Working Papers Firms and Region
No. R2/2008

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The spatial embeddedness of multi-national enterprises' research activity

A bibliometric analysis

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Karlsruhe 2008
ISSN 1438-9843

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1 Introduction and research question

Undoubtedly, large companies such as multi-national enterprises (MNEs) command sufficient resources to manage research, development and innovation projects based on own capabilities. Nevertheless, innovation is nowadays widely understood as complex and interactive process, including contributions and feedback loops from different sources. This basic understanding of the complex and interactive innovation process as a knowledge-generating and implementing, social process has been incorporated in the innovation system approach. The concept explicitly includes firms' environments through their network focus and their interactive comprehension of innovation. Besides the approach of national innovation systems, which refers to the general cultural and institutional context in which innovation takes places, i.e. to rules, norms, laws, habits and standards, and which considers innovation in its national framework (cf. Edquist 1997; Lundvall 1992; Nelson 1993), the concept of regional innovation systems acknowledges that innovation patterns and network structures may differ between different territories of a national state (cf. Braczyk et al. 1998; Cooke 1998; Cooke et al. 2004). This approach specifically emphasizes proximity relations between innovation actors, as well as region-specific innovation determinants. Though this view may at first sight contradict globalisation tendencies, research on this topics came to the conclusion that firms' "home bases", not easily transferable tacit knowledge as well as personal communication and the facilitating spatial proximity are crucial location factors for firms in the context of global competition. Moreover, the importance of not easily transferable, thus location-specific tacit knowledge, firms' competencies, as well as local suppliers and customers have an important role in firms' production and innovation activities (cf. Heidenreich 2004: 369/370), the output of which is offered on international markets.

The relevance of spatial proximity and the importance of positive externalities from agglomeration are also highlighted in the cluster concept. According to the general understanding, clusters are spatial concentrations of enterprises, research institutions and intermediaries of a branch or related branches, which are linked by value-added chains. The central strengths of clusters are learning and innovation advantages (Malmberg/Maskell 2002). It is therefore obvious that MNEs participate for their innovation activities by being part or even the driver of a cluster.

Since MNEs can be interpreted as global networks of control and coordination between the different subsidies, the question arises how networks within a MNE and location-based networks (be they regional, national or international) interact and complement each other. Regarding innovation and the creation of new knowledge, so far little is known on the relationship between multinationals and their regional environment, be it a regional innovation system or a specific cluster. Usually the expectation is expressed that MNEs and their subsidies enrich the regional innovation potential by embedding into vertical customer-supplier networks and into horizontal networks between other firms, research and transfer organizations. Whether this is really the case and which interactions exist between the sub-national (i.e. regional) and the global scale is this an open question. Regions and clusters, as companies, are not closed containers, whose economic strengths exist independently of their international environment. Especially those regions and clusters which possess a well advanced and internationally competitive science and technology base are heavily dependent on globally available knowledge and human resources and have to find ways to attract these resources by gluing them to their territories. As a matter of fact, regional innovation systems are open, world-wide connected spaces, which must assert themselves in global competition (Koschatzky 2005).

It is therefore worthwhile to investigate two interrelated questions. Firstly, is innovation activity of MNEs is embedded in regional innovation systems and clusters, and secondly, does the MNE as a complex organisation maintain knowledge flows across several regional innovation systems in different locations.[1]

The following empirical study has two objectives:

1. Description of the regional distribution of innovative activity in order to localize innovation capabilities in geographical space. Methodologically, this analysis is based on the inventor address in patents that are held by MNEs as patent assignees.
2. Investigation to what extent MNEs engage in technology-specific networks with universities and public research institutes and investigation of the spatial distribution of network ties. Collaborative ties with public research

[1] These research questions are part of a project on learning in multinational companies, funded by the German Volkswagen Foundation and directed by Martin Heidenreich (University Oldenburg), Knut Koschatzky (Fraunhofer Institute for Systems and Innovation Research Karlsruhe) and Christoph Barmeyer (IECS - Ecole de Management de Strasbourg).

institutions are interpreted as an indicator for integration in regional innovation systems. This analysis is based on the analysis of research affiliations of patent inventors by matching inventor names with authors in a publication database.

By these two objectives a picture about the spatial pattern of invention activities of MNEs will be drawn and it will be analyzed whether firm and/or country specificies play a role in the organisation of innovation projects.

2 The spatial distribution of inventors and R&D collaborations of multinational enterprises – an analysis based on patents and scientific publications

2.1 Methodology of the patent and publication analysis

2.1.1 The selection of countries, companies and technology fields

In the first step, we chose France and Germany for a contrasting country comparison. Germany with its federal system is a decentralised economy in which the regional dimension, e.g. the "*Länder*" (federal states) plays a predominant role. It could be expected that due to the fact that no urban hierarchy with one major agglomeration exists, but a balanced distribution of several larger cities can be found, knowledge centers and thus innovation networks are much more dispersed than in countries with a much higher spatial concentration. In the past, France was an example of such a centralised economy (Crespy et al. 2007: 1071). Nevertheless, starting in the 1980s, a devolution and decentralisation process took place by which the regional level was strengthened. Examples from recent times are the "pôles de compététivités", a kind of cluster promotion involving small and large firms at the regional level. Taking these two different patterns of spatial organization as a starting point, it seems worthwhile to analyse, even with a small sample of case study firms, whether the regional embeddedness and the networking pattern of MNEs differ between these two countries or show certain similarities.

In a second step, we looked for MNEs which seem to be representative for the technological profile of each country. We also included a practical aspect in the selection process in a way that certain general information about the companies was already available. For France, we chose Rhodia, Freescale, Gemalto (Gemplus), and Renault, for Germany we chose Bayer, IBM Germany, Daimler & Nucellsys, and Siemens.

In a third step, we selected a set of technological fields which covered certain aspects of the product spectrum of each MNE. For this identification process we used the annual reports of the companies and other publicly available information. We carried out patent searches in the technological fields in order to identify the patenting activity and thus the invention activity of each MNE. The final

selection was made on the basis of a sufficient number of patent applications in order to analyse their regional distribution.

2.1.2 The spatial distribution of inventors

Intellectual property rights are of growing importance in global technological competition. Consequently, the R&D activity of MNEs is reflected in a growing number of patent applications at international patent offices. As a patent assignee, the MNE owns the intellectual property of the granted invention and ensuing legal rights. Through the analysis of patent documents we want to find out where the innovative capabilities are located and where the innovative activity leading to these patent applications takes place. The description of the regional distribution of innovative activity is one element in answering the question if and to what extent MNEs are embedded in regional innovation systems.

