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Patent Applications – Structures, Trends and Recent Developments 2019

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0 Summary

Over the past 15 years, the total number of transnational patent filings has been steadily growing. The exception is the year 2008, where a considerably drop of the total filings occurred due to economic crisis. Since 2009, the growth resumed with the filing figures in 2010 already being beyond the level before the economic crisis. Only in the year. In 2014, a stagnation occurred, which only lasted until 2015. Since 2015, however, we can observe a continued increase in worldwide transnational filing figures. The largest technology-providing country at the international level still is the U.S. where a growth of patent filings since the financial crisis can be observed, although the figures only rose slightly in the recent three years. The U.S. is followed by Japan, where also a growth can be found in the recent years. China scores third in the number of transnational filings and has more and more managed to close the distance to Japan. Germany scores fourth behind the U.S., Japan and China, however, a slight growth in filings can once again be observed after 2015. In terms of patent intensities, smaller countries like Switzerland, Sweden and Finland are at the top of the list of the technology-oriented countries analyzed here. Japan, though outscored by China in absolute terms, scores third in terms of patent intensities, even ahead of Finland. Germany and Israel score fifth and sixth within the comparison of patent intensities, followed by South 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 2017. This rate has been quite constant in the last five years. Germany has increased its high-tech shares in the last four years and is now at the same level with France and slightly below Japan. Yet, Denmark, Germany, Japan, Austria, Italy, France and Korea 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, rail vehicles), machinery (agricultural machinery, machine tools, power machines and engines, pumps and compressors) and some areas of electrical engineering, especially electrical equipment for internal combustion engines.

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 2016. 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 their patent filing figures. After 2010, we have seen a decline in the filing figures for German research organizations. Yet, this trend seems to end in 2015, where we can once again observe an increase in transnational patent filings by universities and PROs.

1 Introduction

Patent applications as well as patent grants, which can be seen as the major output indicators for R&D processes (Freeman, 1982; Grupp, 1998), are commonly used to assess the technological performance of countries or innovation systems. Hereby, patents can be seen and analyzed from different angles and with different aims and the methods, while also the definitions applied for analyses using patent data do differ (Moed et al., 2004). Prior art searches as well as the description of the status of a technology can be carried out from a technological point of view. 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, on the other hand, offers an assessment of the technological output of national innovation systems, especially in high-tech areas.

In the current report, we focus on the macro-economic perspective by providing information on the technological capabilities and the technological competitiveness of economies as a whole. Patents are hereby 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 (Schasse et al., 2018). Therefore, we strictly focus on patents as an indication of output (Griliches, 1981, 1990; Grupp, 1998; Pavitt, 1982).

In the report, we provide a brief overview of the developments of transnational patent applications since the early 1990s. However, for the interpretation we especially focus on the recent trends and structures. Besides providing the most recent general patenting trends, we additionally analyze 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 (RPA[1]) 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:

$$RPAkj = 100 * \tanh \ln [(Pkj/\sum j\ Pkj)/(\sum k\ Pkj/\sum kj\ Pkj)]$$

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, 1985), 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. In its current version, the OECD REGPAT database does not contain full regionalized information for the year 2016. In order to be able to provide figures for 2016, we used the average trend of the last three years of patent growth in Germany to estimate the filing number for the federal states for 2016. For the final version of the report, update figures will be provided.

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 “Research 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, 2017) as well as the Federal Report on Research and Innovation 2018 (Federal Ministry on Education and Research, 2018). Gaps within the data for certain years were estimated on the basis of the values of the preceding and following years.

4 Core indicators

In this section, we will describe the recent trends of transnational patent filings since the mid 1990s. All our analyses were carried out for a selected set of technology-oriented countries[2], 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

