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Science and technology in the region: The output of regional science and technology, its strengths and its leading institutions

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We operationalize scientific output in a region by means of the number of articles (as in the SciSearch database) per year and technology output by means of the number of patent applications (as in the database of the European Patent Office) per priority year. All informetric analyses were done using the DIALOG online-system. The main research questions are the following: Which scientific and technological fields or topics are most influent within a region and which institutions or companies are mainly publishing articles or holding patents? Do the distributions of regional science and technology fields and of publishing institutions follow the well-known informetric function? Are there – as it is expected – only few fields and few institutions which dominate the region? Is there a connection between the economic power of a region and the regional publication and patent output? Examples studied in detail are seven German regions: Aachen, Düsseldorf, Hamburg, Köln (Cologne), Leipzig – Halle – Dessau, München (Munich), and Stuttgart. Three different indicators were used, science and technology attraction of a region (number of scientific articles and patents), science and technology intensity (articles and patents per 1,000 inhabitants), and science and technology density (articles and patents per 1 billion EURO gross value added). Top region concerning both attraction and intensity is Munich, concerning density it is Aachen.

Introduction

Are there regional specialties in science and technology? Are there important academic institutions or private companies in a region, which produce many articles and apply for many patents? Does the number of scientific articles and patent applications correlate with the economic situation of a region?

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In informetrics, there is a law of rank distribution (EGGHE & ROUSSEAU, 1990, p. 293) which has some specific formulations as the laws of LOTKA (1926), BRADFORD (1934), ZIPF (1949) and GARFIELD (1977). We will consider the distribution f(x) of some items, e.g. science topics or institutions, sorted by the rank of the rate of publications or of patents. The item with the highest value (i.e. the highest publication or patent number) is rated number one, the second highest is rated number two, and so on. Thus we have a law following the formula

$$f(x) = C / x^a,$$

with C being a constant, a being approximately 2 and x indicating the rank (STOCK, 2000, p. 131). This means a high concentration on few items at the top of the rankings and a lot of items with only low values. For science, this skewness can be observed, too (SEGLEN, 1992). If indeed there were such concentrations on specific scientific and technological fields and on few institutions and companies, what does this mean for regional development or regional policy? Are entire regions dependent on only some top science and technology institutions or companies?

How can we measure such figures? This article tries to introduce methods of information science and especially of informetrics and scientometrics to give answers to these questions. So informetrics and scientometrics can help regional science and regional economics by preparing a sound data base. Furthermore, they can help regional policy by providing data for decisions, e.g. to strengthen given regional scientific and technological advantages or to support or to maintain regionally important research institutions and companies.

This study prepared in-depth descriptions and analyses of science and technology output of seven German regions: Aachen, Düsseldorf, Hamburg, Köln (Cologne), Leipzig – Halle – Dessau, München (Munich), and Stuttgart.

Background

Studies by AUDRETSCH & FELDMAN (1996), FELDMAN (1994), FELDMAN & AUDRETSCH (1999) and JAFFE, TRAJTENBERG & HENDERSON (1993) show that knowledge spillovers are geographically mediated. Feldman found out "that knowledge spillovers from science-based activities are localized and contribute to higher rates of innovation, increased entrepreneurial activity, and increased productivity within geographically bound areas" (FELDMAN, 2000, p. 345). For German regions, FUNKE & NIEBUHR (2000) could show „empirical evidence for the hypothesis that R&D spillovers are geographically bounded and constitute a significant source of regional productivity growth. Proximity matters for knowledge spillovers and growth" (FUNKE & NIEBUHR, 2000, p. 23). In Germany, the intensity of spillovers declines by 50% at a range of 30 kilometers, "i.e., the spillovers decrease rather quickly with distance"

(FUNKE & NIEBUHR, 2000, p. 24). But there are some companies – the most innovative ones in a region – which combine regional, national and international knowledge. "The most innovative firms are shown to access international sources of knowledge. This raises questions over the relative importance of local versus international knowledge spillovers for the most innovative firms" (SIMMIE, 2003, 607). Those companies act in "key metropolitan regions" and "combine a strong local knowledge capital base with high levels of connectivity to similar regions in the international economy" (SIMMIE, 2003, 607).

There are regional strengths of specific scientific or technological areas. Analysing the Science Citation Index 1994–1996, MATTHIESSEN & SCHWARZ (1999) produced a list of research centres in Europe (with London, Paris and Moscow at the top) and of disciplinary strengths and weaknesses of these research centres. For example, Stuttgart shows an extremely high specialization in "resource industrial research", Moscow is highly specialised in geosciences, but low in medicine (MATTHIESSEN & SCHWARZ, 1999, p. 475). They conclude that "the composition of the knowledge base is an important factor in metropolitan competition and also when research-oriented firms are looking for a new location" (MATTHIESSEN & SCHWARZ, 1999, p. 474). There has always been a connection between science and technology output and economic competitiveness, but regarding the "information society" or the "knowledge society", science and technology now play a key role in such societies. "The relationship between urban economic growth and change and the current knowledge level and profile is assessed as positive by many analysts" (MATTHIESSEN & SCHWARZ, 1999, p. 475).

There are some studies on regional research "landscapes" in Germany, mainly using input indicators like research expenditures or manpower and sometimes additionally using patent statistics by the German Patent and Trademark Office (BEISE, 1998; FRANZ & GREIF, 1999; ROSENFELD & ROTH, 2002; INDUSTRIE- UND HANDELSKAMMER REGION STUTTGART, 2003; FUNKE & NIEBUHR, 2000; KELLER, NIEBUHR & STILLER, 2004; KOSCHATZKY et al., 2000, LEGLER, 2000). It can be shown that there are big differences between the German Laender according to patent intensity. While in Baden-Württemberg and Bavaria there are 121 and 155 applications per 100.000 inhabitants to the German Patent Office in 2002, there are 14 in Brandenburg and only 11 each in Sachsen-Anhalt and in Mecklenburg-Vorpommern (KELLER, NIEBUHR & STILLER, 2004, p. 125). The same holds true for Sweden, too, only some regions are strong in research. According to DANELL & PERSSON (2003, p. 216) "the distribution of resources and R&D activities in all sectors is highly concentrated to the three main urban areas. It is also within these three large regions that we find the strongest flow of PhDs and strongest co-authorship links between the sectors, and especially between academia and the private sector. In the other regions there are greater imbalances between the sectors.

In particular they lack private R&D activities, which also limits the flow of people and interaction across sectors within the region. The smaller regions are net exporters of PhDs".

There are some results concerning technology output in German cities and regions, for example in Stuttgart (INDUSTRIE- UND HANDELSKAMMER REGION STUTTGART, 2003, p. 64) based on the German Patent Atlas by the German Patent and Trademark Office (GREIF & SCHMIEDL, 2002). Stuttgart has a strong patent intensity with 140 patent applications per 100.000 inhabitants, Munich follows in second place in Germany with 127 patent applications. What has not been done for Germany, is an investigation of science output and technology output, compared with economic figures such as gross domestic product. Are there connections between regional academic sciences and regional technology output? The paper by BLIND & GRUPP (1999, p. 451) "underlines the mostly positive influence between the public science infrastructure and the industrial science and technology output".

Most of the previously discussed studies use as an output indicator of R&D the number of patents, in Germany patents applied to the national German Patent and Trademark office. Using patent statistics is quite wise (see for example the product "Tech-Line" by NARIN 1999, which works with patent numbers), however, this is not sufficient. Patents do not reflect the state of basic science. So we have to take into consideration also the number of scientific publications. While "modelling the technological competitiveness of nations" and – we might add: "of regions" – "patents and scientific publications should be considered as output measures of competitiveness" (YGLESIAS, 2003, p. 290). So our study analyses both, i.e. scientific publications and patents. This is similar to the study by ZITT, RAMANANA-RAHARY, BASSECOULARD & LAVILLE (2003), who counted the output of publications and patents in 463 regions in the European Union.

The skewness of science and technology output of regions has so far not been studied in detail. But there are findings about nations. The skewness of citation distributions is so large that "the presence or absence of one particularly highly cited paper may drastically change the average citation impact of the field, and thereby the national citation indicator" (AKSNES & SIVERTSEN, 2004, p. 219). For Norway, AKSNES & SIVERTSEN (2004, p. 222) present two main findings, "(1) The average citation rates in national subfields are to a large extent determined by only a few highly cited papers. (2) There are large annual variations in the influence of the few highly cited papers on the average citation rate of the subfield". Our approach is different in that we count publication instead of citation rates. However, we have to look carefully on single institutions and single topics. Is there a high concentration in a single year only or can this concentration be observed over a period of several years?

Findings about scientific and economic output of countries might also require more specific and detailed analyses of certain geographic or governmental regions. Such specific data is mainly needed for regional policy. We do not think that a country profits best if all geographic regions would simply produce equivalent numbers of scientific publications or patents (although a comparing analysis of regions might indirectly lead to this suggestion). This study rather wants to give a new access to regional data and help to recognize local strengths and characteristics, so that they can be supported or utilized. It also should provide an indication of the most active institutions or companies, whose performance might be the subject of further detailed analyses.

We do not measure knowledge spillovers in the regions, but the strengths of science and technology in the regions, i.e. the topics of science and technology output and the institutions or companies which enable the output. In a first step, this study is descriptive: "Which are the principal topics of science and technology in region X in the six years, 1995–2000?" – "Which are the leading institutions or firms producing science and technology output in region X?". In a second step, we are going to analyse the distribution of the main topics and the main institutions: "Is the distribution typically left-sided?" – "Is a region dependent on only few important topics and institutions?". As a third step, at the very end, we will try to compare the regions with regard to science and technology output and additional economic indicators: "What are the top regions in the aspects of science and technology attraction, intensity and density?", "Is there a correlation between science and technology output and gross value added?"

Methodology

Apart from statistical data about the region we used databases as the data source for the informetric parts of our study. For many informetric studies, the DIALOG system was used successfully (HOOD & WILSON, 2003, p. 590–592), however, you have to consider that there are some difficulties with online information systems. "Many of these problems arise from the fact that most databases are created for information retrieval purpose; informetric studies are a secondary use of these databases" (HOOD & WILSON, 2003, p. 593). There are only four online systems offering informetric commands, DIALOG, DIMDI, QUESTEL-ORBIT and STN International.

According to Hood & Wilson, the main problems on the microlevel are spelling errors, a lack of subject indexing consistency, inconsistent representation of author names, journal titles, dates, corporate sources and the field structure. For we try to find the scientific and technological subjects and the corporate source in single regions only, we have two microlevel problems:

1. Are the subjects of the articles and patents with the given classification tools and due to concrete indexing represented correctly?
2. Are the names of the institutions spelled correctly and used in a consistent way?

On the macrolevel, Hood & Wilson note the following difficulties: overlap in databases, coverage, time span, time delay in abstracting, missing data fields, changes in database policy, isolating data types, type of inverted files, field names, relevant information and data standardisation. Being aware of all these difficulties, we have to cape with one macrolevel problem :

3. Which are the "right" databases suitable for our purpose? Or: Using which databases keeps the problems to a minimum?

We use the system of the online information supplier DIALOG (STOCK & STOCK, 2003), because if offers two databases, SciSearch (DIALOG CORP., 2001) and European Patents Fulltext (DIALOG CORP., 2000), which proved to be the "right" databases for our purpose and because DIALOG's retrieval system allows some informetric commands like RANK (DIALOG CORP., Rank).

To start with the third problem: Why are SciSearch and European Patents Fulltext the right databases? SciSearch ("Science Citation Index"; DIALOG file 34) is a multidisciplinary database of scientific journal articles produced by Thomson Scientific and covers the main journals of most science fields, not including social sciences or humanities. SciSearch is a frequently used source in scientometric analyses. For there is a field of corporate source we could look for the addresses and locate the articles by authors from a given region. Though SciSearch is by no means complete it provides a representative pattern of article distributions in the leading scientific journals of the world. European Patents Fulltexts database (DIALOG file 348) covers all patent applications and patents granted by the European Patent Office. It includes those international records for PCT (Patent Cooperation Treaty) transferred to the European Patent Office. Why do we use data from the European Patent Office and not from the German Patent and Trademark Office? An application to a national patent office only is very cheap and does not cause greater problems. So many inventors submit their ideas to their national patent offices for phase one (examination of form) but never start phase two (the examination of content). Companies or inventors submit their best ideas not only within their home country but in other countries too. As an application to the European Patent Office is expensive, only excellent and most promising inventions will be applied there. There is a field in the database for the assignee location. The database is complete.

Our first problem refers to the taxonomies. By SciSearch, all journals are classified according to a rough classification scheme. There is no indexing on the article level. Each journal (and so each article in the journal) is sorted into one or more journal subject categories (SC). We used this SC-field to identify the topics of the science output. Like all other patent databases, European Patents Fulltexts database works with the International Patent Classification (IPC). Each patent document is classified into one or more classes. For IPC shows a very detailed structure, we only used the first four digits to identify the topics of the technology output. The categories used by SciSearch

are not consistent with the IPC. Therefore comparing main subjects of scientific publications and patents is rather difficult and was not yet possible for this study. Such a comparison would probably offer more information about the connectivity of science and technology output and should be regarded in subsequent researches. For doing this, one will need a crosswalk between ISI subject catageories and IPC classes.

As to our second problem, names of institutions are not always correct in the two databases. The "phenomenology of name variations" described by DE BRUIN & MOED (1989, p. 67) could be noticed in our study too. We had much more problems with SciSearch than with European Patents Fulltexts. In all rankings of the institutions and companies we tried to unify the different name variations intellectually, but, because of "the chaotic structure of the addresses" (DE BRUIN & MOED, 1989, p. 69) especially of SciSearch, it is possible that we overlooked the one or other variation. In order to identify an institution or a company we looked at their Internet homepage and compared the addresses given in the Web with the addresses found in SciSearch.

There is a shortcoming in our methodology: A counting of publication rates does not consider the complicated structure in article production in science. Article publications do not have the same relative importance for all scientific disciplines, e. g. on fields like engineering there could be a relatively low share of articles per scientist and per year compared, for example, to medicine. NAJMAN & HEWITT (2003) can show for five disciplines (molecular biology, political science, psychology, philosophy and sociology) that there are indeed different publishing patterns. Consequently, regions where engineering sciences are strong might offer a lower scientific performance. This might have some effect on our obtained results. One should therefore be aware that the analysis would be more accurate if such peculiar discipline-specific publication strategies could be identified and regarded.

The research period for collecting the data was between 1995 and 2000. As an informetric command we utilized RANK (DIALOG CORP., Rank). Since RANK reaches up to 50,000 items (not documents, but field entries) we had in no case problems with our rankings. RANK was designed to work only with phrase-indexed or with numeric fields. All the fields we needed have a phrase-index.

Our search strategy consists of three steps. First, for the description of a region we fed all the names of the cities and their environs (with all spelling variations) into the CS-field, for example "Duesseldorf OR Dusseldorf OR Neuss OR Moenchengladbach OR Monchengladbach OR Ratingen OR …". The second step was to retrieve all the documents published by an author or a patent assignee in a single region from the two databases for the six years separately. In the patent database, we worked with the priority year of the invention. The third step was to rank the findings (a) by topic and (b) by institution and by patent assignee, respectively.

For SciSearch, the following DIALOG commands were used:

(1) b 34
(2) s CS=(Duesseldorf OR Dusseldorf OR …)
(3) s PY=1995
(4) s 1 AND 2
(5a) RANK SC
(5b) RANK CS.

For European Patents Fulltext, the procedure was analogous:

(1) b 348
(2) s CS=(Duesseldorf OR Dusseldorf OR …)
(3) s AY=1995/PR
(4) s 1 AND 2
(5a) RANK (IC1-4)
(5b) RANK PA.

For each region, we chose the same structure of description. We give (in Figure #a) basic information about population and gross value added between 1995 and 2000. This study works with three indicators of science and technology output:

- science and technology attraction: number of article publications (as in the SciSearch database) and number of patent applications (as in the database of the European Patent Office)
- science and technology intensity: number of article publications and of patent applications per 1,000 inhabitants
- science and technology density: number of article publications and of patent applications per 1 billion EURO gross value added.

Attraction is the basic indicator, intensity applies the science and technology output to the population, and density applies it to the economical strength of the region. All data are collected in Table #a. Tables #b and #c show the top ten scientific fields and the top ten scientific institutions in the region by the average number of scientific articles in SciSearch per year. Figure #b presents the distribution of articles by scientific fields with ranks 1 to 30, Figure #c presents the distribution of articles by institutions with ranks 1 to 10. Thus we can find out, whether our distributions follow informetric laws. It must be noticed that these figures show values for an item ranking x^{th} and not for a particular topic or institution. Topics and institutions ranked x^{th} might change from year to year. While Tables #b and #c resp. Figures #b, #c concentrate on science output, Tables #d #e and Figures #d, #e concentrate on technology output in the same way. In a conclusion, we are going to summarize the main findings about the region.

Empirical results
1. Region of Aachen

About the region

The region comprises not only Aachen city but also the district of Aachen, the district of Heinsberg and the district of Dueren, which contain together about 35 smaller towns and communes. The region is located in the state North Rhine-Westphalia in the west of Germany, on the border with Belgium and the Netherlands. Approximately 1,080,000 people live in the entire Aachen area today; 246,000 of them in Aachen city. According to Figure 1a the population has been growing during the period selected for analysis. Figure 1a also shows, that the gross value added of the region has been constantly rising, too. It has grown from 18.8 billion EURO to 21.3 billion EURO from 1995 to 2000. This means an increase of 13% in the whole period or about 2.7% per year. Compared with the other regions the gross value added per inhabitant is rather low.