Many MNEs have centralized units for the legal administration of patent claims, while the R&D units that produce technological inventions are often located in different places. Therefore, the information on patent assignees in patent documents is usually not sufficient to know which firm or sub-unit was involved in the creation of a particular invention. Yet patent documents do not only contain information on patent assignees but also personal information on patent inventors. In order to regionalize patent information, the current study uses address information of patent inventors, assuming that the place of residence of an inventor is usually located in spatial proximity to the enterprise unit where the corresponding R&D activity takes place. By analysing the zip-code information in the inventor address field for all patent applications in the sample, the patents can be allocated to regions.

The common database in all eight cases are applications to the European Patent Office (Euro-PCT), because European patent applications are equal in Germany and France and thus provide greater comparability. By contrast, applications to national patent offices in Germany and France are excluded from the analysis. The publicly accessible database PATDPA of the German Patent and Trade Mark Office (DPMA) was chosen because it offers searchable inventor address fields and more comprehensive address information than any other comparable patent database. This database includes patent information for all EPO applications. The searchable address field is an essential feature in the present context because it allows for the regional classification of patent applications. This patent database contains patents applications, and utility models

filed in Germany. Sources for PATDPA include the German Patent and Trademark Office, European Patent Office and World Intellectual Property Organization. All keyword searches were performed in German and English language since not all patent applications contain full abstracts in English.

An important part of the work consists in the definition of patent samples for each case. Apart from the patent assignee, i.e. the particular MNE of interest, the patent sample is defined through the technology field and the period of analysis. The information on patent assignees, technology field and time period are the basis for document searches in the patent database.

The technology field is defined on the basis of the international patent classification IPC (table 2-1). The IPC is a comprehensive and very detailed taxonomy of patent claims according to areas of technology. It is subdivided in eight main categories and distinguishes in total approximately 60.000 different patent codes. Each patent application classifies the invention according to IPC main and secondary classes. In some cases we used keywords (additionally or exclusively) for field definition which are searched in titles and abstracts. In two cases we used existing field definitions by Fraunhofer ISI (fuel cells and semiconductors).

The period of analysis was usually adapted to the frequency of patent applications in order to include a sufficient number of patents. In each case we therefore conducted test searches to determine the frequency of patent applications in the respective technology fields for different years. The period was extended if necessary to include sufficient numbers of patents for regional analyses.

Table 2-1: Technology fields of the MNE patent samples

	MN Enterprise / Patent applicant	Technology field	IPC	Period
1	Bayer	Medicinal preparations containing organic active ingredients	A61K031	2004
2	IBM Deutschland	Computing	G06	2000-2002
3	Daimler & Nucellsys	Fuel cells in vehicles and system components	H01M008 in combination with other codes and keywords	1987-2004

	MN Enterprise / Patent applicant	Technology field	IPC	Period
4	Siemens	Railways	B61	1999-2001
5	Rhodia	Polyamides	keywords	1997-2002
6	Freescale	Semiconductors	H01L or B81	2003-2004
7	Gemalto (Gemplus)	Chip cards	G06 and key-words	1996-2001
8	Renault	Control or regulating sys-tems	G05B	2000-2004

Source: Fraunhofer ISI

The information given in table 2-1 defines the sample of patent applications that has been searched in the database PATDPA for each MNE. The resulting patent sets vary between 16 (Renault) and 106 (Siemens) patent documents. The size of the patent sample depends not only on the breadth of the technology definition, but also on the patent intensity of the respective technology field, as well as the R&D performance and the intellectual property strategy of the respective MNE. In addition, technologies vary in the average number of inventors per patent application. Thus, the data basis for the regional analysis of inventors varies considerably across the eight cases under study.

On the basis of the patent samples we searched for inventor names and inventor addresses for each MNE. Inventor names are required for the subsequent author search in publication databases. Inventor addresses are searched in order to relate patents to zip-code areas. The results of the spatial analysis are described in section 2.2.

In interpreting the results, it is important to understand how patents are counted in regionalization. The relation between innovative activity and region is operationalised through the inventor's address. Yet many patent applications enlist more than one inventor and more than one inventor address. In analyzing the regional distribution, each inventor address is given equal weight, independent of whether two addresses occur in the same patent or in different documents. Thus, the regional distribution does not represent the frequency of patent documents, but the frequency of inventor addresses (inventor occurrences, abbreviated as "Occ.") By contrast, if one and the same person is named as the inventor of several patent documents, this person is counted once for each document (cf. example in table 2-2).

Table 2-2: Multiple applications per person in the case of Bayer

Applications per person	Frequency
5	1
4	2
3	13
2	23
1	62

2.1.3 Collaborative ties with universities and other public research institutes

In the second part of the bibliometric analysis, we investigate to what extent MNEs engage in technology-specific networks with universities and public research institutes. This analysis is based on an indicator of "patent ties", namely public research affiliations of patent inventors. Thus, our analysis is highly selective in that it focuses on one very strong indicator of collaborative ties. Other types of collaborative linkages between the MNE and the public research landscape are investigated in the qualitative case studies, including such aspects as R&D contracts, personal mobility and informal relations between researchers. All collaborative ties with public research institutions are interpreted as indicators for integration in regional innovation systems.

The methodology for the current analysis was first used by Noyons et al. (2003) who analyzed collaboration patterns of "centres of excellence" in selected fields of nanotechnology and biotechnology and was more fully exploited in a network analysis of German nanotechnology by Heinze (2006). However, this methodology has not been used so far for the analysis of technology collaborations in the case of individual MNEs which patent in different technology fields. Therefore, the methodology had to be adapted and further developed for the present analysis.

The analysis of patent ties is based on the methodological consideration that public research institutions often do not appear as patent applicants even if they are the actual locus of origin of an invention. Rather, patents are applied for by private companies or individual researchers. In order to show these hidden linkages to public research institutions, the inventor names are matched with author names in scientific publication databases which record their institutional affilia-

tion. If an inventor can be shown to be affiliated with a public research institution, this can be interpreted as a very strong indicator of collaborative linkages between the MNE and the public institution.

