

Patent Applications – Structures, Trends and Recent Developments 2017

Peter Neuhäusler, Oliver Rothengatter, Rainer Frietsch

Studien zum deutschen Innovationssystem
Nr. 4-2018

Fraunhofer Institute for Systems and Innovation Research ISI

February 2018

This study was conducted on behalf of the Expertenkommission Forschung und Innovation (EFI). The results and interpretations are the sole responsibility of the institute conducting the study. The EFI exercised no influence on the writing of this report.

Studien zum deutschen Innovationssystem

Nr. 4-2018

ISSN 1613-4338

Publisher:

Expertenkommission Forschung und Innovation (EFI)

Geschäftsstelle

c/o Stifterverband für die Deutsche Wissenschaft

Pariser Platz 6

10117 Berlin

<http://www.e-fi.de/>

All rights, in particular the right to copy and distribute as well as to translate this study, are reserved. No part of the work may be reproduced in any form (by means of photocopy, microfilm or any other process), or using electronic systems be saved, processed, duplicated or distributed, without the written permission of the EFI or of the Institute.

Contact address and further information:

Dr. Peter Neuhäusler

Fraunhofer Institute for Systems

and Innovation Research ISI

Competence Center Policy and Regions

Breslauer Strasse 48

76139 Karlsruhe

Phone: +49-721-6809-335

Fax: +49-721-6809-176

E-Mail: peter.neuhaeusler@isi.fraunhofer.de

Contents

0	Summary	1
1	Introduction	2
2	Data and Methods.....	3
3	Indicators and their Interpretation	4
4	Core indicators.....	5
4.1	International Comparisons.....	6
4.2	Technology Profiles and Specialization Patterns	9
5	International Co-Patenting Trends.....	13
6	Patent Activities of the German Federal States.....	18
7	Patents filed by Universities and Public Research Institutes	20
	References.....	23

Figures

Figure 1:	Absolute number of transnational patent applications for selected countries, 1995-2015	6
Figure 2:	Shares of high-tech patent applications in total patent applications for selected countries, 1995-2015	8
Figure 3:	Germany's technological profile, 2005-2007 vs. 2013-2015	12
Figure 4:	Shares of transnational co-patents in all transnational filings of the respective country.....	14
Figure 5:	Number of transnational filings by federal states.....	18
Figure 6:	Shares of transnational filings by federal states	19
Figure 7:	Patent intensities of the German federal states.....	19
Figure 8:	Number of transnational filings by German research organizations and shares of universities and PROs	20
Figure 9:	Patent intensities by German research organizations	21

Tables

Table 1:	Patent intensities and shares of technological areas, 2015	7
Table 2:	Transnational Patent applications of Germany according by high-technology sectors, 2013-2015	10
Table 3:	Absolute number of transnational co-patents and shares in total transnational co-patents, 2012-2014.....	16
Table 4:	Share of co-patenting partners within the transnational co-patenting portfolio of a given country, 2012-2014	17

0 Summary

The total number of transnational patent applications has been steadily growing over the past 15 years, with the exception of the year 2008, where a considerably drop of the total filings occurred. Since 2009 the growth resumed, in 2010 the totals were already beyond the level before the economic crisis and continued to increase. Only in the year 2014 a stagnation occurred. However, the 2015 saw again a slight increase to about 158,000 patent applications. There are considerable differences in the trends of patent filings in the recent years that lead to stagnation of slow increases in the industrialized countries, whereas the overall trend is mainly driven by upcoming countries, mainly located in Asia.

The largest technology-providing country at the international level is the U.S. where a slight growth in the number of filings between 2014 and 2015 can be observed. The USA is followed by Japan, where the figures also have grown slightly in the last three years of the observation period. . In 2015, it is the first time that China scores third by this indicator due to the massive growth of patent filings since 2008. Germany thus only scores fourth, also because the number of filings stayed rather stable since 2012. In terms of patent intensities, rather the smaller countries Switzerland and Sweden are at the top of the list of the technology-oriented countries analyzed. Japan scores third on this indicator, followed by Finland, Germany, Israel and Korea. A closer look at high-tech patent filings reveals a rate of about 63% of high-technology patents in total worldwide patenting in the year 2015. This rate has been quite constant in the last three years. Germany scores fourth in terms of high-tech shares but has slightly lost ground since 2002. Although Germany files about twice as many high-tech patents than France in absolute terms it has fallen behind France in relative terms. Yet, Denmark, Japan, Germany, Italy, Switzerland and India are the countries that show the strictest focus on high-level technologies, while many other countries are more active in leading-edge technologies. When looking at Germany's country-specific technology profiles specializations, i.e. comparative advantages, in three main areas can be observed: transport (automobiles and engines as well as rail vehicles), machinery (agricultural machinery, machine tools, power machines and engines) and some areas of electrical engineering like electrical equipment for internal combustion engines and vehicles and power generation and distribution.

When looking at the shares of transnational co-patents in all transnational patents of the respective inventor country, the largest figures can be found in Switzerland (36%) in 2014. It is followed by Great Britain (24%), Sweden (21%) and France (16%). With a share of 14%, Germany is slightly ahead of the US in terms of co-patent shares with 13%.

The regionalization of German patent filings shows that Bavaria and Baden-Württemberg are the largest German "Bundesländer" with regard to the number of patent filings, followed by North-Rhine Westphalia. These three German regions account for about two thirds of the German transnational filings, while only half of the employees are located in these countries,

i.e. the patent intensity is comparably high. The Northern and Eastern German states score at the lower ranks, seen from an absolute as well as a relative perspective.

The analysis of filings by universities and public research institutes shows that the number of transnational patent filings has been increasing between 2000 and 2010. This growth has been even more intensive for universities than for public research institutes, which has led to a convergence in the number of patent filings between universities and public research institutes. Yet, in the recent years, the patenting figures for German research organizations have declined. Besides the fact that the total number of filings by German inventors has slightly decreased over the years, this can at least partly also be explained by the fact that especially international filings by research organizations were slightly decreasing, while national filings remained rather constant.

1 Introduction

The technological performance of countries or innovation systems is mostly measured by patent applications as well as patent grants, which can be seen as the major output indicators for R&D processes (Freeman, 1982; Grupp, 1998). Patents can be seen and analyzed from different angles and with different aims and the methods and definitions applied for analyses using patent data do differ (Moed et al., 2004). A technological view allows prior art searches as well as the description of the status of a technology. Seen from a micro-economic perspective, the evaluation of individual patents or the role of patent portfolios in technology-based companies might be in focus. A macro-economic angle offers an assessment of the technological output of national innovation systems, especially in high-tech areas.

In this report, we focus on the macro-economic perspective by providing information on the technological capabilities and the technological competitiveness of economies as a whole. As already mentioned, patents are used as an output indicator of R&D processes. However, R&D processes can also be measured by the input – for example, in terms of expenditures or human capital. In order to achieve a more precise approximation of the "black box" of R&D activities (Schmoch and Hinze, 2004), both perspectives – i.e. input and output – are needed. The input side, however, has been widely analyzed and discussed in other reports, also in this series (see for example Schasse et al., 2012). Here, we therefore strictly focus on patents as an indication of output (Griliches, 1981, 1990; Grupp, 1998; Pavitt, 1982). This report gives a brief overview of the developments of transnational patent applications since the early 1990s. However, we especially focus on the recent trends and structures. We will further focus on analyses of international cooperation structures in terms of co-patents. Moreover, we will provide a more differentiated look at the German technology landscape at the level of regions, i.e. the German "Bundesländer". Finally, we will analyze patents filed by German universities and public research institutes to gain insights into the technological performance of the German science system. Here, we

will only look at the applicant structure, i.e. only universities and research institutes that are named as the patent applicant are taken into account.

Since this year's report is in the form of a short study, we will only provide a brief explanation on data and methods as well as the indicators and their interpretation in the following two chapters. More detailed explanations and interpretations can be consulted in the earlier reports within this series.

2 Data and Methods

The patent data for this study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from more than 80 patent authorities worldwide. The list of research-intensive industries and goods (NIW/ISI/ZEW-Lists 2012) are used for the differentiation of 38 high-technology fields (Gehrke et al., 2013). By using PATSTAT as the basis of our analyses, we are able to apply fractional counting of patent filings. We do this in two dimensions: on the one hand, we fractionally count by inventor countries and, on the other hand, we also fractionally count by the 38 technology fields of the high-tech list, implying that cross-classifications are taken into account. The advantages of fractional counting are the representation of all countries or classes, respectively, as well as the fact that the sum of patents corresponds to the total, so that the indicators are simpler to be calculated, understood, and more intuitive.

The patents in our analyses are counted according to their year of worldwide first filing, which is commonly known as the priority year. This is the earliest registered date in the patent process and is therefore closest to the date of invention. As patents are in this report – first and foremost – seen as an output of R&D processes, using this relation between invention and filing seems appropriate.

At the core of the analysis, the data applied here follows a concept suggested by Frietsch and Schmoch (2010), which is able to overcome the home advantage of domestic applicants, so that a comparison of technological strengths and weaknesses becomes possible – beyond home advantages and unequal market orientations. In detail, all PCT applications are counted, whether transferred to the EPO or not, and all direct EPO applications without precursor PCT application. Double counting of transferred Euro-PCT applications is thereby excluded. Simply speaking, all patent families with at least a PCT application or an EPO application are taken into account.

