology of locations in one particular industry



There are different types of locations that may benefit (or not) from different types of externalities. Locations that generate the most inter-industry technological externalities are core locations that can be represented in areas 1 and 2 on the figure. If core locations are also specialised into the selected industry and generate intra-industry technological externalities, they are classified into area 2 as opposed to area 1. Intermediate locations belong to area 3 and lower-order locations area 4. For every industry there can be several distinct intermediate higher-order centres that do not necessarily correspond to the core locations. Therefore, industries' innovative activity would not have a tendency to all concentrate in the core locations over time, i.e. locations would not tend to belong all to areas 2 and 4 only.

In addition, the path-dependent and cumulative nature of technological learning would imply a long-term international differentiation in localised technological patterns not only at the industry, but also at the more precise technology level. An assessment of any location's technological positions and strengths or weaknesses over time would need to take into account the specific social, cultural and institutional factors that have influenced the selection of industrial and technological sectors promoted or left behind. All centres that are specialised in the same industry are still expected to have distinct technological focuses from one another at the more precise technological level.

3. Locational Hierarchy and the Impact of Multinationals

The role of MNCs has been stressed as increasingly becoming the main source of both the creation and diffusion of technology. Large MNCs have increasingly adopted an internationally integrated approach to their technological development, reorganising a more refined international (and within the EU) division of labour within industries as well as between them (Dunning 1996, Zander 1995). The growing role of the reorganisation of technological activity of MNCs as a source of competitive success has become recognised to have an important impact on the shape and character of local innovation systems and growth prospects (Dunning 1996, Nelson 1996). Globalisation makes the understanding of locational specificity more important. Although it is empirically difficult to distinguish between the various aspects of the nature of the linkages between the multinational firm and geographical centres, it is still possible to analyse the effects that they have in particular cases. The role of MNCs in shifting the geographical dispersion of the creation of new technology across affiliates is affecting the technological profile and capabilities of their particular home and host countries in Europe. From a location perspective, this paper discusses the most prominent features of these effects that refer to the geographical concentration and specialisation of innovative activity into different locations.

The impact of MNCs will vary between industries and, for a given industry, the impact is argued to depend on the relative position of their home and host locations in a geographical hierarchy (Janne 2002). On the one hand, the ability of MNCs to make use of internationally integrated networks and the composition of their foreign-located technological activity have been argued to depend on the relative position of their home location in a geographical hierarchy (Cantwell and Janne 1999). MNCs originating from higher order locations in an industry are argued to have a higher propensity to pursue internationally integrated strategies for innovation than MNCs from lower order locations, and consequently have a greater impact on the geographical allocation of innovative activities. These MNCs may establish geographically dispersed networks of affiliates that progressively specialise in each location in accordance with local strengths, and perhaps also diversify as a consequence. Their affiliates may be more likely to develop an ability (and ambition) develop their own technological competencies and promote localised inter-firms as well as international intra-firm spillovers. MNCs from lower order centres would rather replicate abroad their own domestic lines of specialisation, treating their host locations as more general reservoirs of resources. The rationale for these arguments is in terms of inter-firm differences in innovative and organisational capability, but also differences in absorptive capacity or the ability to recognise and utilise knowledge from the external environment, which are related to the location-specific characteristics of innovation.

On the other hand, the technological strategies of MNCs in particular locations will also depend on the relative position of their host locations in a geographical hierarchy. Core higher order regional locations may be more likely to attract foreign-owned research because they represent a general source of skills and expertise rather than a source of specific capabilities in some particular fields (Cantwell and Iammarino 1998, 2000, Cantwell and Noonan 2001). Accordingly, locations at the top of the hierarchy would have a broader profile of technological specialisation and attract a broader range of foreign-owned innovative activities than those at the bottom, although they may also locally develop lines of specialisation. By contrast, lower order locations will tend to be more narrowly specialised in a few technological fields and potential foreign-owned research will more likely aim at exploiting that specific indigenous expertise.

The potential impact of MNCs on the concentration of technological activity and its specialisation in any location is argued to depend on the interactions between the

MNCs' international strategies for innovation in that location and the relative position of that location in a geographical hierarchy. It may be discussed in terms of the strategies of the indigenous MNCs, the impact and type of foreign-owned affiliates attracted.

