

# The spatial dimension of patenting by multinational firms in Europe

**Citation for published version (APA):**

Verspagen, B., & Schoenmakers, W. W. M. E. (2002). *The spatial dimension of patenting by multinational firms in Europe*. (ECIS working paper series; Vol. 200211). Technische Universiteit Eindhoven.

**Document status and date:**

Published: 01/01/2002

**Document Version:**

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

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# **The Spatial Dimension of Patenting by Multinational Firms in Europe**

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Working Paper 02.11

Department of Technology Management

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September 2002

# **The Spatial Dimension of Patenting by Multinational Firms in Europe**

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First draft, June 2002

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# **The Spatial Dimension of Patenting by Multinational Firms in Europe**

By Bart Verspagen and Wilfred Schoenmakers

## **Abstract**

We investigate the spatial pattern of patenting by the world's largest multinational enterprises (MNEs). Based on a summary of the theoretical literature on R&D by MNEs and the spatial nature of knowledge generation and knowledge spillovers, we expect spatial concentration of patenting by these large MNEs. A database is developed that provides information on patenting by European region (we use 125 regions) at the aggregated MNE group level. This database is used to describe a number of features of the spatial pattern of patenting by MNEs in Europe. The main findings in this respect are that MNEs patenting activities are strongly concentrated in a relatively small number of regions and that the share of foreign patenting in total patenting varies greatly by firm. In an attempt to shed light on the mechanisms behind these tendencies, we use patent citations to measure the spatial concentration of knowledge flows and spillovers between firms, and within the same firm between different regional locations. For the majority of cases, we find that units between which patent citations occur are located relatively near to each other, which indeed points to the spatial character of patent citations. This holds for between-firms citations and within-firms citations. Moreover, we find a distinct time pattern associated to knowledge flows (as indicated by patent citations): the spatial scope of these flows first broadens but then narrows down again.

## 1. Introduction

Even though the notion of globalization has often been used without a very clear and precise definition, it has been argued that this development makes the role of space disappear (see Morgan, 2001 for an overview of these arguments and further references). The essence behind this argument is that with modern communication technologies, interaction between organizations and people can be effectively implemented over large distances, and hence physical presence is no longer a prerequisite to interact with a region's economic, social and technical system.

At the same time, it has been argued that technology and knowledge generation is an exception to the globalization trend. For example, Patel and Pavitt (1991), in an analysis of patenting by the world's largest multinational enterprises (MNEs), conclude that technology is an important case of 'non-globalization'. By this, they mean that the MNEs in their sample undertake the largest part of their R&D activities in their home base country. However, even their analysis, as well as subsequent evidence provided by, e.g., Le Bas and Sierra (2002), indicates that although the largest part of R&D by MNEs is performed in the home base, the part that is done abroad is non-negligible. For example, Le Bas and Sierra (2002) find that close to one fifth of total R&D by the MNEs in their sample is performed abroad. We are thus left with the impression that R&D activities by MNEs are subject to 'globalization', but to a lesser extent than other activities, such as production, investment and marketing by the same firms.

Does this imply the 'death of geography' in the field of innovation systems, as Morgan (2001) asked? The analysis here will argue exactly the opposite, i.e., that the tendency to perform R&D abroad implies a strengthening of the notion of regional innovation systems. The line of reasoning will rest on one important argument, namely that due to the existence of specific skills and competencies in people who are not perfectly mobile, technological capabilities of specific regional innovation systems cannot be tapped into easily from a distance. Thus, an MNE wishing to make use of such specific knowledge will have to acquire presence in the region, either by setting up a greenfield R&D facility, or by taking over an existing firm well embedded in the region's innovation system. It is exactly modern communication technology that makes it possible to do this in a way that will enable sufficient integration of the foreign unit into the MNE's own organization. Thus, one might take an, admittedly, extreme point of view and argue that it is exactly modern communication technology that opens up the possibility to reach out and tap a region's innovation system, exactly by being present in the form of foreign R&D.

This is not a new vision on the role of regional innovation systems as a continuing factor even in the days of Internet. Consequently, the paper's contribution is not aimed at providing a new theoretical argument to support this vision. Instead, the paper aims at providing some empirical evidence in support of the importance of regional innovation systems in Europe. For this purpose, it uses an extensive database on patenting by the world's largest MNEs from European locations. To our knowledge, this paper presents the first analysis of its kind, i.e., providing a comprehensive European regional overview of patenting activities by the world's largest firms.

The rest of the paper is organized as follows. The next section will provide a short overview of the main theoretical starting points for our empirical analysis. The main parts of the literature that will be surveyed are the business literature on foreign R&D activities by MNEs, and the economics and geographical literature on the local nature of knowledge and knowledge spillovers. Section 3 will present our database, and discuss the way in which we implement our indicators. Section 4 provides an overview of how R&D activities by the firms in our sample is spread over Europe's regions. Section 5 will go deeper into the issue of knowledge flows, by using patent citations indicators. Finally, section 6 will provide the main conclusions.

## **2. Overview of the literature**

The empirical research in the next sections of this paper will investigate two main hypotheses. The first is that there is now ample reason for multinational enterprises (MNEs) to locate at least part of their R&D activities outside the home country. The second is that in choosing in which (foreign) region to locate these R&D activities, a limited number of regions will be favoured more than other regions. This section aims to provide a concise survey of the existing literature dealing with these topics.

From the theoretical point of view, support for the first hypothesis has come from the business literature on MNEs (e.g., Dunning and Narula, 1995, Cantwell and Janne, 1999, Patel and Vega, 1999). Although Patel and Pavitt (1991) assessed foreign R&D as an important case of 'non-globalization', subsequent literature has indeed concluded that foreign R&D is on the rise. For example, Le Bas and Sierra (2002, p. 600), on the basis of patent data for 350 large firms known to be strong innovators, conclude that for the period 1994-1996, 19.5% of their total patents stem from R&D performed outside the home country of the firm. The number was 15.8% for the period 1988-1990. They also report cases where up to 60% of all patents stems from foreign research.

The theoretical explanation for this trend points to two motives for locating R&D abroad. The first one can be called asset-exploiting foreign R&D (Dunning and Narula, 1995). In this case, firms seek to exploit their existing technological capabilities (developed by home base R&D) by means of performing R&D that is aimed at adapting products and technologies to local circumstances in a foreign country. This would happen if firms need to adapt their existing products to local taste, to local circumstances such as climate, or when additional peripheral products are in need in a foreign location. Similar motives may exist for other parts of the value-chain of a firm, such as marketing or production.

Because this type of R&D is specifically aimed at the foreign locale, it will under many circumstances be most efficient to undertake them in the specific foreign country or region. This has the advantage of close interaction with local people and other production factors, and to perform prototype testing under actual local circumstances. What is essential about this type of foreign R&D is that it is a substitute to domestic R&D, and does not add in a radically new way to the specific technological capabilities of the firm.

The second type of foreign R&D is called asset-seeking (Dunning and Narula, 1995). This argument starts from the assumption that different regions are characterized by different knowledge bases, something that will be discussed below. The specific nature of the foreign technological knowledge base pulls the firms into doing foreign R&D. Instead of building on its existing technological capabilities and seeking to extend these to foreign circumstances, the firm now aims at utilizing the local knowledge base to develop new capabilities that are complementary to its existing capabilities. The tapping into local knowledge bases may either be aimed at the (semi-)public research infrastructure, such as universities and research institutes, or at knowledge developed by other firms. The firm may use this knowledge to expand its existing products and technologies into new technological directions, or to fuse its existing line of business with new developments in certain technological fields.

This paper does not aim to investigate whether foreign R&D is dominated by either one of the two forms asset-exploiting or asset-seeking R&D, which is the dominating research question in the business literature (e.g., Patel and Vega, 1999, Le Bas and Sierra, 2002, Criscuolo, Narula and Verspagen, 2001). However, the distinction between the two forms of foreign R&D is important because they have different implications for the spatial dimension of knowledge. Whereas the asset-exploiting motivation for foreign R&D does not have particular implications for the spatial nature of knowledge development or knowledge flows, the asset-seeking is crucially linked to space. In order to see this, one must realize that the asset-seeking argument pre-assumes that knowledge bases differ between locations, and that they cannot easily be tapped into from a distance (e.g., the home base of a MNE). The asset-seeking strategy of foreign R&D would not be necessary if researchers in the home base lab of a MNE would be able to use the knowledge base of a foreign region. In other words, the asset-seeking argument assumes that geography matters.

This brings us into the second research hypothesis formulated at the beginning of this section. Continuing the line of argument, the choice for a particular region in terms of foreign R&D location will depend on two factors: the nature of the region's local knowledge base, and the extent to which the entering firm will be able to tap into this knowledge base. These two factors are extensively covered in the literature on the spatial nature of knowledge systems (see, e.g., Morgan, 2001, for an overview).

Traditionally, one may point to two factors that enhance the local concentration of certain types of knowledge building or R&D. First, there is the traditional argument about agglomeration economies that is related to the availability of common resources. Examples of these common resources include a specialized workforce of skilled engineers with experience in a certain field of research, a university offering a specialized degree relevant for the type of R&D, specialized firms that can supply certain types of instruments and/or services, or even a notion such as technological culture (Saxenian, 1994). When these types of resources are important inputs into the R&D process, an emerging spatial cluster of R&D activities may provide important advantages to the 'members' of such a cluster, and thus a self-reinforcing process may set in that leads to strong spatial concentration. The fact that this argument is based on well-known spatial theory does not make it less powerful in explaining the spatial nature of innovation systems.