In addition to the absolute numbers, patent intensities are calculated, which ensures better international comparability. The figures for the patent intensity are calculated as the total number of patents per 1 million workers in the respective country.

For the analyses of patents in different technological fields, patent specializations are calculated. For the analysis of specializations, the relative patent share (RPA¹) is estimated. It indicates in which fields a country is strongly or weakly represented compared to the total patent applications. The RPA is calculated as follows:

$$RPA_{kj} = 100 * \tanh \ln [(P_{kj}/\sum_j P_{kj})/(\sum_k P_{kj}/\sum_{kj} P_{kj})]$$

where P_{kj} stands for the number of patent applications in country k in technology field j.

Positive signs mean that a technology field has a higher weight within the country than in the world. Accordingly, a negative sign represents a below-average specialization. Hereby, it is possible to compare the relative position of technologies within a technology portfolio of a country and additionally its international position, regardless of size differences.

3 Indicators and their Interpretation

International Co-patents

The cooperation structures in international patenting resemble the internationalization of R&D activities and are able to indicate the extent to which countries are cooperating with each other. This is based on the assumption that each collaboration that leads to a cooperative patent application is associated with the exchange of knowledge about the patented invention. The analysis of cooperation structures in patenting thus allows us to draw conclusions about international knowledge flows. It is assumed that usually implicit or experiential knowledge is exchanged (Polanyi, 1966), which will later "explicitly" be stated in the form of a patent application. By analyzing patent applications, however, our focus remains on the explicable and explicit knowledge (Grupp, 1998).

In sum, we will focus on the transnational co-patent filings of the countries under analysis. As with the general patent trends, we will apply fractional counting by inventor countries, i.e. a country is only assigned the fraction of a patent depending on the number of inventors from the given country.

Patent filings by German federal states

With the help of the regionalization of patent filings from Germany, we aim to answer the question, which of the federal states contribute most strongly to the patent activities of Germany as a whole. Economic, and thereby also innovative activities are not equally distributed over geographical space. A regionalized patent statistic therefore allows taking a closer look at the structural composition of the German innovation landscape, which allows us to identify regional technology trends as an important precondition for the composition and framing of regional innovation policies in Germany.

¹ Revealed Patent Advantage.

As with the general patent trends, we will apply fractional counting by inventor countries. For the identification of the German federal states in patent filings, we use the NUTS-code information from the OECD REGPAT database, complemented with address information obtained from the German Patent and Trademark Office (DPMA). For filings that could not be assigned a NUTS code with the help of these two data sources, we resorted to the patent family information within the PATSTAT database. In the case that address information could be obtained from any other than the transnational filing, this address information was assigned to the transnational filing.

Patent filings by German Universities and Public Research Institutes

Patents filed by universities and public research institutes (PRI) help us to assess the technological output of research organizations in Germany. Patents filed by universities and PRI were identified within the PATSTAT database with the help of keyword searches, including the names of the universities with different spelling variations and languages as well as a search for the names of the respective cities, also including spelling variations and languages. In the case of the Technical University of Munich, for example, patents are filed under the names “TECHNICAL UNIVERSITY OF MUNICH”, “TECHNISCHE UNIVERSITAET MUENCHEN”, or “TU MUENCHEN”. All different spelling variations are taken into account.

The figures for the patent intensities are calculated as the total number of patent filings per 100 employees (full-time equivalents) in the respective universities. The data on university employees were extracted from the German Federal Statistical Office (Statistisches Bundesamt, 2013) as well as the Federal Report on Research and Innovation 2012 (Federal Ministry of Education and Research (BMBF), 2012). Gaps within the data for certain years were estimated on the basis of the values of the preceding and following years.

4 Core indicators

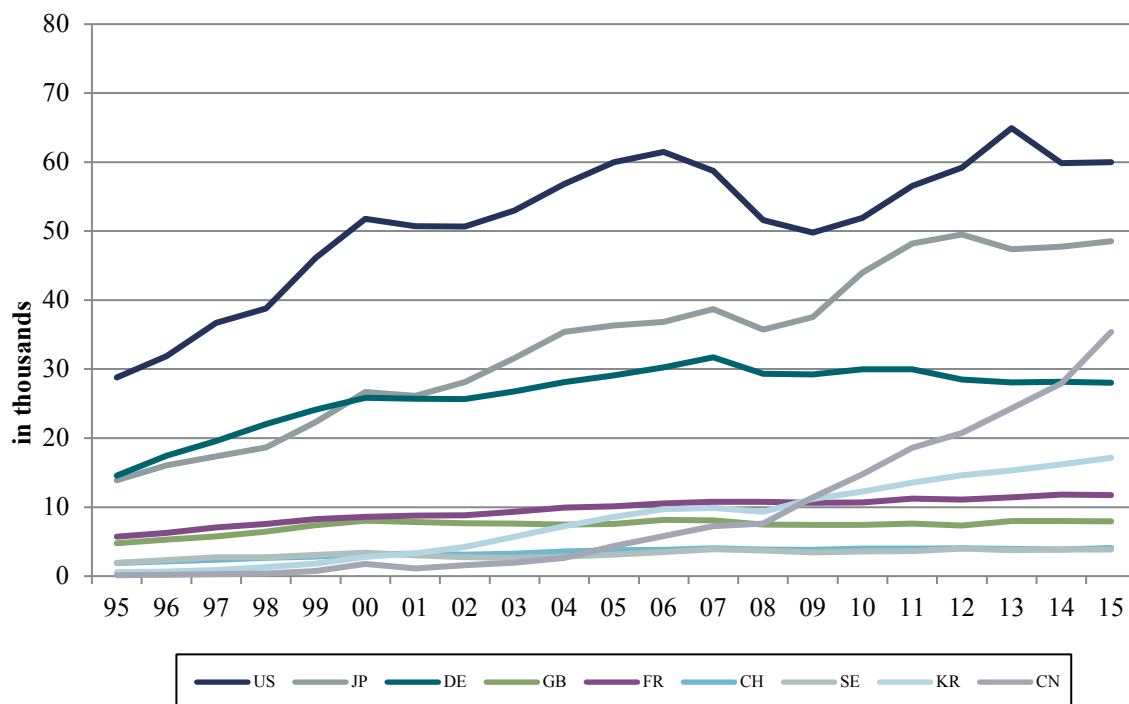
Within this section, the recent trends of transnational patent filings since the 1995 will be described. The analyses were carried out for a selected set of technology-oriented countries², although, for reasons of presentation, not every country is displayed in each figure. Besides a country-specific view, we will provide a distinction between low- and high-technology areas (Gehrke et al., 2013).

² These are: Belgium, Denmark, Germany, Finland, France Israel, Italy, Japan, Canada, Korea, The Netherlands, Austria, Poland, Sweden, Switzerland, Spain, United Kingdom, USA, Brazil, Russia, India, China, South Africa as well as the group of EU-28 member states.

4.1 International Comparisons

The absolute number of transnational patent filings by inventor countries is displayed in Figure 1. The largest technology-providing country at the international level is the USA, where a comparatively large growth of patent filings since the financial crisis can be observed. Although there has been a slight decline between 2013 and 2014, the figures have stabilized afterwards and further growth can be expected. The USA is followed by Japan, where the figures have slightly declined between 2012 and 2013. Since then, however, a slight growth can be observed. In 2015, it is the first time that China scores third by this indicator due to the massive growth of patent filings since 2008. Germany thus only scores fourth, also because the number of filings stayed rather stable since 2012. Following behind these four countries, there is a large group of countries led by Korea, France and Great Britain. Korea has grown strongly in terms of patent filings since 2000 onwards and has thus managed to leave behind France and Great Britain in the total number of transnational applications since 2009. Sweden and Switzerland follow Great Britain with nearly 4,000 transnational filings in 2015 and a rather constant development.

Figure 1: Absolute number of transnational patent applications for selected countries, 1995-2015



Source: EPO – PATSTAT; Fraunhofer ISI calculations

The absolute data presented so far, however, is affected by size effects. An adjustment to these size effects is shown in Table 1, where patent intensities per one million employees are depicted. This sheds new light on the country ranks. Although the US is the largest country in absolute terms when it comes to patent filings, it only scores thirteenth in terms of patent intensities. Rather the smaller countries like Switzerland, Sweden and Finland are

at the top of the list of the technology-oriented countries analyzed here. Japan, Germany and South Korea are first among the larger countries in terms of patent intensities. Japan ranks third by this indicator this year, followed by Germany and Korea at ranks five and seven. This, on the one hand, resembles a strong technology orientation and the technological competitiveness. On the other hand, it is also a sign of a clear and strict international orientation and an outflow of the export activities of these countries as patents are an important instrument to secure market shares in international technology markets (Frietsch et al., 2014).