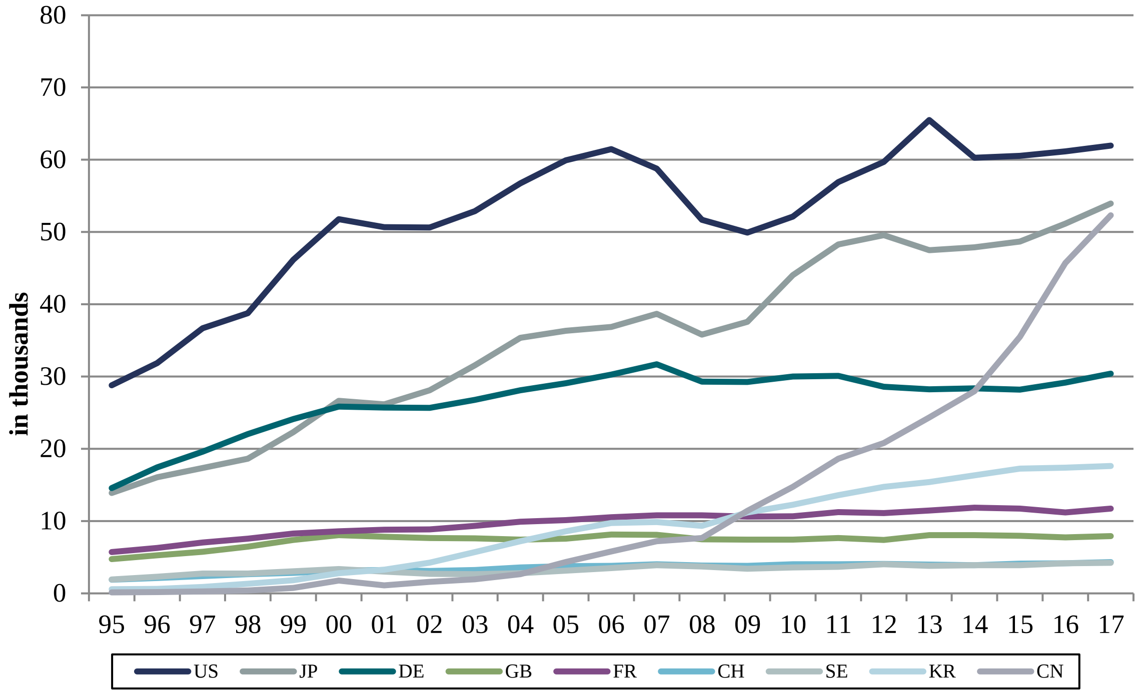
2 These are: Belgium, Denmark, Germany, Finland, France Israel, Italy, Japan, Canada, Korea, The Netherland, Austria, Poland, Sweden, Switzerland, Spain, United Kingdom, USA, Brazil, Russia, India, China, South Africa as well as the group of EU-28 member states.

high-technology areas (Gehrke et al., 2013). In addition, we will provide more in-depth technology field analyses.

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 in 2017 is the USA, where still a growth of patent filings since the financial crisis can be observed, although the figures only rose slightly in the recent three years. The USA is followed by Japan, where a growth in filings can be found in the recent years. China scores third in the number of transnational filings and has more and more managed to close the distance to Japan in terms of patent filings. Germany scores fourth behind the U.S., Japan and China also because the number of filings stayed rather stable since 2012. Since 2013, however, a slight growth in filings can once again be observed. Following behind these four countries is a large group of countries led by Korea, France and Great Britain. In the latter two countries, the figures have rather stagnated or even slightly declined after 2014. 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 more than 4,000 transnational filings in 2017 and a slight growth in filings over the years.

Figure 1: Absolute number of transnational patent applications for selected countries, 1995-2017



Source: EPO – PATSTAT; Fraunhofer ISI calculations

The absolute filing figures we have seen so far is affected by size effects. An adjustment to these size effects is shown in Table 1, where patent intensities per one million employees are provided. When looking at the country ranks from this angle, a completely new picture emerges. Although the U.S. is the largest country in terms of absolute filing figures, it only scores thirteenth in terms of patent intensities. Smaller countries like Switzerland, Sweden and Finland are at the top of the list of the technology-oriented countries analyzed here. Japan, though outscored by China in absolute terms, scores third in terms of patent intensities, even ahead of Finland. Germany and Israel score fifth and sixth within the comparison of patent intensities, followed by South Korea. These high patent intensities resemble a strong technology orientation and technological competitiveness of these countries. However, it is also a sign of a clear 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, 2017