The number of gainfully employed people was growing from 411,500 in 1995 to 455,900 in 2000. The average number of unemployed people during this period is about 44,700; it rises slightly from 1995 to 1997 and then decreases again.

The region of Aachen is an important area for natural science and engineering. The Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH Aachen) is specialized on these subjects. Approximately 30,000 students currently attend this university. More than 50% of them are enrolled in courses on natural sciences or engineering. It is the only university in this region, but not the only research institute: The Forschungszentrum Jülich (former: Kernforschungsanlage Jülich or KFA Jülich) is a centre for governmental and non-governmental research programs and projects with about 4,200 employees, approximately 1,500 of them are scientists, who research in the following fields: matter, energy, life and earth, information and environment. These divisions are represented by six institutes on an average corresponding roughly to the classical sciences of physics, chemistry, biology, medicine and engineering.

Among the regional companies Philips is the most important one. With up to 5,000 employees Philips was the biggest employer in the region in the years 1995 to 2000.

The study shows that the region of Aachen produces a large number of scientific publications. With an average of 2.59 publications per 1,000 inhabitants it is ranked second among the regions analysed. The amount of publications is rising between 1995 and 2000 (see Table 1a).

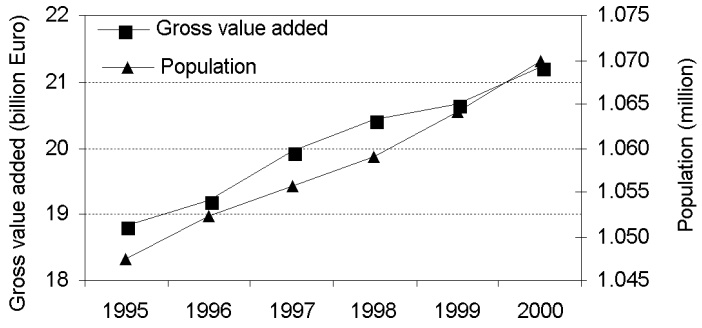

Figure 1a. Region of Aachen: Population and gross value added.
(Source: Landesamt für Datenverarbeitung und Statistik NRW)

Table 1a. Region of Aachen: Article publications and patent applications
Sources: SciSearch; European Patents Fulltext; Landesamt für Datenverarbeitung und Statistik NRW

Number of article publications	1995	1996	1997	1998	1999	2000	Average
Total	2,486	2,574	2,825	2,746	2,816	3,018	2,744
per 1000 inhabitants	2.37	2.45	2.68	2.59	2.65	2.82	2.59
per billion EURO gross value added	132	134.05	141.63	134.51	136.18	142.11	136.75

Number of patent applications	1995	1996	1997	1998	1999	2000	Average
Total	191	226	246	320	459	474	319.33
per 1000 inhabitants	0.18	0.21	0.23	0.30	0.43	0.44	0.30
per billion EURO gross value added	10.14	11.77	12.33	15.68	22.196	22.32	15.74

Sum of article publ.s and patent appl.s	1995	1996	1997	1998	1999	2000	Average
Total	2,677	2,800	3,071	3,066	3,275	3,492	3,064
per 1000 inhabitants	2.56	2.66	2.91	2.90	3.08	3.26	2.90
per billion EURO gross value added	142.14	145.82	153.97	150.18	158.37	164.43	152.48

Science output

There are two major institutions responsible for publications, namely the Technische Hochschule Aachen and the Forschungszentrum Jülich, the latter being one of the institutions with the highest number of patents in this region. The top ten regional institutions publishing scientific articles are all parts of either the university or the Forschungszentrum (Table 1c). This shows that these two are of an enormous value to the region. The ranking of publishing institutes also shows that the single departments of these major institutions follow an informetric distribution (Figure 1c): i.e. there are

few institutes at the top with very high results followed by many others on a similarly low level. According to Table 1c the departments on the first three ranks are clearly separated from the following main field. As can be seen from Figure 1c, this separation is getting less pronounced during the years.

A similar informetric distribution can be found in the ranking of the most important scientific subjects, shown in Figure 1b. Generally, the numbers of publications per scientific field are in fast decline and reach a rather constant level being ranked seventh or eighth. But comparing the graphs of the single years, it seems that the informetric distribution is being reduced: The distance between the leading positions and the main field is getting smaller from 1995 to 2000. Nevertheless there still is a significant dominance of some disciplines at the top of the ranking. Table 1b also shows disciplines being most important to Aachen during the whole period. These scientific fields match to the above mentioned regional structure of Aachen, most important are various sub-disciplines of physics and also physical chemistry. Clearly at the top of the general ranking is "physics, condensed matter". This and the next three major scientific fields are clearly separated from the main field by a big gap.

Only few changes can be observed in the rankings of scientific fields during the single years. Certain disciplines in physics stay on the top ranks all the time. Changes can mainly be found below rank 5, where single disciplines enter and others leave the top ten. For example there is a clear regression of the field "metallurgy and metallurgical engineering": While it is ranked 6th in the years 1995 and 1996, it does no longer appear in the top ten during the following years. Other new disciplines enter the top ten, for example "neurosciences" in 1998 (reaching rank 5 in 2000) or "biochemistry & molecular biology" in 1996 (rank 7 in 2000).

Another interesting aspect concerning the article publications is the fact that lots of articles were published in co-operation with foreign institutes from various countries, especially with the Instituto Nazionale di Fisica Nucleare in Bologna (Italy), the CCLRC Rutherford Appleton Laboratory (RAL) Oxfordshire (UK) and the Queen Mary University of London (UK). Many of the cooperating institutes are specialized in physics.

Table 1b. Region of Aachen: Publications ranked by scientific fields. The top 10 results
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Scientific field
1	227	Physics, condensed matter
2	201	Physics
3	189	Materials science
4	180	Physics, applied
4	180	Chemistry, physical
6	96	Physics, particles & fields
7	95	Nuclear science & technology
8	89	Biochemistry & molecular biology
8	89	Engineering, electrical & electronic
10	83	Neurosciences

Table 1c. Region of Aachen: Publications ranked by institutions. The top 10 results
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Institution
1	173	Forschungszentrum Jülich, Institut für Festkoerperforschung
2	113	Forschungszentrum Jülich, Institut Schichten & Grenzflaechen
3	102	RWTH Aachen, Institut Physik
4	64	Forschungszentrum Jülich, Institut Kernphysik
5	36	Forschungszentrum Jülich, Institut Biotechnologie
6	35	RWTH Aachen, Institut Anorganische Chemie
7	34	RWTH Aachen, Institut Organische Chemie
8	21	RWTH Aachen, Institut Theoretische Physik
9	20	Forschungszentrum Jülich, Institut Plasmaphysik
10	19	Forschungszentrum Jülich, Euratom Asso.

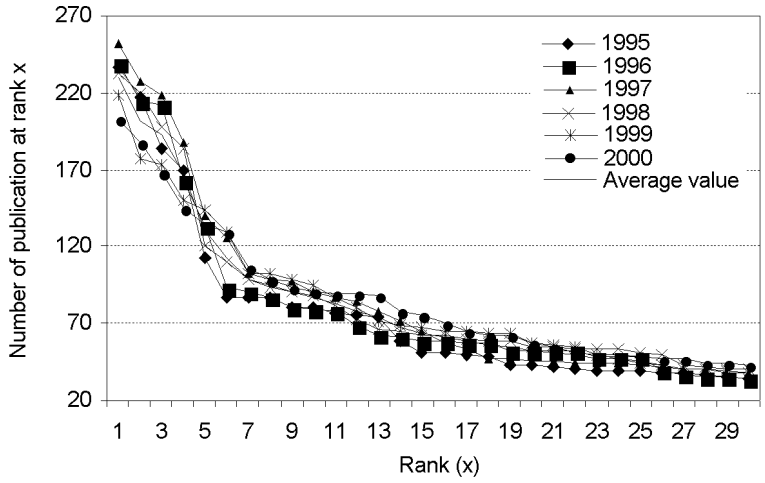

Figure 1b. Region of Aachen: Publications ranked by scientific fields. The distribution of the top 30 results.
Source: SciSearch

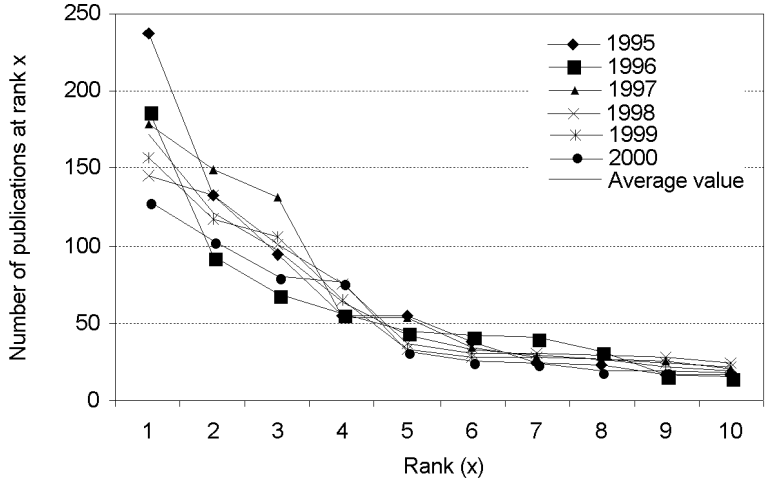

Figure 1c. Region of Aachen: Publications ranked by institutions. The distribution of the top 10 results.
Source: SciSearch

Technology output

In contrast to the amount of publications, the average number of patents in the region of Aachen in comparison with the other regions is very low, although actually rising (see Table 1a). During the five years the total amount of patents grows from 191 in 1995 to 474 in 2000. This means an increase of 148% in the whole period or 29.6% per year.

The main part of patents is also held by only few different institutions. Besides the Forschungszentrum Jülich another institution responsible for patents in the region of Aachen is Philips. Aachen has been one of the locations which were most important to the Philips group in Germany, with focus on light and glass. In our studies Philips is on top rank on the list of Aachen's patent assignees since 1998. Therefore we considered Philips to ho have an extremely high value for this region. But only few months after we had collected our data, it was decided to stop the production of cathode-ray tubes, one of the most important parts of Philips Aachen. It is not yet sure, weather the regional Philips glass factory will be shut down, too. We now expect this development to be an enormous loss for the region and suppose that it will be interesting to regard further developments.

Other institutions worth being mentioned in context with patents are the Gruenenthal GmbH (producing chemical- and pharmaceutical articles with focus on the fields pain, infections and gynaecology), the FEV Motorentechnik GmbH (offering engineering services, especially supply of test cell, instrumentation and measurement equipment) and the Aixtron AG (manufacturing technical supply for the production of semiconductors). All other institutions do not list more than five patents per year even though they do appear in the top ten rank of the region (see Table 1e). Due to the small number of generally published patents even single engineers (who are not members of a major institution or company) are listed among the top ten patent assignees in some of the observed years.

Again we see an informetric distribution. Figure 1e shows that this is even getting more and more obvious from 1995 to 2000, meaning that especially Philips is getting more and more dominant among the patent assignees.

In Figure 1d you can see that the mentioned growth of the number of patents is also connected with the development of an informetric distribution concerning the research fields. While from 1995 to 1998 all IPC-Classes, to which belong the regional patents, appear on a similar low level, the numbers of patents ranked first (rank one to seven) show a sudden increase in 1999/2000. Especially the number of patents being part of the classes A61K, H01J, H01M and C23C is rising high after 1998. This can be accounted for by the rising amount of patents from the main institutions Philips (H01J and H01M), Gruenenthal (A61K) and Aixtron AG (C23C).

Table 1d. Region of Aachen: Patents ranked by IPC-Classes. The top 10 results. Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	IPC-Class	Explanation
1	17	A61K	Preparations for medical, dental, or toilet purposes
2	14	H01L	Semiconductor devices; electric solid state devices
2	14	H01J	Electric discharge tubes or discharge lamps
4	13	H01M	Processes or means, e.g. batteries, for the direct conversion of chemical energy into electrical energy
5	12	G01N	Investigating or analysing materials by determining their chemical or physical properties
6	10	C12N	Micro-organisms or enzymes; compositions thereof
7	9	H04N	Pictorial communication, e.g. television
7	9	C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture
7	9	G06F	Electric digital data processing
10	8	H04L	Transmission of digital information, e.g. telegraphic communication

Table 1e. Region of Aachen: Patents ranked by patent assignees. The top 10 results. Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	Patent assignee
1	94	Koninklijke Philips Electronics NV
2	24	Forschungszentrum Jülich GmbH
3	17	Gruenenthal GmbH
4	9	FEV Motorentechnik GmbH
5	5	Aixtron AG
6	4	SIG Combibloc GmbH
7	3	Impella Cardiotechnik GmbH
7	3	Sicowa Verfahrenstechnik für Baustoffe Gmbh & Co KG
7	3	Talbot GmbH & Co KG
7	3	Wirth Maschinen- und Bohrgeraete-Fabrik GmbH

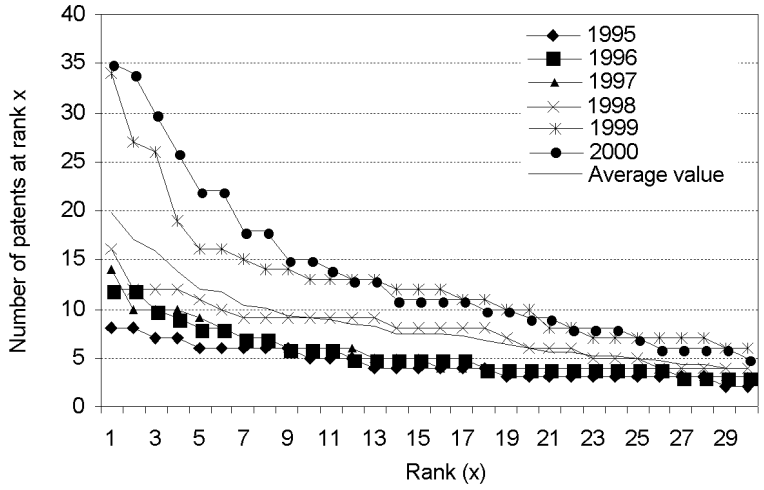

Figure 1d. Region of Aachen: Patents ranked by IPC-Classes. The distribution of the top 30 results. Source: European Patents Fulltext

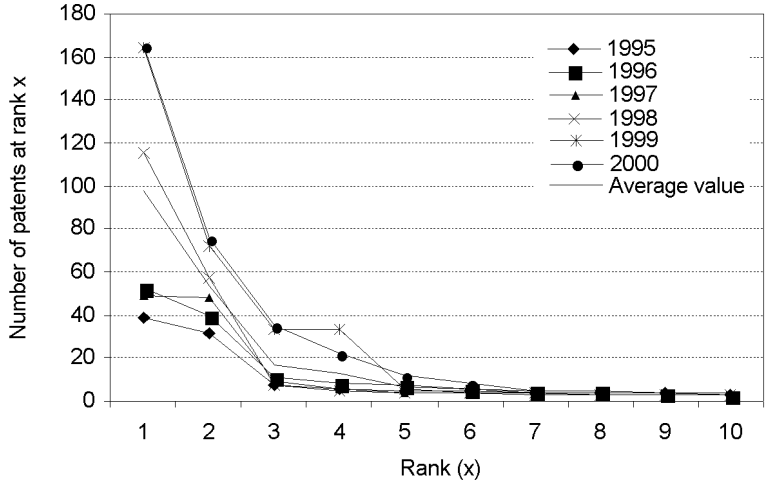

Figure 1e. Region of Aachen: Patents ranked by patent assignees. The distribution of the top 10 results. Source: European Patents Fulltext

Comparing the rankings of the single years you can notice various changes within the top ten – but they do not experience a recognizable development. Table 1d shows a general ranking of the ten most important fields for the whole period.

There is no international co-operation on patent subjects which is comparable to the co-operation for publications. We could only recognize that the Forschungszentrum Jülich keeps up major co-operations, for example with the Degussa AG and the BASF AG.

Conclusions

The region of Aachen seems to be growing in all analysed aspects: The number of inhabitants, of the fully employed people and the gross value added are rising between 1995 and 2000. There is as well an increased growth in patents as in the number of publications, the latter low explicit, though.

Generally, the region of Aachen produces a large number of scientific publications but only a small number of patents. This leads to the suggestion that the two represented aspects – scientific research and industrial innovation – are not really connected here. As the gross value added in Aachen is quite low in comparison with other analysed regions, the question which arises is whether the high number of scientific publications does have an impact on the productivity of companies or on the economic growth of the region of Aachen at all.

We found out that scientific and technological publications in the region of Aachen are based on only few leading institutions: the RWTH Aachen (scientific publications), the Forschungszentrum Jülich (scientific publications and patents) and Philips (patents). Among the patent assignees, Philips was even strengthening this position, before an important Philips company, LG Philips Displays, has been closed down in 2004. It remains to be seen how the region will develop after the loss of one of its most productive companies.

We have seen that the subjects of publications and patents are concentrated in a similar – informetric – way. The most important scientific fields are condensed matter physics, physics in general, material science, applied physics, and physical chemistry. There is a high concentration on the top topics, and we can find a typical informetric distribution. In technology, there is a lower concentration, top topics are preparations for medical, dental or toilet purposes, semiconductor devices, electric discharge tubes or lamps, conversion of chemical into electrical energy, and analysing materials.