The second factor that may explain the spatial nature of knowledge is related to the nature of knowledge itself. Here the distinction between knowledge and information becomes of crucial importance. While information is by its very nature rather easy to codify, this is often not the case for knowledge (see, e.g., Johnson, Lorenz and Lundvall, 2002). Knowledge, contrary to information, has a high degree of tacitness. This implies that it must be transmitted by close personal interaction as in a teacher-pupil relationship, or by a combination of codified sources, experimentation and hands-on trial-and-error applications on the knowledge-receiving end.

This argument was first introduced into the literature on firms' technological capabilities and regional innovation systems by Von Hippel (1994). He used the term 'sticky knowledge' to indicate that knowledge cannot be transferred at non-significant costs between individuals or regions. As a logical outcome of this, he argued that firms aiming at tapping into a knowledge base that has been developed in a certain region, would locate in this region. In this way, they would be able to hire some of the engineers with experience in the field, to set up partnerships with firms in the region, and so on.

This argument is also found in the literature on the local nature of patent citations, which are often taken as an indication of knowledge spillovers (e.g., Jaffe, Trajtenberg and Henderson, 1993, Jaffe and Trajtenberg, 1996, Maurseth and Verspagen, 2002). The issue here is whether or not patent citations (and hence knowledge spillovers) between firms, or from (semi-) public knowledge institutes to firms, depend on geographical distance. The above quoted studies find that both in the U.S. and Europe, such a relationship indeed exists. Thus, knowledge spillovers tend to be more intense between parties that are located close to each other in space.

Based essentially on a combination of this 'spatial argument' and the theory of MNEs outlined above, Cantwell and Iammarino (2001) have suggested that Europe is characterized by a division into three types of regions: higher order regions, intermediate order regions and lower order regions. The last category is characterized by low technological activity, while the first two categories have high technological activity. What distinguishes higher-order regions from intermediate order regions is the range of their activities over fields and the change of this. Intermediate order regions "attract innovative activities for a specific set of specialized expertise which can be accessed by asset-seeking large firms", whereas higher order regions are "more likely to attract a broad range of both indigenous and foreign innovative activities ... large firms and [MNEs] located there will generally try to extend their established lines of specialization through intra-firm networks" (Cantwell and Iammarino, 2001, pp. 1010-1011). Cantwell and Iammarino (2001) define exactly one higher order region in eight different European countries and investigate regional specialization and the change of this over time. Their data source is US patents.

Our aim below will be to investigate the distribution of innovative activities by large MNEs in European regions. We will follow the literature by using patents as a source of information. However, contrary to, for example, Cantwell and Iammarino, we will use European patents. This may be considered as an important complement to the existing analysis based on US data, because the European patent system may be more relevant for European based



activities. We will not, like Cantwell and Iammarino, focus the analysis on a small set of predetermined regions, but instead take a broad view including 125 regions in the current 15 European Union countries plus Switzerland and Norway.

### **3. The database**

This paper follows in a tradition that uses patents as an indicator of technological activity. As has been noted before (e.g., Griliches, 1990, Basberg, 1987), this indicator is far from perfect. Some of the most well-known problems are that not all innovations are patented, not all patents are commercialized, that patents may vary wildly with regard to innovative size, and that the so-called propensity to patent (percentage of all inventions that is patented) varies by industry. Nevertheless, most authors surveying these issues tend to conclude that patent statistics can be useful indicators. For example, as a conclusion of an analysis comparing innovation count data and patent data as indicators of innovation at the regional level for the USA, Acs, Anselin and Varga (2002, p. 1080) conclude that their “empirical evidence suggests that patents provide a fairly reliable measure of innovative activity”.

Our data source is the European Patent Office (EPO) database on patent applications. We select all patent applications<sup>1</sup> with a priority date in the years 1994-1997 (inclusive), whether they are granted, have been rejected (or withdrawn), or are still under review. Unfortunately, for the purpose of identifying within-firm patent applications, we cannot rely upon the information that EPO supplies in the “applicant name” field. In that field, one may find personal names or names of firms or organizations. In the case of firms, however, it may be the name of an independent firm, a firm that is (partly) owned by a different firm, or the name of some form of a larger conglomerate or holding firm. The EPO database contains approximately 180,000 unique names in the “applicants” field.

Our sample of firms is limited to large multinational firms that appeared on the Fortune 500 list in 1997, supplemented by a few large firms from the Fortune lists in earlier years. Of these, we selected a subsample of firms active in high- to medium tech sectors. For these firms, we made use of the Dun & Bradstreet Linkages database to construct a list of their subsidiaries. The Dun & Bradstreet Linkages database includes only full, i.e., one hundred percent, subsidiaries. We refer to this list as the “group”. The version of the Dun & Bradstreet Linkages database we used is from late 1998, and represents thus the mother-daughter relationships at, or in fact slightly before that point in time. Of course these connections have not always been like they were in 1998. This is the reason why we will use only a limited set of years for our patent database. When analysing patent counts per firm, we use 1997 as the best approximate year, and we can be fairly confident that our data are correct in the large majority of cases. When it comes to analysing patent citations, we need to take into account a longer period, because the dates of cited and citing patents usually lie apart several years. We use the period 1994 – 1997 in this case. Even for this set of years, there will be some errors introduced by the fact that we do not have complete ownership data for the full period, but it is our attempt to minimize this error.

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<sup>1</sup> We will use the term ‘patents’ loosely, i.e., also when we refer to patent applications.

A further practical problem results from the fact that there is not a one-to-one correspondence between the subsidiary names in the Dun & Bradstreet Linkages database and the names in the “applicant” field of the EPO database. We made a pre-selection from the EPO database by searching for different parts of the names found in the Linkages data. The results from this pre-selection were then compared, usually on a one-to-one basis, to the group list from Linkages.

Some names that were found in the pre-selection from the EPO database could not be identified using the D&B database. In many of these cases, the name found in the EPO database was partly identical to the name of the (subsidiary) firm we were looking for. This may, for example, happen if the applicant name is the name of a plant, rather than the legal entity it belongs to. In order to be able to learn more about these firms, we constructed a table with the applicant names and addresses from the EPO database. In this way we could compare not only the applicant’s name but also the address to the data found in Linkages. If the applicant was not found in the D&B database, but the applicant’s name was almost identical and the address was identical to other daughter firms of the same multinational, then we included the name in the group list.

A final note refers to the case when companies merge, and the original company name under which they applied for a patent might be lost. This could mean that we would not find these patents, although they belong to the multinational firm under investigation. Therefore we also looked at different parts of the company name, thereby eliminating as much as possible this bias.

A total of 171 firms were investigated in this way. From this large sample, only firms with a minimum of 25 patents during 1994-1997 were included in the analysis (see below for a note on how patents were counted). The resulting dataset comprises 87 firms, divided over the following sectors (numbers in brackets are the number of firms in the analysis): chemicals (13), pharmaceuticals (9), petroleum (8), electronics (13), computers (5), semiconductors (1), telecommunications (6), aerospace (5), industrial and farm equipment (6), basic metals (4), motor vehicles (13), scientific, photo and control equipment (3). The annex gives a list of the firms involved. In the parts of the analysis below that refer to sectors, we will usually regroup the sectors into three large groups (electronics: computers, semiconductors, electronics, telecommunications; chemicals: pharmaceuticals, chemicals, petroleum; other: aerospace, industrial and farm equipment, basic metals, motor vehicles, scientific, photo and control equipment).

In order to capture the geographical dimension of the data, we specify 125 European regions, largely based on the NUTS regional classification applied by Eurostat. We use essentially the same regional breakdown as in Maurseth and Verspagen (2002), which includes both NUTS 1- and 2-digit regions. However, the number of countries in the regional sample was extended relative to the analysis in Maurseth and Verspagen. The countries in the database now include Norway, Sweden, Finland, Denmark, Ireland, the United Kingdom, the Netherlands, Germany, Belgium, Luxembourg, France, Italy, Spain, Portugal, Greece, Switzerland and Austria. In the case of Germany and Austria, small urban regions (Bremen, Hamburg, and Vienna) were merged with neighbouring or surrounding regions to avoid too small

geographical entities. For Ireland, Finland and Luxembourg, we do not have a regional breakdown and these countries are included as a single region. For Switzerland, Norway and Denmark, the classification used was not based on NUTS, but instead on national administrative definitions (in Switzerland it was based on Cantons, in Norway on Fylken, in Denmark on Landsdelen) A full list of regions used is available in the annex.

The assignment of patents to regions is done by using the postal code of the inventor address. The exact procedure used to do this is similar to Caniëls (1999). A patent usually has more than one inventor. The inventors are (legally) different from the applicants. Applicants are usually firms or other organizations, inventors are usually persons. In this paper, we select patents by their applicants (i.e., the multinational firms groups), but assign patents to geographical regions by their inventors. The reason for this is that some firms always apply for a patent from their headquarters, even when a patent was invented in a different region. By nature of the research question, we are interested in the geographical location of the inventor rather than the applicant, because this corresponds closer to where the actual research that led to the patent was undertaken. In order to cope with multiple inventors and/or applicants of a single patent, we apply a fractional counting method. Suppose a patent has  $n$  inventors and  $m$  applicants ( $n$  is usually larger than 1,  $m$  usually equal to one). Suppose that of the  $n$  inventors  $n_a$  (smaller or equal to  $n$ ) are located in region A, and that  $m_b$  (smaller or equal to  $m$ ) of the  $m$  applicants are subsidiaries of firm B. Then a fraction  $1/(n_a m_b)$  of the patent is assigned to location A of firm B. In this way, every patent will count as one in the total number of patents for the sample, unless some inventors are located outside our sample of European countries, or some of the applicants are not subsidiaries of a firm in our sample. The procedure does imply that the number of patents assigned to a firm or a region will in most cases be a fractional number rather than an integer.