Table 1: Patent intensities (patent applications per 1m employees) and shares of technological areas, 2015

	Total	Less R&D-intensive	High-Tech of which are:		Leading-edge technologies	High-level technologies			
SUI	823	406	49%	450	55%	155	19%	295	36%
SWE	801	258	32%	559	70%	324	40%	235	29%
JPN	761	310	41%	467	61%	172	23%	295	39%
FIN	741	311	42%	436	59%	252	34%	184	25%
GER	701	315	45%	401	57%	131	19%	270	39%
ISR	671	225	34%	460	69%	263	39%	197	29%
KOR	661	246	37%	430	65%	206	31%	225	34%
DEK	625	255	41%	376	60%	129	21%	247	39%
AUT	584	300	51%	293	50%	105	18%	187	32%
NED	550	264	48%	293	53%	152	28%	141	26%
FRA	439	189	43%	260	59%	113	26%	147	33%
BEL	436	204	47%	240	55%	109	25%	131	30%
USA	403	142	35%	267	66%	138	34%	130	32%
EU-28	342	154	45%	195	57%	78	23%	118	34%
GBR	257	112	44%	150	58%	71	28%	79	31%
ITA	254	140	55%	124	49%	31	12%	92	36%
CAN	191	72	38%	121	63%	67	35%	54	28%
ESP	140	70	50%	72	52%	29	21%	43	31%
POL	59	28	47%	32	54%	13	21%	19	33%
CHN	46	13	29%	34	74%	21	45%	13	29%
RSA	21	12	58%	9	41%	4	17%	5	24%
RUS	15	6	43%	8	58%	5	32%	4	26%
BRA	7	4	54%	4	48%	1	17%	2	31%
IND	6	2	34%	4	69%	2	33%	2	35%

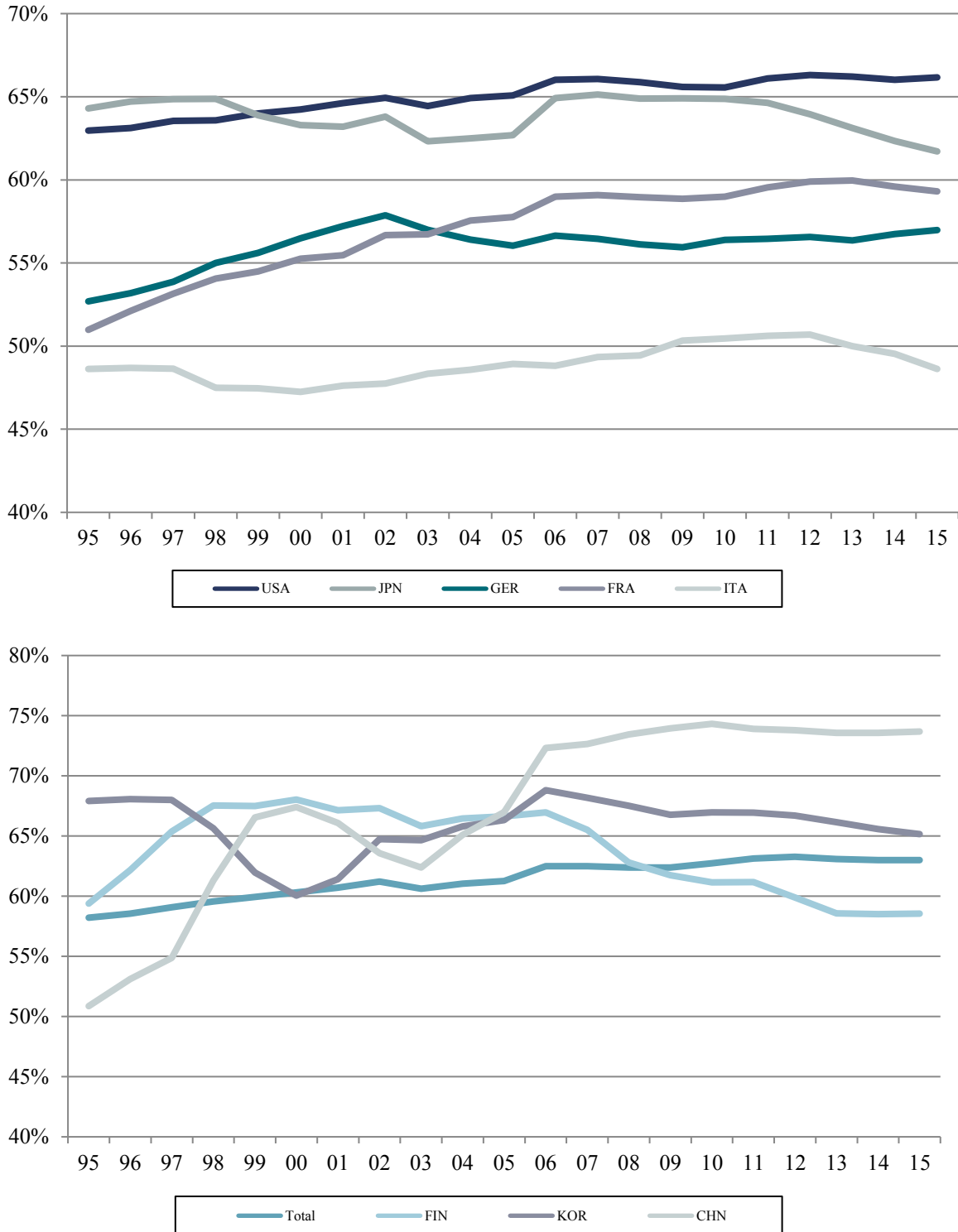
Source: EPO – PATSTAT; OECD, The World Bank, Fraunhofer ISI calculations

Note: In a few cases, shares of patents in certain IPC-classes are assigned to leading-edge as well as high-level technologies, which might lead to double-counts. The shares therefore might slightly exceed 100%.

In addition to the general patent intensities, Table 1 offers a differentiation of the patent intensities by technological areas and displays the respective shares on total patent filings. Especially South Africa shows rather large activities in less R&D intensive fields, followed by Italy, Brazil, Austria, Spain and interestingly Switzerland. China, Sweden, Israel, India, the U.S., Korea, Canada and Japan, on the other hand, show the largest shares of patents in high-technology fields. Regarding China, Sweden, Israel, the U.S., Canada, India as well as Finland, this mostly is the result of large shares of patents in leading-edge technologies. In the case of India and Israel, this can at least partly be explained by a high orientation

towards the US market, which is the most important national market for high-tech products. In high-level technologies, on the other hand, the countries with the largest shares are Denmark, Japan, Germany, Italy, Switzerland and India.

Figure 2: Shares of high-tech patent applications in total patent applications for selected countries, 1995-2015



Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 2 shows the trends in high-tech shares within the national profiles of selected large countries. While the average share of total transnational high-tech patent applications rose from about 59% in 1995 to 63% in 2015, some countries underwent a considerable change of their patenting patterns in high-tech areas. The USA is at the top of the countries with regard to high-tech shares and shows constantly increasing trends over the years until 2006. From then on, we can observe a rather stable stagnating trend with some decreases during the financial crisis and a slight rise after 2010.

Japan is the second most high-tech active country in terms of transnational patenting. It had clearly lost ground compared to the U.S. between 2003 and 2005 but has managed to catch up afterwards. From 2011 onwards, however, a decreasing trend in Japanese high-tech shares can be observed. France was able to increase its high-tech share over the years, although we see a slight decline after 2013. Germany has encountered a growth in high-tech shares until 2002. After that year, a decline until 2005 became visible. From 2006 onwards, the German high-tech shares stabilized at a rather high level. Especially since 2013, however, a slight growth can be observed. Italy encountered increases up to 2012, but from then a decrease similar to Japan can be found.

The lower panel of Figure 2 shows that the high-tech shares of Korea have been decreasing after 2006, although the absolute number of filings from Korea increased considerably. Since 2009, a stabilization of Korea's high-tech shares can be observed, although a slightly decreasing trend is still visible especially after 2012. In the case of China, the high-tech shares have started to grow after it joined the WTO and the TRIPS agreement in 2001. This growth is especially visible between 2003 and 2006. Since then, a moderate growth until 2010 and a stagnation afterwards can be found.

4.2 Technology Profiles and Specialization Patterns

In this section, we provide a deeper insight into the transnational patent applications by German inventors according to the classification of 38 technology fields of the high-tech sector (Gehrke et al., 2013). The absolute number, specialization and the percentage growth of German transnational patent applications by technology fields are displayed in Table 2. The highest growth rates between 2005-2007 and 2013-2015 can be observed in the fields of "aeronautics", "rubber goods", "electrical machinery, accessory and facilities" and "rail vehicles". Among the fields that are growing most slowly in Germany are three rather small fields, namely "photo chemicals", "nuclear reactors and radioactive elements" and "office machinery". Yet, also the chemistry related fields "biotechnology and agents", "pesticides", "pharmaceuticals", "organic basic materials" and "other special chemistry", can be seen as comparably slowly growing fields within the German technology profile, followed by the ICT related fields of "broadcasting engineering", "computers" and "communications engineering". In general, it can be found that most electronics related fields and certain fields in mechanical engineering are growing rather strongly, whereas chemistry and pharmaceuticals as well as ICT related fields do not show very high growth rates. Some fields related to the

mechanical engineering sector, where Germany has its particular technological strengths, e.g. "automobiles and engines", "machine tools", "special purpose machinery" show moderate to low growth rates in recent years, whereas other fields like "agricultural machinery", "pumps and compressors" and "power machines and engines" have rather large growth rates.