2. Region of Düsseldorf

About the region

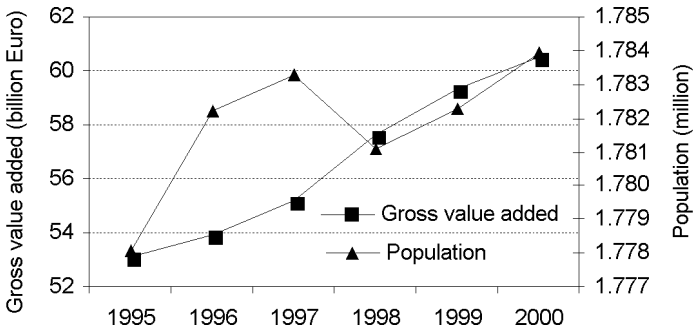

Figure 2a. Region of Düsseldorf: Population and gross value added

Table 2a. Region of Düsseldorf: Article publications and patent applications.
Sources: SciSearch; European Patents Fulltext

Number of article publications	1995	1996	1997	1998	1999	2000	Average
Total	1,596	1,604	1,848	1,903	1,760	1,725	1,739
per 1000 inhabitants	0.90	0.90	1.04	1.07	0.99	0.97	0.98
per billion EURO gross value added	28.19	28.33	32.64	33.61	31.08	30.47	30.72
Number of patent applications	1995	1996	1997	1998	1999	2000	Average
Total	610	759	977	1075	1231	1271	987
per 1000 inhabitants	0.34	0.43	0.55	0.60	0.69	0.71	0.55
per billion EURO gross value added	10.77	13.41	17.26	18.99	21.74	22.45	17.44
Sum of article publ.s and patent appl.s	1995	1996	1997	1998	1999	2000	Average
Total	2,206	2,363	2,825	2,978	2,991	2,996	2,726
per 1000 inhabitants	1.24	1.33	1.58	1.67	1.68	1.68	1.53
per billion EURO gross value added	38.96	41.73	49.89	52.6	52.83	52.91	48.15

The region of Düsseldorf is formed by the districts of Mettmann and Neuss, as well as by the cities of Düsseldorf and Mönchengladbach. Its total area is 1,370.9 km^2. Between 1995 and 2000, the number of inhabitants was on average 1,781,808, out of which 715,548 were employed. The average yearly total gross margin at manufactures' net costs was 56,616 million EURO. If one just looks at the total gross margin at manufacturers' net costs per inhabitant, the average value was 31,774 EURO.

In the same period, the region of Düsseldorf published on average 1,739 articles per year. 0.98 publications were issued per 1,000 inhabitants, whereas the ratio between publications and total gross margin was 30.72 : 1 billion EURO.

Regarding the patent applications, the region of Düsseldorf registers an average value of 987 per year. 0.55 patent applications were issued per 1,000 inhabitants, whereas the ratio between patent applications and total gross margin was 17.44 : 1 billion EURO.

Science output

The medical faculty of the Heinrich-Heine-University published most of the articles between 1995 and 2000. With 731 articles it is the leading institution. From the 731 published articles, 291 are published by the department of neurology. The department of dermatology produced 287 articles, and 153 articles were submitted by the Diabetes Institute.

The mathematical-scientific faculty of the Heinrich-Heine-University follows in second place with 680 articles. It consists of several institutes. There are both research and didactics in the subjects of mathematics, physics, chemistry, pharmacy, biology, psychology, geography and geology. Düsseldorf, being a center of biotechnological research, is closely co-operating with the research center of Jülich, where the research of enzyme technology and several other projects e.g. in the area of the environmental technology are located. The Düsseldorf biomedical research center published 157 articles, whilst the Institute of Physical Chemistry & Structure Chemistry published 154 articles. 130 articles originated from the Institute of Physical Chemistry & Electrical Chemistry, 126 articles from the Institute of Inorganic Chemistry & Structure Chemistry and 113 articles from the Institute of Theoretical Physics.

The Max-Planck-Institute is ranked with 196 published articles top in the list of scientific productivity. The Max-Planck-Institute for iron research works on interdisciplinary basic research in the area of iron and steel and related materials and even in the areas of intermetallic compounds.

Table 2b. Region of Düsseldorf: Publications ranked by scientific fields. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Scientific field
1	49	Neurology
2	48	Dermatology
3	33	Iron & steel
4	26	Biomedicine
5	26	Physical chemistry & structure chemistry
6	26	Diabetes
7	22	Physical chemistry & electrical chemistry
8	21	Inorganic chemistry & structure chemistry
9	19	Theoretical physics
10	13	Gastroenterology hepatology

Table 2c. Region of Düsseldorf: Publications ranked by institutions. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Institution
1	49	Universität Düsseldorf, Zentrum für Neurologie
2	48	Universität Düsseldorf, Zentrum für Dermatologie
3	42	Universität Düsseldorf
4	33	Max Planck Institut, Abteilung Eisenforschung
5	26	Universität Düsseldorf, Biomedizinisches Forschungszentrum
5	26	Universität Düsseldorf, Institut für Physiologische Chemie
5	26	Universität Düsseldorf, Diabetes-Forschungsinstitut
8	22	Universität Düsseldorf, Institut für Physikalische Chemie und Elektrochemie
9	21	Universität Düsseldorf, Institut für Anorganische Chemie und Strukturchemie
10	19	Universität Düsseldorf, Institut für Theoretische Physik

Based on the articles published yearly, there cannot be seen any trends for the institutes. Only the department of neurology achieves a relatively constant distribution of articles over the years. Outside the Düsseldorf region, there are also co-operating institutions and companies, which are the KFA Jülich GmbH with 10 articles, the Russian Academy of Sciences / Institute of Automation & Electrometry with 8 articles and the Bayer AG Institute of Toxicology with 7 articles.

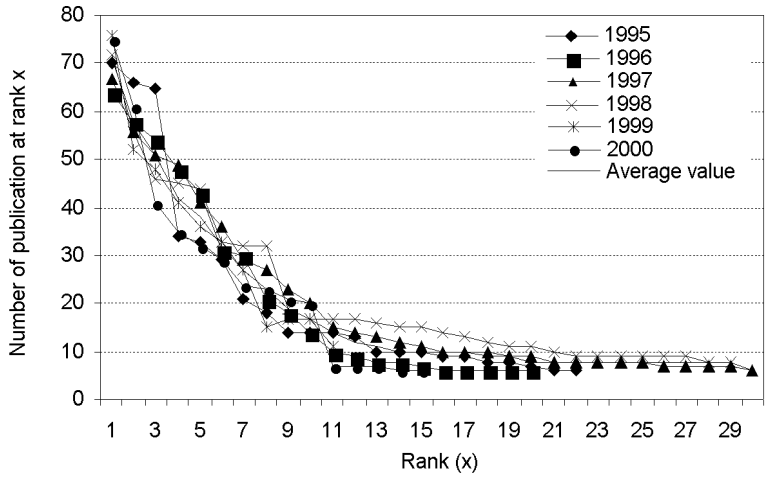

Figure 2b. Region of Düsseldorf: Publications ranked by scientific fields. The distribution of the top 30 results. Source: SciSearch

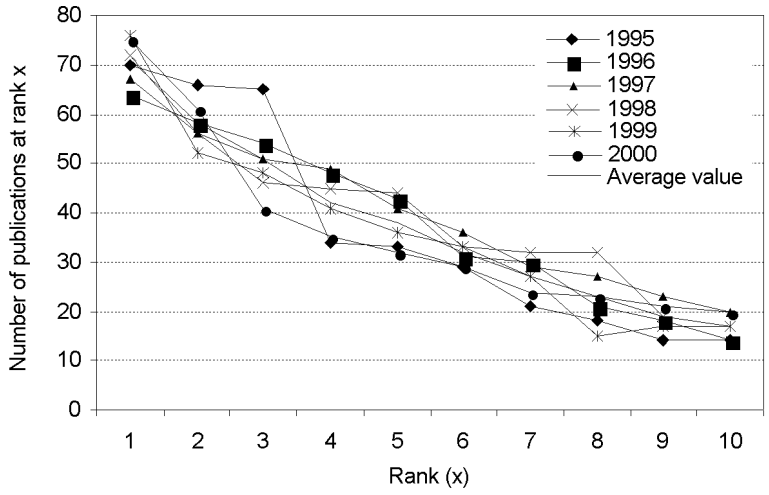

Figure 2c. Region of Düsseldorf: Publications ranked by institutions. The distribution of the top 10 results. Source: SciSearch

Technology output

Henkel AG is the clear leader concerning the patent applications between 1995 and 2000. It operates in three strategic areas of competence - Home and Personal Care, Adhesives, Sealants and Surface Treatment. The number of patent applications per year is around 150 and increases strongly to 234 in 1997. In the following two years, the number rises to 285. In this period world novelties like e.g. Persil Tabs and Poly Re-Nature Cream were introduced. This accounts for the surprising increase of patent applications in those years. In the year 2000, the number increases slightly to 257. At the Henkel AG the main areas of patent applications were, as can be seen by the IPC classes, cosmetics and shoe care products (C11D), in particular shampoo and soap products as well as deodorants and soap based cleaning products (A61K). The ranking for the years 1995 to 2000 shows that the section of patents C11D with 785 patents is ahead of section A61K with 614 patents. Section C11D starts in 1995 with 82 patents. This number rises slowly in the following years with a boom in 1997 continuing through 1999 (144, 172, 212) and decreasing sharply to 106 in the year 2000. In this very year, there are more patent applications in section A61K than in C11D for the first time, namely 141 and in section C12N, ranked second with 110.

In the whole period, Henkel reaches 1293 patents, followed by Vodafone/ Mannesmann AG with 1056 patents. Until 1999, there are in single years variations among rank two and four (the number staying constant on around 80 patent applications). The fusion with SMS Demag AG and SMS Schloemann-Siemag forced up the numbers again in 1999 to 196 and 2000 to 198. The Vodafone Group Plc provides an extensive range of mobile telecommunication services, including voice and data communications.

In the years 1997 and 1998, the Cognis Deutschland GmbH, a former subsidiary company of the Henkel AG, ranks second with 129 and 142 patent applications. This globally operating specialty chemical company is divided into five strategic business units: Oleo Chemicals, Care Chemicals, Nutrition & Health, Functional Products, and Process Chemicals.

In the lower positions there are: Degussa AG, Germany's third-largest chemicals group and international leader in the field of specialty chemicals with 477 patents. Henkel Ecolab GmbH is the leading global developer and marketer of cleaning, sanitizing, pest elimination, maintenance and repair products and services. Others are Schlafhorst AG, a textile machine manufacturer; Pierburg AG, which works in the air supply and pumps division; Huf Huelsbeck & Fuerst GmbH, a producer of mechanical and electronic key systems, lock sets, steering locks and remote control systems for the automotive industry; Thyssen Krupp Stahl AG, a supplier of steel, capital goods and services and Dr. Hahn GmbH, which develops hinges for metal and PVC doors.

Table 2d. Region of Düsseldorf: Patents ranked by IPC-Classes. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	IPC-Class	Explanation
1	131	C11D	Detergent compositions
2	102	A61K	Preparations for medical, dental, or toilet purposes
3	46	B21B	Rolling of metal
4	40	B22D	Casting of metals; casting of other substances by the same processes or devices
5	38	E05B	Locks; accessories therefor; handcuffs
6	36	C07C	Acyclic or carbocyclic compounds
7	29	C12N	Micro-organisms or enzymes; compositions thereof
8	24	C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture
9	22	C08G	Macromolecular compounds obtained otherwise than by reactions only involving carbon-to-carbon unsaturated bonds
10	21	B01J	Chemical or physical processes

Table 2e. Region of Düsseldorf: Patents ranked by patent assignees. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	Patent assignee
1	216	Henkel Kommanditgesellschaft auf Aktien
2	178	SMS Demag AG/ Mannesmann AG/ Vodafone/ SMS Schloemann-Siemag AG (seit 1999)
3	106	Cognis Deutschland GmbH
4	80	Degussa AG
5	24	Henkel-Ecolab GmbH & Co OHG
6	15	W Schlafhorst AG & Co; Mönchengladbach
7	12	Pierburg AG; Neuss
7	12	Huf Hulsbeck & Furst GmbH & Co KG; Velbert
9	11	Thyssen Krupp Stahl AG
10	8	Dr Hahn GmbH & Co KG; Mönchengladbach

These firms are producing largely in the IPC section B (performing operations; transporting) i.e. in B21B (rolling of metal, 275 patents), B22D (casting of metals, 240 patents). Obviously, there is a lower number of patents in section B than in the life-style and chemical sections A and C in all the years.

Outside the Düsseldorf region, there are also co-operating companies: KFA Jülich GmbH with 19 and Main Management Inspiration AG, Hergiswil, with 16 patent applications.

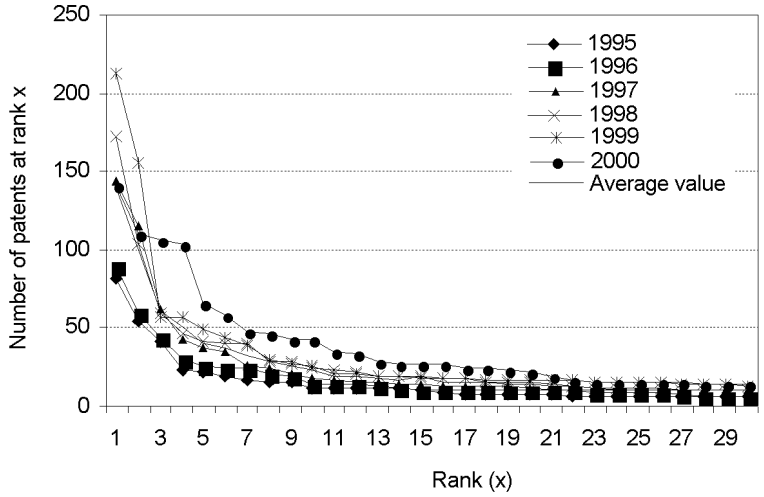

Figure 2d. Region of Düsseldorf: Patents ranked by IPC-Classes. The distribution of the top 30 results.
Source: European Patents Fulltext

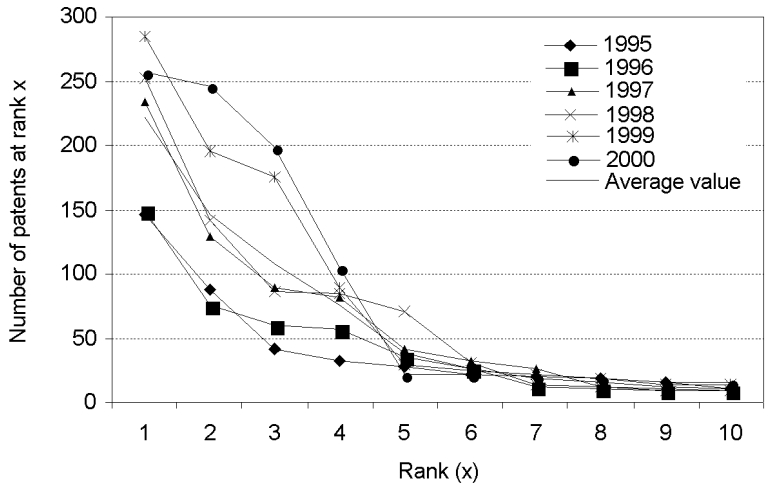

Figure 2e. Region of Düsseldorf: Patents ranked by patent assignees. The distribution of the top 10 results.
Source: European Patents Fulltext

Until 1999 the high number of patents of the IPC class C11D (detergent compositions) accounts for a strong interest in this field. In 1999, however, the number

of patents in this class decreased from 212 to 106. Another strong interest can be seen at the IPC class A61K. The number of patents rose since 1995 continuously. Only in 1999, a short stagnation can be registered. This development probably reflects the boom of the wellness and cosmetic industries. The number of patents being part of the IPC class B21B (rolling of metal) remained relatively constant from 1995 through 1999 and dropped to zero in the year 2000. A slightly rising interest can be seen within the IPC class B22D (casting, powder metallurgy) as well. The patents rose steadily from 23 to 66 citations per year. There is only one represented notation from section E (fixed constructions): E05B (lock, accessories therefore; handcuffs) which reflects an increasing interest (from 22 to 47 citations per year). Patents within the IPC class C07C (acydic or carbocylic compound) were continuously quoted more frequently per year. The most remarkable development can be observed in the number of patents of the IPC classes C12N (micro-organism or enzyme) and C12P (fermentation or enzyme). The year 1999 shows a trebling of patents to 49 and 30 respectively. This results most likely from a new emphasis on biotechnology. The field of biotechnology is supported by higher national allowances and is a trend-setting field of technology as well. The interest in macromolecular compounds has diminished strongly since 2000. Patents of the IPC class C08G were quoted at an average rate of 23 times a year. In the year 2000, it was not even quoted once. The patents of the IPC classes B01J (chemical or physical processes) were quoted in two years only: 1996 and 1999.

Conclusions

Between 1995 and 2000, the total gross margin at manufacturers' net costs per inhabitant was on average 31,774 EURO. Considering the development of the article publications and patent applications, the region of Düsseldorf has a high gross margin per inhabitant, but generally a low number of published articles and in particular of patent applications, which is the decisive aspect. The following reasons are possible:

(1) Advertising is Düsseldorf's main focus. Düsseldorf is the undisputed number one of German advertising locations handling accounts worth 4.68 billion EURO. In advertising, there are only few articles and few patents. Düsseldorf's success is based on Germany's three largest advertising companies being headquartered here. BBDO Group Germany, Grey Global Group Deutschland and Publicis Gruppe Deutschland account for half of the revenues generated by the 10 leading agencies in the sector. Seven of Düsseldorf's leading agencies are listed in the sector's top 100. This means that every third EURO earned by advertising in Germany went to Düsseldorf.