#### **4. The spread of patenting over European regions**

As was already noted above, it has been argued that R&D is an important case of ‘non-globalization’ (Patel and Pavitt, 1991). Table 1 shows that argument is valid only for a relatively small part of our sample of multinational firms. The table gives the share of patents originating from foreign regions with priority date in 1997. The table includes only European firms, since we do not have data for patenting in locations other than European regions (i.e., the home base of the Japanese and US firms in the sample). The numbers given refer to all firms in the given sector, or the total sample.

The mean of the share of patents originating from foreign locations differs between the sectors in the database: it varies from 0.15 to 0.24. The highest values are found for the British company BTR (100%), the Swedish company Electrolux (81%), the Swiss company ABB (61%)<sup>2</sup>, and the French company Alcatel (52%). These are the only companies with more than half of their patenting activity abroad. Whether or not these values constitute a case

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<sup>2</sup> ABB is one of the companies for which it is hard to determine the home base. We have used Switzerland, while Sweden would have been the other candidate country. There are two other companies for which this is difficult: Unilever and Royal Dutch Shell. We decided to use the Netherlands as the home base for these countries (the UK was the other choice available).

of non-globalization is a matter that is open for discussion. Compared to other parts of the operations of these firms, it is probably low (although we do not have any data to support this point), but in any case 15-25% of all R&D activities by these firms is not a marginal number. In addition, it has to be born in mind that this number would increase if one takes into account patents in the US or other non-European parts of the world.

The median of the share of foreign patents is in all cases smaller than the mean, which indicates that the distribution is skewed towards the left side, i.e., towards firms with low values for the internationalization of R&D. This could be taken as support for the non-globalization argument, but even in this case the median value is clearly above 10% for the two largest sectors in our database, i.e., chemicals and electronics. The median value is clearly lower for the other sectors in the database. Finally, the standard deviation is rather large for all sectors, indicating that there is indeed a large variety between firms with regard to their level of R&D globalization.

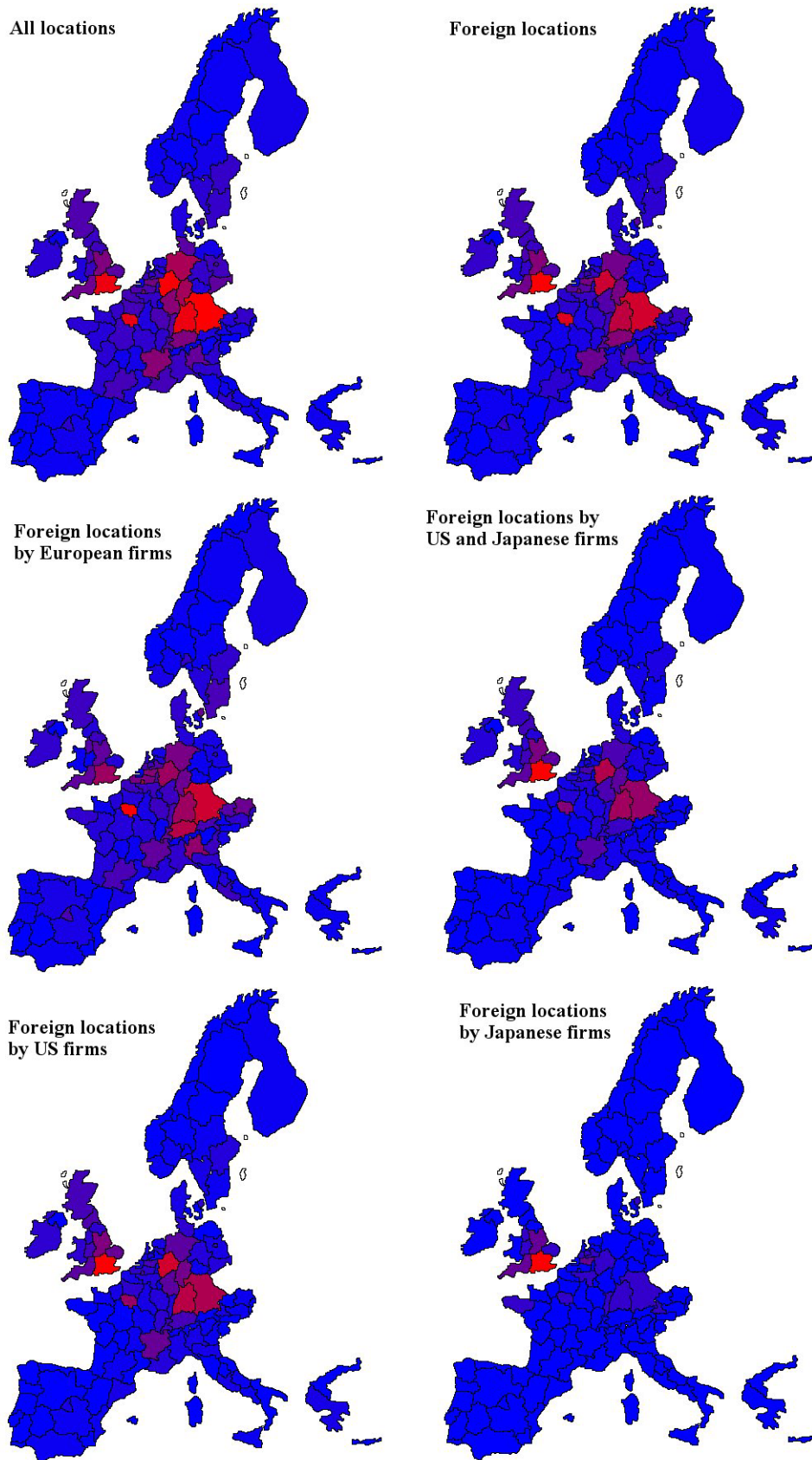
**Table 1. Share of patents invented in foreign regions in Europe by European based MNEs, 1997**

Sector / sample	Number of firms	Mean	Median	Standard deviation
Total sample	52	0.18	0.11	0.21
Chemicals, pharmaceuticals, petroleum	21	0.18	0.13	0.13
Computers, electronics, telecommunication	12	0.24	0.15	0.27
All other sectors	19	0.15	0.05	0.24

Source: own calculations on the basis of EPO data. Other sectors include: aerospace, industrial and farm equipment, basic metals, motor vehicles, scientific, photo and control equipment.

In order to provide an overview of which European regions attract most R&D activity by the firms in our sample, we construct the maps in Figure 1. The shading of the maps is an indication for how many firms have a positive number of patents from that particular region. Pure blue indicates the lowest number in the map (zero in all cases), while pure red indicates the highest number in the map (this varies per map). Each map corresponds to a different subset of the firms in the sample.

The map in the upper-left corner refers to the total of 87 firms in the sample. What is clear is that the central part of the map is most in demand in terms of locations for R&D. Three German regions (two in the south and one in the mid-west), the Southeast of the UK (London) and the region around Paris are on top of the list. These regions all attract around 45 regions, i.e., slightly more than half of all the firms in the sample are active in these regions. Other regions in the center of the map also rank relatively high, including most other regions in West Germany, South of the Netherlands, North-West of Italy, and Southeast of France. Outside the cluster of regions in the center, only some isolated regions attract a significant amount of firms: the regions around Stockholm, Madrid, Rome, as well as Scotland and Ireland.



**Map 1. The presence of large MNEs R&D activities in European regions (blue indicates a low amount of firms, read a high amount of firms)**

In comparison with the list of higher order regions defined by Cantwell and Iammarino (2001), we find that their regions are included in the top of our list as well. However, our results clearly show that in terms of the sheer numbers of firms active in regions, the criterion of having only one region per country is rather restrictive. In Germany, we have, besides Baden Wuerttemberg, which is Cantwell and Iammarino's higher order region, at least two other regions attracting very significant activity: Bayern and Nordrhein-Westfalen. In France, there is the area around Grenoble beside Paris (which is Cantwell and Iammarino's higher order region), while in the UK there is Cornwall and Devon as well as the area around Cambridge besides the Southeast (Cantwell and Iammarino's choice). It must be noted that their definition is not only based on the number of patents or the number of firms active. Still, the map clearly shows that for a broader analysis aimed at describing and analyzing the innovative activity of MNEs, a broad regional view is useful.

The pattern changes only slightly if we leave out the R&D activities of the European firms in the home country (e.g., for a firm that we labeled German, we did not include any German regions in the counts). This is displayed in the map in the right-upper corner. The most prominent difference with regard to the previous map is that the three top German regions are now somewhat less pronounced, although still quite high up on the list. Now the regions around London and Paris are leading the ranking (35-40 firms). The relative fall of the German regions is, of course, due to the strong prominence of German firms in the list used to construct the ranking of the first map. We also find that a number of higher order regions of Cantwell and Iammarino are no longer very prominent when only foreign activities are considered. This is the case for Stockholm, and, to a somewhat lesser extent, the area around Brussels.