Table 2: Transnational Patent applications of Germany according by high-technology sectors (absolute, specialization, and growth), 2013-2015

Technology Field	Abs.	RPA	% Growth (05-07=100)
aeronautics	933	11	169.1
rubber goods	384	16	159.9
electrical machinery, accessory and facilities	529	-5	147.4
rail vehicles	302	75	142.3
power generation and distribution	2085	20	133.3
agricultural machinery	631	59	129.6
units and equipment for automatic data processing machines	750	-82	120.6
lamps, batteries etc.	1591	-9	117.6
pumps and compressors	811	47	114.4
air conditioning and filter technology	1930	29	114.4
Scents and polish	42	-22	111.5
medical instruments	2643	-17	108.6
electrical appliances	638	16	105.0
optics	618	-39	104.6
power machines and engines	3525	52	103.5
electrical equipment for internal combustion engines and vehicles	1284	65	103.4
technical glass, construction glass	99	-100	101.5
machine tools	2454	59	100.4
mechanical measurement technology	1185	37	98.1
inorganic basic materials	376	-12	97.3
optical and photooptical devices	63	-81	97.0
electronics	1278	-24	95.4
optical and electronic measurement technology	2627	-18	92.6
automobiles and engines	5483	66	85.8
communications engineering	3877	-64	85.2
weapons	235	46	81.2
special purpose machinery	3214	21	80.7
other special chemistry	914	1	75.3
computer	1725	-73	74.5
organic basic materials	1503	5	73.5
broadcasting engineering	521	-88	71.0
pharmaceuticals	1018	-45	67.8
biotechnology and agents	1449	-50	66.8
pesticides	428	0	60.4
electronic medical instruments	639	-65	59.3
office machinery	39	-82	37.8
nuclear reactors and radioactive elements	6	-90	35.4
photo chemicals	2	-62	29.9

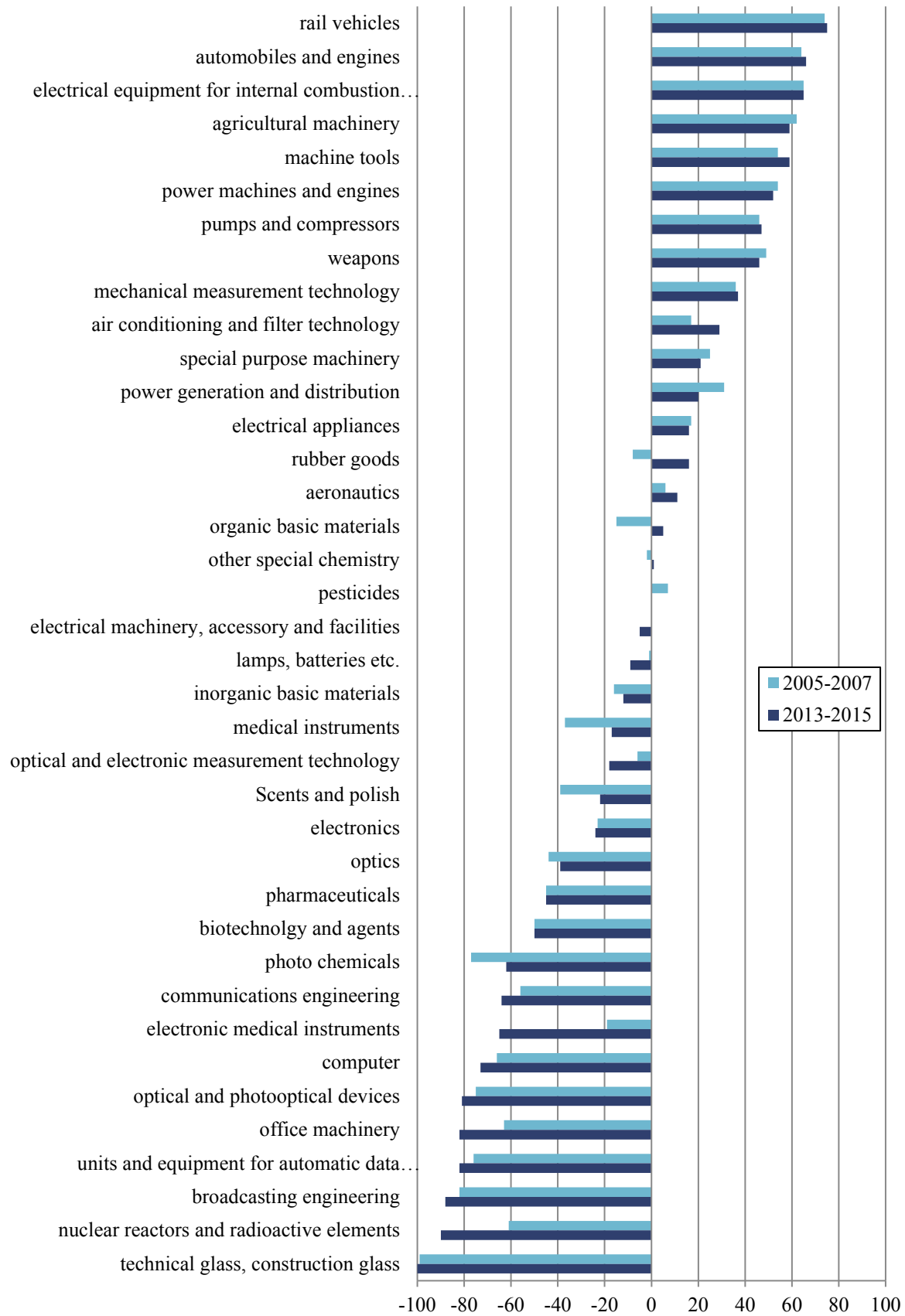
Source: EPO – PATSTAT; Fraunhofer ISI calculations

The specialization (RPA) of the German technology profile of the years 2005-2007 and 2013-2015 is displayed in Figure 3. Germany is specialized, i.e. has comparative advantages, in three main areas: transport (automobiles and engines as well as rail vehicles),

machinery (agricultural machinery, machine tools, power machines and engines) and some areas of electrical engineering like electrical equipment for internal combustion engines and vehicles and power generation and distribution.

An average activity rate in patenting can be found in the chemical sectors ("organic basic materials", "other special chemistry", "pesticides", "rubber goods"). Comparative disadvantages, reflected in negative specialization indices, can be observed in pharmaceuticals, biotechnology, information and communication technologies as well as optics and optical devices, meaning that Germany does not have an outstanding profile in these sectors in international technology markets. All of these trends can be found in both time periods, i.e. the specialization profile of Germany is rather stable over time. Major changes can be found in "organic basic materials", "rubber goods" and "air conditioning and filter technology", where Germany has become more specialized in.