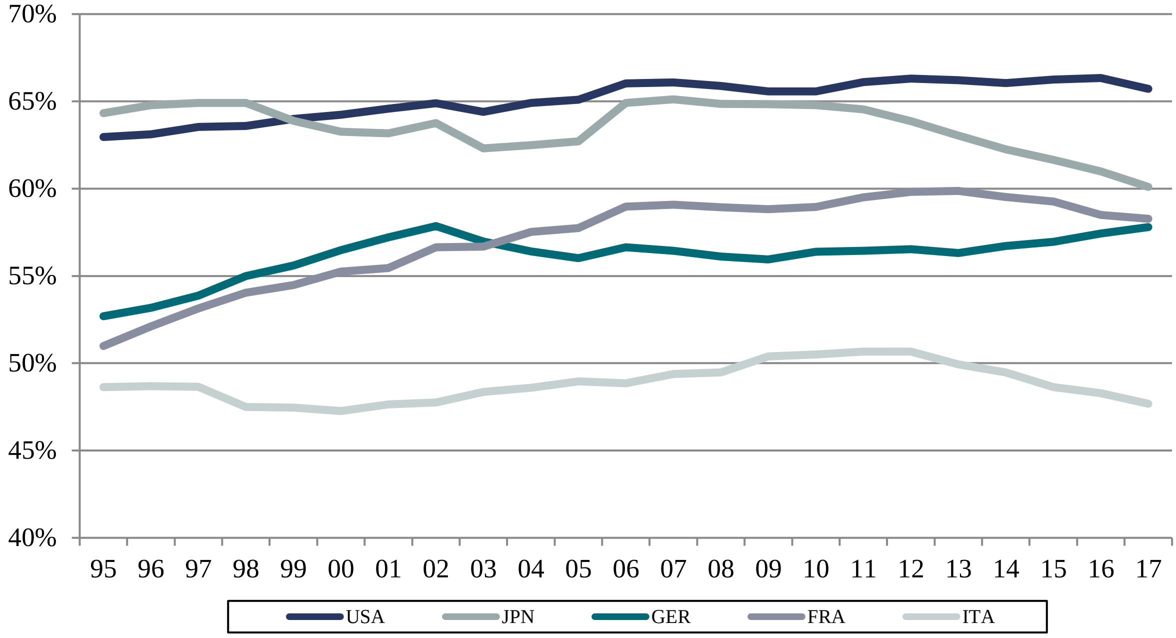
	Total	**Less R&D-intensive**		**High-Tech** of which are:		Leading-edge technologies		High-level technologies	
SUI	934	472	51%	480	51%	176	19%	305	33%
SWE	843	270	32%	594	71%	343	41%	251	30%
JPN	826	351	43%	494	60%	178	22%	315	38%
FIN	793	343	43%	454	57%	260	33%	193	24%
GER	730	322	44%	423	58%	141	19%	282	39%
ISR	665	231	35%	446	67%	243	37%	203	30%
KOR	660	265	40%	413	63%	190	29%	222	34%
DEK	656	268	41%	398	61%	112	17%	286	44%
AUT	621	304	49%	323	52%	109	17%	215	35%
NED	570	270	47%	310	54%	174	31%	135	24%
BEL	444	215	48%	235	53%	105	24%	131	29%
FRA	436	191	44%	255	58%	106	24%	148	34%
USA	404	146	36%	264	65%	137	34%	128	32%
EU-28	349	157	45%	199	57%	79	23%	120	34%
ITA	249	139	56%	118	47%	32	13%	86	34%
GBR	248	107	43%	147	59%	68	27%	80	32%
CAN	183	74	40%	112	61%	60	33%	51	28%
ESP	134	70	52%	66	49%	25	19%	41	30%
CHN	69	23	34%	47	69%	28	40%	20	29%
POL	46	23	49%	24	52%	9	20%	15	32%
RSA	18	10	57%	8	44%	3	16%	5	28%
RUS	17	8	47%	9	54%	4	26%	5	28%
BRA	9	5	54%	4	47%	2	17%	3	30%
IND	6	2	37%	4	66%	2	32%	2	33%