Firstly, inward and outward technological investments are likely to create complementary opportunities for the upgrading and widening of the local knowledge base of the leading higher order locations. Indigenous MNCs 'augment' their home-based technological assets by tapping into foreign sources, while the relative strength of indigenous innovative capabilities may encourage a positive interaction between foreign-owned and local innovative activity and a reinforcement of the local innovative capacity. Furthermore, locations at the top of the hierarchy tend to have a broader profile of technological specialisation and attract a broader range of foreign-owned innovative activities than those at the bottom. For intermediate and lower order centres, the presence of MNCs may have a beneficial or an adverse impact on the development of indigenous technological capability, depending on the strength of the indigenous base. As local expertise is relatively specialised in specific fields, foreign-owned affiliates may in this case be competing more directly with indigenous rivals, and dominate and/or eventually displace the local technological capacity of indigenous firms. Conversely, foreign-owned MNCs may as well strengthen a location of specific excellence and support the development of related complementary activities within a particular industry. Some intermediate higher order centres have traditional indigenous capabilities in a specific industry which can be supported and upgraded by foreign-owned research as well as own MNCs. In addition, strong indigenous firms in a particular industry may compete with foreign-owned firms of the same industry and deter some of them from establishing in the same area.

Secondly, the emergence of more closely integrated international networks in the organisation of MNCs is likely to reinforce countries' or regions' patterns of technological specialisation, especially when these operations are located in an economically integrated region such as the EU. Whilst specific innovative activities remain embedded in dispersed locations, a potential systemic advantage of MNCs is to be able to access such disparate sources of knowledge, building networks of learning through the development of internationally integrated strategies for innovation. Countries have tended to narrow their technological specialisation and become more focused on areas of historical competitive advantage. Simultaneously, the major firms, as a result of a shift towards technology-sourcing strategies, have tended to disperse research facilities geographically to gain access to complementary paths of technological development to support their core strengths (Cantwell 1995, Cantwell and Janne 1999). In this sense, the processes of technological globalisation and geographical specialisation may be complementary.

As they engage in greater cross-border technological differentiation, MNCs originating from higher order centres are more likely to reinforce the specialisation characteristics of the foreign locations in which they invest than MNCs originating from lower-order centres. By contrasts, MNCs from lower order centres, as they replicate abroad their established lines of specialisation, would rather contribute to a broadening of activity in the locations to which they are attracted. In addition, affiliates originating from a higher order centre tend to have a stronger impact on the host location's innovative capability than affiliates originating from a lower order centre by promoting more actively either localised inter-firms and/or more global intra-firm spillovers depending on the strength of the indigenous base. On the one hand, they will be better able and therefore more likely to interact with the local business environment, create local inter-firms networks and contribute to the local knowledge pool if the indigenous technological environment is relatively strong. On the other hand, they will be more likely to tap into available specialised resources and focus more on intra-firm integration of knowledge within the multinational network if the indigenous base is weak, which may have an adverse effect on the host location's innovative capability.

4. Hypotheses

The paper's main hypotheses from a host location perspective may be summarised as follows. Hypotheses 1 and 2 concern the concentration and specialisation of innovative activity, and hypotheses 3 and 4 the impact of MNCs.

1. The concept of technological comparative advantage still matters to explain the geographic concentration of innovative activities in Europe, referring to the

sector-specific characteristics of local innovation systems and emphasising on dynamic agglomeration forces. Core-periphery and industry-specific hierarchies do not necessarily overlap, and different phenomena of agglomeration may be specific to particular types of locations.

2. Locations show different technological characteristics, and in particular, different technological specialisation patterns of their firms, according to their position in the broadly defined hierarchy. Locations closer to the top of the hierarchy would have a broader profile of technological specialisation than those at the bottom, although they also locally develop lines of specialisation. Lower-order locations would tend to be more narrowly specialised in a few technological fields that are relevant to a particular industry.

3. The extent to which a location may potentially benefit from foreign-owned MNCs depends on the characteristics and strength of its indigenous base. A relatively strong indigenous environment may be better able to encourage positive feedback between foreign and indigenous innovative activity through localised inter-firms spillovers for innovation than a relatively weak environment. Simultaneously, a strong indigenous base will attract a relatively large proportion of MNCs that want to access its general or specialist expertise and facilities.