Figure 3: Germany's technological profile, 2005-2007 vs. 2013-2015



Source: EPO – PATSTAT; Fraunhofer ISI calculations

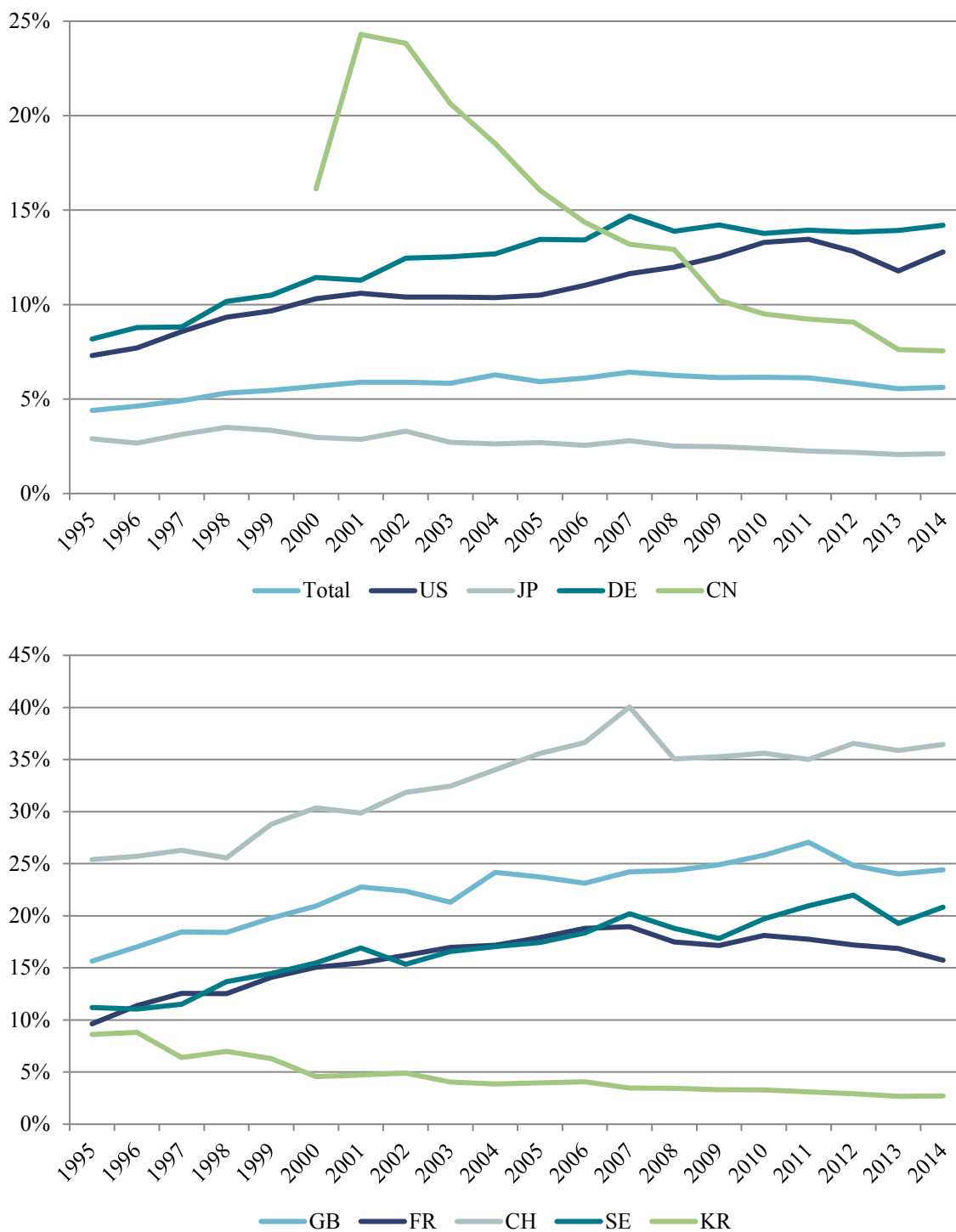
5 International Co-Patenting Trends

The co-patenting trends by countries are depicted in Figure 4. Here, the shares of transnational co-patents (with OECD countries) in all transnational patent filings of the respective country are shown. This gives us an idea of the cooperation intensity of the countries. Large shares imply that many inventors from a given country are cooperating internationally. The top-panel of the figure first of all provides the results for the larger countries in comparison. The lower-panel shows the results for the smaller countries.

The total share of co-patents in all filings has constantly been increasing over the years until 2007. In 1995, only about 4.4% of all transnational filings were international co-patents. In 2007, this share lay at 6.4%, implying that international cooperation has gained importance over the years. From 2007 onwards, however, the share started to slightly decline until a share of 5.6% in 2014 was reached. Especially there seems to be a somewhat larger drop since 2011. This is a more general trend that is visible in a larger number of countries, e.g. the US, Japan, Great Britain, France and Sweden. In 2014, however, the figures started to rise again in most countries. Germany has also been affected by a slight decline since 2007, yet there has been a slight growth since 2010. Germany is also one of the few countries in our comparison where no drop in 2012 can be found.

Among the countries in our comparison, Switzerland has the largest co-patenting shares with 36% in 2014. It is followed by Great Britain (24%), Sweden (21%) and France (16%). With a share of 14% in 2014, Germany is slightly ahead of the US in terms of co-patent shares with 13%. Between 2011 and 2013, the U.S. shares were declining while the German shares slightly grew. However, in 2014 the shares of the U.S. started to grow again, which narrowed the gap to Germany. A closer look at China reveals that, although starting from a very high level, the co-patenting rates have constantly decreased since 2003. Still, about 8% of all Chinese transnational filings are international co-patents. In comparison with the remaining Asian countries, here Japan and Korea, this share still is comparably large. Japan shows a more or less constant co-patenting rate of 2% to 3% over the years, although a slight decline becomes visible. Similar values can be observed for Korea, at least since the year 2000, but at a slightly higher level with shares between 3% and 5% over the years.

Figure 4: Shares of transnational co-patents in all transnational filings of the respective country



Source: EPO – PATSTAT; Fraunhofer ISI calculations

For these two Asian countries, this resembles their general underrepresentation in international science and innovation collaborations (Schubert et al. 2013; Weissenberger-Eibl et al. 2011), which also has to do with their industry structure that is dominated by very large firms. Furthermore, the Japanese and also the Korean large enterprises were hardly conducting R&D abroad. More recently, the governments in both countries set up programs to overcome these shortcomings, especially with respect to the public science system. They

also realized that international collaboration is a crucial factor in nowadays innovation activities. Apart from Korea, however, it becomes evident that most of the smaller countries have higher co-patenting rates than their large counterparts, which corroborates the findings from the literature that cooperation is mostly sought to either access international markets or resources.

Table 3 is designed to allow an assessment of the most important cooperation partners for each of the countries under analysis. The values above the diagonal in the table provide the share of co-patents between two countries in all transnational co-patents. In the area below the diagonal line, the absolute numbers of co-patent filings between the two respective countries are depicted. In the last column, the share of a country's total co-patents in all transnational co-patents worldwide is shown. The US has the highest share of co-patents in all transnational co-patents with a value of 24.7%. However, as opposed to the trends in Figure 4 (above), this share is affected by the size of a country, i.e. larger countries in terms of patenting take advantage over smaller countries. The US is followed by Germany with a share of about 13.8%. Great Britain and France score third and fourth with a share of 7.2% and 7.1%, respectively. Although a small country in absolute terms, Switzerland reaches rather high shares in total transnational co-patents (6.1%) as it is very cooperation intensive. Yet, Switzerland ranks only sixth after China with a share of 6.7%. Switzerland is followed by Canada, India and Japan with values between 3% and 4%. Although it is the second largest country in terms of transnational patent filings, Japan only reaches a share of about 3.2%. This resembles the trends found above, implying that its innovation system is relatively isolated compared to the German or the US system for example; but also compared to the Chinese one. A similar effect, yet at a lower level, can also be found for South Korea.

In Table 4, the importance of collaboration partners for each of the countries is displayed. It is measured as the share of co-patents with the respective partner country and color-coded to allow an easier identification of patterns. The colors thus indicate the importance of collaboration partners for each country from green to red. The most important collaboration partner for Germany, for example, is clearly the US. More than 25% of all German co-patents are filed in cooperation with a US inventor. The next largest partners are Switzerland, France, Austria and Great Britain. This can at least partly be explained by geographical proximity of these countries to Germany. What is striking when looking at the table is that the US is the most important partner for many of the countries in our comparison, while the US itself cooperates most strongly with China, Germany, Great Britain and Canada. Germany is also an important partner for many countries, which is also true for China. China itself is highly oriented towards cooperating with US inventors. More than 54% of all Chinese co-patents are filed in cooperation with a US inventor, followed by Germany with 9% and Japan with 7%. Yet, this might at least partly have to do with research facilities and production sites of foreign companies in China (Ernst 2006). In sum, the US, and to a certain extent also Germany, still are the most important cooperation partners for the countries in comparison.

Table 3: Absolute number of transnational co-patents and shares in total transnational co-patents, 2012-2014

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA
AT		0,04%	0,01%	0,03%	0,40%	0,02%	1,08%	0,02%	0,02%	0,11%	0,05%	0,09%	0,00%	0,01%	0,09%	0,02%	0,00%	0,04%	0,01%	0,01%	0,06%	0,20%	0,00%
BE	40		0,01%	0,04%	0,07%	0,12%	0,52%	0,01%	0,08%	0,01%	0,56%	0,21%	0,01%	0,03%	0,09%	0,07%	0,02%	0,34%	0,03%	0,00%	0,05%	0,69%	0,00%
BR	9	8		0,02%	0,03%	0,01%	0,09%	0,01%	0,02%	0,00%	0,04%	0,03%	0,01%	0,01%	0,01%	0,01%	0,00%	0,01%	0,00%	0,00%	0,02%	0,25%	0,00%
CA	32	40	19		0,06%	0,16%	0,22%	0,02%	0,03%	0,02%	0,18%	0,26%	0,04%	0,06%	0,04%	0,05%	0,03%	0,05%	0,01%	0,02%	0,17%	2,68%	0,01%
CH	401	72	28	59		0,15%	1,96%	0,06%	0,09%	0,06%	1,13%	0,26%	0,02%	0,09%	0,35%	0,06%	0,02%	0,09%	0,05%	0,02%	0,13%	0,99%	0,01%
CN	25	118	6	163	152		0,58%	0,07%	0,03%	0,21%	0,21%	0,35%	0,03%	0,10%	0,04%	0,46%	0,14%	0,06%	0,02%	0,06%	0,28%	3,60%	0,00%
DE	1086	529	88	221	1984	582		0,21%	0,22%	0,27%	1,48%	0,96%	0,10%	0,24%	0,50%	0,39%	0,09%	0,69%	0,20%	0,12%	0,40%	3,44%	0,03%
DK	17	9	8	22	59	71	212		0,02%	0,07%	0,06%	0,13%	0,00%	0,04%	0,02%	0,01%	0,00%	0,04%	0,02%	0,00%	0,20%	0,30%	0,00%
ES	19	85	22	30	94	34	221	16		0,01%	0,21%	0,17%	0,04%	0,02%	0,08%	0,02%	0,00%	0,08%	0,01%	0,01%	0,06%	0,37%	0,00%
FI	109	12	3	19	59	215	274	74	15		0,02%	0,11%	0,01%	0,06%	0,04%	0,02%	0,00%	0,02%	0,05%	0,02%	0,21%	0,22%	0,00%
FR	53	567	44	180	1141	212	1496	57	217	24		0,48%	0,05%	0,10%	0,28%	0,15%	0,04%	0,17%	0,06%	0,03%	0,12%	1,65%	0,01%
GB	93	214	35	263	266	357	969	134	168	112	482		0,08%	0,19%	0,13%	0,20%	0,09%	0,27%	0,04%	0,04%	0,23%	2,85%	0,03%
IL	0	15	9	39	23	26	99	2	42	7	50	78		0,03%	0,02%	0,01%	0,02%	0,01%	0,00%	0,02%	0,01%	0,95%	0,00%
IN	9	32	12	65	89	98	238	43	21	57	103	193	35		0,04%	0,06%	0,14%	0,09%	0,03%	0,01%	0,07%	1,81%	0,00%
IT	88	88	14	39	350	45	507	18	80	37	278	135	25	42		0,04%	0,01%	0,06%	0,04%	0,02%	0,09%	0,54%	0,00%
JP	19	68	6	47	56	466	391	12	17	24	149	202	7	61	38		0,17%	0,03%	0,00%	0,01%	0,04%	1,42%	0,00%
KR	1	18	1	26	19	144	93	4	1	2	36	94	17	140	11	169		0,03%	0,00%	0,05%	0,01%	0,61%	0,00%
NL	41	342	15	52	93	64	697	38	78	23	172	277	12	89	57	33	33		0,03%	0,01%	0,06%	0,93%	0,01%
PL	12	29	1	7	54	23	201	20	12	46	58	41	3	33	37	5	2	26		0,02%	0,03%	0,12%	0,00%
RU	10	3	3	22	23	58	126	2	6	24	27	37	24	7	22	13	54	14	17		0,01%	0,39%	0,00%
SE	58	55	25	176	132	279	404	205	57	210	125	236	14	71	86	36	8	58	33	8		0,65%	0,00%
US	203	693	254	2711	996	3632	3478	302	373	219	1665	2882	958	1823	550	1433	613	934	126	390	658		0,06%
ZA	0	3	1	6	7	1	34	1	0	0	12	26	2	3	5	2	2	9	0	2	4	63	
Total	2325	3040	611	4238	6157	6771	13930	1326	1608	1565	7148	7294	1487	3264	2552	3254	1488	3157	786	892	2938	24956	183