(2) Moreover, key industries are trade, media, services and fashion. In 2001, Düsseldorf's industrial foreign trade turnover achieved 4.5 billion EURO. This corresponds to about 39% of Düsseldorf's total turnover. The media industry employs

15,000 people, whilst 1.400 companies with an annual turnover of 15 billion EURO are located in the fashion sector.

(3) The main activities of Düsseldorf observe the service industries. The second most important consultant hub in Germany with more than 500 companies from this industry is located here. 27,000 people are employed are in the sectors of consulting, IT consulting, auditing as well as legal and tax advisory practices. Headquarters or main branches of renowned companies are from the following sectors: consultants, insurances, banks and architecture. Similar to advertising, in the other service industries there are only few articles and few patents.

In terms of the article publications in the region of Düsseldorf, the Heinrich-Heine-University is the leading institution. However, compared to the other regions, Düsseldorf ranks on lower positions with an average of 1,739 articles published yearly. The distribution of scientific topics follows the informetric law, top fields are neurology, dermatology, and iron & steel. The distribution of scientific institutions does not follow the informetric curve, there is no concentration on only some top institutions.

Companies from the biotech sector find excellent conditions in the BioRegion Rheinland. There are more than 130 biotech companies in North-Rhine-Westphalia, 29 of these in the Düsseldorf area alone. 9,000 students of the Heinrich-Heine-University belong to medical and scientific faculties. Start-up firms originating from the Heinrich-Heine-University generate more than 50% of all German biotech company revenues. Another biotech center "Bio Park Flehe" is now developed by the Heinrich-Heine-University.

In technology, there are informetric curves for both, the distribution of the ICP-classes and the distribution of the patent assignees. Top patent assignees are Henkel and Vodafone / Mannesmann, top technical areas in Düsseldorf are detergents and preparations for medical, dental, or toilet purposes.

3. Region of Hamburg

About the region

The Free and Hanseatic City of Hamburg, one of the 16 states of the federation, is the second largest city in Germany with approximate 1.7 million inhabitants. In this sense it is a city as well as a state. Hamburg is also a cultural and commercial center of all Northern Germany. The metropolitan region consists of 3.5 million people – for all of them, Hamburg is the shopping and cultural metropolis. The municipal area with its 755 km^2 is seven times the size of Paris and 2 ½ times that of London. For this very reason Hamburg presents an exceptionally high standard of living and housing. With 30 m^2 living space per person, Hamburg enjoys the largest average personal living space of all big cities in the world. We are going to analyse the state of Hamburg as its region and leave out the smaller towns around, because these are situated in the state of Lower Saxony.

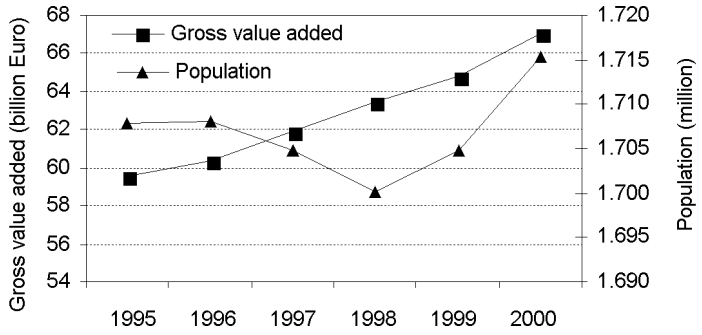

Figure 3a. Region of Hamburg: Population and gross value added

Table 3a. Region of Hamburg: Article publications and patent applications.
Sources: SciSearch; European Patents Fulltext

Number of article publications	1995	1996	1997	1998	1999	2000	Average
Total	2,604	2,655	3,150	3,123	3,304	3,167	3,001
per 1000 inhabitants	1.52	1.55	1.85	1.84	1.94	1.85	1.76
per billion EURO gross value added	43.73	43.94	50.89	49.17	51.00	47.18	47.65
Number of patent applications	1995	1996	1997	1998	1999	2000	Average
Total	543	646	791	783	848	977	764.67
per 1000 inhabitants	0.32	0.38	0.46	0.46	0.50	0.57	0.45
per billion EURO gross value added	9.12	10.69	12.78	12.33	13.09	14.56	12.10
Sum of article publ.s and patent appl.s	1995	1996	1997	1998	1999	2000	Average
Total	3,147	3,301	3,941	3,906	4,152	4,144	3,765
per 1000 inhabitants	1.84	1.93	2.31	2.30	2.44	2.42	2.21
per billion EURO gross value added	52.85	54.63	63.67	61.50	64.09	61.74	59.75

In 1995 Hamburg had a population of 1,707,901 million, in 2000 the population grew to 1,726,363. The gross added value amounts to 59,549 million EURO in 1995. Until 2000 it grew gradually to 67,122. The average gross added value between 1995 and 2000 is 62,883 million EURO and on average 36,843 EURO per inhabitant.

Science output

The number of scientific articles increased from 2,604 in the year 1995 to 3,304 in 1999 and decreased to 3,167 in the year 2000. Top in the list of the thirty most important disciplines of publications from 1995 to 2000 are biochemistry and molecular biology, alltogether there are 786 entries. Particles and fields physics (548) are second ranked, followed by hematology (464), oncology (448), physics (377), cardiac and cardiovascular systems (376), cell biology (327), condensed matter physics (323),

immunology (319) and neurosciences (301). Between 1995 and 2000 only a slight change in the order of the ranking took place, but all entries show at least some growth.

Table 3b. Region of Hamburg: Publications ranked by scientific fields. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Scientific field
1	131	Biochemistry & Molecular Biology
2	91	Physics, Particles & Fields
3	77	Hematology
4	74	Oncology
5	63	Physics
5	63	Cardiac & Cardiovascular Systems
7	55	Cell Biology
8	54	Physics, Condensed Matter
9	53	Immunology
10	50	Neurosciences

Table 3c. Region of Hamburg: Publications ranked by institutions. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Institution
1	153	DESY Deutsches Elektronen-Synchrotron Hamburg
2	97	Universität Hamburg, Institut für experimentelle Physik
3	85	Universität Hamburg, Institut für organische Chemie
4	67	Universitätsklinikum Hamburg-Eppendorf
5	61	Universität Hamburg, Institut für anorganische und angewandte Chemie
6	56	Max Planck Institut für Meteorologie
7	48	Universität Hamburg, Institut für theoretische Physik
8	36	Universität Hamburg, Institut für angewandte Physik
9	33	Universität Hamburg, Heinrich Pette Institut für experimentelle Virologie
10	25	Universität Hamburg, Institut für technische und makromolekulare Chemie

Among the ten institutions with the highest output of scientific publications are seven institutes belonging to the University of Hamburg as well as the University Hospital Hamburg-Eppendorf. The institutes are all concerned with different aspects of physics or chemistry. Other scientific departments of the university also dominate the following 20 ranks, which are not shown in Table 3c. Besides the university there are two other important institutions: the Max Planck Institute for Meteorology and DESY (Deutsches Elektronen-Synchrotron), a research centre with focus on particle physics. DESY holds the first rank among the institutions in every single year during the observed period.

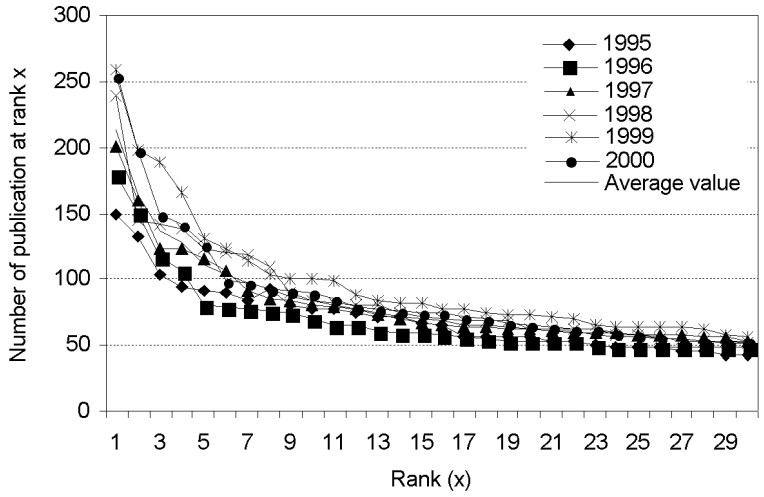

Figure 3b. Region of Hamburg: Publications ranked by scientific fields. The distribution of the top 30 results. Source: SciSearch

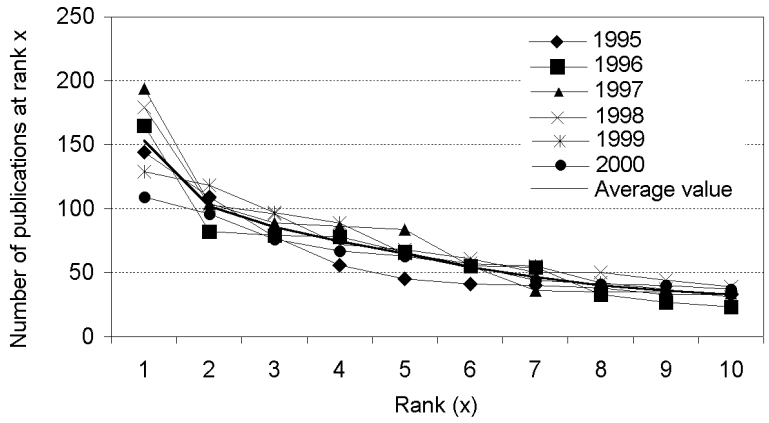

Figure 3c. Region of Hamburg: Publications ranked by institutions. The distribution of the top 10 results. Source: SciSearch

The list of the national and international partners of the Hamburg scientists starts with the Istituto Nazionale di Fisica Nucleare (INFN) in Italy, second is the University

of London, then RWTH Aachen (physics III), the University of Chicago (department for physics), Rutherford Appleton (UK), the University of Birmingham, the University of Tokyo (physics), CERN, the University of Freiburg in Germany (physics), and the University of Munich (physics).

Technology output

The company of Philips Electronics NV is ranked first in the top ten list from 1995 until 1997. There are 158 patents in 1995, but the number of patents decreases to only 49 patents in the year 2000. Beiersdorf AG is ranked first from 1998 until 2000. Beiersdorf AG which deals with medical goods shows a continous rise from 1995 with 89 patents until 2000 with 225 patents. In 1995 Philips Patentverwaltung applied for 146 patents and for 172 in 1997. However, from 1998 (98 patents) the patent application activity constantly sinks to zero patents in 2000. Hauni Maschinenbau AG applied for 22 patents in 1995, in 1997 it has zero patents, after that the number of patents increased again until 2000 with 49 patents. Daimler Chrysler Aerospace shows a decreasing development. In 1995 it applicated for 21 patents, in the rankings of 1999 and 2000 it is no longer represented. Phoenix AG is in a similar situation. It started off with 13 patents and lost the top ten ranking place in 2000.

Table 3d. Region of Hamburg: Patents ranked by IPC-Classes. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	IPC-Class	Explanation
1	65	A61K	Preparations for medical, dental or toilet purposes
2	18	C09J	Adhesives; adhesive processes in general
3	15	A61F	Filters implantable into blood vessels
4	14	G01N	Investigating or analysing materials
5	13	A24C	Machines for making cigars or cigarettes
5	13	B65D	Containers for storage or transport of articles or materials, e.g. bags, barrels
7	12	H04N	Pictorial communication, e.g. television
8	11	B64D	Equipment for fitting in or to aircraft
8	11	G01R	Measuring electric variables
8	11	H01J	Electric discharge tubes or discharge lamps

Table 3e. Region of Hamburg: Patents ranked by patent assignees. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	Patent assignee
1	169	Beiersdorf AG
2	122	Philips Electronics NV
3	98	Philips Patentverwaltung
4	26	Tesa AG
4	26	Hauni Maschinenbau
6	18	Philips Corporate
7	16	Phoenix AG
8	14	Airbus Deutschland
9	12	Daimler Chrysler Aerospace
10	10	Still GmbH

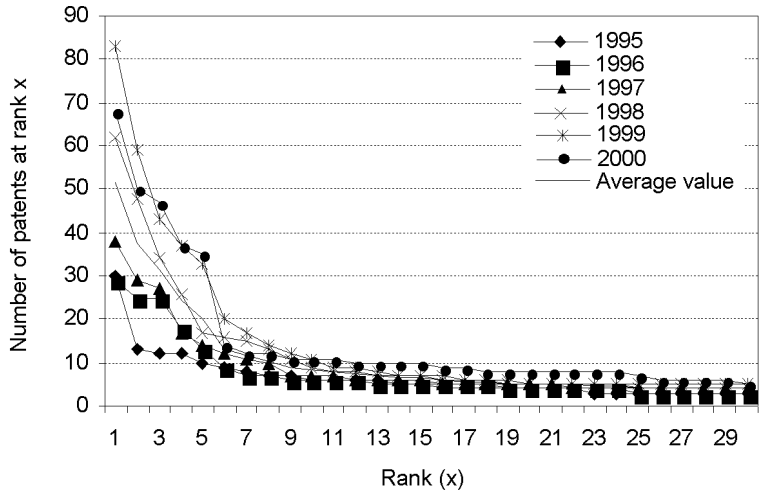

Figure 3d. Region of Hamburg: Patents ranked by IPC-Classes. The distribution of the top 30 results.
Source: European Patents Fulltext

Table 3d shows the main fields (by IPC-Classes) to which the assigned patents belong. A connection between these fields and some of the leading patent assigning companies can be seen: The Beiersdorf AG (ranked first in Table 3e) is concentrated on medical innovations which can be found on the ranks one and three in Table 3d, the Tesa AG, a Beiersdorf subsidiary (rank four in 3e), is specialised on adhesive products (rank two in 3d), television products (rank seven in 3d) can be connected to Philips (ranks two, three and six in 3e), and finally Hauni Maschinenbau (rank four in 3e) produces engines for the tobacco industry (rank five in 3d).

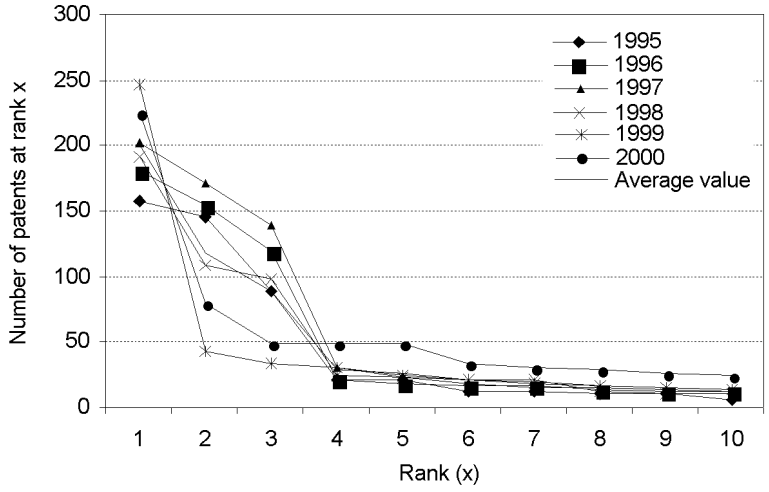

Figure 3e. Region of Hamburg: Patents ranked by patent assignees. The distribution of the top 10 results.
Source: European Patents Fulltext

Conclusion

Over the years 1995–2000 Hamburg is growing in terms of population and gross value added. The number of articles and patent applications is also growing. The topics of both, articles and patents, are highly concentrated following the informetric law. In science, top fields are biochemistry including molecular biology and particle and field physics, in technology, principal topics are preparations for medical, dental or toilet purposes and adhesives. The rank distributions of patent assignees and of scientific institutions follow the informetric law (with Beiersdorf and Philips at the top of the patent assigness and with several institutes of the University of Hamburg and DESY at the top of the scientific institutions).

4. Region of Cologne (Köln)

About the region

The region consists of one major city (Cologne), two smaller cities (Leverkusen and Bonn) and many small villages which can be divided into Rhein-Erftkreis, Rhein-Sieg-Kreis, Oberbergischer-Kreis, Bergischer-Kreis and Remscheid. The river Rhine is the centre of the region. With more than three million people in this area, of them living one

third in Cologne City, it is one of the most populated regions in Germany. The population outside Cologne City is spread over the whole area. There are two big universities, many research institutes, educational establishments and many colleges. Cologne University is also one of the biggest universities in all Germany with nearly 65,000 students.

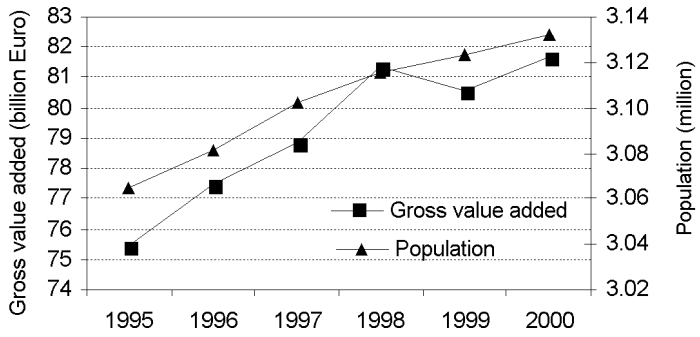

Figure 4a. Region of Cologne: Population and gross value added

Table 4a. Region of Cologne: Article publications and patent applications.
Sources: SciSearch; European Patents Fulltext

Number of article publications	1995	1996	1997	1998	1999	2000	Average
Total	3,601	3,926	4,253	4,378	4,527	4,650	4,223
per 1000 inhabitants	1.17	1.27	1.36	1.40	1.44	1.48	1.35
per billion EURO gross value added	47.70	50.60	53.90	53.70	56.10	56.90	53.28
Number of patent applications	1995	1996	1997	1998	1999	2000	Average
Total	1,127	1,154	1,190	1,280	1,404	1,589	1,291
per 1000 inhabitants	0.36	0.37	0.38	0.41	0.45	0.51	0.41
per billion EURO gross value added	14.90	14.80	17.90	15.70	17.40	19.40	16.27
Sum of article publ.s and patent appl.s	1995	1996	1997	1998	1999	2000	Average
Total	4,728	5,080	5,443	5,658	5,931	6,239	5,513
per 1000 inhabitants	1.54	1.65	1.75	1.82	1.90	1.99	1.78
per billion EURO gross value added	62.67	65.55	69.00	69.53	73.61	76.40	69.56

Most of the publications are from the two universities Cologne and Bonn. Three of the biggest companies that have a large influence in this region and on its employment rate are Bayer Leverkusen (chemical and pharmaceutical factory, employs about 120.000 people), Ford Cologne in Cologne (car building and developing) and Telekom in Bonn. The unemployment rate has decreased to about 9% during the past years in this region. About 1,4 million people are employed and about 130,000 are unemployed.