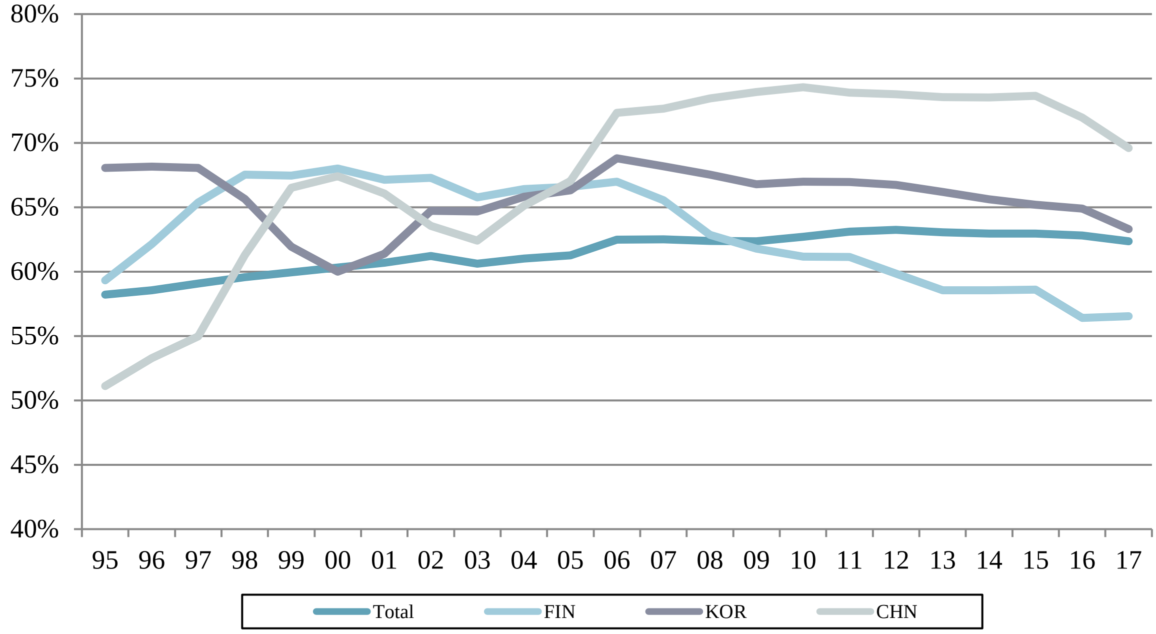
Source: EPO – PATSTAT; OECD, The World Bank, Fraunhofer ISI calculations

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. In less R&D intensive fields, especially South Africa shows rather large activities followed by Italy, Brazil, Spain and interestingly Switzerland. Sweden, China, Israel, India, the U.S., Korea, Canada, Denmark and Japan, on the other hand, show the largest shares of patents in high-technology fields, which is a picture that has already been found in earlier reports of this series. Regarding China, Sweden, China, Israel, India, the U.S. and Canada, this mostly is the result of large shares of patents in leading-edge technologies, while for Japan, Korea and Denmkark this is to a larger extent a result of large shares in high-level technologies. In the case of India and Israel, this can mostly be explained by a high orientation towards the U.S. market. In high-level technologies, the countries with the largest shares are Denmark, Germany, Japan, Austria, Italy, France and Korea.

Figure 2: Shares of high-tech patent applications in total patent applications for selected countries, 1995-2017





Source: EPO – PATSTAT; Fraunhofer ISI calculations

In Figure 2 (upper and lower panel), the trends in high-tech shares within the national profiles of selected large countries are depicted. The average share of total transnational high-tech patent applications rose from about 58% in 1995 to 62% in 2017, but has stagnated since 2011 and even slightly decreased in 2017. The single countries, however, underwent a considerable change of their patenting patterns in high-tech areas. The USA has long been at the top of the countries under observation with regard to high-tech shares. It showed constantly increasing trends over the years until 2006. From then on, we can observe a rather stable stagnating trend at a high level with some decreases during the financial crisis and a slight rise after 2010. In 2017, we can find a decrease in high-tech shares compared to 2016.

Japan and Korea were the second and third most high-tech active countries in terms of transnational patenting. However, both have clearly lost ground compared to the U.S. at the end of the 1990s and beginning of 2000s, but have managed to catch up afterwards. From 2011 onwards, however, a decreasing trend in Japanese high-tech shares can be observed, which can also be found for Korea, though the decrease was steeper for Japan. Still, however, both countries still show comparably large shares in high-tech patents. In the case of China, the high-tech shares have started to grow significantly 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. In 2016 and 2017, we can even see a decline in China's high tech shares. Yet, with 70%, it still has the largest share of high-tech patents in our comparison.