Source: EPO – PATSTAT; Fraunhofer ISI calculations

Table 4: Share of co-patenting partners within the transnational co-patenting portfolio of a given country, 2012-2014

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA
AT		1%	1%	1%	7%	0%	8%	1%	1%	7%	1%	1%	0%	0%	3%	1%	0%	1%	2%	1%	2%	1%	0%
BE	2%		1%	1%	1%	2%	4%	1%	5%	1%	8%	3%	1%	1%	3%	2%	1%	11%	4%	0%	2%	3%	2%
BR	0%	0%		0%	0%	0%	1%	1%	1%	0%	1%	0%	1%	0%	1%	0%	0%	0%	0%	0%	1%	1%	1%
CA	1%	1%	3%		1%	2%	2%	2%	2%	1%	3%	4%	3%	2%	2%	1%	2%	2%	1%	2%	6%	11%	3%
CH	17%	2%	5%	1%		2%	14%	4%	6%	4%	16%	4%	2%	3%	14%	2%	1%	3%	7%	3%	4%	4%	4%
CN	1%	4%	1%	4%	2%		4%	5%	2%	14%	3%	5%	2%	3%	2%	14%	10%	2%	3%	7%	9%	15%	1%
DE	47%	17%	14%	5%	32%	9%		16%	14%	18%	21%	13%	7%	7%	20%	12%	6%	22%	26%	14%	14%	14%	19%
DK	1%	0%	1%	1%	1%	1%	2%		1%	5%	1%	2%	0%	1%	1%	0%	0%	1%	3%	0%	7%	1%	1%
ES	1%	3%	4%	1%	2%	1%	2%	1%		1%	3%	2%	3%	1%	3%	1%	0%	2%	2%	1%	2%	1%	0%
FI	5%	0%	0%	0%	1%	3%	2%	6%	1%		0%	2%	0%	2%	1%	1%	0%	1%	6%	3%	7%	1%	0%
FR	2%	19%	7%	4%	19%	3%	11%	4%	13%	2%		7%	3%	3%	11%	5%	2%	5%	7%	3%	4%	7%	7%
GB	4%	7%	6%	6%	4%	5%	7%	10%	10%	7%	7%		5%	6%	5%	6%	6%	9%	5%	4%	8%	12%	14%
IL	0%	0%	1%	1%	0%	0%	1%	0%	3%	0%	1%	1%		1%	1%	0%	1%	0%	0%	3%	0%	4%	1%
IN	0%	1%	2%	2%	1%	1%	2%	3%	1%	4%	1%	3%	2%		2%	2%	9%	3%	4%	1%	2%	7%	2%
IT	4%	3%	2%	1%	6%	1%	4%	1%	5%	2%	4%	2%	2%	1%		1%	1%	2%	5%	2%	3%	2%	3%
JP	1%	2%	1%	1%	1%	7%	3%	1%	1%	2%	2%	3%	0%	2%	1%		11%	1%	1%	1%	1%	6%	1%
KR	0%	1%	0%	1%	0%	2%	1%	0%	0%	0%	1%	1%	1%	4%	0%	5%		1%	0%	6%	0%	2%	1%
NL	2%	11%	2%	1%	2%	1%	5%	3%	5%	1%	2%	4%	1%	3%	2%	1%	2%		3%	2%	2%	4%	5%
PL	1%	1%	0%	0%	1%	0%	1%	2%	1%	3%	1%	1%	0%	1%	1%	0%	0%	1%		2%	1%	1%	0%
RU	0%	0%	0%	1%	0%	1%	1%	0%	0%	2%	0%	1%	2%	0%	1%	0%	4%	0%	2%		0%	2%	1%
SE	2%	2%	4%	4%	2%	4%	3%	15%	4%	13%	2%	3%	1%	2%	3%	1%	1%	2%	4%	1%		3%	2%
US	9%	23%	42%	64%	16%	54%	25%	23%	23%	14%	23%	40%	64%	56%	22%	44%	41%	30%	16%	44%	22%		34%
ZA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

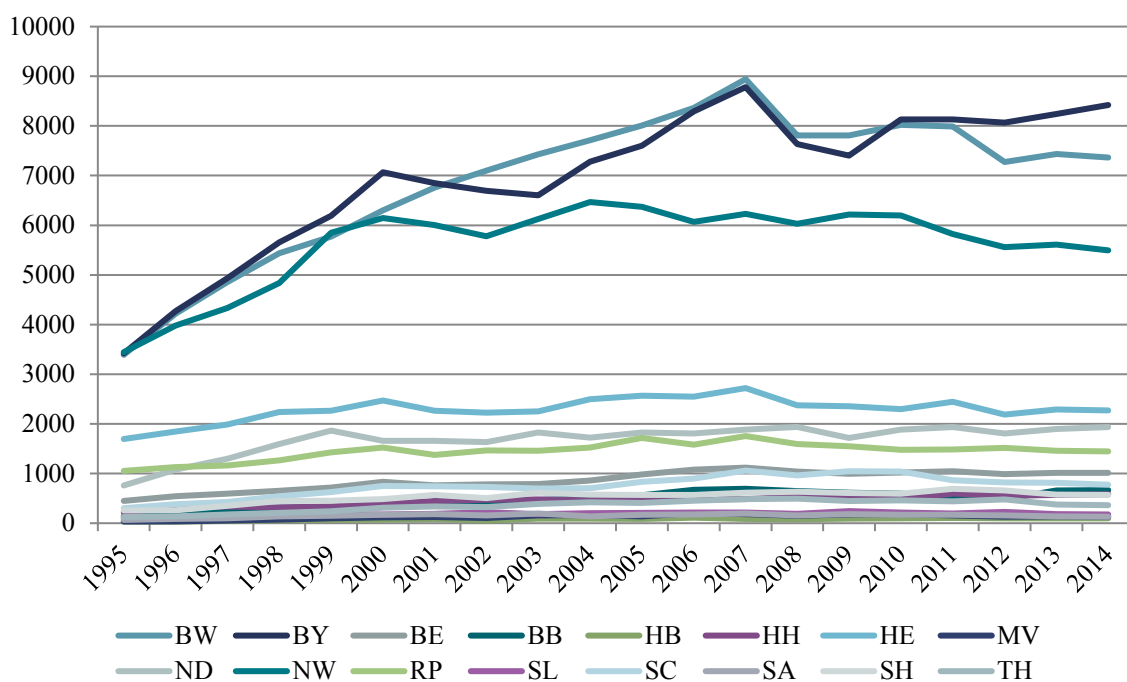
Note: The colors in the table indicate the importance of collaboration partners for a given country (vertically). Green resembles the most important partners (largest share of co-patents in a country's total co-patents), red resembles the least important partners.

6 Patent Activities of the German Federal States

In Figure 5, the absolute numbers of transnational patent filings based on the address of the inventor are plotted.³ Between 1995 and 2007, the number of filings increased for all German federal states, with slight decreases during the recent economic crisis. Between 2010 and 2012, we see stagnating figures for Bavaria and Baden-Württemberg, although we find a rising trend after 2012 for Bavaria while there is stagnation for Baden- and a slight decrease in North Rhine-Westphalia.