There is a consistent increase in population, employment, gross value added, patents, publications etc. The regional gross value added is on average 79.24 billion EURO. It increased in the years from 1995 until 2000 with an average rate of 1.3%.

Science output

The top scientific institutions are the Universities of Cologne and Bonn. The main research areas are physics and biochemistry. The universities have research partnerships with many different foreign universities, for example the universities of Chicago, Tokyo, Carleton etc. The emphasis of these cooperations is placed in the physics area.

The amount of the publications increased by about one thousand during the past five years. This increase corresponds to 1.48 articles per 1,000 inhabitants (year 2000) in relation to 1.17 articles in 1995. It should be mentioned that even though Bonn (about 38,000 students) has a much smaller university than Cologne the publication amount is almost the same.

Table 4b. Region of Cologne: Publications ranked by scientific fields. The top 10 results.
Sources: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Scientific field
1	244	Biochemistry & Molecular Biology
2	220	Astronomy & Astrophysics
3	193	Neuroscience
4	164	Pharmacology & Pharmacy
5	140	Clinical Neurology
5	140	Hematology
7	138	Physics
8	137	Surgery
9	123	Plant Science
10	117	Cardiovascular System & Cardiac

It is striking that there are many articles on subjects of biochemistry, molecular biology, astrophysics, astronomy, neuroscience, pharmacology and pharmacy. The yearly top ten do not show a wide variation except for the year 1998. The scientific fields of microbiology, cell biology and meteorology represent the leading research topics. It is also striking that the subject clinical neurology appears only in 1997 in the top 10 list with a great increase but this could be explained by the mad cow desease and its development. Generally speaking, the research topics do not change.

Table 4c. Region of Cologne: Publications ranked by institutions. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Institution
1	127	Universität Köln, Institut für Theoretische Physik
2	110	Universität Bonn, Institut für Physik
3	109	Universität Bonn, Institut für Radioastronomie
4	84	Universität Bonn, Institut für Organische Chemie / Biochemie
5	80	Universität Bonn, Institut für Anorganische Chemie
6	68	Universität Köln, Institut für Anorganische Chemie
7	63	Universität Köln, Institut für Züchtungsforschung
8	55	Universität Köln, Institut für Genetik
9	50	Universität Köln, Institut für Nuclearphysik
10	46	Universität Köln, Institut für Organische Chemie

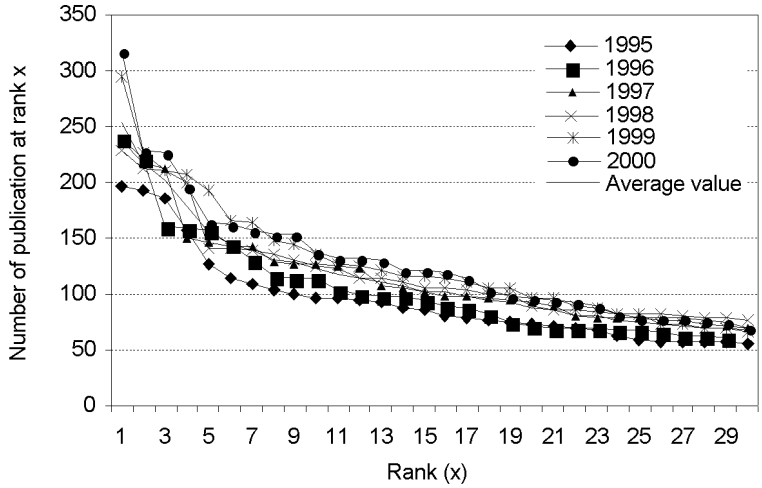

Figure 4b. Region of Cologne: Publications ranked by scientific fields. The distribution of the top 30 results.
Source: SciSearch

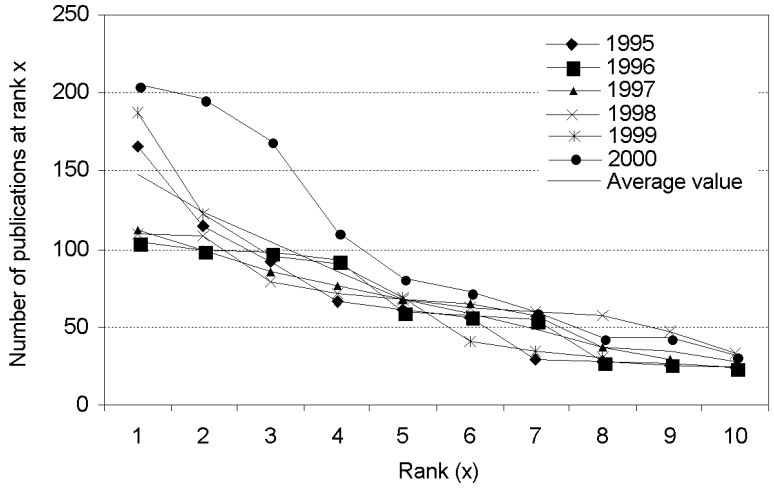

Figure 4c. Region of Cologne: Publications ranked by institutions. The distribution of the top 10 results. Source: SciSearch

Technology output

Most patents are assigned to the big companies such as Bayer, Ford and Telecom. The leading patent applicant in the researched time is definitely Bayer Leverkusen which has more than 506 patents per year (average). The second ranked company - Telekom – has only 87 patents per year. Telekom shows a big increase in patents during the past years which can be explained by the new demand and extension of mobile phones and its technology. The third leading position takes Ford Company but its patent assignments show a very strong decrease.

It is striking that a company like Bayer with so many patents does not appear in the list of scientific articles. This can be explained by the fact that the company does not publish anything of its basic research and does not cooperate with universities in basic research. There is not much co-operation between the universities and companies.

Table 4d. Region of Cologne: Patents ranked by IPC-Classes. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	IPC-Class	Explanation
1	118	C07D	Heterocyclic compounds
2	96	C07C	Acyclic or carbocyclic compounds
3	83	A61K	Community health
4	81	A01N	Agriculture / preserve
5	75	C08G	Macromolecular compounds – carbon-to-carbon-unsaturated bonds
6	50	C08L	Macromolecular compounds, e.g. pesticides, herbicides,
7	49	C08F	Macromolecular compounds – only involving carbon
8	46	C12N	Biochemistry, beer, spirits, wine, vinegar ... – microorganisms or enzymes, pest repellents or attractants, plant growth
9	41	C08K	Macromolecular compounds – use of inorganic or non-marcormolecular organic substances
10	33	B01J	Performing operations, transporting chemical or physical process e.g. Catalysis

Table 4e. Region of Cologne: Patents ranked by patent assignees. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	Patent assignee
1	506	Bayer AG
2	87	Deutsche Telekom AG
3	85	Ford-Werke Aktiengesellschaft
4	28	Moeller GmbH
5	26	Emitec Gesellschaft für Emissionstechnologie
6	24	Deutsches Zentrum fur Luft- und Raumfahrt
7	20	Dynamit Nobel GmbH Explosivstoff- und Systemtechnik
8	17	Agfa-Gevaert AG
9	13	Leybold Vakuum GmbH
10	12	B A R M A G AG

The only institution, which is represented at the top of the patent ranking and which co-operates with university research is the Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center). It is ranked sixth with an average of 24 patents yearly and co-operates with the two mentioned universities and many other research laboratories.

The leading topics of the assigned patents are mostly chemistry and similar subjects in accordance with the leading company Bayer.

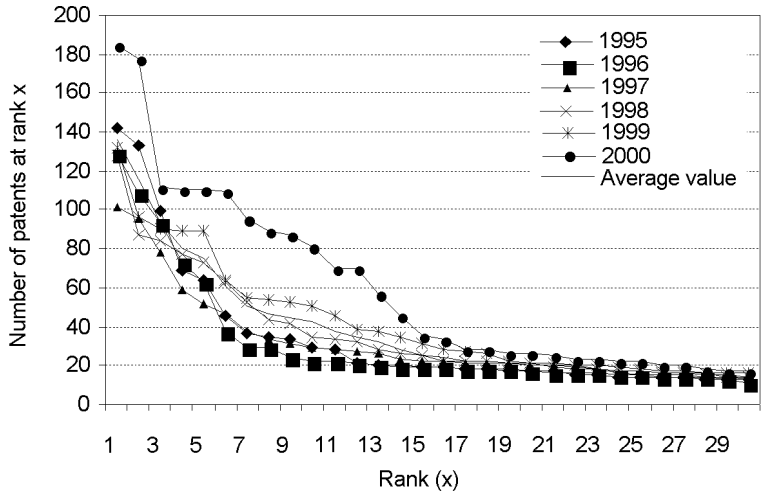

Figure 4d. Region of Cologne: Patents ranked by IPC-Classes. The distribution of the top 30 results.
Source: European Patents Fulltext

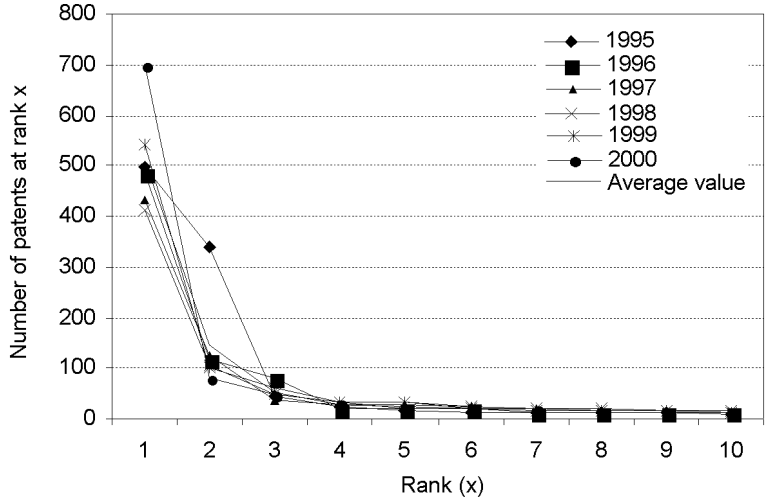

Figure 4e. Region of Cologne: Patents ranked by patent assignees. The distribution of the top 30 results.
Source: European Patents Fulltext

Conclusions

In the Cologne region, all indicators are increasing between 1995 and 2000. Concerning science output, there is no high concentration in terms of the informetric law. But there are some scientific fields showing a high output like biochemistry including molecular biology, astronomy resp. astrophysics, and neuroscience, and there are institutions with a high output, especially institutes of physics and chemistry of the universities in Cologne and in Bonn. In technology, there is evidence for informetric distributions of topics and of companies. The main topics are heterocyclic compounds, acyclic and carbocyclic compounds, community health, and other chemistry branches. Top patent assignees are Bayer, Telecom (with increasing activity), and Ford (with decreasing activity).

5. Region of Leipzig/Halle/Dessau

About the region

The region of Leipzig/Halle/Dessau is located in the east of Germany (in the three Lands Saxony, Saxony-Anhalt and Thuringia) and consists of three cities and 17 districts including the Thuringian district Altenburger country and covers altogether 13,665 km². The governmental district of Leipzig consists of the following units: Delitzsch, Torgau – Oschatz, Döbeln, Muldentalkreis, Leipziger Land and the city of Leipzig. The governmental district of Halle consists of: Saalkreis, Merseburg – Querfurt, Burgenlandkreis, Sangerhausen, Mansfelder Land and the city of Halle. The governmental district of Dessau consists of Wittenberg, Bitterfeld, Köthen, Bernburg, Anhalt – Zerbst and the city of Dessau.

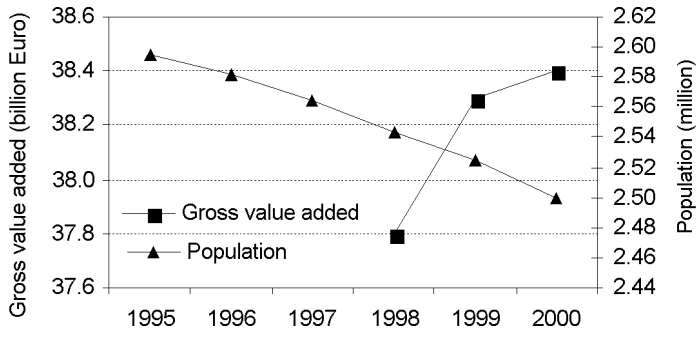

Figure 5a. Region of Leipzig: Population and gross value added

The number of inhabitants in the region decreases each year. The majority of the population lives in the district of Leipzig (approx. 1,099,512). Approx. 883,459 people lived in the district of Halle and approx. 556,689 in the district of Dessau on the average. The regional employment sank between 1995 and 1998 from 965,549 to 869,986, rose to 885,350 in 1999 and then decreased again in the year 2000 to 860,885. The gross value added increased gradually between the years 1998 and 2000 and reached 38,411 billion EURO in the year 2000.

The number of scientific articles rose from 1995 gradually. In 1995 about 1,500 articles were published (0.56 publications per 1000 inhabitants), and in 2000 the amount doubled to more than 3,000 (1.22 per 1000 inhabitants).

Table 5a. Region of Leipzig: Article publications and patent applications.
Sources: SciSearch; European Patents Fulltext

Number of article publications	1995	1996	1997	1998	1999	2000	Average
Total	1,447	1,764	2,424	2,622	2,843	3,040	2,357
per 1000 inhabitants	0.56	0.68	0.95	1.03	1.13	1.22	0.93
per billion EURO gross value added	–	–	–	69.29	74.17	79.14	74.2
Number of patent applications	1995	1996	1997	1998	1999	2000	Average
Total	38	66	72	95	98	84	75.5
per 1000 inhabitants	0.01	0.03	0.03	0.04	0.04	0.03	0.03
per billion EURO gross value added	–	–	–	2.51	2.56	2.19	2.42
Sum of article publ.s and patent appl.s	1995	1996	1997	1998	1999	2000	Average
Total	1,485	1,830	2,496	2,717	2,941	3,124	2,432
per 1000 inhabitants	0.57	0.71	0.97	1.07	1.16	1.25	0.96
per billion EURO gross value added	–	–	–	71.8	76.72	81.33	76.62

Science output

The most important fields of regional activity are biochemistry and molecular biology with 695 publications in the years 1995 until 2000, then physical chemistry (500 publications), condensed matter physics (484), neurosciences (469) and cardiac and cardiovascular systems (408). Biochemistry and molecular biology is ranked first except for the year 1995.

Table 5b. Region of Leipzig: Publications ranked by scientific fields. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Scientific field
1	116	Biochemistry & molecular biology
2	83	Chemistry, physical
3	81	Physics, condensed matter
4	78	Neurosciences
5	68	Cardiac & cardiovascular systems
6	65	Pharmacology & pharmacy
7	60	Physics, applied
8	57	Hematology
9	55	Chemistry
10	53	Materials science

Table 5c. Region of Leipzig: Publications ranked by institutions. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Institution
1	94	Max Planck Institut für Mikrostrukturphysik Halle
2	51	Martin-Luther-Universität Halle-Wittenberg, Fachbereich Physik
3	34	Universität Leipzig, Institut für theoretische Physik
3	34	Universität Leipzig, Fakultät für Physik und Geowissenschaften
5	20	Universität Leipzig, Institut für Anorganische Chemie
6	18	Max Planck Institut für neuropsychologische Forschung Leipzig
7	16	Universität Leipzig, Institut für Analytische Chemie
8	15	Martin-Luther-Universität Halle-Wittenberg, Institut für Anorganische Chemie
8	15	Universitätsklinikum Leipzig, Institut für Pathologie
10	14	Martin-Luther-Universität Halle-Wittenberg, Institut für Organische Chemie

One of the most active institutions is the Max–Planck-Institute, i.e. its department of micro structure physics with 563 publications in the years 1995 until 2000. 308 articles were published by the physics department of the University of Halle-Wittenberg. The institute of theoretical physics at the University of Leipzig published 205 scientific texts. Thus one can state that the region of Leipzig/Halle/Dessau is mainly strong in the chemical and physical areas.