Whereas traditional approaches found that 4 % of patents are filed by universities and an additional 3 % by other public research institutions as *patent assignees,* Noyons et al. claim that at least 50 % of all European patent applications in nanotechnology originate from public research institutions, if hidden linkages are acknowledged (2003: 51). Our own findings corroborate that there are cases in which a large number of patent inventors also publish in scientific journals, as in the case of Bayer Healthcare. However, across our case studies we found only selected cases in which matched authors were affiliated with public research institutes. Our own experience with the Science Citation Index, the database also used by Noyons et al., shows that there is a strong likelihood of false hits in matching patent inventors with SCI authors. Therefore, we amended the matching process through author searches in the multidisciplinary database Scopus and the German Engineering database "DOMA Maschinenbau und Anlagenbau" which is produced by FIZ Technik, Karlsruhe. These databases allow for more refined author searches because they include full first names and allow for more precise assignments of authors to research affiliations. On this basis we were able to substantially reduce the likelihood of false hits.

The definition of the patent sample and the search for inventors (section 2.1.1) is the point of departure for the subsequent matching process with author names. The matching process includes the following methodological steps which are carried out for each MNE case:

1. Selection of database: Depending on the field of technology, we either use the multidisciplinary database SCI or the German engineering literature database DOMUS as the basis for the author search. SCI has a strong bias toward English language journals and is particularly suitable for life sciences and also information technology. Therefore, the conditions for German and French authors are similar. Since other fields of engineering literature are less well covered by the SCI, DOMA is used for the cases of Daimler and Siemens.
2. Field definition: For each MNE we define a science and technology field which corresponds to the technology field of the patent sample. This field definition builds on given subject categories in each database (table 2-3).

3. Search for author names. In the case of SCI searches all instances of matching are checked in the database Scopus in order to identify false hits.
4. Analysis of public research affiliations by patent inventors.

Table 2-3: Delineation of science and technology fields

	MN Enterprise	Database	Subject Categories
1	Bayer Healthcare	SCI/ Scopus	Pharmacology & Pharmacy; Biochemistry & Molecular Biology; Organic Chemistry; Peripheral Vascular Disease; Medicinal Chemistry; Cardiac & Cardiovascular Systems; Hematology
2	IBM Deutschland	SCI/ Scopus	Computer Science, Theory & Methods; Computer Science, Software Engineering; Computer Science, Hardware & Architecture; Electrical & Electronic Engineering
3	Daimler/ NuCellsys	DOMA	Direct conversion of energy into electrical energy (Energiedirektumwandlung in elektrische Energie, Energiespeicher); specific drives (spezielle Fahrzeugantriebe)
4	Siemens Transportation Systems	DOMA	Rail Vehicles (Schienenfahrzeuge, Seil- und Schwebebahnen); Automotive Engineering (Fahrzeugtechnik)
5	Rhodia	SCI/ Scopus	Physical Chemistry; Organic Chemistry; Polymer Science; Materials Science, Multidisciplinary; Inorganic & Nuclear Chemistry; Chemical Engineering; Applied Chemistry; Materials Science, Coatings & Films; Materials Science, Composites
6	Freescale	SCI/ Scopus	Applied Physics; Physics, Condensed Matter; Electrical & Electronic Engineering; Materials Science, Multidisciplinary; Nanoscience & Nanotechnology; Computer Science, Hardware & Architecture
7	Gemalto	SCI/ Scopus	Electrical & Electronic Engineering; Computer Science, Theory & Methods; Computer Science, Hardware & Architecture; Computer Science, Software Engineering; Computer Science, Interdisciplinary Applications; Telecommunications
8	Renault	SCI/ Scopus	Instruments & Instrumentation; Automation & Control Systems; Electrical & Electronic Engineering; Computer Science, Cybernetics; Computer Science, Information Systems; Computer Science, Interdisciplinary Applications

2.2 Results of the patent and publication analysis

2.2.1 Bayer Healthcare

Enterprise self-description: "Bayer HealthCare is a globally active company with sites on all five continents. Bayer HealthCare markets products from its four divisions Animal Health, Bayer Schering Pharma, Consumer Care, Diabetes Care via regional and national distribution companies."
http://www.bayerhealthcare.com; last accessed 3.8.2007

Several test searches were conducted to identify a suitable technology field on an aggregate level. On the basis of these test searches, we decided to use the IPC class A61K031 as the technological definition.

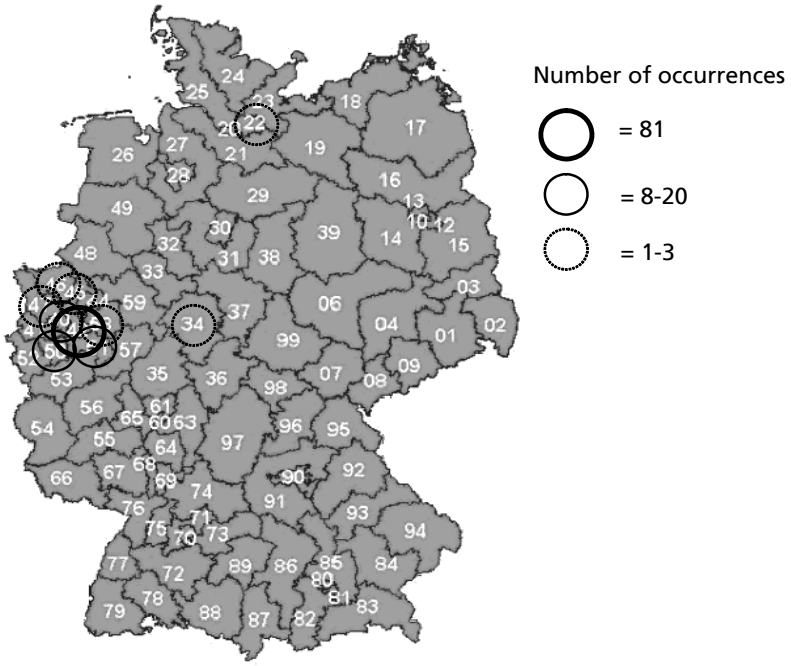
The resulting patent set includes 11.7 % of all European patent applications by Bayer AG or Bayer Healthcare with priority year 2004 (197 in total).

Table 2-4: Patent set for Bayer case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Medicinal preparations containing organic active ingredients	A61K031	2004	23	101	84% DE 10% JP

- 84 % of all inventors (occ.) have German addresses; another 10 % are located in Japan (table 2-4). The rest comes from Croatia, France, Spain and the USA.
- The geographical distribution of inventors (figure 2-1) shows a strong regional concentration in and around Wuppertal. Wuppertal is the place of the Bayer Healthcare Pharma Research Centre.