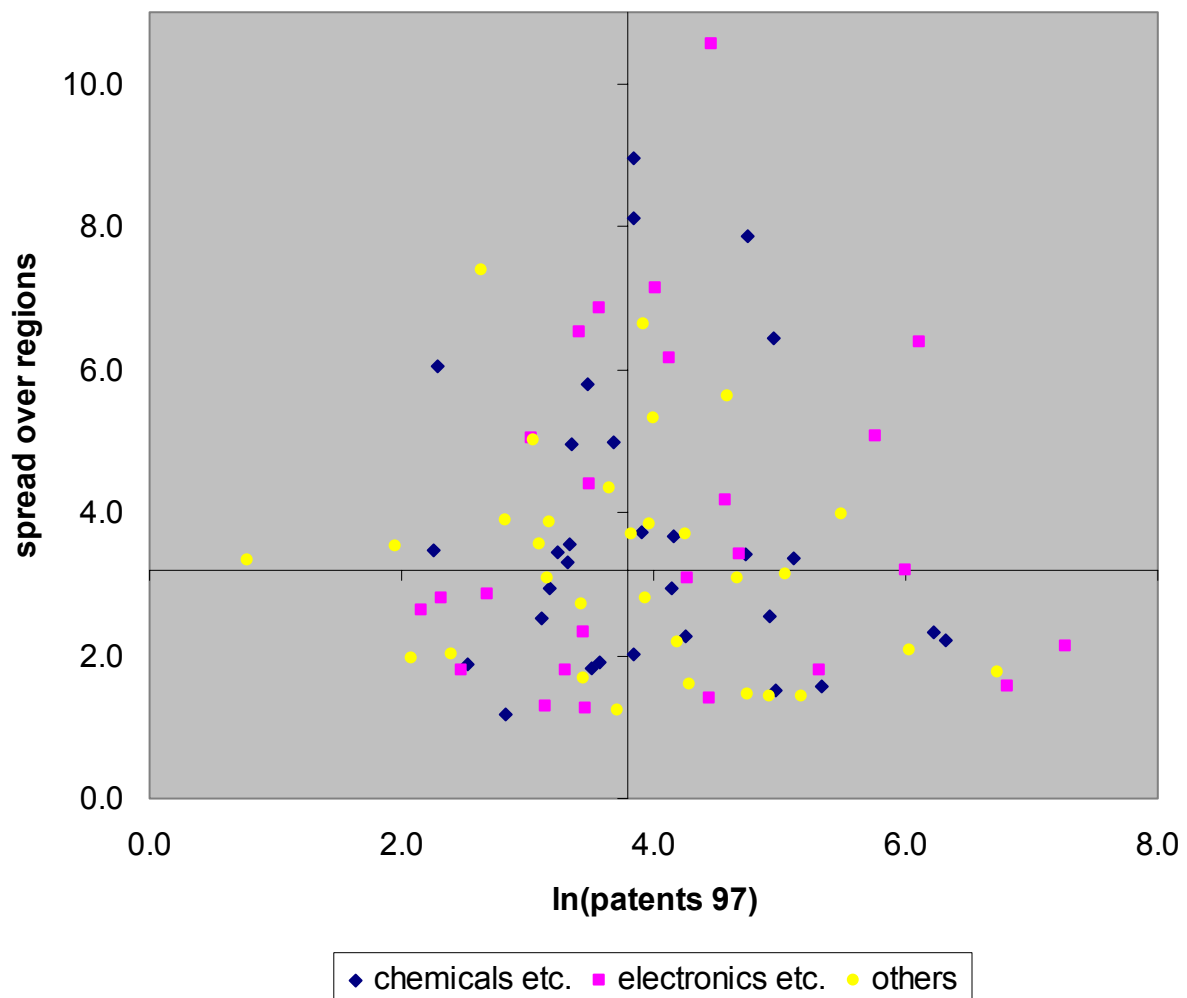
The next four maps refer to a subset of the second map, i.e., they each single out a specific category of foreign activities. The third map (center-left) displays all foreign activities by European firms. What is notable here is that the regions around Paris are much favoured as compared to the other top locations from the previous maps. London and most German regions (with the slight exception of Bayern in the South of Germany) clearly attract less European firms than Paris does in this map. The picture is quite opposite with regard to the Japanese and US firms taken together. This is in the center-right picture. Here the Southeast of the UK (London) and, to a lesser extent, Germany stand out. What is notable also is the almost complete absence of Japanese and US firms from other parts of Europe than Central Europe. Thus, there are virtually no activities by non-European firms either in South-Europe or in the North.

Among the non-European firms, the US firms are a larger group than the Japanese firms. The last two maps single out the data for these two groups separately. The US firms are in the lower-left corner. Here we see some activity in most of the central regions that were seen before. However, London and the German regions particularly attract the US firms. The few Japanese firms that are active in Europe (right-bottom corner) are mostly concentrated in the area around London.

Concluding, we observe a tendency for R&D activities by MNEs to be concentrated in relatively few regions in Europe. Large parts of Europe do not see any, or very little R&D

activities by the firms in our sample. Moreover, foreign R&D activities tend to be aimed at an even smaller set of regions, with US and Japanese firms being again somewhat more selective than European firms doing R&D in foreign European countries.

Given the rather concentrated pattern of MNE presence in European regions, it becomes of interest to look at the spread of patenting over regions at the level of individual firms. One indicator that can be used for this is the Herfindahl-equivalent-number-of-regions indicator, which can be calculated in a manner similar to what is commonly done in the field of industrial economics to calculate market concentration. The indicator starts by calculating the share of each region in total (European) patenting of a firm. The sum over all regions of the squared of this share is then calculated. Finally, the inverse of this result is calculated. The result can be interpreted as the number of regions that would generate the same value of the indicator, but with equal shares of patenting in all regions. The larger (smaller) this value is, the more (less) spread out are the R&D activities of the particular firm.



**Figure 1. The number of patents vs. the average spread of patenting over European regions, firm level**

The indicator is displayed in Figure 1, against the logarithm of the total number of patents for each firm in Europe for the period 1994-1997. The two axes drawn in the figure correspond to the median values of the indicators, so that we have exactly one quarter of the total population of firms ( $n=87$ ) in each quadrant. There is no clear relationship between the two indicators in the graph. High values of the spread over regions are found for intermediate values of total patenting rather than the extremes of this distribution. There are also no clear differences between the three sectors in the graph.

The minimum for the spread variable lies slightly above one, which would correspond to the case where almost all patenting of a firm is concentrated in a single region. The highest value for this indicator is reached at a value just under 11 (for the Swedish company Electrolux, the next highest value is the US company Du Pont), while the median is at 3.2. It has to be born in mind that, due to the fact that not all locations of a firm have the same amount of patents, the actual number of locations that a firm patents from is usually higher than what is in the figure. Together, for example, the 87 firms in the sample cover 1168 foreign locations in 1997, or an average of slightly more than 13 per firm. The overall picture is then one in which most firms have significant foreign patenting activities, but these are concentrated in a limited number of regions, both from a European spatial one, and from the point of view of the number of locations per firm. There are also some firms, however, which patent from a large number of regions and source a large share of their total patents from foreign (European) countries.

## **5. Geographical distance and patent citations in Europe**

So far, it has been shown that the R&D activities of MNEs in Europe are indeed concentrated in a limited number of regions. No attention has been paid, however, to the mechanisms that may lead to this tendency. Above, two possible reasons for spatial concentration of knowledge activities were given: the availability of common resources leading to agglomeration economies, and the spatially sticky nature of knowledge flows and knowledge spillovers. This section will investigate the issue of sticky knowledge flows and spillovers in a more detailed way. In order to do this, we need to operationalize two additional dimensions in the database: distance and knowledge flows/spillovers.

The starting point for measuring the distance between regions is the classification in terms of NUTS units introduced above. The distance between two regions  $p$  from  $q$  is measured by counting the (minimum) number of borders on the NUTS map one has to cross to reach region  $p$  from  $q$ . For example, if  $p$  and  $q$  are border regions, the distance will be one, if there is one region between  $p$  and  $q$ , the distance will be two. For the sake of this calculation, some regions with sea areas between them have been defined as actual neighbours, in order to make all regions reachable from all other regions. This is an admittedly naïve way of measuring distance, which could be improved in a number of ways, such as measuring actual distance in kilometers or miles, or by measuring virtual distance in terms of traveling time. However, the method is used widely in the literature (e.g., Hagget, Cliff and Frey, 1977). Moreover, the analysis in Maurseth and Verspagen (2002) showed that for a subset of regions in the present sample, the results do not differ substantially between the present distance measure and a more sophisticated one based on actual distance in kilometers.



In order to measure knowledge flows or spillovers, we will follow earlier contributions to the literature, and resort to patent citations for doing this. Patent documents contain a detailed description of the patented innovation. In addition to the name and address of the innovator and the applicant, which we have used above, they also contain references to previous patents, i.e. patent citations. The legal purpose of the patent references is to indicate which parts of the described knowledge are claimed in the patent, and which parts have been claimed earlier by other patents. From an economic point of view, however, the assumption is that a reference to a previous patent indicates that the knowledge in the latter patent was in some way useful for developing the new knowledge described in the citing patent. This is the line of reasoning offered in the studies by e.g., Jaffe, Trajtenberg and Henderson (1993), Jaffe and Trajtenberg (1996 and 1998) and Maurseth and Verspagen (2002) as referred to above. The detailed case study by Jaffe, Fogarty and Banks (1998) on a limited sample of patents, as well as Jaffe, Fogarty and Banks (2000) conclude that patent citations are a “valid but noisy measure of technology spillovers”.