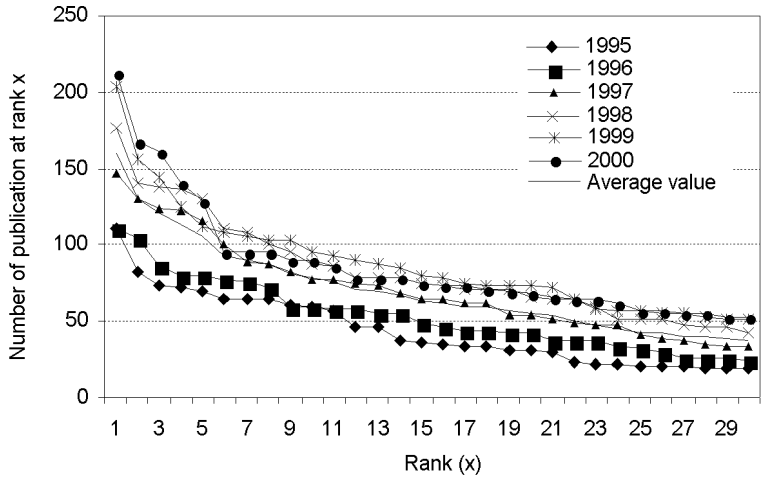

Figure 5b. Region of Leipzig: Publications ranked by scientific fields. The distribution of the top 30 results.
Source: SciSearch

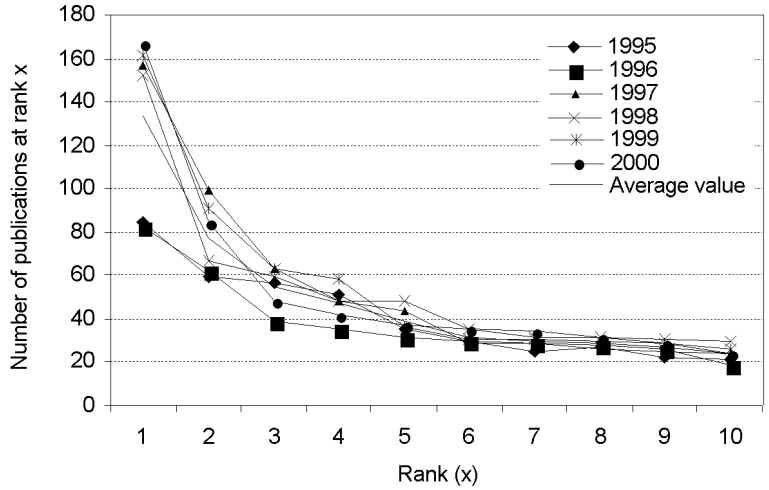

Figure 5c. Region of Leipzig: Publications ranked by institutions. The distribution of the top 10 results.
Source: SciSearch

Technology output

The Region of Leipzig/Halle/Dessau is a weak region as far as the patent assignment is concerned. With a total amount of 453 assignments in the period 1995 through 2000, the region is ranked last compared to other German regions. From the beginning of the period until 1999 numbers were doubling. The year 2000 shows a stagnation.

Table 5d. Region of Leipzig: Patents ranked by IPC-Classes. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	IPC-Class	Explanation
1	9	G01N	Investigating or analysing materials by determining their chemical or physical properties
2	7	A61K	Preparations for medical, dental, or toilet purposes
3	4	C08L	Compositions of macromolecular compounds
3	4	C02F	Treatment of water, waste water, sewage, or sludge
5	3	C12N	Micro-organisms or enzymes; compositions thereof
5	3	B01J	Chemical or physical processes, e.g. catalysis, colloid chemistry; their relevant apparatus
5	3	C08J	Working-up; general processes of compounding; after-treatment not covered by subclasses
5	3	C07D	Heterocyclic compounds
5	3	C07K	Peptides
10	2	B65D	Containers for storage or transport of articles or materials, e.g. bags, barrels, bottles, boxes, cans, cartons, crates, drums, jars, tanks, hoppers, forwarding containers; accessories, closures, or fittings therefor; packaging elements; packages

Table 5e. Region of Leipzig: Patents ranked by patent assignees. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	Patent assignee
1	7	Buna Sow Leuna Olefinverbund GmbH
2	4	UFZ-Umweltforschungszentrum Leipzig-Halle GmbH
3	1	NOELLE-KRC Energie- und Umwelttechnik GmbH
3	1	SKW Stickstoffwerke Piesteritz GmbH
3	1	Gunter Slowik
3	1	ACGT ProGenomics AG
3	1	KataLeuna GmbH Catalysts
3	1	Jurgen Kohlmann
3	1	FEW Chemicals GmbH
3	1	Probiodrug AG

Buna Sow Leuna Olefinverbund located in Schkopau, district of Halle, is ranked first in the patents ranking. This company produces plastics such as polyethylene and rubber at four different locations in this region. Since 2000 this company is a part of The Dow Chemical Company. As is shown by the name „chemical triangle" which denotes a part of Saxony-Anhalt chemical companies are very important to this region. One of them having a comparatively high share in the patent assignment is the SKW Stickstoffwerke Piesteritz, a factory producing nitrogen. Another important patent assignee is the UFZ, a center for environmental research, founded by the Federal Ministry of Education and Research of Germany and the regional governments of Saxony and Saxony-Anhalt.

Buna Sow Leuna Olefinverbund is the leader in patent assignments for this region, followed by UFZ. Together they form the top of the patent concentration as shown in Table 5e. But this picture was mainly formed before 1998. During that year, the total amount of all patent assignments to Buna Sow Leuna Olefinverbund was stagnating and a deconcentration development started. From then on patents were assigned to Probiodrug AG, ACGT Progenomics AG, SKW, the UFZ and several others, changing from year to year. This deconcentration can, with some exceptions, also be observed in the IPC-classes of the assigned patents.

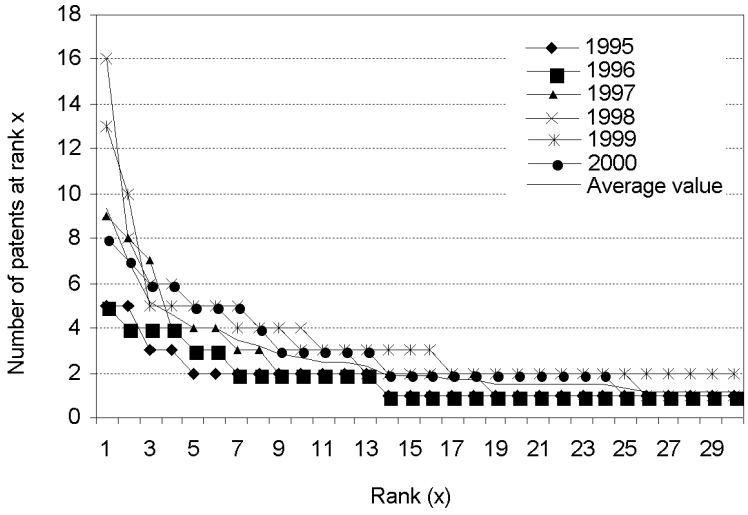

Figure 5d. Region of Leipzig: Patents ranked by IPC-Classes. The distribution of the top 30 results.
Source: European Patents Fulltext

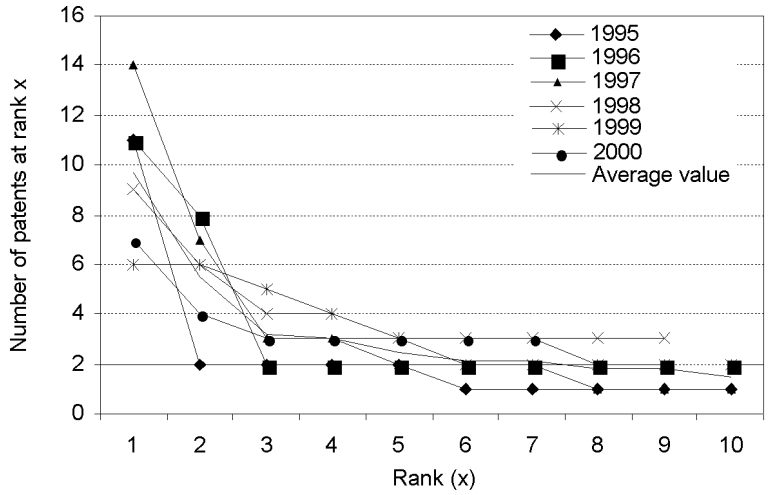

Figure 5e. Region of Leipzig: Patents ranked by patent assignees. The distribution of the top 10 results.
Source: European Patents Fulltext

Conclusion

The Leipzig/Halle/Dessau region is very weak in terms of all the indicators. But there are some trends for an increasing development. So the science attraction, the number of scientific articles, doubled between 1995 and 2000. The distributions of science fields and of institutions follow the typical informetric distribution with biochemistry including molecular biology, physical chemistry and physics institutes. Main institutions are two Max-Planck-Institutes and institutes of the University of Halle-Wittenberg and of the University of Leipzig. The activity of the region of Leipzig/Halle/Dessau in terms of technology is very low. There is a change in the top patent topics and in the top companies around the year 1998.

6. Region of Munich (München)

About the region

In the state development scheme Bavaria is divided into 18 planning regions. Greater Munich (here planning region no. 14) is located in the centre of the governmental district of Upper Bavaria and apart form the Land capital, Munich, it covers the districts of Dachau, Ebersberg, Erding, Freising, Fürstenfeldbruck, Landsberg on the Lech, Munich and Starnberg. It is the most densely populated

planning region: almost 2.4 million inhabitants live in an area of approximately 5,504 km^2 (1.2 million people live in the Land capital Munich). The region consists of a wide ranging infrastructure. A lot of universities, research institutions and educational centers provide a high potential of innovation as well as an appropriate offer of qualified jobs. The region of Munich is the place of renowned companies like BMW and worldwide-known companies like Siemens have their establishments in this region.

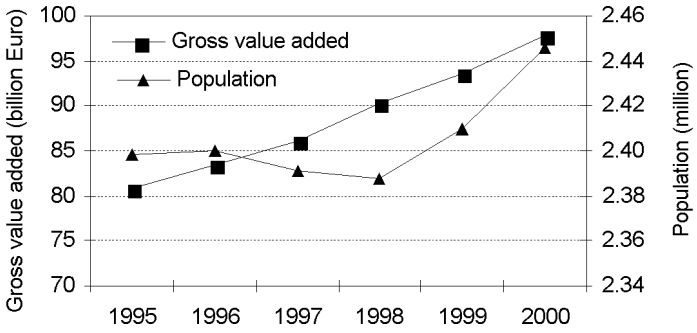

Figure 6a. Region of Munich: Population and gross value added

Table 6a. Region of Munich: Article publications and patent applications.
Sources: SciSearch; European Patents Fulltext

Number of article publications	1995	1996	1997	1998	1999	2000	Average
Total	6,885	7,354	8,045	8,330	8,723	8,514	7,975
per 1000 inhabitants	2.87	3.06	3.36	3.49	3.62	3.48	3.31
per billion EURO gross value added	85.31	88.02	93.51	92.15	93.27	87.14	89.9
Number of patent applications	1995	1996	1997	1998	1999	2000	Average
Total	2,038	2,763	3,334	3,750	3,996	4,265	3,358
per 1000 inhabitants	0.85	1.15	1.39	1.57	1.66	1.74	1.39
per billion EURO gross value added	25.25	33.07	38.75	41.48	42.73	43.65	37.49
Sum of article publ.s and patent appl.s	1995	1996	1997	1998	1999	2000	Average
Total	8,923	10,117	11,379	12,080	12,719	12,779	11,332
per 1000 inhabitants	3.72	4.22	4.76	5.06	5.28	5.22	4.71
per billion EURO gross value added	110.56	121.09	132.26	133.63	136.00	129.79	127.22

The number of employed persons with about 1.4 million remains nearly constant. Considering the population growth in the years between 1995 and 2000 we can see a stagnation between 1995 and 1998 and a rise from 1998 to 2000. The gross value added of the region is constantly rising. In 1995 gross value added amounted to about 81 billion EURO and rose up to 97 billion EURO in the year 2000.

Science output

Between the years 1995 and 2000 47,851 scientific articles were published in Munich. We can observe an increase from 6,885 (1995) to 8,514 (2000). If we compare the above mentioned numbers to the number of articles in the region, we can see an increase in the publications per 1000 inhabitants (1995: 2.87 up to 3.48 in 2000).

Table 6b. Region of Munich: Publications ranked by scientific fields. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Scientific field
1	588	Astronomy & astrophysics
2	419	Biochemistry & molecular biology
3	321	Physics
4	291	Neurosciences
5	250	Physics, condensed matter
6	241	Hematology
7	231	Physics, applied
8	214	Immunology
9	210	Engineering, electrical & electronic
9	210	Oncology

Table 6c. Region of Munich: Publications ranked by institutions. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Institution
1	183	GSF Forschungszentrum für Umwelt und Gesundheit. München, Neuherberg
2	163	Max Planck Institut für extraterristische Physik. München
3	120	Technische Universität München. Institut für anorganische Chemie
4	99	Max Planck Institut für Physik und Astrophysik. München.
5	98	Max Planck Institut für Astrophysik. München, Garching
6	93	Technische Universität München. Physik Department. München, Garching
7	86	European Southern Observatory, München Garching.
7	86	Max Planck Institut für Quantenoptik. München Garching
9	79	Ludwig-Maximilians-Universität München (LMU), Sektion Physik
10	21	Technische Universität München. Walter Schottky Institut, München, Garching

The ranking of publications of the scientific fields between the years 1995 and 2000 shows a similar sum of publications per scientific field for each year. At the top of the ranking list we can always find the scientific field astronomy & astrophysics. In this field we can find 471(1995) to 707 (1999) publications and during the years 1995–2000

588 articles were published on an average per year. Astronomy & astrophysics are followed by biochemistry & molecular biology on the second rank. The number of publications varies from 365 to 455. The third place is occupied by different scientific fields each year, e.g. physics, hematology and neurosciences.

First in the list of publications by institutions between the years 1995 and 2000, excluding the years 1995 and 1996, is GSF Forschungsinstitut (1995: rank 2; 1996: rank 3). GSF started its work with the setting up of the Experimental and Training Centre for Radiation Protection in 1960. Today, GSF has several research institutions (for experimental genetics, human genetics, bioinformatics, and molecular radiobiology). The aims of the research are to recognise health risks for humans and risks to the environment, to elucidate mechanisms of disease development, to assess the load-bearing capacity (and limits) of the environment and of the defence mechanisms of the human body, and to develop concepts for long-lasting prevention and cure. In this way, the GSF has developed the scientific basis to protect man and the natural basis of human life in the future. Research into the interactions between genes and the environment is thus a common basis for all research activities in the GSF.

In the years 1995 and 1996 the Max-Planck Institut für extraterrestrische Physik is ranked first (1997: Rank 3; 1998: Rank 4; 1999: Rank 2; 2000: Rank 6). The institute was founded in 1963 as a division of the Max-Planck-Institut für Physik und Astrophysik and established as an independent institute in 1991. Its main research topics are astronomical observations in spectral regions, which are accessible only from space because of the absorbing effects of the Earth's atmosphere, as well as in-situ measurements in near-Earth space investigating the collisionless interaction of cosmic plasmas. Different institutions are ranked second, e.g. Technische Universität München/Institut für anorganische Chemie, Max-Planck Institut für Physik und Astrophysik, Technische Universität München/Institut für anorganische Chemie, Technische Universität München/Institut für anorganische Chemie, Max-Planck Institut für extraterrestrische Physik, Max-Planck Institut für Physik und Astrophysik.

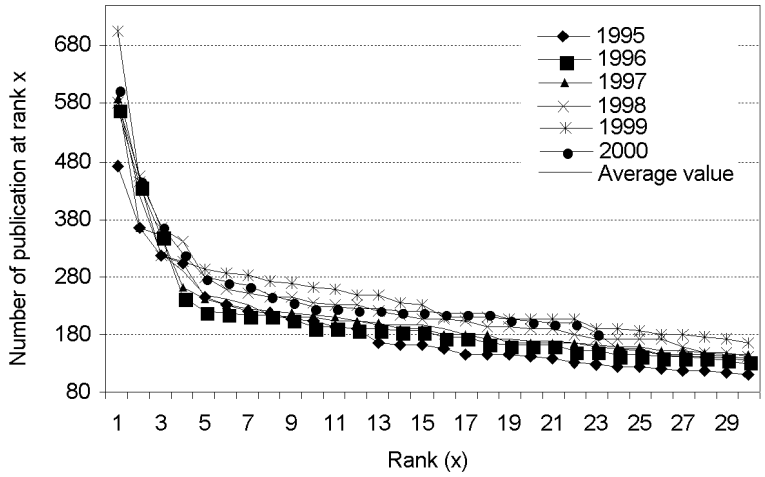

Figure 6b. Region of Munich: Publications ranked by scientific fields. The distribution of the top 30 results.
Source: SciSearch

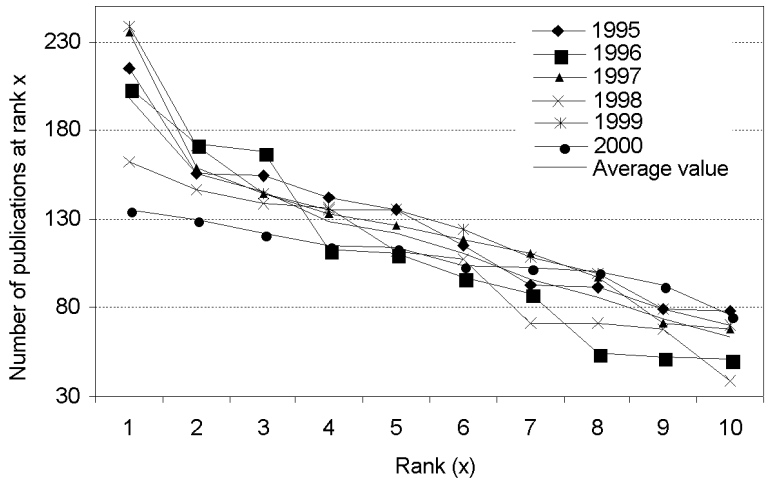

Figure 6c. Region of Munich: Publications ranked by institutions. The distribution of the top 10 results.
Source: SciSearch

Technology output

Between the years 1995 and 2000 there are 20,146 patent applications marked by a constant yearly increase. While in the year 1995 we have 2,038 patent applications, this number doubles in the year 2000 to 4,265 patent applications. Considering the patent applications per head we can see an increase from 0.85 (1995) to 1.74 (2000) patents. The number of patent applications by Siemens Corporation is above average. Between the years 1995 (983) to 2000 (1,589) Siemens applied for altogether 8,916 patents and therefore ranked first. With about 30 locations and 35,000 employees Munich is one of the most important branches of the Siemens Corporation in Germany. The Munich headquarter is responsible for Automation and Control, Information and Communications, Medical and Transportation. Almost half of the business areas, including a large number of research and development centers, are located in Munich. Apart from the Siemens Corporation, also Infineon Technologies AG, OSRAM GmbH, Siemens Business Services GmbH und Co. OHG, Siemens Gebaeudetechnik GmbH und Co. OHG, Siemens & Shell Solar GmbH and Fujitsu-Siemens Computers GmbH are located in Munich. After branching off from Siemens in the year 1997, Infineon Technologies takes the second rank until the year 2000. Infineon is a leading innovator in the international semiconductor industry. It designs, develops, manufactures and markets a broad range of semiconductors and complete system solutions targeted at selected industries. Its products serve applications in the wireless and wireline communications, automotive, industrial, computer, security and chip card markets. Its product portfolio consists of both memory and logic products and includes digital, mixed-signal and analogue integrated circuits, or ICs, as well as discrete semiconductor products and system solutions. In the years 1995 and 1996 the second rank is occupied by Bayerische Motorenwerke (BMW).