Figure 2-1: Regional distribution of inventors for Bayer Healthcare



Results of the publication analysis

The publication search was performed for publications with at least one German author in the subject categories pharmacology & pharmacy; biochemistry & molecular biology; organic chemistry; peripheral vascular disease; medicinal chemistry; cardiac & cardiovascular systems; and haematology in the period of 2002-2004. Of all 76 inventor names searched, 48 were identified as authors in the publication database SCI (63 %). This is the largest share of authors identified among all eight case studies. The search in Scopus identified 45 authors (59 %) who are affiliated with Bayer in the period under consideration. Four authors have German university affiliations (table 2-5). Three other author names are ambiguous, i.e. at least two scientists with identical surname and forename are publishing within the same scientific area.

- 63 % of the Bayer inventors (48 individuals) are authors of scientific publications in the SCI
- 5 % of Bayer inventors (4 individuals) are affiliated with different German universities

Table 2-5: Public research affiliations of patent inventors in the case of Bayer

Affiliations with Bayer and University	**University Münster, Institute of Arteriosclerosis Research (1 author)**
	University Cologne, Institute of Organic Chemistry (1 author)
University affiliations only	University Hamburg, Institute for Vegetative Physiology und Pathophysiology (1 author)
	University Düsseldorf, Institute for Pharmaceutical Technology (1 author)

Source: Scopus, analysis by Fraunhofer ISI

2.2.2 IBM Deutschland

Enterprise self-description: "With around 1,800 employees IBM Deutschland Entwicklung GmbH in Böblingen is one of the largest innovation centres of IBM worldwide."
http://www.ibm.com/de/; last accessed 3.8.2007

On the basis of test searches we chose 2000-2002 as the period of reference and we used the IPC class G06 as technological definition of our patent sample (table 2-6).

Table 2-6: Patent set for IBM Deutschland case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Computing, Calculating, Counting	G06	2000-2002	64	172	37% DE 53% US

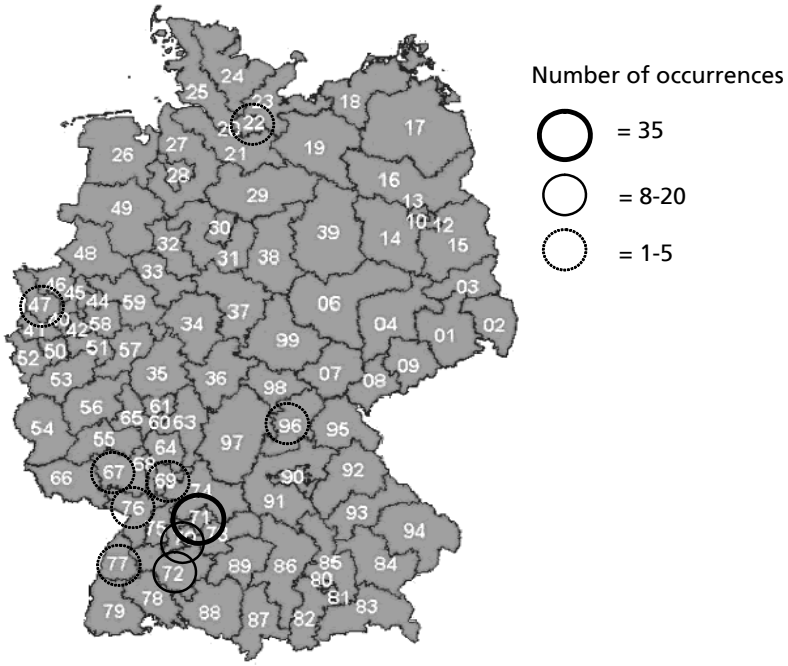
- 37 % of all inventors (occ.) have German addresses, while 53 % are located in the US. Further international locations are shown in table 2-6.

Table 2-7: IBM Deutschland: International distribution of inventors

ID	Occ	CY	City
1	2	AU	New South Wales
2	6	CA	Ontario
3	3	CH	Zürich
4	1	CN	Hong Kong
5	74	DE	several
6	2	FR	Marseille, Paris
7	1	GB	Portsmouth
8	111	US	several
Total	200		

- The geographical distribution of inventors (figure 2-2) shows a strong regional concentration in and around Böblingen. Böblingen is the place of the IBM Deutschland Entwicklungs GmbH.

Figure 2-2: Regional distribution of inventors for IBM Deutschland



Results of the publication analysis

The publication search was performed for publications with at least one German author in the subject categories computer science, theory & methods; computer science, software engineering; computer science, hardware & architecture; and electrical & electronic engineering in the period of 1999-2001. Of all 68 inventor names searched, 6 were identified as authors in the publication database SCI (8.8 %). One author address is related to the IBM software group whereas the five other names are false hits. These results indicate that German patent inventors employed by IBM Deutschland tend to publish little in ISI journals.

- In the case of IBM Deutschland, there are no indications of strong linkages with German public research institutions in the selected technology field.

2.2.3 Daimler and NuCellsys

Enterprise self-description: "NuCellsys GmbH is a 50/50 joint venture between Daimler Chrysler and Ford Motor Company (…). In the framework of the fuel cell alliance between DaimlerChrysler, Ford und Ballard the responsibility of NuCellsys is system development and design, component and software development as well as system validation and system integration. Since 2003 there is a low volume production of fuel cell systems."
http://www.nucellsys.com/; last accessed 3.8.2007

The patent set was defined on the basis of existing field definitions for fuel cells and system components (by Fraunhofer ISI). The patent sample includes all years from 1987 (first EP) to 2004 (table 2-8). As patent applicants we searched for either Daimler or NuCellsys.

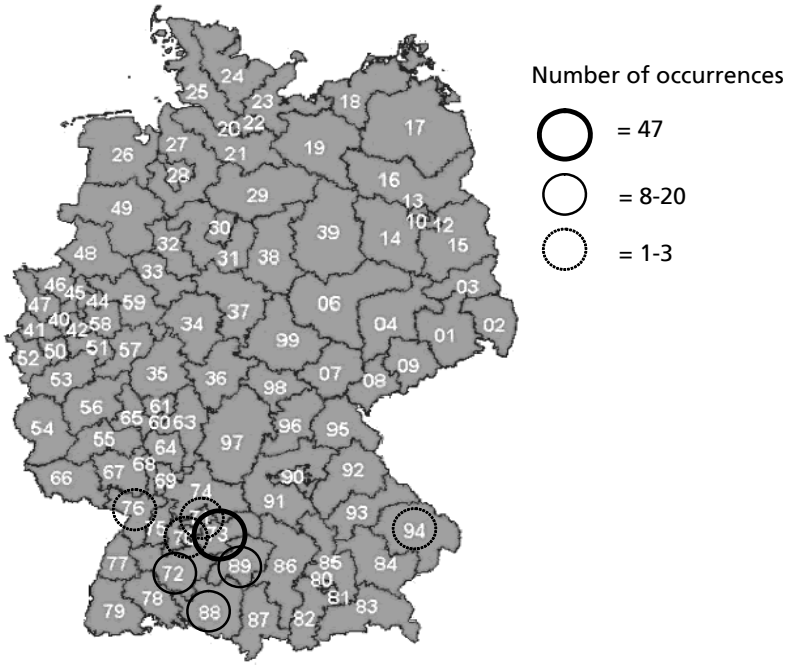
Table 2-8: Patent set for Daimler/NuCellsys case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Fuel cells in vehicles and system components	H01M0-08 combined with other codes and keywords	until 2004	40	76	77% DE 22% CA