   As a consequence, foreign-owned affiliates located in core and intermediate strong locations are likely to offer opportunities for the upgrading of the indigenous technological capability. In locations that are the lowest in the hierarchy, foreign-owned affiliates that compete with indigenous firms to tap into local specialised resources may gradually dominate and supplant them.

   In this context, MNCs originating from higher order centres are more likely to have a significant impact on the further development or decline of the host indigenous innovative capability than MNCs originating from lower order centres.

4. The specialisation pattern of intermediate and lower-order locations is likely to be reinforced by the innovative activities of their foreign-owned MNCs. This is

particularly likely the higher is the position of MNCs' location of origin in the hierarchy, as they have a higher propensity to pursue a strategy of cross-border technological differentiation than wider replication of own established technologies. By contrast, core locations are likely to attract a wide range of MNCs conducting a wide range of technological activities that contribute to the accumulation of a more general local knowledge pool.

One implication is that dominant foreign affiliates in lower-order locations may focus locally on a type of technological specialisation that conflict with the host location's objectives, for example when associated with low value-added activities.

5. Some preliminary empirical evidence in the European chemical and pharmaceutical industry

A preliminary investigation of the innovative activity of the German, British and Belgian regions in the chemical and pharmaceutical industry is presented in this paper, with a focus on hypotheses 1 and 3.

The technological specialisation of firms in specific locations and the position of locations in Europe are examined using data on European-located firms' patents granted in the US for the 1969-95 period. The limits as well as significance of patent statistics as an indicator of technological innovation have been investigated in the literature (e.g. Acs and Audretsch 1989, Griliches 1990, Archibugi 1992) and will not be repeated here. In particular, patent data offer the most accessible and detailed internationally comparable indicator for innovative activities across technological sectors. The patent database distinguishes the name of the patenting company (and therefore its country of origin), the location of the corporate research facilities responsible for the invention, and the type of technology being created. Large firms have also been allocated to their primary industry of output according to the product distribution of their sales and the chemical and pharmaceutical industrial group was selected. German, British and Belgian regions are defined according to the Nomenclature of Territorial Units for Statistics (NUTS) established by Eurostat as an agreed definition of the European member states' regions[2]. Patents were attributed to regions at the NUTS 1 level according to the location of investors.

The relative specialisation patterns of firms located into one region have been calculated using 'Revealed Technological Advantage' (RTA) indices across industrial groups. The RTA index in a particular industrial group i of all firms located in a specific region r is defined as these firms' share of world patenting in that industry, relative to their share of total world patenting:

$$RTA_{ir} = (P_{ir} / \Sigma_r P_{ir}) / (\Sigma_i P_{ir} / \Sigma_r \Sigma_i P_{ir})$$

Where: P_{ir} = number of US patents granted in the industrial group i to firms located in a particular region r

The index varies around unity, so a value greater than one suggests that the group of firms is comparatively advantaged or specialised in the considered industrial activity compared to other firms, and a value less than one shows comparative disadvantage.

Following hypothesis 1, a geographical hierarchy of regional centres can be established for the chemical and pharmaceutical industry according to the strength of their technological specialisation in that industry. German, British and Belgian regions are ranked according to the strength of their technological specialisation, or 'revealed advantage', for the purpose of defining a regional hierarchy in that industry in Table 1. Leading, higher order centres in the industry are expected to be those that have the highest comparative technological advantages, measured by the RTA index and inversely for lower order centres. However, small regions that have been granted only low number of patents in the US may show substantial inter-industry variation in the RTA index and some very high or low values that may be misleading for the purpose of cross-region comparison. The hierarchy should not be interpreted too strictly but considered in a broader context, allowing for a more qualitative assessment of European regions. More information would also be needed in order to

[2] The NUTS nomenclature provides a uniform and in principle coherent hierarchical breakdown of territorial units for the EU, which is essentially based on the updated institutional divisions in the member states (Eurostat 1995).

evaluate the actual significance of slightly different values of the RTA index for different locations, e.g. where several - ‘higher order’ - centres exhibit RTA values well above one.