We will use citations between European patents as a measure of knowledge flows. Data on patent citations in Europe are obtained from the European Patent Office (REFI tapes). There are important differences between the European and U.S. patent systems. Firstly, the EPO patent examiners, rather than the inventors or the applicants, add the large majority of the patent citations, which implies that the inventors may not have been aware of the cited patent. In the case of the U.S. patent system, inventors add the majority of the citations. The reason behind this difference is that the U.S. system requires inventors to provide a complete description of the technical state-of-the-art while the European system does not ask for this.

Still, it is obvious that a citation link in the European case can be seen as an indicator of technological relevance. Thus, if patent citations are shown to be more frequent between patents that result from R&D labs that are located relatively near to each other, this would indicate that the type of geographical clustering of knowledge generation activities and knowledge flows that we have pointed to above, is indeed a relevant phenomenon. Moreover, citations in the European system may indicate potential spillovers. Although this potential may not have been realized in all cases, it is reasonable to assume that since patents are public knowledge, professional R&D laboratories would have a reasonable knowledge about existing patents in their field. This is why we argue that European patent citations are a useful indicator of clustering of technology activities, be it with or without knowledge spillovers.

It should be emphasized that knowledge spillovers are a much broader concept than what is captured by patent citations (U.S. or European). In terms of the distinction by Griliches introduced above, patent citations focus on a specific form of pure knowledge spillovers. Rent spillovers are completely left out. Even within the category of pure knowledge spillovers, patent citations (to the extent that they are related to spillovers) are only a part of the complete story. For example, in order for patent citations to take place, both the spillover-receiving and spillover-generating firm must be actively engaged in R&D and apply for (European) patents.

In addition, patents are an ultimate example of codified knowledge, because they require an exact description of technological findings according to legally defined methods. Thus, one

can have little hope of identifying tacit knowledge flows by means of the paper trails that patent citations leave. One may assume, however, that the codified knowledge flows of patent citations go hand-in-hand with more tacit aspects of knowledge flows. However, this argument remains speculative, and one must therefore realize that our analysis will only refer to a very specific and limited form of knowledge generation activities and knowledge flows, and our data have important imperfections. The approach has, however, the advantage that we can make use of a very detailed and precise database.



**Figure 2. Typical citation pattern**

Patent citations involve a time lag. The typical pattern for the number of citations received by a patent is displayed in Figure 2. Just after the patent has been applied for, only little citations to it will appear. The number of citations rises until it reaches a peak after (for the case of EPO patents) two or three years. Then the number of citations gradually falls to zero over a prolonged period that may take up to 20 years. Our choice for which patents to take into account as cited patents involves a trade-off between two factors. On the one hand, we want to stay as close as possible to 1997 because of the fact that ownership relations for our sample of firms refer to that year. On the other hand, we want to allow for a long enough period for a substantial number of citations to occur. We settle the trade-off by looking at cited patents that have priority date in 1994, and citing patents in the years 1994 – 1997. This means that we cut off all citations after 1997, as indicated by the vertical line in Figure 2.

Because a patent citation involves two patents, the way of counting changes slightly. In principal, the fractional way of counting is maintained, but we will look only at whether the number of citations between two units is positive or zero. As a unit that may cite or be cited, we will take the location of a firm in a region. Thus, if firm A has patenting from regions  $i$  and  $j$ , and firm B has patenting from regions  $p$  and  $q$ , all possible citation links include  $Ai-Ai$ ,  $Ai-Aj$ ,  $Ai-Bp$ ,  $Ai-Bq$ ,  $Aj-Ai$ ,  $Aj-Aj$ ,  $Aj-Bp$ ,  $Aj-Bq$ ,  $Bp-Ai$ ,  $Bp-Aj$ ,  $Bp-Bp$ ,  $Bp-Bq$ ,  $Bq-Ai$ ,  $Bq-Aj$ ,  $Bq-Bp$ ,  $Bq-Bq$ . Note that because citations are directional (it matters who cites and who is cited),  $Ai-Aj$  is different from  $Aj-Ai$ . Note also that we include citations between members of the same MNE group, both if they are located in the same region (e.g.,  $Ai-Ai$ ) and if they are located in different regions (e.g.,  $Ai-Aj$ ). An additional dimension is added by time. If firm A has patenting from region  $i$  in 1994, and firm B has patenting from region  $p$  in 1994 and 1997, the possible citation links include  $Ai(94)-Ai(94)$ ,  $Ai(94)-Bp(94)$ ,  $Ai(94)-Bp(97)$ ,  $Bp(94)-Ai(94)$ ,  $Bp(94)-Bp(94)$  and  $Bp(94)-Bp(97)$ .

Our approach will be to identify all combinations of firms/regions/years that may cite each other, simply by enumerating them as in the above simplified examples. This is important,

because the evidence presented above suggests that we cannot pre-suppose that patenting activity is randomly distributed over space. If it were, we could simply compare the spatial distance between firms/regions with positive citations to the overall mean distance on our European maps. Now that it turns out that the regions that are heavily involved in patenting are a non-random selection from the complete sample of regions, we have to take into account the underlying distribution of patenting over regions. This can be done by looking at which of the potential citation links are actually realized (i.e., lead to positive citations), and see whether or not these links are characterized by relative closeness on the map.

**Table 2. The number of citation links with positive citations, within and between MNE groups, by sector, cited patents in 1994, citing patents 1994-1997**

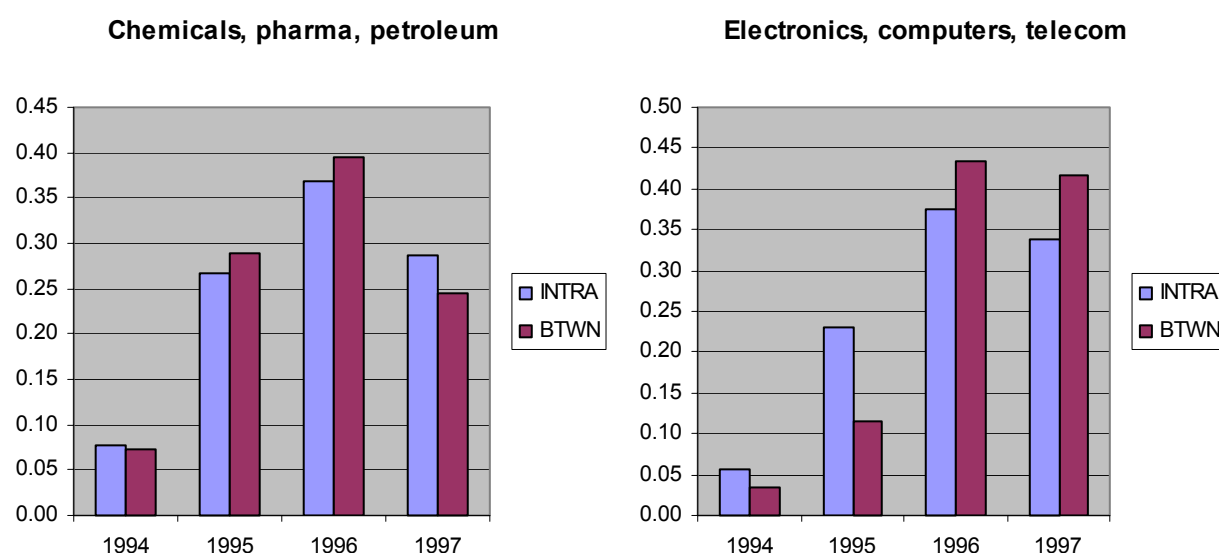
<b>Sector</b>	<b>Between or within groups citations</b>	<b># positive citations</b>	<b># zero citations</b>	<b>% positive</b>
Chemicals, pharma, petroleum	Between	274	766473	0.04
Chemicals, pharma, petroleum	Within	679	30910	2.15
Chemicals	Between	113	217661	0.05
Chemicals	Within	429	19083	2.20
Pharmaceuticals	Between	21	43247	0.05
Pharmaceuticals	Within	180	6692	2.62
Petroleum	Between	14	28016	0.05
Petroleum	Within	70	5135	1.34
Electronics, computers, telecom	Between	397	401768	0.10
Electronics, computers, telecom	Within	299	26405	1.12
Electronics	Between	187	136493	0.14
Electronics	Within	218	16282	1.32
Computers	Between	2	5088	0.04
Computers	Within	11	2501	0.44
Telecommunications	Between	29	17099	0.17
Telecommunications	Within	64	7228	0.88
Automobiles	Between	56	81423	0.07
Automobiles	Within	106	8865	1.18

Source: own calculations based on EPO data. Some sectors not documented due to the small amount of positive citations

The first notable finding on citations is that the number of positive citations links is small relative to the potential number of such citations. This is documented in Table 2. The third column in the table gives the number of citation links with positive citations, where citation links are defined in the way explained above. The next column gives the number of potential citation links that have zero citations. Adding these two columns then yields the potential number of citation links, as it was enumerated in the example above. The last column calculates the number of positive citation links as a percentage of the potential number of citation links (positive links plus zero links). This number is always small, never exceeding 3%. It is higher for within group citations, indicating that knowledge flows relatively more often between units that are part of the same MNE group than between units that are part of different groups. In fact, the fraction of between group citation links that is positive never

exceeds 0.2 %, whereas is only falls below 1% for two of the cases in the table (computers and telecommunications) for within firms citations. We thus conclude that knowledge flows between the MNEs in our sample as indicated by patent citations are a relatively rare phenomenon.