- 77 % of all inventors (occ.) have German addresses, while 22 % are located in Canada, related to the alliance of Daimler / NuCellsys with the Canadian enterprise Ballard.

- The geographical distribution of inventors (figure 2-2) shows a strong regional concentration in and around Nabern / Kirchheim-Teck which is the location of NuCellsys.

Figure 2-3: Regional distribution of inventors for Daimler and NuCellsys



Results of the publication analysis

The publication search was performed for publications with at least one German author in the subject categories "Direct conversion of energy into electrical energy" (Energiedirektumwandlung in elektrische Energie, Energiespeicher)" and "Specific drives" (Spezielle Fahrzeugantriebe)" in the publication database DOMA in 1998-2007. Of all 76 inventor names searched, 17 were identified as authors of publications in the publication database DOMA (22 %). Nine of these authors are affiliated with DaimlerChrysler in Stuttgart, Kirchheim/Teck or Ulm, four authors have public research affiliations, and two authors were affiliated with other firms than Daimler. For two authors, affiliations could not be identified.

- In the case of Daimler/NuCellsys, strong university linkages, as indicated by patent assignee-inventor relationships, are not confined to the regional surroundings of Nabern-Kirchheim/Teck (table 2-9).

Table 2-9: Public research affiliations of patent inventors in the case of Daimler/NuCellsys

University affiliations only	Institut für Kraftfahrwesen Aachen (ika) RWTH Aachen
	Institut für Solare Energieversorgungstechnik (ISET), Universität Gesamthochschule Kassel
	Fachbereich Maschinenbau und Produktion, Fachhochschule Hamburg
	Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW), Ulm

Source: DOMA, analysis by Fraunhofer ISI

2.2.4 Siemens Transportation Systems

Enterprise self-description: "As single source supplier and system integrator, the Transportation Systems Group combines all the expertise necessary to cover all areas of rail transportation: Mega Cities & Urban Transport; Commuter & Intercity Transport; Airport Links & People Mover; High Speed & Main Line; Freight & Traction."
http://www.transportation.siemens.com/ts/de/pub/home.htm; last accessed 3.8.2007

As in all other cases, several test searches were conducted to identify a suitable technology field on an aggregate level. On the basis of these test searches, it was decided to use the broad IPC class B61. The time period was 1999 - 2001.

Table 2-10: Patent set for Siemens Transportation Systems case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Railways	B61	1999-2001	106	162	62% DE 23% AT 13% CH

- 62 % of all inventors (occ.) have German addresses, while 23 % are located in Austria and 13 % in Switzerland. The regional distribution of inventors in these two countries is shown in table 2-11 and table 2-12.

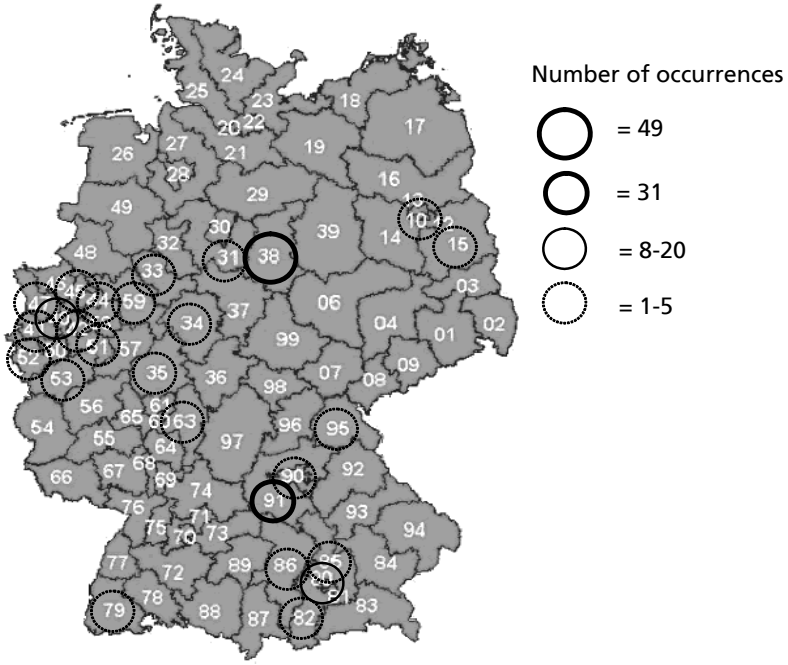
Table 2-11: Regional distribution of inventors for Siemens Transportation Systems in Austria

ID	Occ	Zip-Code	City
1	2	12	Wien
2	1	21	Gaweinstal
3	2	22	Deutsch-Wagram
4	4	34	Klosterneuburg
5	30	80	Graz
6	2	80	Feldkirchen
7	3	81	Wundschuh
8	2	82	Stubenberg
9	2	87	St. Lorenzen
10	6	88	Scheifling

Table 2-12: Regional distribution of inventors for Siemens Transportation Systems in Switzerland

ID	Occ	Zip-Code	City
1	1	63	Huenenberg
2	6	80	Zürich
3	5	81	Daenikon
4	2	83	Dietlikon
5	5	84	Winterthur
6	3	85	Frauenfeld
7	2	86	Grünigen
8	2	87	Kuesnacht
9	1	88	Thalwil
10	4	89	Wettswil

Figure 2-4: Regional distribution of inventors for Siemens Transportation Systems



- The geographical distribution of inventors shows a polycentric structure with concentrations in Braunschweig, Erlangen and in the area of Düsseldorf (figure 2-4). Another regional centre is Graz. The polycentric structure of innovation activity is probably related to the comparatively broad field definition in this case.