In addition, regions may generate more general agglomeration economies across industries, leading to the emergence of core centres that are likely to be the largest, most prosperous, populated and centrally located in Europe. A hierarchy of core and peripheral regions can therefore be identified, using data on regions’ overall economic significance (GDP per capita), population density (population/km^2) and overall relative amount of technological activity (patents per capita) as shown in Table 1. Hence, the proposal that core-periphery and industry-specific hierarchies differ from each other may be investigated by calculating correlation coefficients between the technological comparative advantage of regions in the chemical and pharmaceutical industry, as measured by the RTA index, and the other variables reflecting regions’ importance as above described. Rank correlation coefficients are presented in Table 2. None of the variables associated with the size and economic significance of regions is significantly correlated to the RTA index of industry specialisation, which would support hypothesis 1.

[Tables 1 and 2]

The geographical concentration of innovative activity of indigenous and foreign-owned firms in German, British and Belgian regions is shown in Table 3, as well as the overall contribution of foreign-owned firms in total regional research activity. These may be used to investigate further the regions’ characteristics and their position in a more broadly defined hierarchy. The relative importance of regions in the hierarchy is argued to influence the amount, type and significance of foreign-owned activities and, as a consequence, the location and technological strategy of MNCs that they attract.

[Table 3]

According to hypotheses 3, the proportion of technological activities that is foreign-owned is expected to be higher in core and lower-order regions than in intermediate ones. While core locations may attract a wide range of numerous MNCs conducting a wide range of technological activities and regard affiliates as offering opportunities for the upgrading of the indigenous technological capacity, lower-order locations may conversely perceive a potential technological dependency problem from the presence of foreign-owned MNCs. The technological comparative advantage of a strong intermediate higher-order location in one industry is likely to attract the development of foreign-own technological activities into that industry by providing access to a specialised local knowledge pool and inter-firms networks for innovation. However the proportion of the location's technological activity which is foreign–owned is expected to remain relatively small compared to the strong indigenous capacity. The strong competitiveness of local firms in the chemical and pharmaceutical industry may also tend to discourage some of the potential inward investors in that industry.

Spearman's correlation coefficients are presented in Table 4 for the distributions across regions of the RTA indices in the chemical and pharmaceutical industry, patents granted to indigenous and foreign firms and foreign-owned share of total patents for 1969-95 (as shown in Table 3). The geographical distributions of indigenous and foreign patenting are significantly positively correlated as well as respectively with the RTA distribution. This is consistent with the proposal that overall foreign-owned affiliates are increasingly attracted to the regions to tap into the local resources for innovation. Foreign-owned affiliates in the chemical and pharmaceutical industry tend to establish in regions which have a technological comparative advantage in that industry and host the most indigenous firms. There is no significant correlation with the foreign-owned shares of the total patents of regions, coherently with the proposal that the foreign–owned proportion of region's technological activity is high for 'general core' and lower-order regions, and low for 'specialised core' and intermediate regions.

[Table 4]

At the national level, the share of patents attributed to foreign-owned research represents about 7 per cent of the total in Germany, 37 per cent in the UK and 86 per cent in Belgium (Table 3). The relatively low proportion of patenting activity attributed to foreign-owned firms in Germany may reflect the strong higher order position of Germany and indigenous German firms in the chemical and pharmaceutical industry.

A regions' hierarchy may be discussed into more details referring to Tables 1 and 3. The principal German, British and Belgian innovative regions in the chemical and pharmaceutical industry are identified and a hierarchy is investigated according to their specific characteristics in terms of industry-specific specialisation, patents and GDP per capita, population density, attractiveness for and dependence on foreign-owned MNCs.

The regional distribution of indigenous and foreign-owned firms' patents in Germany concentrates in five Länder, accounting for about 95 per cent of the total number of patents attributed to research (indigenous or foreign-owned) in this country (Table 3). These regions are Baden Wuerttemberg, Bayern, Hessen, Nordrhein-Westfalen and Rheinland-Pfalz. Relatively small regions in terms of innovative activity include the five regions from former East Germany (i.e. Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt and Thueringen). Baden Wuerttemberg and Bayern are not among the top regions when ranked according to the relative strength of their specialisation in the chemical and pharmaceutical industry (Table 1). These regions also host in relative terms the most patents from foreign-owned research (28.1 and 22.4 per cent respectively in Table 3). In these regions, the contribution of foreign-owned research to regional totals is higher than the national average (25.8 and 12.7 per cent respectively compared with 7.3 per cent on average).