There are also important differences between sectors. The three chemicals sectors are relatively homogenous, with only small differences between them in terms of the percentage of positive citation links. This is not the case for the electronics related sectors. The three chemicals sectors, both taken together and separately, also show low levels of between groups citations, as compared to the electronics sectors. Within group citation, on the other hand, is relatively high in the chemicals related sectors. This fits well with the impression of chemicals technology as highly cumulative and based on technological capabilities that are highly firm specific.

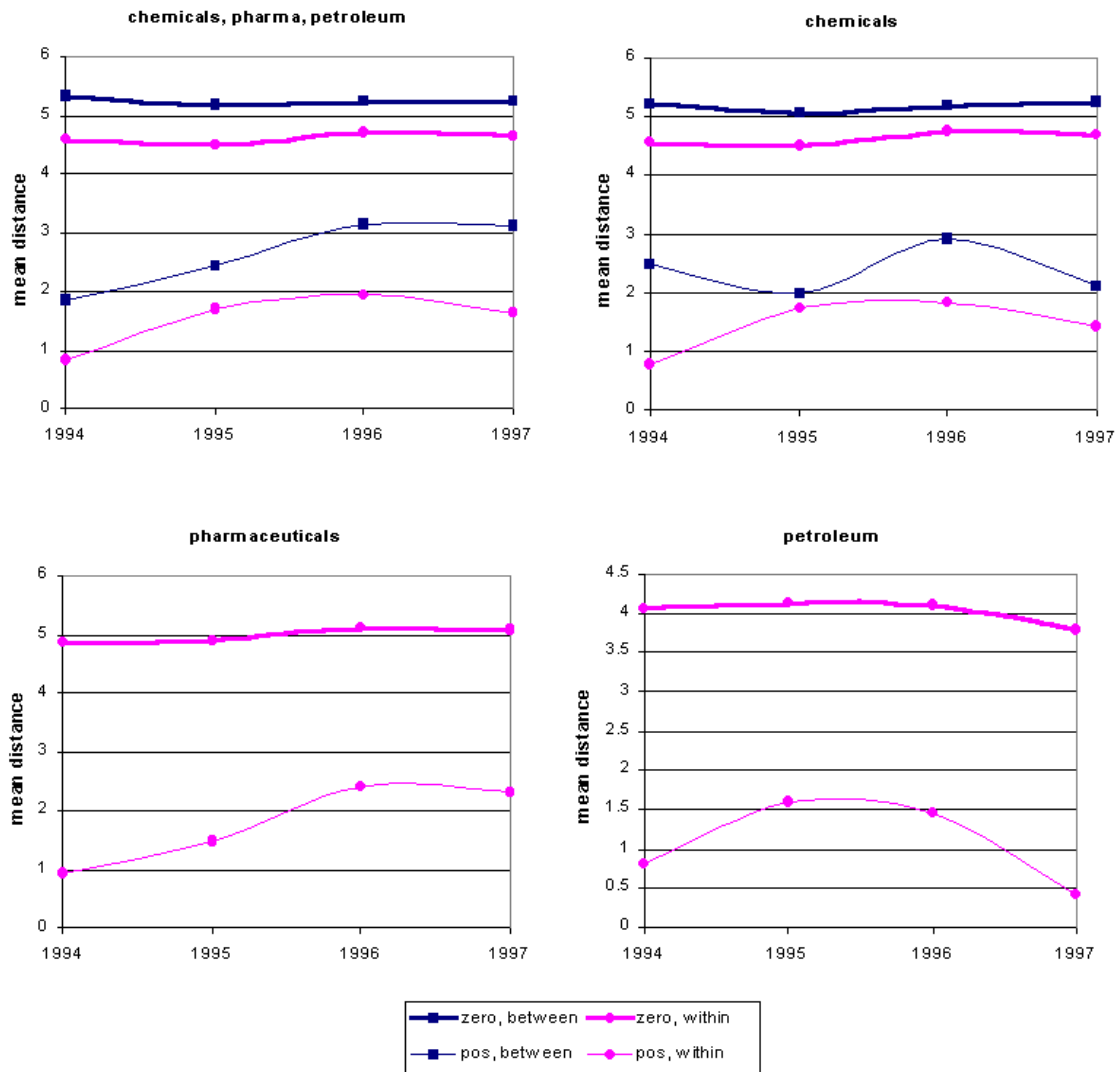


**Figure 3. Citation patterns by sector and for within and between MNEs citations**

We now turn to a more detailed analysis of citation patterns over time. For the two broad sectors that have been defined (chemicals etc. and electronics etc.), there are enough positive citation links to make a comparison over time between within and between groups citations. This is done in Figure 3. The bars in the figure show the fraction of all positive citations occurring in each of the years 1994-1997. The left bar for each year is for within group citations only, the right one for between groups citations. Bars of equal shading are scaled to one within each graph.

The influence of time on the number of citations is similar to the stylized graph in Figure 2. All series have a peak in 1996, i.e., 2 years after the cited patent was filed. The number of citations occurring in the same years as the cited patent (1994) is quite small, typically around 5%. The rate at which the number of citations rises from 1994 onwards differs by sector. For the chemicals sectors, there is not a very large difference between within and between groups citations. In fact, between groups citations rise somewhat more rapidly than within groups

citations. In electronics, the picture is quite different. Here between groups citations significantly lag behind within group citation. Only around 15% of all between groups citations occurs in the period 1994-1995, versus around 25% for within group citations. Thus, we seem to have evidence that knowledge diffuses more rapidly within firms than between firms only for the electronics sector.



**Figure 4. The impact of distance and time on patent citations, within and between MNEs, chemicals**

Finally, we analyze the relationship between citations, distance and time together at the sectoral level. To do this, we start by dividing the potential citation pairs into four segments according to the two criteria within/between groups and zero/positive citations. We also calculate the distance between the two regions involved in the citation link. Then, for each of the four resulting segments, we calculate the (unweighted) mean of the distance of all citation links in the segment. This will enable us to compare the average distance for positive citation links with that of zero citation links. In light of the theoretical discussion above, we would

expect that the distance for the positive citation links would be lower than for the zero citation links.

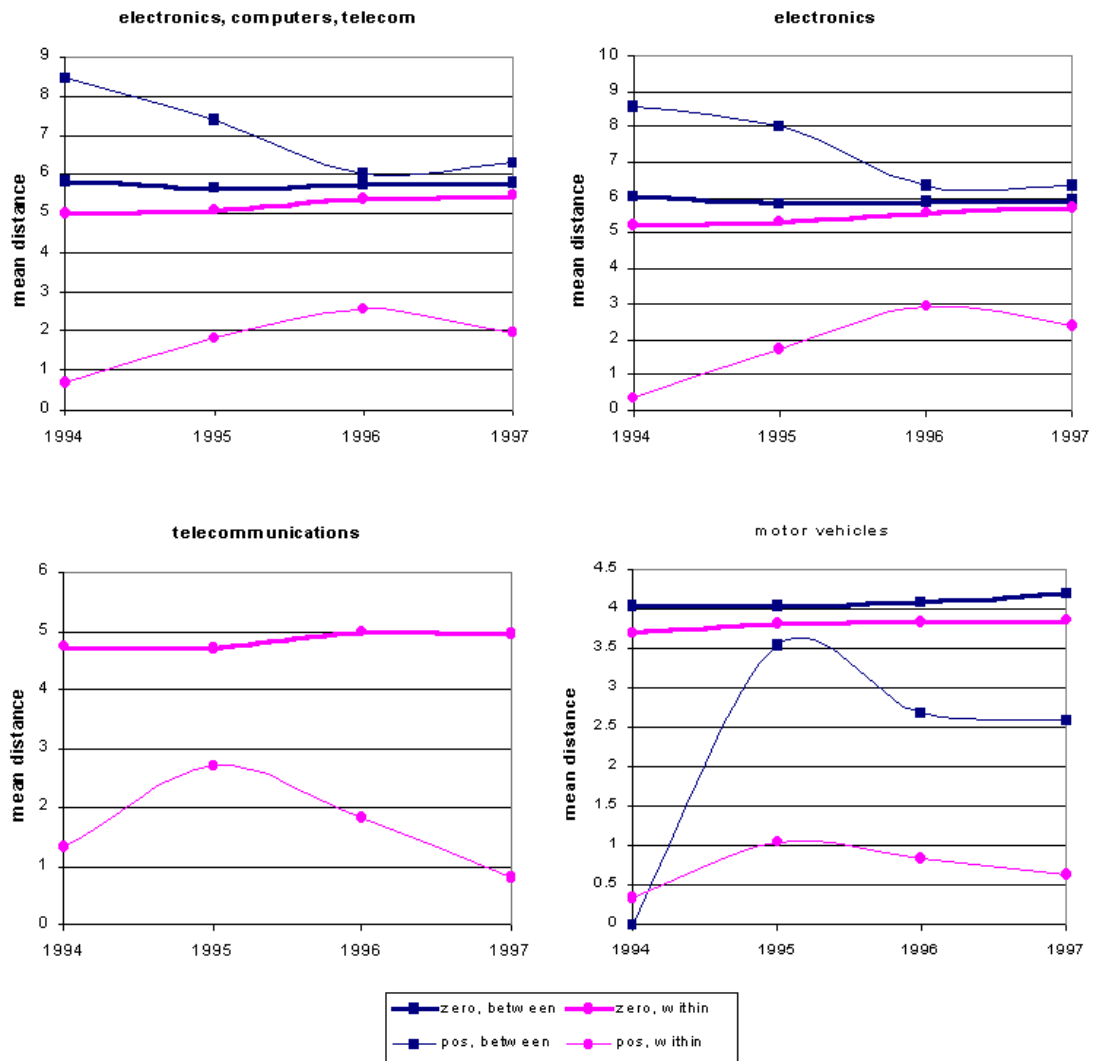
In addition, we can look at the development of average distance over time within each segment of positive citations. Jaffe and Trajtenberg (1996) found that as time passes since the application of the cited patent, patent citations span a wider geographical distance. Such a phenomenon is broadly in accordance with the notion of knowledge diffusion as a spatial phenomenon (Hägerstrand, 1967), implying that knowledge will first diffuse to spatial units close to where the knowledge originated, and subsequently diffuse to a larger spatial area. This theory nicely complements the vision of knowledge as a spatially sticky phenomenon that was discussed above.