Results of the publication analysis

The publication search was performed for publications with at least one German author in the subject categories "Rail Vehicles" (Schienenfahrzeuge, Seil- und Schwebebahnen) and "Automotive Engineering" (Fahrzeugtechnik) in the publication database DOMA in 1998-2002. Of all 31 inventor names searched, eight were identified as authors in the publication database DOMA (26 %) all of whom have Siemens addresses.

- Besides one individual linkage to the Technical University Darmstadt the results for Siemens Transportation Systems do not indicate embeddedness in regional innovation networks with public research institutes.

2.2.5 Rhodia

Enterprise self-description: Rhodia Polymide is one of seven enterprises of the Rhodia group. "The second largest producer in the world of polyamide 6.6, Rhodia Polyamide is prioritizing the development of its leadership positions in intermediates, upstream of a fully integrated polyamide chain (adipic acid, ADN, HMD, phenol, nylon salt, polymers) and in engineering plastics."
http://www.rhodia.com/; last accessed 3.8.2007

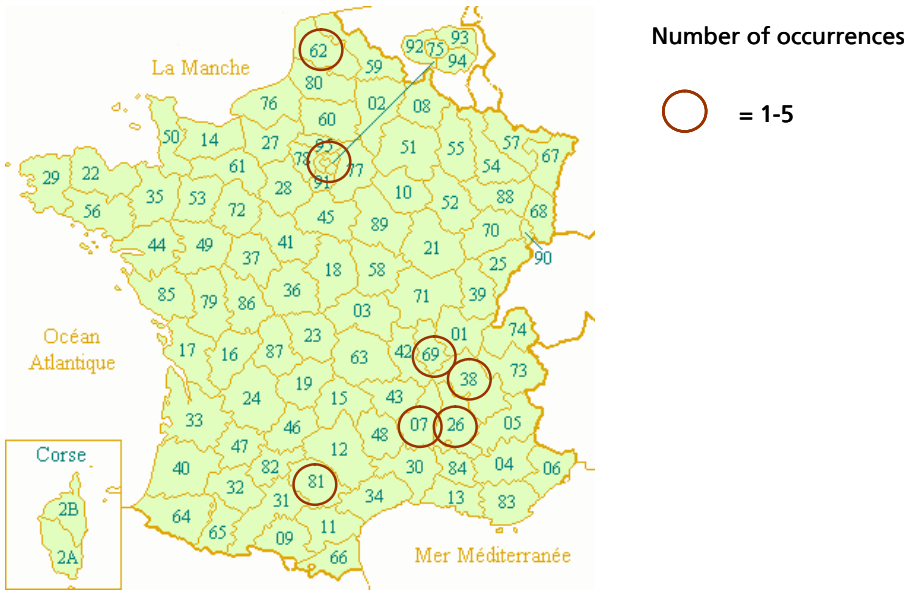
On the basis of test searches, it was decided to use keywords in the field of polyamide research as the technological definition, so that the patent sample relates primarily to this field.

Table 2-13: Patent set for Rhodia case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Polyamide	Keywords	1997-2002	17	24	32% FR 44% IT 22% CH

- 32 % of all inventors (occ.) have French addresses; another 44 % are located in Italy and 22 % in Switzerland.

Figure 2-5: Regional distribution of inventors for Rhodia



- The geographical distribution of inventors (Figure 2-1) shows a moderate regional concentration in and around Lyon (Département 69). Another regional centre of innovation activity is Milano, Italy.

Results of the publication analysis

The publication search was performed for publications with at least one French author in the subject categories physical chemistry; organic chemistry; polymer science; materials science, multidisciplinary; inorganic & nuclear chemistry; chemical engineering; applied chemistry; materials science, coatings & films; materials science, composites in the period of 1997-2003. Of all 23 inventor names searched, seven were identified as authors in the publication database SCI (30 %). Four authors have addresses with Rhodia or Rhône-Poulenc in France, one author is affiliated with Rhodia in Italy, one author information is missing. Two authors have public research affiliations (table 2-14).

Table 2-14: Public research affiliations of patent inventors in the case of Rhodia

Affiliations with Rhodia and CNRS	CNRS Sophia Antipolis (1x)
CNRS affiliation only	Unité Mixte CNRS Institute de Physique et Chemie des Materiaux de Strasbourg IPCMS, Grp Surfaces-Interfaces, Strasbourg (1x)

Source: Scopus, analysis by Fraunhofer ISI

- In the case of Rhodia, strong linkages exist with public research institutions (CNRS institutes) in Sophia Antipolis (Département 06) and Strasbourg (Département 67).

2.2.6 Freescale

Enterprise self-description: "Freescale Semiconductor, Inc. is a global leader in the design and manufacture of embedded semiconductors for the automotive, consumer, industrial, networking and wireless markets. The privately-held company is based in Austin, Texas, and has design, research and development, manufacturing or sales operations in more than 30 countries."
http://www.freescale.com/; last accessed 3.8.2007

On the basis of prior research by Fraunhofer ISI, it was decided to use the IPC classes H01L and B81 as the technological definition. The period of the patent sample was 2003-2004 (table 2-15).

Table 2-15: Patent set for Freescale case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Semiconductors	H01L or B81	2003-2004	102	350	8.3% FR 84.3% USA

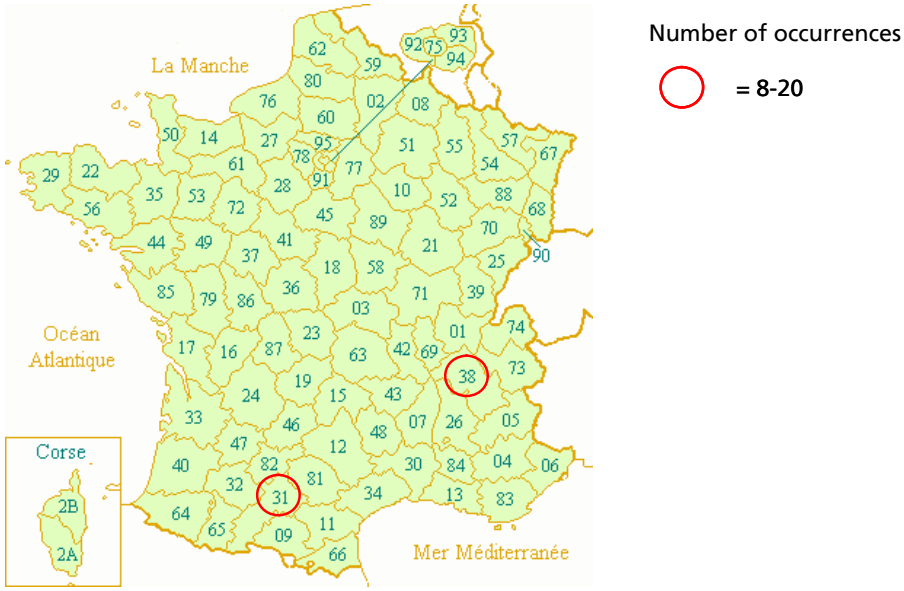
- 84 % of all inventors (occ.) have US addresses, only 8.3 % are located in France (table 2-15).