This suggests that the location decisions of foreign-owned firms in these regions go beyond the mere existence of a relevant indigenous knowledge specialisation in the chemical and pharmaceutical industry, taking into account broader or general regional advantages. These two bordering regions are identified in the literature as core regions at both the levels of Germany and Europe. They are described as dynamic centres which benefit from locational advantages associated with attractive overall economic and social infrastructures (European Community 1993, Commission of the EC 1990, 1994, Cantwell and Noonan 2001, Cooke and Morgan 1994). They have relatively high values of patents and GDP per capita. Foreign-owned firms may have been attracted to these regions by their transport, telecommunication, and educational or other institutional infrastructures, including dynamic networked small and medium size companies, known as 'Mittelstand'. The geographic proximity of Baden Wuerttemberg to France and Switzerland may also have been a reason for the establishment of foreign-owned firms in that region. For example, Baden Wuerttemberg has attracted foreign-owned firms in the areas of general engineering, mechanics and electronics due to its local engineering strengths related to the motor vehicle industry (Cantwell and Noonan 2001). However, indigenous research in this industry is relatively well represented in the two regions (Table 3: 6.3 and 12.1 per cent of total national domestic patenting), especially in Bayern as corroborated by its RTA index of just about 1 (Table 1).

[Table 2]

Nordrhein-Westfalen, Hessen and Rheinland-Pfalz are the three regions in which indigenous research is most concentrated, representing respectively 41.8, 19 and 16.2 per cent of total indigenous patenting (Table 3). Table 1 indicates a particularly strong technological advantage of these länder in the chemical and pharmaceutical industry, with Rheinland-Pfalz recording the highest value of the RTA index at 3.25. Controlling for regional size and overall performance, the three länder also show high performances in terms of patents per capita and GDP per capita, but an average population density (Table 1). The indigenous regional strength in the industry, which reflects Germany's historical comparative advantages in chemicals and pharmaceuticals, has most likely contributed to the attractiveness of these regions for foreign-owned research facilities as a specialised and also more general reservoirs of expertise in chemical and pharmaceutical technologies. Whilst Nordrhein-Westfalen and Hessen have attracted a substantial share of foreign-owned research in the industry, they have amongst the lowest proportion of the respective regional totals attributed to the innovative activity of large foreign-owned firms (3.6, 4.8 and 1.5 per cent respectively in Table 3). The strength of indigenous innovative activity may suggest that foreign-owned affiliates' research is feeding into these higher order regional centres in the chemical and pharmaceutical industry, as well as tapping into the local knowledge base.

Niedersachsen has the particularity, as presented in Table 3, of playing host to a significant amount of foreign-owned research activity (8.4 per cent), although it is a less attractive location to indigenous German firms (1.6 per cent). While the region is comparatively specialised in the chemical and pharmaceutical industry, it is not highly ranked (Table 1), and nearly a third of its patenting activity (29.2 per cent) is accounted for by foreign MNCs (Table 3). Cantwell and Noonan (2001) have found a significant overall increase of foreign-owned research activity in this region over the same period 1969-95. Although innovative activity overall is not highly concentrated in Niedersachsen (as measured by patents per capita), it is relatively well placed in terms of GDP per capita and population density (Table 1). It may be argued that Niedersachsen has benefited from its geographical proximity with the strong indigenous centre of Nordrhein-Westfalen in the chemical and pharmaceutical industry. In this sense, congestion effects in the higher order region may have 'pushed' foreign firms to locate instead in the adjacent region (Cantwell and Noonan 2001).

In the UK, the two most important regions for the concentration of indigenous and foreign-owned firms are the South East and North West (Table 3). Foreign-owned research has agglomerated particularly in the South East, accounting for about 57 per cent of total foreign-owned activity in the UK. The South East, including the Greater London area, is the most prosperous region of the UK and has been identified as a core British centre (Cantwell and Iammarino 2000, Harris 1988). As similarly discussed in the case of Baden Wuerttemberg, foreign-owned MNCs may have been mostly attracted by the general characteristics of the regional system of innovation rather than more industry-specific local expertise. As argued by Cantwell and Iammarino (2000), the overall British model is similar to that of the South East, characterised by agglomeration economies in a broad range of sectors, whose dynamism may be defined in terms of the socio-economic local environment (e.g. general expertise, services and infrastructure,…). A lower order region such as the South West has a weak indigenous activity in the industry, and some foreign-owned presence that may have be owing to its close geographical proximity to the South East.