France was able to increase its high-tech share over the years, although we see a slight decline after 2013, which still continues. 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 growth can be observed. Each year, the high-tech shares of Germany increased up to a level of 58% in 2017. Italy encountered increases up to 2012, but from then a decrease similar to Japan can be found. Finland, on the other hand, shows decreasing shares since 2006; a trend that still continues.

4.2 Technology Profiles and Specialization Patterns

In this section, a deeper insight into the transnational patent applications by German inventors according to the classification of 38 technology fields of the high-tech sector is provided (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 largest growth rates between the period 2007-2009 and 2015-2017 can be found in "agricultural machinery", "rubber goods", which both have been growing also in earlier periods, "power generation and distribution", "electrical machinery, accessory and facilities" and "units and equipment for automatic data processing machines". Among the fields that are growing most slowly in Germany are three rather small fields, namely "photo chemicals", "office machinery" and "nuclear reactors and radioactive elements" but also "technical glass/construction glass", "pesticides" and "weapons". Here, a declining trend has already been observed in earlier reports of this series. Yet, also further chemistry related fields, e.g. "pharmaceuticals", "organic basic materials", "biotechnology and agents", "other special chemistry" and "organic basic materials", can be seen as comparably slowly growing fields within the German technology profile, followed by the ICT related fields of "broadcasting engineering", "electronics" and " computers".

Table 2: Transnational Patent applications of Germany according by high-technology sectors (absolute, specialization, and growth), 2015-2017

Technology Field	**Abs.**	**RPA**	**% Growth** (07-09=100)
agricultural machinery	916	73	212,2
rubber goods	426	25	168,9
power generation and distribution	2342	27	135,0
electrical machinery, accessory and facilities	603	7	131,3
units and equipment for automatic data processing machines	803	-80	131,0
rail vehicles	295	69	125,2
aeronautics	878	-14	122,0
communications engineering	4903	-52	113,6
electrical appliances	707	14	112,6
optics	640	-44	111,6
mechanical measurement technology	1248	27	109,4
medical instruments	2774	-14	108,8
optical and photooptical devices	72	-81	107,7
lamps, batteries etc.	1765	-7	107,0
pumps and compressors	772	37	106,4
Scents and polish	43	-18	105,8
automobiles and engines	5670	67	104,3
optical and electronic measurement technology	2794	-18	102,0
electrical equipment for internal combustion engines and vehicles	1253	63	102,0
air conditioning and filter technology	1946	30	101,3
machine tools	2574	62	101,2
computer	1883	-69	90,9
power machines and engines	3300	53	90,3
electronics	1369	-23	89,4
special purpose machinery	3296	21	88,3
broadcasting engineering	551	-88	84,8
inorganic basic materials	335	-13	82,3
other special chemistry	886	0	79,1
organic basic materials	1405	6	76,2
pharmaceuticals	1067	-46	75,7
biotechnolgy and agents	1486	-52	75,6
electronic medical instruments	798	-58	73,3
technical glass, construction glass	70	-100	67,6
weapons	204	36	65,9
pesticides	392	1	57,9
nuclear reactors and radioactive elements	8	-84	47,7
office machinery	46	-74	46,5
photo chemicals	2	-65	40,0