Considering the International Patent Classification (IPC) we can see that the class of semiconductor devices (HO1L) occupies the first rank, with 1,587 patent registrations, during the years 1995 to 2000. This group includes conveying systems for semiconductor wafers, use of semiconductor devices for measuring and details scanning-probe apparatus. During the years 1995 to 1998 the IPC class of selecting (switches, relays, selectors; electronic switches) (H04Q) is ranked second. In 1999 and 2000 the transmission of digital information (H04L) is ranked second.

Co-operating with international institutions is vital for the region of Munich. Working together with Rutherford Appleton Laboratory (RAL) is especially important. Between the years 1995 and 2000 it has a share in 228 publications. CCLRC (Council for the Central Laboratory of the Research Councils) Rutherford Appleton Laboratory (RAL) is located in Oxfordshire, near Didcot, and is conveniently situated for air, rail and road networks. RAL has a staff of around 1,200 who support the work of over 10,000 scientists and engineers, mainly from the university research community.

Table 6d. Region of Munich: Patents ranked by IPC-Classes. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	IPC-Class	Explanation
1	262	H01L	Semiconductor devices; electric solid state devices not otherwise provided for
2	182	H04Q	Selecting
3	154	G06F	Electric digital data processing
4	152	H04L	Transmission of digital information, e.g. Telegraphic communication
5	111	H04B	Transmission
6	110	H04M	Telephonic communication
7	80	G01N	Investigating or analysing materials by determining their chemical or physical properties
8	69	G06K	Recognition of data; presentation of data; record carriers; handling record carriers
8	69	H01H	Electric switches; relays; selectors; emergency protective devices
10	68	B60R	Vehicles, vehicle fittings, or vehicle parts, not otherwise provided for

Table 6e. Region of Munich: Patents ranked by patent assignees. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	Patent assignee
1	1,469	Siemens Aktiengesellschaft
2	316	Infineon Technologies AG
3	193	Bayerische Motoren Werke (BMW) Aktiengesellschaft
4	166	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung
5	111	BSH Bosch und Siemens Hausgeraete GmbH
6	52	Wacker-Chemie GmbH
7	51	Patent-Treuhand-Gesellschaft für Elektrische Glühlampen mbH, München
8	38	Max-Planck-Gesellschaft zur Förderung der Wissenschaften, München
9	35	Giesecke & Devrient GmbH
10	24	Epcos AG

Its main facilities enable research into new materials and structures, for example from battery electrolytes to turbine blades, X-ray laser research, space-based astronomy, the co-ordination of particle physics and many other topics. The second rank in terms of co-operation is always occupied by the University Birmingham, Department Physics and Space with 126 publications.

Finally, we added the numbers of published articles and the registered patents. The sum is 55,218. During 1995 and 2000 the number of publications and patents rises from 8,923 (1995) to 12,719 (2000). If we relate these numbers to the number of inhabitants (per 1,000 inhabitants) we can see an increase of publications and patents from 3.72 (1995) to 5.22 (2000).

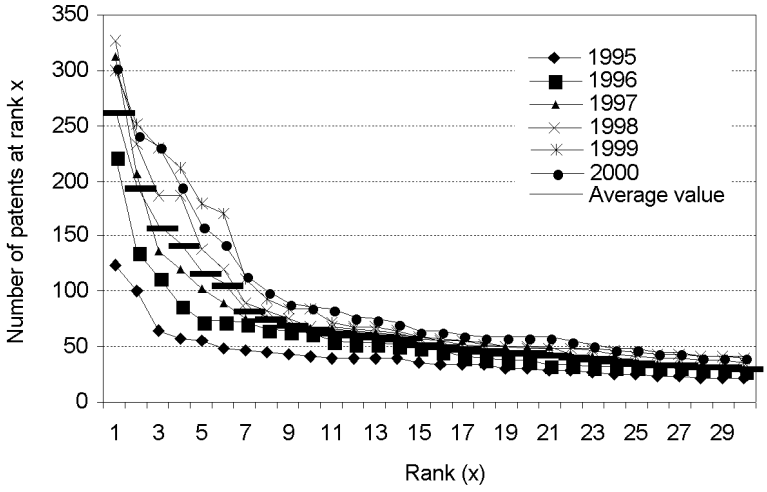

Figure 6d. Region of Munich: Patents ranked by IPC-Classes. The distribution of the top 30 results.
Source: European Patents Fulltext

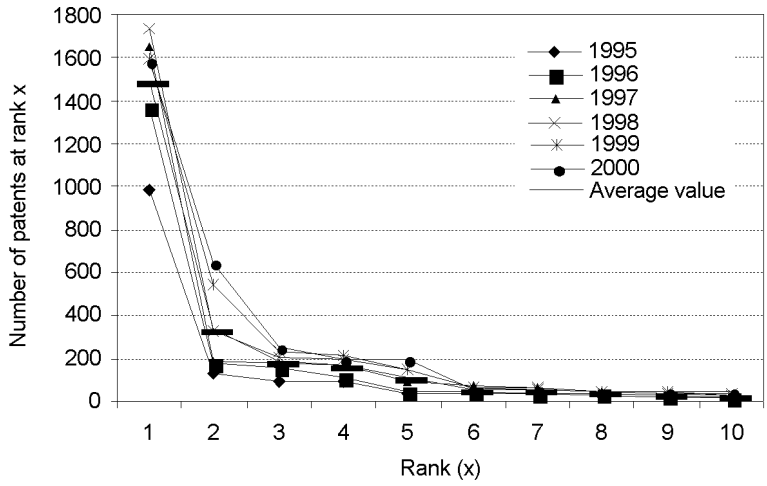

Figure 6e. Region of Munich: Patents ranked by patent assignees. The distribution of the top 10 results.
Source: European Patents Fulltext

Conclusions

You may infer either from the amount of publications or from the amount of patents in the region of Greater Munich that it is the most successful region of the Federal Republic of Germany as regards to the output of regional science and technology, its strengths and its leading institutions. In our study we could not examine the roots of this success, but we can make the assumption that it is supposedly a mixture of the leading companies Siemens, Infinion, BMW, EADS and others as well as the successful policy pursued by the Bavarian Government during the last fifty years. Especially the policy of privatization and the investment of the earned money into the education sector serve as a basis of the scientific success of the region of Greater Munich. This again is one of the most important advantages of the region of Greater Munich, which attracts many of the worldwide biggest multinational companies. STERNBERG & TAMASY (1999, p. 367) point out the role of Siemens for the Munich region. "A survey of Munich's R&D-intensive SMEs shows that Siemens positively influences the innovative milieu. However, Siemens does not dominate the SMEs so strongly that a one-sided dependency threatens them; rather, they enjoy diverse and intraregional co-operation in innovation". Especially the distribution of the patent assignees perfectly follows the informetric law.

7. Region of Stuttgart

About the region

The greater region of Stuttgart is situated in the southwest of Germany in the state Baden-Württemberg: It consists of 179 municipalities comprising the city of Stuttgart (the state capital of Baden-Württemberg) and five counties: Böblingen, Esslingen, Göppingen, Ludwigsburg and Rems-Murr county. Altogether the region measures 3,654 km^2 (approx. 10% of the state's area). About 2.6 million people live in the Stuttgart region which is about 25% of the inhabitants of Baden-Württemberg. The population rate continuously increased from 1995 to 2000. The Stuttgart region is known for its industries and its economy. The gross value added amounts to 74.188 billion EURO per year on average. The gross value added increased during the years from 68.678 billion EURO in 1995 to 80.825 billion EURO in 2000. During the years the rate of gross value added per inhabitant has also increased continuously. On average it is about 28,657 EURO per annum.

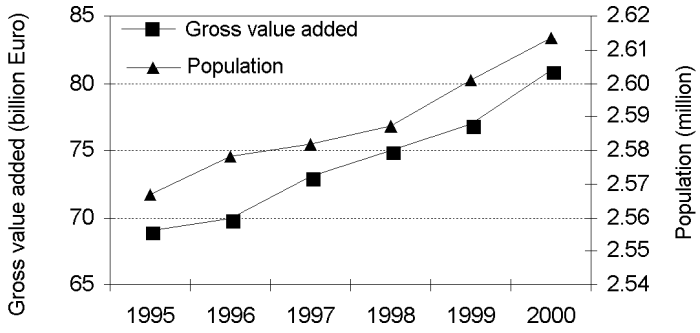

Figure 7a. Region of Stuttgart: Population and gross value added.
Source: Statistisches Landesamt Baden-Würtemberg

Altogether 26,816 article publications and patents were published and assigned from 1995 to 2000 in the Stuttgart region. During this period the rate of publications and patents has increased continuously. This indicates that there are about 4,469 publications and patents per year on average. In relation to the population, there are 1.73 documents per inhabitant. The rate of documents per gross value added amounts from 47.5 to 59 documents per billion EURO a year.

Table 7a. Region of Stuttgart: Article publications and patent applications.
Sources: SciSearch; European Patents Fulltext

Number of article publications	1995	1996	1997	1998	1999	2000	Average
Total	2,301	2,474	2,539	2,904	2,863	2,747	2,638
per 1000 inhabitants	0.90	0.96	0.98	1.12	1.10	1.10	1.03
per billion EURO gross value added	33.35	35.34	34.78	38.72	37.18	33.91	35.55
Number of patent applications	1995	1996	1997	1998	1999	2000	Average
Total	1,175	1,439	1,884	1,938	2,200	2,352	1,831
per 1000 inhabitants	0.45	0.56	0.73	0.74	0.85	0.9	0.71
per billion EURO gross value added	17.03	20.56	25.81	25.84	28.57	29.04	24.48
Sum of article publ.s and patent appl.s	1995	1996	1997	1998	1999	2000	Average
Total	3,476	3,913	4,423	4,842	5,063	5,099	4,469
per 1000 inhabitants	1.35	1.52	1.71	1.87	1.95	1.95	1.73
per billion EURO gross value added	47.5	52.57	56.89	60.34	60.98	58.76	56.17

Science output

In total the Stuttgart region published 15,528 scientific articles between 1995 and 2000 covered by SciSearch, which is about 2,638 per year on average. 1998 can be identified as the year of the highest productivity during this period with 2,904 publications. Although the figures slightly decline in 1999 and 2000, the number of publications has increased on the whole from 1995 (2,310) until 2000 (2,747). Concerning the publication rate per 1,000 inhabitants the same tendency becomes apparent. It increased from 0.90 in 1995 to 1.12 in 1998 and decreased until the year 2000 (1.10). This results in an average of 1.03 publications.

Table 7b. Region of Stuttgart: Publications ranked by scientific fields. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Scientific field
1	337	Physics, condensed matter
2	229	Materials science
3	174	Physics, applied
4	136	Chemistry, physical
5	116	Physics
6	91	Metallurgy & metallurgical engineering
7	75	Crystallography
8	73	Chemistry, inorganic & nuclear
9	53	Engineering, electrical & electronic
10	43	Biochemistry & molecular biology

Table 7c. Region of Stuttgart: Publications ranked by institutions. The top 10 results.
Source: SciSearch (Documents: Average number of documents per year)

Rank	Documents	Institution
1	465	Max-Planck-Institut für Festkörperforschung
2	271	Max-Planck-Institut für Metallforschung
3	62	Universität Stuttgart, Abt. anorganische Chemie
4	48	Universität Stuttgart, Abt. Physik
5	39	Bosch GmbH
6	34	Universität Stuttgart, Abt. organische Chemie
7	32	Universität Stuttgart, Abt. technische Biochemie
8	30	Universität Stuttgart, Abt. theor. & angew. Physik
9	21	Universität Stuttgart, Abt. Mathematik
10	10	Universität Stuttgart, Abt. physische Elektronik

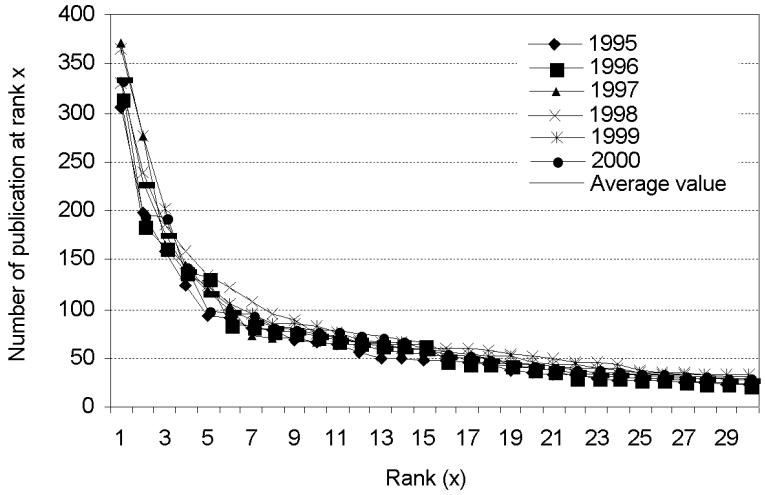

Figure 7b. Region of Stuttgart: Publications ranked by scientific fields. The distribution of the top 30 results.
Source: SciSearch

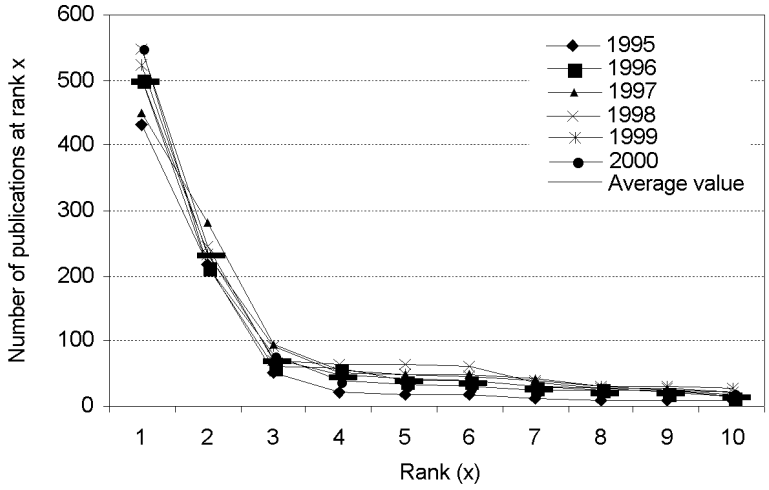

Figure 7c. Region of Stuttgart: Publications ranked by institutions. The distribution of the top 10 results.
Source: SciSearch

The ranking of the top 10 disciplines shows a plain dominance of physics and chemistry (in general). Condensed matter physics takes first place every year (337 publications on average), followed by materials science (229 on average) and applied physics (173.5 on average), which is superseded only once in 1998 by the discipline of crystallography.

Corresponding to the disciplines, the list of the top 10 institutions is dominated by only three names: The Max-Planck-Institutes, the University of Stuttgart and the Robert Bosch GmbH. Max-Planck-Institutes are part of the Max Planck Society for the Advancement of Science which is an independent, non-profit research organization that primarily promotes and supports research at its own institutes. They perform basic research in the interest of the general public in the natural sciences, life sciences, social sciences, and the humanities. There are two Max-Planck-Institutes out of 80 situated in Germany since 1969 – one for solid state research and one for metals research. They take the first two places (in sequence as listed before) during the surveyed years. The University of Stuttgart and several of its departments, mainly the fields of physics, chemistry, biochemistry and mathematics, take up between 6 and 7 places in the annual top 10. The Robert Bosch GmbH was founded in 1886 and has got 236 locations worldwide. 57 of them are situated in Germany. In the year 2002, the enterprise had an annual turnover of 35 billion EURO worldwide and 9.6 billion EURO in Germany. Bosch's business divisions are automotive technology, industrial technology and consumer goods and building technology. It is represented in the ranking list every year, but its number of publications (234 in total from 1995–2000) reaches only 7.78% of the publications by the Max-Planck-Institute for Solid State Research, which issued 3,007 publications. The two Max-Planck-Institutes in the Stuttgart region published 4,415 articles.