Contrary to the German länder, large company research in the British regions is more dependent upon foreign-owned companies. The South East is significantly dependent upon foreign-owned firms where they account for 44.2 per cent of the total. Furthermore, it has a comparative advantage in the chemical and pharmaceutical industry, with a RTA value of 1.33 (Table 2), which may also reflect British indigenous competencies in this industry (Cantwell and Hodson 1991, Cantwell et al 1999). In the chemical and pharmaceutical industry, an increase in foreign-owned activity has nevertheless been associated with a process of reinforcement of national indigenous strength (Cantwell et al 1999), although this might not be the case for every individual region. The important and relatively increasing proportion of foreign-owned research in the UK relative to that of indigenous firms has found differing interpretations (Cantwell et al 1999). This trend may reflect the restructuring of British-owned firms and consequent relocation of some of their research facilities abroad, along with a move of MNCs to more internationally integrated strategies for innovative activity. It may also mirror a more liberal British approach to inward and outward foreign direct investments.

In the North West, indigenous firms' concentration of research activity (29.9 per cent) is twice as important as that of the research undertaken by foreign-owned affiliates (15 per cent), and the proportion of foreign-owned patents (22.8 per cent) is lower than the national average (Table 3). Overall, the North West shows a significant comparative advantage in the chemical and pharmaceutical industry (RTA of 2.29). Hosting research facilities of all the largest British-owned companies in the chemical and pharmaceutical industry and attracting foreign investments, the North West may be considered as an important intermediate regional centre in the UK for that industrial group.

In Belgium, Vlaams Geweest holds the highest share of the total number of patents granted to large firms located in that country, followed by the region of Brussels. A significant innovative gap is often stressed between these two regions and Région Wallonne. Indigenous research activity in the chemical and pharmaceutical industry is led by the Solvay company which, although mainly located in Brussels, carries out some research as well in both Vlaams Geweest and Région Wallonne. By contrast, foreign-owned innovative activity is greatly concentrated in Vlaams Geweest, accounting for over 80 per cent of patents granted to foreign-owned firms. While Brussels and Vlaams Geweest are highly specialised in the chemical and pharmaceutical industry (RTAs of 2.27 and 2.71 respectively in Table 1), they both depend heavily on foreign-owned research, which may also correspond to the above-average external openness of a small country such as Belgium. The contribution of foreign-owned research in Vlaams Geweest is especially high, accounting for an above-national average share of 96.1 per cent (Table 1). The regional number of patents per capita for Vlaams Geweest seems relatively low when compared to other regions (Table 1), which may indicate a relatively poorer performance overall. The values of GDP per capita and population density are relatively high and may reflect the relatively centralised position of the region in the EU.

The analysis indicates that Baden Wuerttemberg, Bayern and the South East regions can be defined as 'core' higher order regions, owing to their strong indigenous position, overall strength, attractiveness to foreign-owned MNCs and lack of strong specialisation in the chemical and pharmaceutical industry in particular. Nordrhein-Westfalen and Hessen may be identified as 'core' higher order region generally but also more specifically in the chemical and pharmaceutical industry. These regions concentrates indigenous activities and foreign-owned affiliates in the industry and their domestic firms' patenting activity dominates over the total of patenting emanating from the regions. The North West may be considered as a specialised intermediate higher order centre in the chemical and pharmaceutical industry in which indigenous capabilities have developed. Vlaams Geweest may be seen as lower in the hierarchy to account for its relatively high specialisation and higher dependence on foreign-owned research. Niedersachsen may similarly depend on its proximity to Nordrhein-Westfalen. Weaker regions such as South East, Scotland, Northern Ireland and former Eastern European regions are lying closer to the bottom end of the hierarchy.

The hierarchy produced needs to be evaluated with flexibility as a continuum of possible positions in which a region may be classified and a dynamic approach would also be required to account for the evolution of regions over time. Finally, it is also argued that regions may offer a different variety of technological knowledge and expertise and incentives to firms according to their position in the hierarchy, relating to hypotheses 2 and 4. The technological specialisation of foreign-owned affiliates in each location would become more closely related to the local indigenous specialisation pattern and reinforce the region's specialisation the higher is the position of their parent firms' location of origin, and the lower is the position of the host location in the geographical hierarchy. This needs to be investigated in future research.