Table 2-16: Freescale: International distribution of inventors

ID	Occ	CY	Country Name
1	1	BE	Belgium
2	11	CN	China Hong Kong
3	4	CN	China Tianjin
4	29	FR	France
5	1	IE	Ireland
6	9	MY	Malaysia
7	295	US	USA
Total	350		

- The geographical distribution of French inventors (figure 2-6) shows Toulouse and Grenoble as the two locations of innovation activity.

Figure 2-6: Regional distribution of inventors for Freescale



Results of the publication analysis

The publication search was performed for publications with at least one French author in the subject categories applied physics; physics, condensed matter; electrical & electronic engineering; materials science, multidisciplinary; nanoscience & nanotechnology; computer science, hardware & architecture in the period 2002-2004. Of all 45 inventor names searched, 12 were identified as authors in the publication database SCI (26.7 %). Of these 12 authors, eight are located in France and four in USA. Some of the French authors are affiliated with Motorola Digital DNA Laboratories, Toulouse (two authors), or Freescale semiconductors France (one author). Remarkably in this case, four French authors have public research affiliations without indications of Freescale affiliations. Furthermore, these authors each have a large number of publications (ranging from 44 to 181 documents per author) and are highly cited (ranging from 72 to 2,509 citations per author; scopus database) (table 2-17).

- 9 % of Freescale inventors (4 individuals) are affiliated with French public research institutions in Toulouse.
- Some of the inventors are highly cited scientists in their respective fields.

Table 2-17: Public research affiliations of patent inventors in the case of Freescale

CNRS and University affiliations	CNRS Laboratoire de Chimie de Coordination, Toulouse (2 authors)
	Université de Toulouse, Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS-CNRS) (1 author)
	Université Paul Sabatier, Laboratoire de Génie Electrique Toulouse (1 author)

Source: Scopus, analysis by Fraunhofer ISI

2.2.7 Gemalto

Enterprise self-description: "A world-leader in digital security (…) We provide end-to-end digital security solutions, from the development of software applications through design and production of secure personal devices such as smart cards, SIMs, e-Passports and tokens to the management of deployment services for our customers."

http://www.gemalto.com/, last accessed 3.8.2007

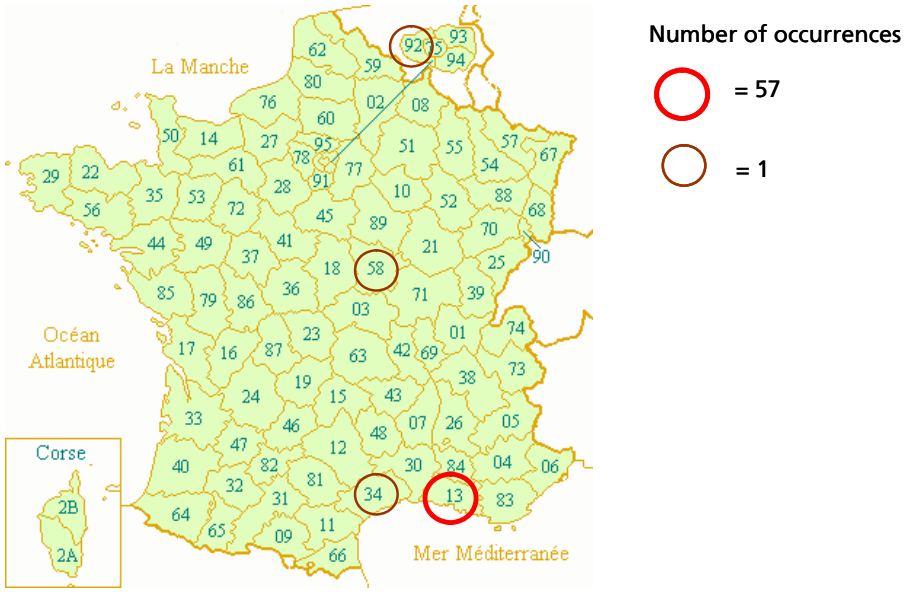
Several test searches were conducted to identify a suitable technology field on an aggregate level. On the basis of these test searches, it was decided to combine the IPC class G06 with keywords for the technological definition. The period for the patent sample was adapted to the target patent (table 2-18).

Table 2-18: Patent set for Gemalto case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Chip cards	G06 and keywords	1996-2001	35	39	87% FR, 10% DE

- 87 % of all inventors (occ.) have French addresses; another 10 % are located in Germany (table 2-18).
- The geographical distribution of inventors (figure 2-1) shows a strong regional concentration in Marseille (Département 13).

Figure 2-7: Regional distribution of inventors for Gemalto



Results of the publication analysis

The publication search was performed for publications with at least one French author in the subject categories electrical & electronic engineering; computer science, theory & methods; computer science, hardware & architecture; computer science, software engineering; computer science, interdisciplinary applications; telecommunications from 1997-2002. Of all 37 inventor names searched, eight were identified as authors in the publication database SCI (21.6 %). Three

authors have Gemplus as corporate source whereas the five other authors are false hits. One author has "INRIA Sophia Antipolis" as a second affiliation mentioned in Scopus. Sophia Antipolis is a "technopôle" located between Cannes and Nice (Département 06), and thus close to the location of most inventors in this case.