Figure 4 displays the results for the chemicals sectors. The thin lines indicate the development of average distance over time for the positive citations segments, the thick lines do the same for the zero citations segments. For pharmaceuticals and petroleum, the segment for positive citations between groups is too small (21 and 14 cases, respectively) to make the results reliable, so these lines are omitted from the graphs. The first thing that is obvious, is that the lines for positive citations are well below the lines for zero citations for all cases. In other words, positive citation links show a lower mean distance between the two regions involved than zero citation links. It must be noted, however, that the standard deviation of the distances within all segments is rather large. This suggests that a test for statistical significance of the difference between the mean distance of positive and zero citations would not reject the null hypothesis of equal means, although it is not quite clear which test could be used since the distributions of the distances involved appear to be non-normal (skewed to longer distances). On the other hand, the fact that for all four graphs we find the same result, namely that positive citations have lower mean distance than zero citations, is suggestive of a systematic tendency rather than a random phenomenon.

With regard to knowledge flows as a spatial process, the results are quite interesting. Starting with the graph for all three chemicals sectors together (upper left corner), we do observe an initially increasing mean distance. That this is not due to a change in the underlying distribution of patenting (as opposed to citation) activity over space is indicated by the fact that the lines for zero citations remain largely flat over time. Thus, we do find that, on average, knowledge diffuses first to nearby spatial units, and only later on to regions further away. However, after two years, a peak is reached, and the graph levels off, and even starts to decline marginally. This general pattern is common between citations between groups and citations within groups, although the decline is more significant for the within groups citations.

The decline of average distance for the last year (1997) can be interpreted in terms of an assumed interaction between spatial distance and the specificity of knowledge for the regional innovation system. In such an interpretation, the flow of knowledge to spatial units further away (i.e., the increasing part of the curve) corresponds at the same time to a broadening of the field of application of the knowledge. This follows from an assumption that each regional system has its own specific pattern of technological interests and applications. After the knowledge has become older and hence more obsolete, it loses its relevance to areas of

application that are further away from the original field in which it was developed. This implies that the spatial reach of the knowledge flows declines, and hence that the curve would fall (or in a less strong case, level off). Obviously, there is an element of speculation in this interpretation, but it would be possible to test this proposition in future research by looking at the technology classes in which citations occur, and by extending the time period of citations beyond the four years we have used here.



**Figure 5. The impact of distance and time on patent citations, within and between MNEs, electronics and motor vehicles**

The observed general time pattern for the three chemicals sectors as a whole is, to the extent that data is available, more or less repeated for the individual sectors. The one exception is the curve for between groups citations in chemicals. This curve starts from a relatively high level of mean distance. However, it must be noted that this particular observation is based on only four citation links, and hence may be influenced by random factors. The eventual decline is

strongest for within group citations in the petroleum sector. This sector also shows a rather early peak, i.e., at the year 1995. Finally, it is observed that all peaks of the observed curves for positive citations are well below the level indicated by the mean distance for zero citations. Also, as could reasonably be expected, there are no trends in the curves for zero citations.

Figure 5 displays the same indicators for the electronics sectors and motor vehicles. Computers has too little citations in either category to provide reliable results, for telecommunications it is only possible to calculate reliable results for within group citations. In the electronics graphs, the findings differ substantially between within group and between groups results. For the electronics sectors together as well as for the electronics sector in a narrow interpretation, between groups citations start off at a mean distance that is above the mean distance for zero citations for that segment. The two curves then converge more or less to the mean distance of zero citations links. This result is obviously in contract to the expectations based on the theoretical discussion above. Closer inspection shows that this is largely driven by two firms: Nokia and Ericsson. Of the 187 between groups citations in electronics (narrowly defined), 87 have distance larger than 6 (which is about the mean distance of zero citations). Of these 87 cases, only 8 (or 9%) do not involve either Nokia or Ericsson. Although these Scandinavian firms do a large part of their research abroad, their domestic patents citing other patents add long distance citations to the sample.

The other curves in the figure are consistent with the patterns already observed in the previous graphs. They show mean distances below the values for the corresponding category of zero citations, as well as the typical hill-shaped pattern that was discussed above. Still, there are some differences between the various curves. In telecommunications and motor vehicles, the peak of the curves occur rather early, i.e., 1995, as opposed to 1996 or the other sectors.

Summarizing, we do find some support for the hypothesis of spatial concentration of knowledge spillovers/flows. In general, positive citation links between regions are characterized by lower mean distance between the citing and cited region than for potential citation links that do not lead to positive citations. There are, however, also exceptions to this tendency (Nokia and Ericsson in electronics), indicating that other (firm specific) factors also play a role, and sometimes may be dominating. We also find evidence for a spatial pattern of knowledge diffusion, i.e., at first citations occur at low distance, after which the spatial reach of the citation process increases. We do observe, however, a leveling off, or even reversal of this process.

## **6. Summary and conclusions**

The aim of this paper was to provide (further) empirical evidence for the argument that even in an age of ‘globalization’, regional innovation systems matter. To this end, a database on patenting by 87 large multinational enterprises (MNEs) from European regions was used. Several empirical findings stand out.

First, it was found that the degree to which the firms in the sample perform their R&D in foreign countries varies. The data on this phenomenon are limited to European firms. Of



these, the percentage of foreign patenting in total patenting varied between virtually zero and 100%. The mean was around one fifth, which is comparable to previous findings in the literature (e.g., Le Bas and Sierra, 2002).

Second, it was shown that a limited set of European regions attracts by far the largest part of (foreign) R&D activity by the firms in our sample. Almost all these regions are located in the central part of Europe, more specifically in the United Kingdom, France, Germany, Switzerland, the Netherlands and Belgium. South Europe attracts very little R&D activity by the firms in our sample, and only some very limited number of Northern European regions ranks high. We take this as evidence of the fact that regional technological capabilities (still) matter in the decision of our MNEs on where to locate (foreign) R&D. We also observe differences in terms of where to locate between European, Japanese and US firms.

Third, it was found that there is no clear linear or monotonic relationship between the size of a firm's R&D activity and its tendency to spread over more locations. In fact, it was found that the firms with intermediate levels of activity are most likely to have a large spread over European regions.

Fourth, we tested whether or not technology flows as indicated by patent citations are localized in space. We analyzed both flows between MNEs and flows within MNEs, i.e., between a firm's different regional locations. It was found that for all cases where enough data exists, knowledge flows within a MNEs have an important local component, i.e., that these flows are more intense between units of the firm that are nearby than between units of the firm that are further apart. The same finding holds for most cases of knowledge flows between MNEs, although there are exceptions to the phenomenon in this case. Specifically, it was found that in electronics, the citation flows involving two large Scandinavian firms, i.e., Nokia and Ericsson can be characterized as 'long distance'. This shows that besides geographical factors, knowledge flows are also characterized by a number of other, often firm-specific factors.

Finally, we used the citations data to test the hypothesis that knowledge first diffuses to nearby locations, and subsequently reaches a larger spatial realm. We found evidence supporting this hypothesis, again for citations within MNEs and between MNEs, although the case was stronger for citations within MNEs. Moreover, we found that during the early stages of the knowledge diffusion process, the spatial reach of knowledge increases, but after a while (usually two years), the reach declines again. This was attributed to the regional specificity of knowledge, although more empirical works needs to be done to substantiate this argument further.

Overall then, the results support the conclusion that regional innovation systems in Europe still matter, at least as far as large MNEs are concerned. This is a conclusion that both has important policy implications, and has implications for further research in the field. With regard to policy, one might expect that European regional cohesion be at stake, especially because of the localized nature of knowledge flows and spillovers. This means that there might be self-reinforcing tendencies for rapid growth based on the application of new knowledge. However, further research is necessary to see what role is played in this by

smaller firms than the ones in our sample, and whether or not the localized nature of spillovers is also relevant for spillovers related more to production than the flows that we analyzed.