6. Conclusions

A better understanding of the forces behind the technological agglomeration and specialisation of locations, their characteristics and limitations may help locations formulate policies to achieve greater control over the development of their innovative capability. There is a need to identify the diversity of roles that different types of agglomeration externalities and MNCs may play. In this context, the ability of locations to develop and operate different strategies for their technological activities is claimed to depend on their position in a geographical hierarchy.

This paper argues that there are different phenomena of agglomeration explaining the pattern of spatial concentration of innovative activity, based on specialised or general technological externalities, which are specific to particular types of regions and can be used to draw a geographical hierarchy. It provides a conceptual basis for defining such a hierarchy, identifying core, intermediate and lower-order locations, which is industry-specific and increasingly influenced in its dynamics by MNCs. In this sense technological comparative advantages still matter to explain the spatial agglomeration and dispersion of innovative activity. The technological strategies of MNCs also influence both the host locations in which MNCs operate and their home location. In particular, the emergence of more integrated international networks in the organisation of MNCs is likely to have an impact on the accumulation and specialisation mechanisms of innovative activity across locations, especially when these operations are located in an economically integrated region such as the EU.

The paper suggests a hierarchy of German, British and Belgian regions for the chemical and pharmaceutical industry. It is built according to the strength of the regions' technological specialisation in the industry and takes into account other location characteristics such as the location's performance, population density, its attractiveness for and dependence on foreign-owned MNCs. As different patterns emerge and run simultaneously, the problem remains for a region to identify or forecast changes in indigenous technological capabilities, and the role of foreign firms in the process. From a host location perspective, the paper argues that the types of agglomeration forces at play in the region, strategies by incoming MNCs and their interaction are important factors to consider. The characteristics of the geographical pattern of technological activity for any industry, which defines a hierarchy of locations, allow to ascertain the kind of foreign-owned MNCs that a location attracts and their likely impact on the local structure of technological activity and competitiveness.

Further research is required on the specific factors that promote or inhibit the ability of locations to leverage or upgrade indigenous fields of innovation and benefit from MNCs. The literature on the geography of innovation has emphasised the role of dynamic agglomeration externalities such as knowledge spillovers and the importance of information and communication technologies, mobility of the labour market and a common set of organisational norms, values and routines for its creation. There is also wider scope for further research on the role and behaviour of MNCs' subsidiaries.

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Table 1: values of Revealed Technological Advantages (RTAs) in the chemical and pharmaceutical industry, total patents per capita, GDP per capita and population density by host region, ranked according to the RTAs for the purposes of determining a hierarchy.

Region	RTAs index 1969-95	Patents per capita (100,000 people) 1969-95	GDP/per capita (PPP) EUR12=100	Population density (pop/km2)
Rheinland-Pfalz	3,25	215,38	100,9	193
Vlaams Geweest	2,71	45,48	105,7	428
Nordrhein-Westfalen	2,70	148,29	110,8	514
North	2,69	38,67	85,3	201
Hessen	2,52	220,44	140	276
North West	2,29	76,59	90	872
Brussels	2,27	64,36	164,4	5922
Berlin	1,86	108,97	116,3	3876
Scotland	1,68	18,46	92,8	65
Yorkshire and Humberside	1,65	30,59	89	323
Wales	1,65	34,09	83,2	139
Thueringen *	1,59	3,28	30	158
Région Wallonne	1,45	28,26	84,2	194
South East	1,33	96,99	119	648
East Anglia	1,26	49,64	99,8	165
Sachsen *	1,13	2,96	33	255
Niedersachsen	1,03	46,80	101,9	158
Bayern	1,02	191,43	120,9	164
Sachsen-Anhalt *	0,91	2,36	35	137
Saarland *	0,88	18,92	107,6	419
Brandenburg *	0,80	3,03	36	88
Baden Wuerttemberg	0,77	187,03	124,5	280
Northern Ireland *	0,76	2,66	75,1	113
Schelswig-Holstein	0,57	39,81	96,9	168
Hamburg	0,45	66,77	194,5	2209
East Midlands	0,40	52,09	94,5	258
South West	0,37	41,02	94,8	198
West Midlands	0,28	82,42	90,5	405
Bremen *	0,16	26,08	149,7	1691
Mecklenburg-Vorpommern *	0,03	6,01	33	80

Note: * indicates a number of patents less than 50 for 1969-95

Source:
Patents: 1969-95, US patent database developed at the University of Reading, with the support of the US Patent and Trademark Office.
Population: average in 1984 (Eurostat 1991), average at 1.1.1990 for former Eastern European regions (Commission of the European Community 1990)
Population density: population/km2 1991 (Commission of the European Community 1994)
GDP per capita: average 1989-91 GDP per capita (PPP) EUR12=100 (Commission of the European Community 1994)

Table 2: Spearman's correlation coefficients between the RTA distribution across regions and the other variables as in Table 1.