Table 2-19: Public research affiliations of patent inventors in the case of Gemalto

Affiliations with Gemalto and research institute	Institute Nationale de Recherche en Informatique and Automatique INRIA Sophia Antipolis (1 author)

Source: Scopus, analysis by Fraunhofer ISI

2.2.8 Renault

Enterprise self-description: "Renault is committed to the development implementation of new technologies into every aspect of our vehicles. Renault's engineers cover every angle – roadholding, safety, comfort, soundproofing, etc. – in their relentless quest to make motoring a pleasurable experience."
http://www.renault.co.uk, last accessed 3.8.2007

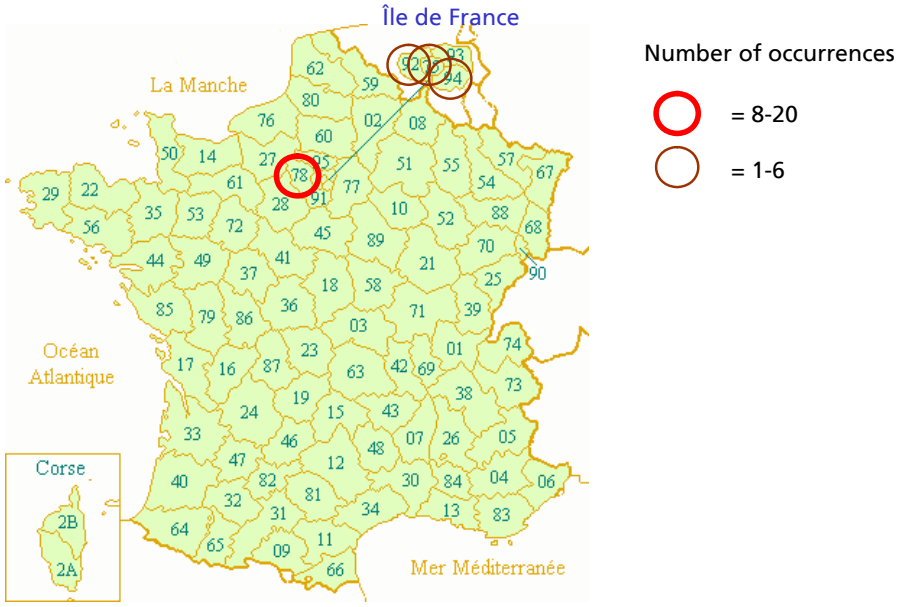
On the basis of test searches, it was decided to use the IPC class G05B as the technological definition. The period of the patent sample was 2000-2004 (table 2-20).

Table 2-20: Patent set for Renault case study

Technology field	IPC	Period	EP	Inventors (persons)	% country (occ. ina)
Control or regulating systems	G05B	2000-2004	16	19	100% FR

- 100 % of all inventors (occ.) in this field have French addresses, but the number of patents is comparatively small.
- The geographical distribution of inventors (Figure 2-8) shows a regional concentration in and around Versailles and Paris.

Figure 2-8: Regional distribution of inventors for Renault



Results of the publication analysis

The publication search was performed for publications with at least one French author in the subject categories instruments & instrumentation; automation & control systems; electrical & electronic engineering; computer science, cybernetics; computer science, information systems; computer science, interdisciplinary applications from 1999-2004. Of all 19 inventor names searched, three were identified as authors in the publication database SCI (15.8 %). Two authors have addresses with Renault Guyancourt, one is a false hit.

- In the case of Renault, there are no indications of strong linkages with French public research institutions.

3 Overview of results and conclusions

The spatial distribution of inventors in the eight cases of MNEs shows that inventors are regionally clustered around particular R&D centres in either Germany or France, but it also shows that in most cases there are significant contributions to the selected technology fields from inventors living in other countries. In the particular cases of IBM Deutschland and Freescale, most of the inventors are from the USA, in the case of Rhodia the majority lives in Italy. The only case investigated with 100 % inventors in the target country is Renault. The polycentric structure of the inventor distribution in the case of Siemens is probably due to the broad technology definition in this particular case.

The regional concentration of inventors is in line with assumptions about the role of spatial and cultural proximity in innovation processes (e.g. Ponds et al. 2007). On the basis of this concentration of human capital with a unique set of technological competences and know-how it is plausible to further explore personal linkages to other institutions which might constitute a regional innovation system or a cluster. These findings are corroborated and extended by the results of the present publication analysis. An overview of the matching results is given in table 3-1.

Table 3-1: Public research affiliations in eight MNE cases

	MNE	number of inventors	matched authors	% matched authors	public R&D affiliations	% public R&D affiliations of all inventors
1	Bayer	76	48	63.2	4	5.3
2	IBM Deutschland	68	1	1.5	0	0.0
3	Daimler Nucellsys	76	17	22.4	4	5.3
4	Siemens TS	31	8	25.8	0	0.0
5	Rhodia	23	7	30.4	2	8.7
6	Freescale	45	12	26.7	4	8.9
7	Gemalto	37	3	8.1	1	2.7
8	Renault	19	2	10.5	0	0.0

Source: Analysis by Fraunhofer ISI

Patent ties with public research institutions were identified in five of eight cases with varying frequencies (no ties for IBM Deutschland, Siemens Transportation Systems and Renault). The relative frequency of public research affiliations is difficult to compare across our cases since the underlying patent samples are diverse in terms of technology fields and total number of inventors. Taking this heterogeneity into account, the case of Bayer Healthcare is clearly distinguished by its high share of authors who publish in SCI journals, followed in large distance by Rhodia. The share of public research affiliations is highest for Freescale, closely followed by Rhodia.

- The case of Freescale is remarkable from a regional innovation perspective: While only 8 % of the inventor occurrences in this case are located in France, the company has the highest share of public research affiliations in our case sample and its patent ties involve highly productive and often-cited authors who are all affiliated with public research institutions in Toulouse.

Perhaps with the exception of Freescale, our findings do *not* support the idea that collaborative ties with public research institutes are confined to regional innovation systems on small geographical scales.

- The cases of Bayer Healthcare and Daimler / NuCellsys in particular make it clear that important collaborative ties to public research institutes need not be confined to the close vicinity of the corporate R&D center but can be spread across larger distances.

This finding underlines the value of distributed competences at different locations in the German research system (Münch 2007). In earlier studies about the diffusion of computer integrated manufacturing (CIM) technologies we already found out that due to the polycentric and decentralized system in Germany a fairly homogeneous access to expertise and knowledge is possible so that location does not really matter (Koschatzky 2001). With regard to the case study enterprises, networks are more spatially dispersed in Germany than in France where the local endowment with knowledge resources seems to play a more important role. Given the quality of the transport and communication infrastructure, Germany as a whole might qualify as the appropriate scale for a "regional" innovation system in globalized competition, and, depending on the technology field, perhaps more so than any of the sub-regions investigated in this study. At least with regard to the aspect of knowledge accessibility this would contradict the recent political enthusiasm for spatially confined regional clustering. The

situation may be different in France as this country has still a more hierarchical and centralized public research infrastructure. Nevertheless, such conclusions are tentative and need to be scrutinized in further empirical research.

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