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## **Annex I. MNEs and sectors in the sample**

### **Aerospace**

1. United Technologies Corporation
2. Allied Signal Inc.
3. British Aerospace Public Limited Company
4. Textron Inc.
5. Aerospatiale

### **Chemicals**

1. Du Pont de Nemours and Company Inc.
2. BASF A.G.
3. Bayer A.G.
4. Hoechst A.G.
5. The Dow Chemicals Company
6. Imperial Chemical Industries Plc.
7. Rhone-Poulenc
8. Compagnia di partecipazione assicurative ed.
9. Norsk Hydro ASA
10. Akzo Nobel NV
11. Henkel KgaA
12. Monsanto Company
13. Cea-Industrie

### **Computers, Office equipment**

1. International Business Machines Corporation
2. Hewlett-Packard Company
3. Fujitsu Limited
4. Canon Inc.
5. Xerox Corporation

### **Electronics, Electrical Equipment**

1. General Electric Company
2. Siemens AG
3. Sony Corporation
4. Royal Philips Electronics
5. ABB Asea Brown Boveri Ltd
6. Motorola Inc.
7. Telefonaktiebolaget Lm Ericsson
8. Electrolux AB
9. Sharp Corporation
10. Emerson Electric Co.
11. GEC General Electric Co. p.l.c.
12. Nokia Corporation

### **Electronics, Semiconductors**

1. Texas Instruments Inc.

### **Industrial and farm Equipment**

1. Thyssen AG
2. Mannesmann AG
3. IRI
4. Caterpillar Inc.
5. BTR plc.
6. Deere & Company

### **Metals**

1. Fried. Krupp AG Hoesch-Krupp
2. Usinor
3. Metallgesellschaft A.G.
4. Degussa AG

### **Motor Vehicles and Parts**

1. General Motors Corporation
2. Ford Motor Company
3. Daimler-Benz AG
4. Volkswagen Ag
5. Giovanni Agnelli. Soc. Accomandita.(Fiat)
6. Renault
7. Bayerische Motoren Werke AG
8. Peugeot S.A.
9. Robert Bosch GmbH
10. AB Volvo
11. MAN AG
12. Johnson Controls Inc.
13. TRW Inc.

**Petroleum Refining**

1. Royal Dutch/ Shell Group
2. Exxon Corporation
3. The British Petroleum plc
4. Elf Aquitaine
5. ENI S.p.A.
6. Total S.A.
7. Den Norske Stats Oljeselskap A.S.
8. PetroFina S.A.

**Pharmaceuticals**

1. Merck & Co Inc.
2. Johnson & Johnson
3. Novartis group
4. Bristol-Myers Squibb Company
5. American Home Products Corporation
6. Glaxo Wellcome plc
7. Roche Holding Ltd.
8. Smithkline Beecham plc
9. Pfizer Inc.

**Scientific, Photo, Control Equipment**

1. Minnesota Mining and Manufacturing Company
2. Eastman Kodak Company
3. Fuji Photo Film Co. Ltd.

**Telecommunication**

1. Deutsche Telekom
2. British Telecom
3. France Telecom
4. Telecom Italia
5. Alcatel
6. Koninklijke KPN NV

## Annex II. The regions

For the following countries/regions, the NUTS classification has been used:

<b>Austria</b>		<b>France</b>	
AT11	Burgenland	FR1	Ile De France
AT12+AT13	Niederösterreich	FR21	Champagne-Ardenne
AT21	Kärnten	FR22	Picardie
AT22	Steiermark	FR23	Haute-Normandie
AT31	Oberösterreich	FR24	Centre
AT32	Salzburg	FR25	Basse-Normandie
AT33+AT34	Tirol And Vorarlberg	FR26	Bourgogne
<b>Belgium</b>		FR3	Nord-Pas-De-Calais
BE1	Brussels Hfdst.Gew	FR41	Lorraine
BE2	Vlaams Gewest	FR42	Alsace
BE3	Region Wallonne	FR43	Franche-Comte
<b>Germany</b>		FR51	Pays De La Loire
DE1	Baden-Württemberg	FR52	Bretagne
DE2	Bayern	FR53	Poitou-Charentes
DE3	Berlin	FR61	Aquitaine
DE4	Brandenburg	FR62	Midi-Pyrenees
	Bremen And		Limousin
DE5+DE9	Niedersachsen	FR63	
	Hamburg And		Rhone-Alpes
DE6+DEF	Schleswig-Holstein	FR71	
DE7	Hessen	FR72	Auvergne
	Mecklenburg-		Languedoc-Roussillon
DE8	Vorpommern	FR81	
DEA	Nordrhein-Westfalen	FR82	Provence-Alpes-Cote D'azur
	Rheinland-Pfalz And		Corse
DEB+DEC	Saarland	FR83	
DED	Sachsen	<b>Greece</b>	
DEE	Sachsen-Anhalt	GR1	Voreia Ellada
DEG	Thüringen	GR2+GR3	Kentriki Ellada And Attiki
<b>Spain</b>		GR4	Nisia Aigaiou, Kriti
ES11	Galicia	<b>Italy</b>	
ES12+ES13	Asturias And Cantabria	IT1	Nord Ovest
ES21+ES22	Pais Vasco, Navarra		Lombardia
+ES23	And Rioja	IT2	
ES24	Aragon	IT31	Trentino-Alto Adige
ES3	Madrid	IT32	Veneto
ES41	Castilla-Leon	IT33	Friuli-Venezia Giulia
ES42	Castilla-La Mancha	IT4	Emilia-Romagna
ES43	Extremadura	IT51	Toscana
ES51	Cataluna	IT52	Umbria
ES52	Valenciana	IT53	Marche
ES53	Baleares	IT6	Lazio
ES61	Andalucia	IT7	Abruzzo-Molise
ES62	Murcia	IT8	Campania
ES7	Canarias	IT9	Sud
		ITA	Sicilia
		ITB	Sardegna

**Netherlands**

NL1	Noord-Nederland
NL21	Overijssel
NL22	Gelderland
NL23	Flevoland
NL31	Utrecht
NL32	Noord-Holland
NL33	Zuid-Holland
NL34	Zeeland
NL41	Noord-Brabant
NL42	Limburg

**Portugal**

PT11	Norte
PT12	Centro
PT13	Lisboa E Vale Do Tejo
PT14	Alentejo
PT15	Algarve

**Sweden**

SE01+SE02	Stockholm And Östra Mellansverige
SE03+SE04	Småland And Sydsverige
SE05	Västsverige
SE06	Norra Mellansverige
SE07	Mellersta Norrland
SE08	Övre Norrland

**United Kingdom**

UK1	North
UK2	Yorkshire And Humberside
UK3	East Midlands
UK4	East Anglia
UK5	South East
UK6	South West
UK7	West Midlands
UK8	North West
UK9	Wales
UKA	Scotland
UKB	Northern Ireland

For the following countries, a national classification has been used:

**Norway**      **Based on Fylken**

NO1	Akershus, Oslo
NO2	Hedmark, Oppland
NO3	Østfold, Busekrud, Vestfold, Telemark
NO4	Aust-Agder, Vest-Agder, Rogaland
NO5	Hordaland, Sogn og Fjordane, Møre of Romsdal
NO6	Sør-Trøndelag, Nord-Trøndelag
NO7	Nordland, Troms, Finnmark

**Switzerland**      **Based on Cantons**

CH1	Jura, Neuchâtel, Fribourg, Vaud, Geneva Argovia, Appenzell Inner-Rhodes, Appenzell Outer-Rhodes, Basel-Country-Basel-Town, Berne, Glarus, Lucerne, Nidwalden, Obwalden, St. Gallen, Schaffhausen,
CH2	Schwyz, Solothurn, Thurgovia, Uri, Zug, Zurich
CH3	Valais, Ticino, Grisons

**Denmark**      **Based on postal regions**

DK1	Hillerød, Helsingør, København
DK2	Fyn, Sjaelland ex. Hillerød, Helsingør, København
DK3	Jylland

The following countries have been included as a single region:

Finland  
Ireland  
Luxemburg





Eindhoven Centre for Innovation Studies

## WORKING PAPERS

Ecis working papers 2001-2002 (September 2002):

- 01.01 H. Romijn & M. Albu  
*Explaining innovativeness in small high-technology firms in the United Kingdom*
- 01.02 L.A.G. Oerlemans, A.J. Buys & M.W. Pretorius  
*Research Design for the South African Innovation Survey 2001*
- 01.03 L.A.G. Oerlemans, M.T.H. Meeus & F.W.M. Boekema  
*Innovation, Organisational and Spatial Embeddedness: An Exploration of Determinants and Effects*
- 01.04 A. Nuvolari  
*Collective Invention during the British Industrial Revolution: The Case of the Cornish Pumping Engine.*
- 01.05 M. Caniëls and H. Romijn  
*Small-industry clusters, accumulation of technological capabilities, and development: A conceptual framework.*
- 01.06 W. van Vuuren and J.I.M. Halman  
*Platform driven development of product families: Linking theory with practice.*
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*Information Technology, Knowledge Processes, and Innovation Success.*
- 01.08 M. Song, H. van der Bij, M. Weggeman  
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- 01.09 M. Song, H. van der Bij, M. Weggeman  
*An empirical investigation into the antecedents of knowledge dissemination at the strategic business unit level.*
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- 02.05 K. Heimeriks  
*Alliance Capability, Collaboration Quality, and Alliance Performance: An Integrated Framework.*
- 02.06 G. Duysters, J. Hagedoorn & C. Lemmens  
*The Effect of Alliance Block Membership on Innovative Performance*
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