Spearman's coefficients Significance (2-tailed)	RTA	PATCAP	GDPCAP	DENSITY
RTA	1,000			
	.			
PATCAP	0,314	1,000		
	(0.091)	.		
GDPCAP	0,092	0,715 **	1,000	
	(0.628)	(0.000)	.	
DENSITY	0,187	0,519 **	0,657 **	1,000
	(0.323)	(0.003)	(0.000)	.

Notes: 30 regions
** Correlation significant at the .01 level (2-tailed)
RTA: RTA index in the chemical and pharmaceutical indutry
PATCAP: total patents 1969-95 per capita
GDPCAP: average 1989-91 GDP per capita (PPP) EUR12=100
DENSITY: population/km2 in 1991
Source: Table 1

Table 3: Patents grants to indigenous and foreign-owned firms in Germany, the UK and Belgium, and foreign-owned companies' percentages of total patents, by host regions for the activities of large firms in the chemical and pharmaceutical industry, 1969-95 (%)

Region	Indigenous firms	Foreign-owned firms	Foreign shares
Baden Wuerttemberg	6,3	28,1	25,8
Bayern	12,1	22,4	12,7
Berlin	2,4	0,7	2,3
Brandenburg *	0,0	0,0	6,3
Bremen *	0,0	0,1	57,1
Hamburg	0,2	1,8	45,5
Hessen	19,0	12,1	4,8
Mecklenburg-Vorpommern *	0,0	0,0	0,0
Niedersachsen	1,6	8,4	29,2
Nordrhein-Westfalen	41,8	20,2	3,6
Rheinland-Pfalz	16,2	3,1	1,5
Saarland *	0,1	0,2	13,6
Sachsen *	0,1	0,6	43,9
Sachsen-Anhalt *	0,0	0,1	18,8
Schelswig-Holstein	0,2	2,0	40,5
Thueringen *	0,1	0,1	11,4
Germany	**100,0**	**100,0**	**7,3**
(Total patents = 41,888)			
North	9,1	3,4	17,8
Yorkshire and Humberside	6,4	3,7	25,6
East Midlands	1,6	2,0	42,6
East Anglia	0,9	5,6	78,9
South East	42,3	57,2	44,2
South West	0,7	2,8	70,8
West Midlands	3,3	1,5	20,7
North West	29,9	15,0	22,8
Wales	2,7	4,7	50,6
Scotland	3,2	3,9	42,1
Northern Ireland *	0,1	0,1	50,0
The UK	**100,0**	**100,0**	**37,0**
(Total patents = 11,535)			
Brussels	52,1	9,0	51,1
Vlaams Geweest	19,7	80,8	96,1
Région Wallonne	28,2	10,2	68,6
Belgium	**100,0**	**100,0**	**85,8**
(Total patents = 2,474)			

Note: * indicates a number of patents less than 50 for 1969-95
Source: US patent database developed at the University of Reading, with the support of the US Patent and Trademark Office.

Table 4: Spearman's correlation coefficients between the distributions across regions of the RTA index indigenous, foreign-owned patents and foreign-owned percentage of total patents in the chemical and pharmaceutical industry, 1969-95

Spearman's coefficients Significance (2-tailed)	INDIG	FOREIGN	FSHARE	RTA
INDIG	1,000			
	.			
FOREIGN	0,870 **	1,000		
	(0.000)	.		
FSHARE	0,057	0,244	1,000	
	(0.766)	(0.194)	.	
RTA	0,682 **	0,541 **	-0,165	1,000
	(0.000)	(0.002)	(0.383)	.

Notes: 30 regions
** Correlation significant at the .01 level (2-tailed)
RTA: RTA index in the chemical and pharmaceutical indutry
INDIG indigenous firms patents in the chemical and pharmaceutical industry
FOREIGN foreign-owned firms patents in the chemical and pharmaceutical industry
FSHARE foreign-owned % of total patents from all firms located in the region
Source: Table 3