The largest number of transnational filings within the German comparison can be found in the south. Bavaria ranks first, with nearly 8,500 filings in 2014, followed by Baden-Württemberg (about 7,400 filings in 2014) and North Rhine-Westphalia at a slightly lower level (about 5,500 filings in 2014). Large parts of the German industry are located in these three countries. It is therefore not surprising that they are responsible for about two thirds of all German transnational filings. At the fourth rank is Hesse, followed by Lower-Saxony and Rhineland-Palatinate, who both reach similar levels in terms of patenting. The remainder of the federal states is at a similar level with 1,000 filings per year or less.

Figure 5: Number of transnational filings by federal states

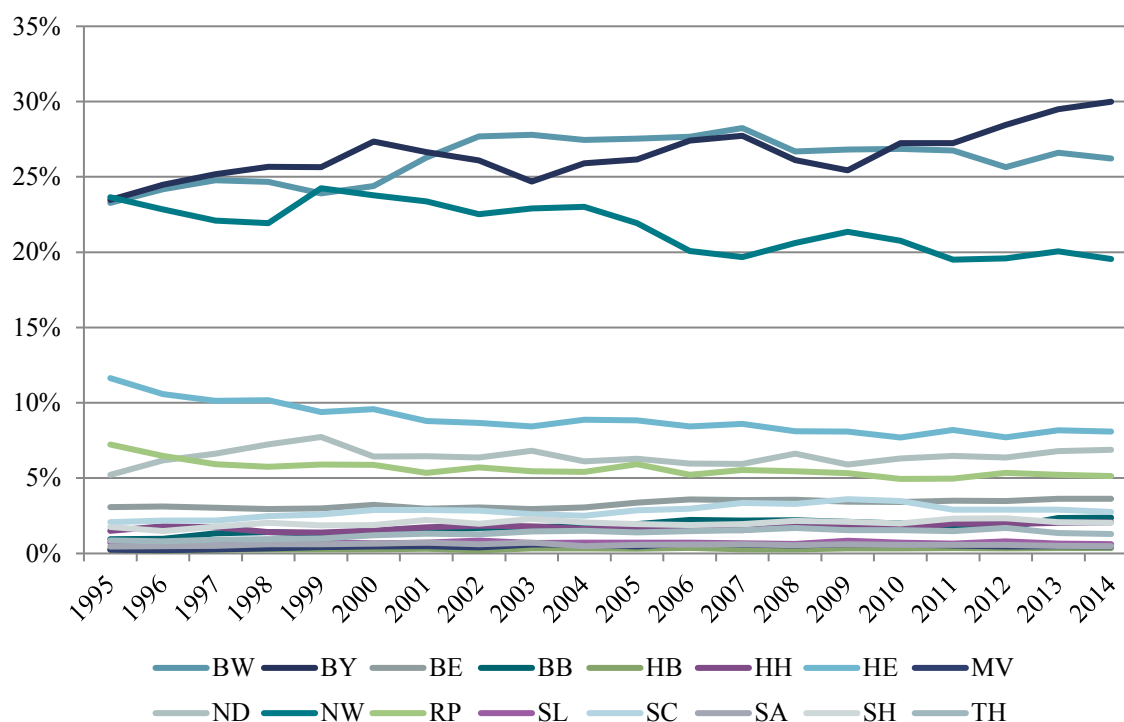


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Note: BW=Baden-Württemberg, BY=Bavaria, BE=Berlin, BB=Brandenburg, HB=Bremen, HH=Hamburg, HE=Hesse, MV=Mecklenburg-West Pomerania, ND=Lower-Saxony, NW=North Rhine-Westphalia, RP=Rhineland-Palatinate, SL=Saarland, SC=Saxony, SA=Saxony-Anhalt, SH=Schleswig-Holstein, TH=Thuringia.

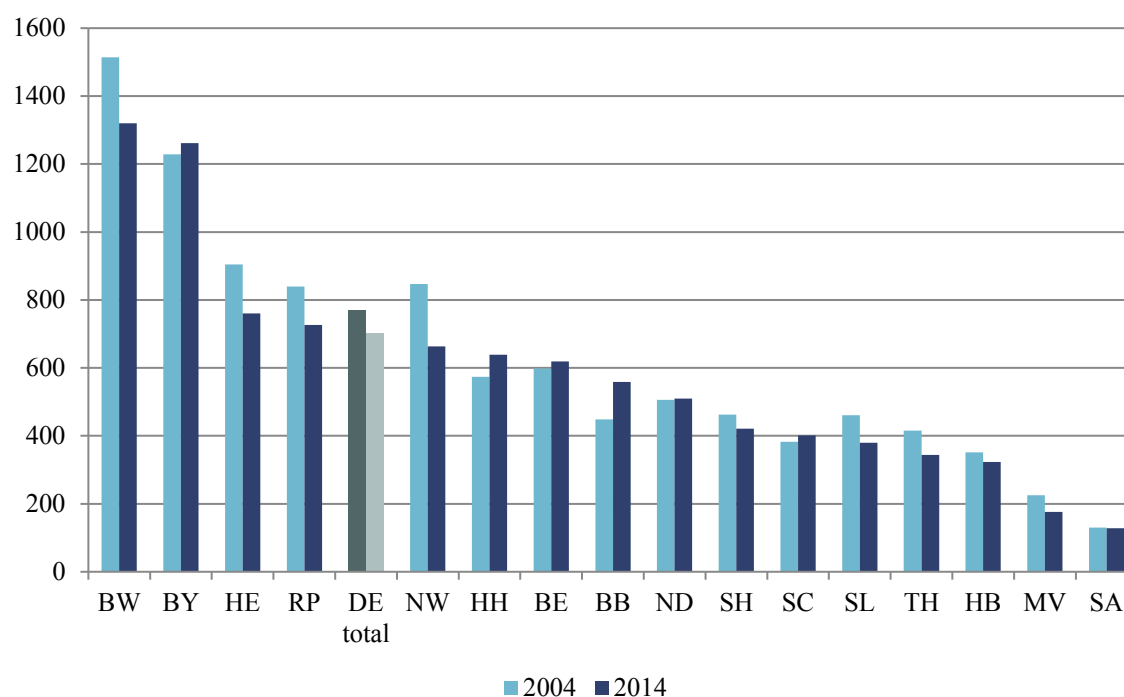
³ Due to the fact that employees cross regional borders when commuting to work, the differentiation by inventor and applicant country makes a difference for the profiles of the German federal states. This has been analyzed more deeply within earlier reports of this series Neuhäusler et al. (2014).

Figure 6: Shares of transnational filings by federal states



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Figure 7: Patent intensities of the German federal states (per 1 million employees)



Source: EPO – PATSTAT; Statistisches Bundesamt, calculations by Fraunhofer ISI

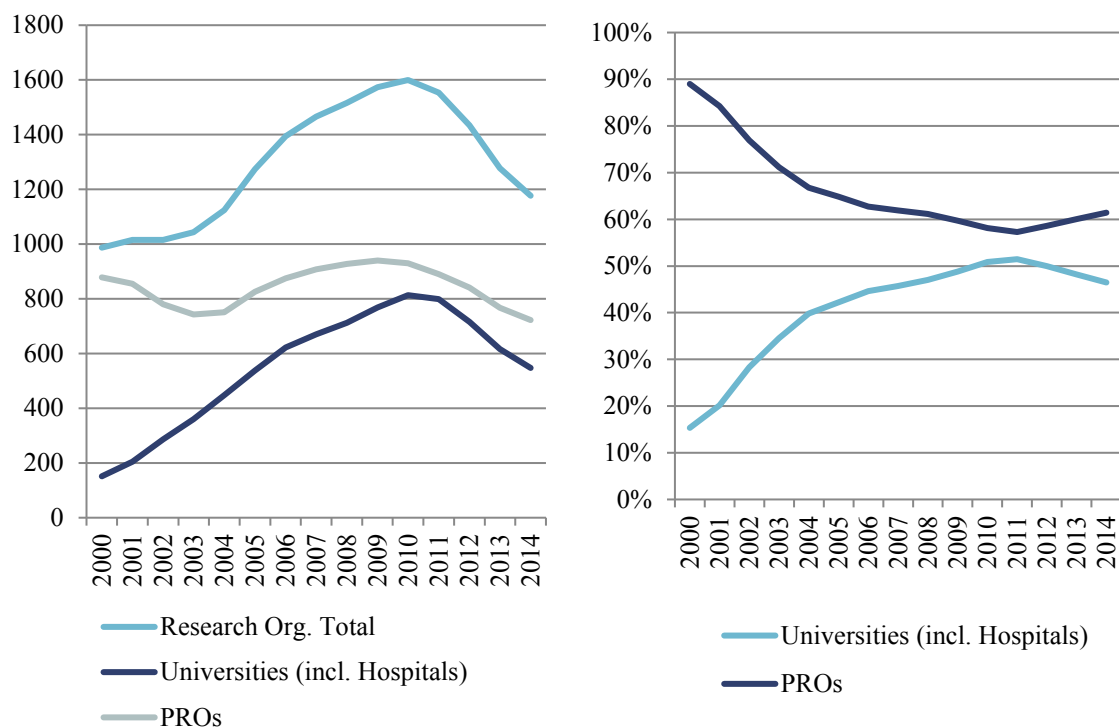
The trends depicted in Figure 5 are also resembled in the share of transnational filings by federal states. (Figure 6). After 2010, we can observe rising shares of Bavaria, while the shares were slightly declining for Baden-Württemberg and North Rhine-Westphalia. Figure 7 shows the patent intensities, calculated as the number of patent filings by a federal

state divided by the number of employees (in millions) in the respective state. Baden-Württemberg and Bavaria also score first by this indicator. Yet, although Baden-Württemberg has lost ground compared to Bavaria, it still has the largest patent intensity. North-Rhine Westphalia, on the other hand, which scored third in absolute terms, loses ground and scores only fifth within this comparison, after Rhineland-Palatinate and Hesse. The Eastern German states have the lowest patent intensity in comparison.