Publications in co-operation with institutes and universities from outside the Stuttgart region mainly took part with the Institute for Organic Chemistry at the University of Würzburg (131 publications between 1995 and 2000). It is situated 150 km north-east of Stuttgart and has been part of the new Chemistry Center of the University since 1969. The co-operation with the Institute of Solid State Physics at the Research Centre of the Russian Academy of Sciences in Chernogolovka (about 50 km north from Moscow) resulted in 64 publications in total.

Technology output

In contrast to the publications, the Stuttgart region has got a large number of patent applications. First of all, we have to mention, that the number of assigned patents has increased every year from 1,175 patents in 1995 to 2,352 patents in 2000. In total there are 10,988 assigned patents during the years 1995-2000. That means, that there are on average 1,831 patents per year, 0.71 patents per thousand inhabitants and 24.63 patents per gross value added in a billion EURO.

Table 7d. Region of Stuttgart: Patents ranked by IPC-Classes. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	IPC-Class	Explanation
1	125	F02M	Supplying combustion engines in general
2	102	B60R	Vehicles, vehicle fittings, or vehicle parts
3	70	F02D	Controlling combustion engines
4	46	B60T	Vehicles brake control systems or parts thereof
5	40	B01D	Separation
6	38	B60S	Servicing, cleaning, repairing, supporting, lifting, or manoeuvring of vehicles
7	33	B60K	Arrangement or mounting of propulsion units or of transmissions in vehicles
8	14	B62D	Motor vehicles, trailers
9	13	H02K	Dynamo-electric machines
10	12	F16D	Couplings for transmitting rotation, clutches, brakes

Table 7e. Region of Stuttgart: Patents ranked by patent assignees. The top 10 results.
Source: European Patents Fulltext (Documents: Average number of documents per year)

Rank	Documents	Patent assignee
1	966	Robert Bosch GmbH
2	286	Daimler-Chrysler AG
3	64	Porsche AG
4	53	Filterwerk Mann & Hummel GmbH
5	49	TRW occupant restraint systems GmbH&Co KG
6	26	Festo AG & Co.
7	13	Behr GmbH & Co.
8	11	Mahle Filtersysteme GmbH
9	9	Alcatel
9	9	Alfred Karcher GmbH & Co.

The ranking of the disciplines, built by the international patent classification, shows a clear dominance of two big patent groups: “combustion engines” and “vehicles in general”. At the top we can find the class “supplying combustions engines in general with combustion mixtures or constituents thereof” with 1,057 assigned patents, followed by “vehicle fittings, vehicle parts not otherwise provided for” with about 756 assigned patents and “controlling combustion engines” with about 482 assigned patents.

Corresponding to the disciplines, the ranking of the patent assignees also shows a clear dominance of a few institutions. On top, you can find the Bosch GmbH, mentioned above, with 5,670 assigned patents. Bosch is the only institution, which has not only got high publication rates, but also a large share of assigned patents.

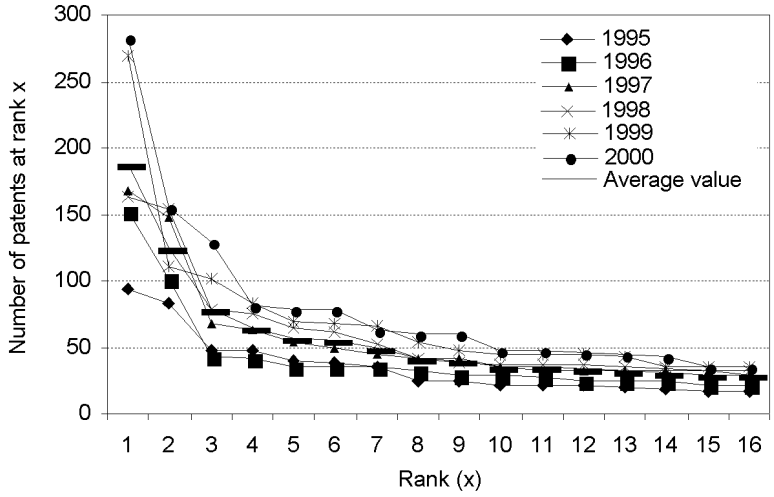

Figure 7d. Region of Stuttgart: Patents ranked by IPC-Classes. The distribution of the top 16 results.
Source: European Patents Fulltext

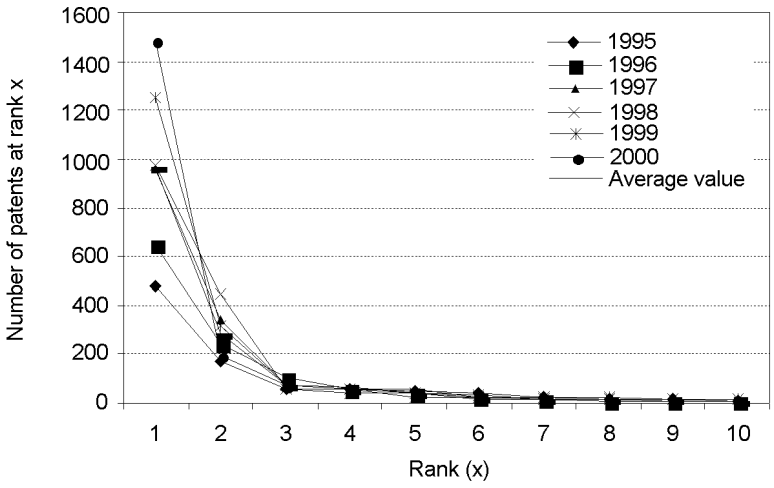

Figure 7e. Region of Stuttgart: Patents ranked by patent assignees. The distribution of the top 10 results.
Source: European Patents Fulltext

The following company is the Daimler-Chrysler AG with 1,694 assigned patents. Daimler-Chrysler is one of the leading automobile companies in the world. In 2002 the enterprise had an annual turnover of about 149.6 billion EURO worldwide. Another automobile company is ranked third place. The "Dr. Ing. h.c. F. Porsche AG" has a total of about 365 assigned patents. The annual turnover amounts to 3.7 billion EURO worldwide and to about 1.1 billion EURO in Germany.

The cooperation with other national and international institutions in terms of patent applications is not very important to the region of Stuttgart. The individual companies have just a few cooperation partners. The most important one is the automotive company BMW headquartered in Munich. Other cooperation partners are for example Temic Telefunken Microtechnics GmbH, a car suppliers industry, and the French automobile company Renault.

Conclusions

Finally, there is to say that the industry in the region of Stuttgart is strongly influenced by the automobile branch and its ancillary industry. In this region, we can find almost ideally perfect informetric distributions of topics, institutes and patent assignees. The science output is highly concentrated on two Max-Planck-Institutes, the technology output shows a strong concentration on the patent activities of Bosch and Daimler-Chrysler.

The regions in comparative analysis

Science and technology attraction, intensity and density

In this chapter, we are going to compare the figures of the seven German regions. First of all, we are analysing rankings of absolute numbers of scientific articles, of patents, and of all documents (i.e., the sum of article publications and patents). This may be an indicator for the regional *science and technology attraction.* This indicator is independent from the region in terms of expansion, since neither the number of inhabitants nor the volume of the gross value added are taken into consideration. This indicator seems to be a little bit unfair to small regions. Companies that are looking for a new site will probably take their decision depending on the attraction because this is an indicator of the real amount of scientific and technological activity. Additionally, companies will analyse the topic structure of a region (as in the Tables #b, #d and in the Figures #b, #d) as well as perhaps the corporate structure of scientific and technological active institutions in the region (as in the Tables #c, #e and in the Figures #c, #e).

Table 8. Science and technology attraction of seven German regions. Absolute numbers of scientific publications and patents in the regions per year (average value of the years 1995–2000)

Rank	Publications	Region	Rank	Patents	Region	Rank	Documents	Region
1	7,975	Munich	**1**	3,358	Munich	**1**	11,332	Munich
2	4,223	Cologne	**2**	1,831	Stuttgart	**2**	5,513	Cologne
3	3,001	Hamburg	**3**	1,291	Cologne	**3**	4,469	Stuttgart
4	2,744	Aachen	**4**	987	Düsseldorf	**4**	3,765	Hamburg
5	2,638	Stuttgart	**5**	765	Hamburg	**5**	3,064	Aachen
6	2,357	Leipzig	**6**	319	Aachen	**6**	2,726	Düsseldorf
7	1,739	Düsseldorf	**7**	76	Leipzig	**7**	2,432	Leipzig

The top region concerning scientific and technological attraction is Munich (see Table 8). It is ranked first with regard to publication output, technological output (patents), and – of course – all documents. Ranked second in terms of scientific articles and all documents is Cologne, ranked second in terms of patents is Stuttgart. A low scientific attraction show Leipzig and Düsseldorf, a low technological attraction show Aachen and again Leipzig. High attraction in terms of technology does not always mean high attraction in terms of science, too. For example, see Stuttgart (rank 2 with patents but only rank 5 with scientific publications) or Aachen (rank 4 with publications and rank 6 with patents)! Some regions (like Stuttgart) are more technologically oriented and some (like Aachen) are more oriented towards science.

We have to remark that the attraction indicator is a comprehensive indicator of science and technology in general. When we analyse the topic structure of the region, we obtain a more detailed view, e.g. the Düsseldorf region is weak all-in-all, but has advantages in neurology, dermatology and iron and steel research and in the technologies of detergent compositions, preparations for medical purposes and rolling & casting of metal. Munich is generally top, but weak in detergents, one of Düsseldorf's top fields.

Our second indicator, *science and technology intensity,* relates the number of articles and patents to the number of inhabitants living in the region (see Table 9). In Munich, there are 3.31 scientific publications per year and per 1,000 inhabitants in the region and additionally 1.39 patent applications per year and per 1,000 inhabitants, which leads to the sum of (rounded) 4.71 science and technology documents per year and per 1,000 inhabitants. Munich is again ranked first among the seven regions. A good second place takes Aachen with science intensity, and Stuttgart with technology intensity.

Table 9. Science and technology intensity of seven German regions. Numbers of scientific publications and patents per 1,000 inhabitants in the regions per year (average value of the years 1995–2000)

Rank	Publ / Inh	Region	Rank	Pat / Inh	Region	Rank	Doc / Inh	Region
1	3.31	Munich	**1**	1.39	Munich	**1**	4.71	Munich
2	2.59	Aachen	**2**	0.71	Stuttgart	**2**	2.90	Aachen
3	1.76	Hamburg	**3**	0.55	Düsseldorf	**3**	2.21	Hamburg
4	1.35	Cologne	**4**	0.45	Hamburg	**4**	1.78	Cologne
5	1.03	Stuttgart	**5**	0.41	Cologne	**5**	1.73	Stuttgart
6	0.98	Düsseldorf	**6**	0.30	Aachen	**6**	1.53	Düsseldorf
7	0.93	Leipzig	**7**	0.03	Leipzig	**7**	0.96	Leipzig

A new indicator is *science and technology density* (see Table 10). It relates the number of scientific articles and patents to the gross value added (GVA) of the region. It provides an answer to the following question: How many articles and how many patents do we get for 1 billion EURO GVA? This indicator shows the relation between the regional economy and the relative importance of science and technology. We have seen in chapter 2 that Düsseldorf's economy is strong in advertising, trade and other services, all branches whose scientific activities are very low. So it is not surprising that the Düsseldorf region is weak in science density. Top region concerning technology density is Munich, top region concerning both science density and the combined science/technology density is the region of Aachen. Ranked third in terms of the combined science/technology density is Leipzig, because it has a very low GVA and a relatively large science output. We are not sure whether this density indicator is indeed a practicable value in economics or in regional science. But we decided to include it in our findings so it might be discussed by experts.

Table 10. Science and technology density of seven German regions. Numbers of scientific publications and patents per 1 billion EURO gross value added in the regions per year (average value of the years 1995–2000)

Rank	Publ / GVA	Region	Rank	Pat / GVA	Region	Rank	Doc / GVA	Region
1	136.75	Aachen	**1**	37.49	Munich	**1**	152.48	Aachen
2	89.90	Munich	**2**	24.48	Stuttgart	**2**	127.22	Munich
3	74.20	Leipzig	**3**	17.44	Düsseldorf	**3**	76.62	Leipzig
4	53.28	Cologne	**4**	16.27	Cologne	**4**	69.56	Cologne
5	47.65	Hamburg	**5**	15.74	Aachen	**5**	59.75	Hamburg
6	35.55	Stuttgart	**6**	12.10	Hamburg	**6**	56.17	Stuttgart
7	30.72	Düsseldorf	**7**	2.42	Leipzig	**7**	48.15	Düsseldorf

Science and technology output and economy

Can we assume a direct proportional link between the output of science and the total gross margin? The higher the total gross margin, the higher were the number of published articles in the respective year. Is such a statement also valid for the patent applications, i.e. the higher the total gross margin, the higher were the number of patent applications? To be more precise: Is there a connection between the economic power of a region (measured in gross value added per inhabitant) and the output of a region in science and technology (measured in science and technology intensity and density)? If there were such a connection, a positive correlation between the economic indicators and the intensity resp. density indicators would be visible. Statistical analysis displays a slightly positive correlation between the combined science/technology intensity and GVA per inhabitant (Pearson: +0.491, $p_{(2tailed)} = 0.263$). The correlation between patent intensity and GVA (Pearson: +0.736, $p_{(2tailed)} = 0.060$) is far more obvious, whereas the correlation between science intensity and GVA (Pearson: +0.320, $p_{(2tailed)} = 0.484$) is clearly lower.

Is there a mutual inspiration of science intensity and technology intensity within the same region? If this is the case, a positive correlation between the indicators 'publications per 1,000 inhabitants' and 'patents per 1,000 inhabitants' should be visible. There is indeed a positive correlation between science intensity and technology intensity (Pearson: +0.626, $p_{(2tailed)} = 0.132$).

The statistic analysis reveals a significant positive correlation between the technology intensity and the economic power of a region. Moreover, there is a significant positive correlation between the number of publications and the number of patents in a region. The relations between science intensity and the economic power seem to be more indirect. Figure 8 clearly illustrates the relationship between regional economic power, science intensity and technology intensity for the regions of Munich, Hamburg, Cologne and Leipzig. All regions lay on the same axis with Munich being top with regard to all three indicators down to Leipzig with the lowest share in regard to the three indicators.

Aachen, Düsseldorf and Stuttgart are outsiders in respect of this connection: The science intensity of Aachen is very high but there is only a low patent intensity and a small GVA per inhabitant. In contrast, the science intensities of Düsseldorf and Stuttgart are very low but the GDPs per inhabitant are exceptionally high.

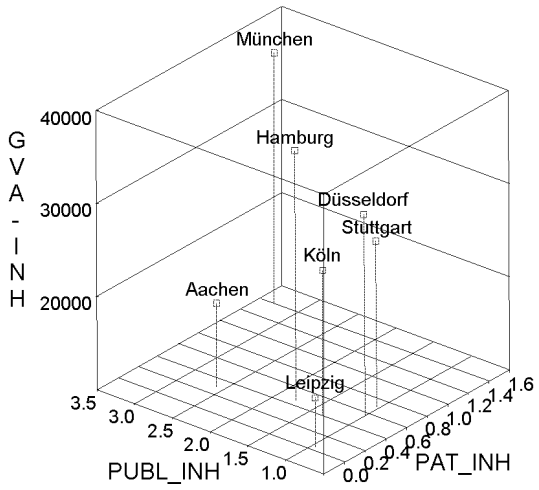

Figure 8. Relations between economic power of a region (gross value added per inhabitant), science intensity (publications per 1,000 inhabitants), and technology intensity (patent applications per 1,000 inhabitants)

Conclusions

In regions, there are highly concentrated scientific and technological specialties. There are also few institutions and companies which are very active in publishing scientific articles and in applying for patents. In most cases, the informetric law holds true for the rank distributions of scientific and technological topics and of institutes resp. companies. So a region is dependent on only few topics and few institutions. Learning about these topics and institutions can be very important to regional policy.

Technology intensity (patents per inhabitants) is statistically significant related to the economic power of a region. Technology intensity itself is significantly related to science intensity. So both, science intensity and technology intensity are important to the regional economy. As to our examples, this is true for Munich, Hamburg, Cologne, and Leipzig. But is does not hold true for all regions in detail. If we look at science and technology density (articles resp. patents per GVA), we can localize some regions (such as Düsseldorf) with a high GVA per inhabitant, but a relatively low science and technology output. Here, other factors (in Düsseldorf, these are advertising, trade and services), which are not science and technology driven, are crucial for the economic strength of a region.

Our method of using online databases and informetric commands in order to localize regional scientific and technological strengths as well as the most active institutes and companies could be proved itself successful. The two databases we used, SciSearch for science and European Patents Fulltext for technology, seem to provide a representative selection of documents, thus a fair picture of science and technology output of a region could be drawn. Finally, the DIALOG system worked without any problems.

Further research

Some further questions and new tasks have aroused, which should be kept in mind for adjacent, more comprehensive studies:

(1) We have to describe the interrelations between scientific articles and patents in a region more precisely, the respective subjects or scientific fields have to be compared and analysed in detail.

(2) It would make sense to study the performance of the different scientific disciplines to compare their specific publication rates and take peculiarities concerning the publication practice into consideration.

(3) More information should be collected to specify the relation between patent output and economic strength, e. g. how many patents are transferred into production or service (and where – possibly this is outside the region) or how much profit is made by them. Data about bibliometric impact as well as data about imported or exported high tech products might complete this.

(4) It could be very useful to develop an economic model to explain the described phenomena, for our findings are only descriptive.

(5) Finally the whole study should be extended to further regions, so that in the ideal case the findings regard a complete country. So companies can utilize such data for their site selections in foreign countries. And so regional policy institutions will find data about the own region in comparison to other regions.

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