7 Patents filed by Universities and Public Research Institutes

Figure 8 presents the total number of patents filed by German research organizations in total, as well as differentiated by universities and public research organizations (PRO). Here, we only look at filings where the university was named as a patent applicant.

Figure 8: Number of transnational filings by German research organizations and shares of universities and PROs



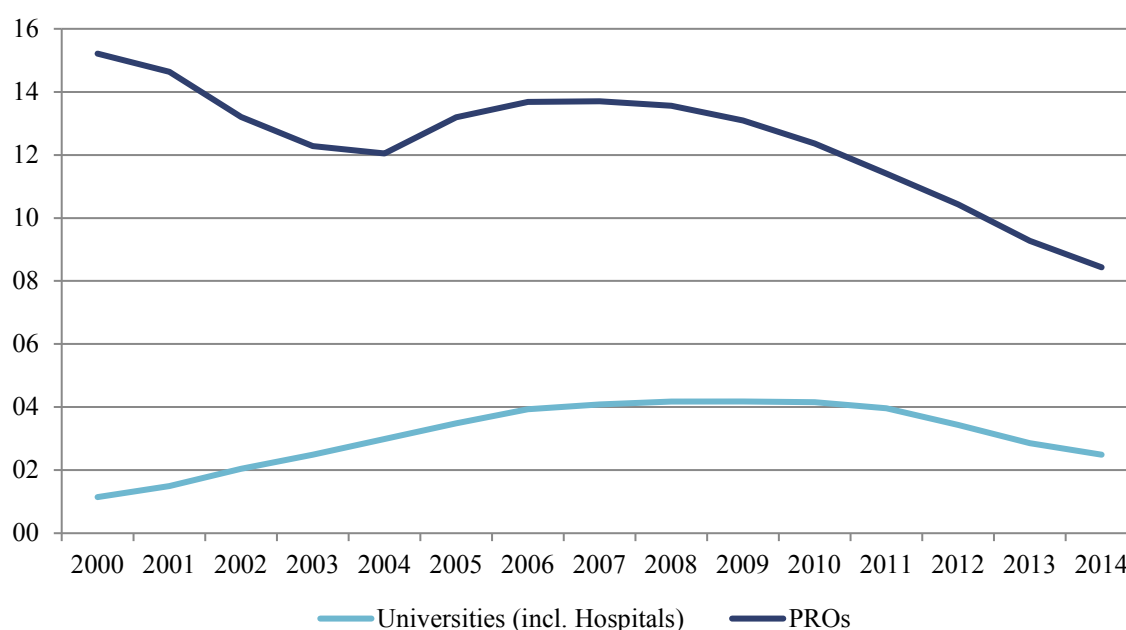
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Note: The sum of patents filed by universities and public research institutes might exceed 100% in certain years due to cooperative patent filings between universities and PRO.

The increase in the number of filings by PRO but especially also by universities in the 2000s indicates that patenting has become more and more important for German research organizations over the last 10 years. This, however, is also associated with legislation changes in Germany, i.e. the abolishment of the traditional professor's privilege ("Hochschullehrerprivileg") in 2002, where the individual ownership of academic patents was replaced by a system of institutional ownership by the universities (Blind et al., 2009; Geuna and Rossi, 2011; Schmoch, 2007). Yet, since 2010, the patenting figures for German research organizations have declined. Besides the fact that the total number of filings

by German inventors has slightly decreased over the years, this can be explained by the fact that especially international filings by research organizations were slightly decreasing. When looking at the national filings at the German Patent and Trademark Office (DPMA) (not shown), it can be observed that the filings for universities as well as PRI have remained at rather constant levels between 2010 and 2012, which means that the innovative output and the research productivity has more or less remained stable while the filing behavior has changed. They file less of their patents internationally and focus on national filings only. The reasons could be cost savings or limited expectations for exploitation opportunities and thereby limited expectations of financial inflows.

Figure 9: Patent intensities (patents per 1,000 employees, full-time equivalents) by German research organizations



Source: EPO – PATSTAT; BMBF Datenportal, calculations by Fraunhofer ISI

In the year 2014, research organizations (in total) were responsible for about 1,200 transnational patent filings. About 550 of those were filed by universities, while about 722 were filed by PROs. It is also interesting to take a look at the development of the shares across universities and PROs. While the shares of university filings and PRO filings in all filings by German research organizations nearly converged in 2010, we now can observe a decline in university shares, i.e. the number of university filings (or at least the number of filings where universities are named as patent applicants) have decreased more rapidly in the recent years than filings by PROs. This could be a sign of overheating effects in the previous years due to policy push effects and self-enforcing effects of her universities. It seems that it now comes back to a more realistic and normal level.

When looking at the patent intensities (Figure 9), i.e. the number of transnational patent filings per 1,000 employees (full-time equivalents), for universities as well as public research institutes, we can see that the patent intensity of universities, at least in terms of

patents where the university is named as an applicant, is comparably low. The intensity of PRO is nearly four times higher than the patent intensity of universities. Yet, this is mostly driven by the fact that PRO, especially the Fraunhofer Society but also the Helmholtz Institutes and parts of the Leibniz Institutes, are more focused on applied research, which explains the high patent intensity compared to universities.

References

- Blind, K., Cuntz, A., Schmoch, U., 2009. *Patentverwertungsstrukturen für Hochschulerfindungen im internationalen Vergleich: Mit den Schwerpunkten USA, Israel und Japan*. Fraunhofer IRB Verlag, Stuttgart.
- Federal Ministry of Education and Research (BMBF), 2012. *Federal Report on Research and Innovation 2012*. Federal Ministry on Education and Research (BMBF), Berlin.
- Freeman, C., 1982. *The Economics of Industrial Innovation*. Pinter Publishers, London.
- Frietsch, R., Neuhäusler, P., Jung, T., van Looy, B., 2014. Patent indicators for macroeconomic growth - The value of patents estimated by export volume. *Technovation* 34 (9), 546–558.
- Frietsch, R., Schmoch, U., 2010. Transnational Patents and International Markets. *Scientometrics* 82 (1), 185–200.
- Gehrke, B., Frietsch, R., Neuhäusler, P., Rammer, C., Leidmann, M., 2013. *Re-definition of research-intensive industries and goods - NIW/ISI/ZEW-Lists 2012*. Studien zum deutschen Innovationssystem Nr. 8-2013. Expertenkommission Forschung und Innovation (EFI), Berlin.
- Geuna, A., Rossi, F., 2011. Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy* 40 (8), 1068–1076.
- Griliches, Z., 1981. Market Value, R&D and Patents. *Economics Letters* 7 (183), 187.
- Griliches, Z., 1990. Patent statistics as economic indicators: A survey. *Journal of Economic Literature* 18 (4), 1661–1707.
- Grupp, H., 1998. *Foundations of the Economics of Innovation - Theory, Measurement and Practice*. Edward Elgar, Cheltenham.
- Moed, H., Glänzel, W., Schmoch, U. (Eds.), 2004. *Handbook of quantitative science and technology research. The use of publication and patent statistics in studies of S&T systems*. Kluwer Academic Publishers, Dordrecht.
- Neuhäusler, P., Frietsch, R., Rothengatter, O., 2014. *Patent Applications - Structures, Trends and Recent Developments 2013*. Studien zum deutschen Innovationssystem Nr. 4-2014. Expertenkommission Forschung und Innovation (EFI), Berlin.
- Pavitt, K., 1982. R&D, patenting and innovative activities: A statistical exploration. *Research Policy* 11 (1), 33–51.
- Polanyi, M., 1966. *Implizites Wissen*. Suhrkamp, Frankfurt am Main.
- Schasse, U., Kladroba, A., Stenke, G., 2012. *Forschungs- und Entwicklungsaktivitäten der deutschen Wirtschaft*. Studien zum deutschen Innovationssystem Nr. 4-2012. Expertenkommission Forschung und Innovation (EFI), Berlin.

- Schmoch, U., 2007. *Patentanmeldungen aus deutschen Hochschulen*. Studien zum deutschen Innovationssystem Nr. 10-2007. Expertenkommission Forschung und Innovation (EFI), Berlin.
- Schmoch, U., Hinze, S., 2004. Opening the Black Box, in: Moed, H., Glänzel, W., Schmoch, U. (Eds.), *Handbook of quantitative science and technology research. The use of publication and patent statistics in studies of S&T systems*. Kluwer Academic Publishers, Dordrecht, pp. 215–235.
- Statistisches Bundesamt, 2013. Personal an Hochschulen 2012. Statistisches Bundesamt, *Fachserie 11, Reihe 4.4*, Wiesbaden.