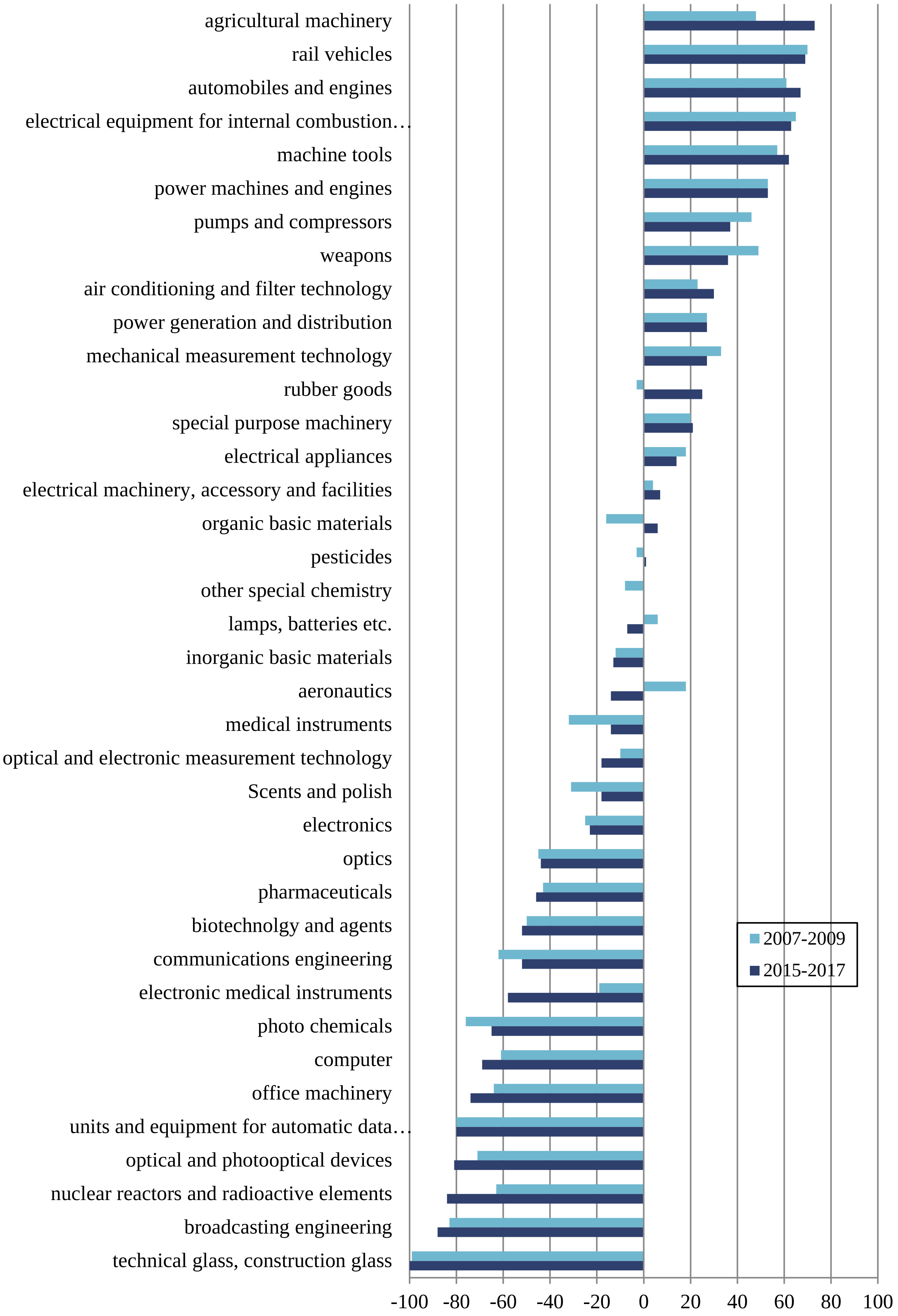
Source: EPO – PATSTAT; Fraunhofer ISI calculations

In general, it can be found that most electronics related fields, certain fields in mechanical engineering (especially electrical machinery as well as power generation and distribution but also rail vehicles) as well as aeronautics, and optics are growing rather strongly, whereas chemistry and pharmaceuticals as well as some of the 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.

The specialization (RPA) of the German technology profile of the years 2007-2009 and 2015-2017 is shown in Figure 3. Germany is specialized, i.e. has comparative advantages, in three main areas: transport (automobiles and engines, rail vehicles), machinery (agricultural machinery, machine tools, power machines and engines, pumps and compressors) and some areas of electrical engineering, especially electrical equipment for internal combustion engines.

An average activity rate in patenting can be found in the chemical sectors (organic basic materials, other special chemistry, pesticides, inorganic basic materials). Comparative disadvantages, reflected in negative specialization indices, can be observed in smaller fields like technical glass, broadcasting engineering, nuclear reactors, but also in computers, units and equipment for automatic data processing and optics and optical devices, implying that Germany does not have an outstanding profile in these sectors in international technology markets (though the there has been large growth especially in automatic data processing equipment). 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 "rubber goods", "organic basic materials", "agricultural machinery", where Germany has become more specialized in and in "aeronautics" and "electronic medical instruments", where Germany has become less specialized in.

Figure 3: Germany's technological profile, 2007-2009 vs. 2015-2017



Source: EPO – PATSTAT; Fraunhofer ISI calculations

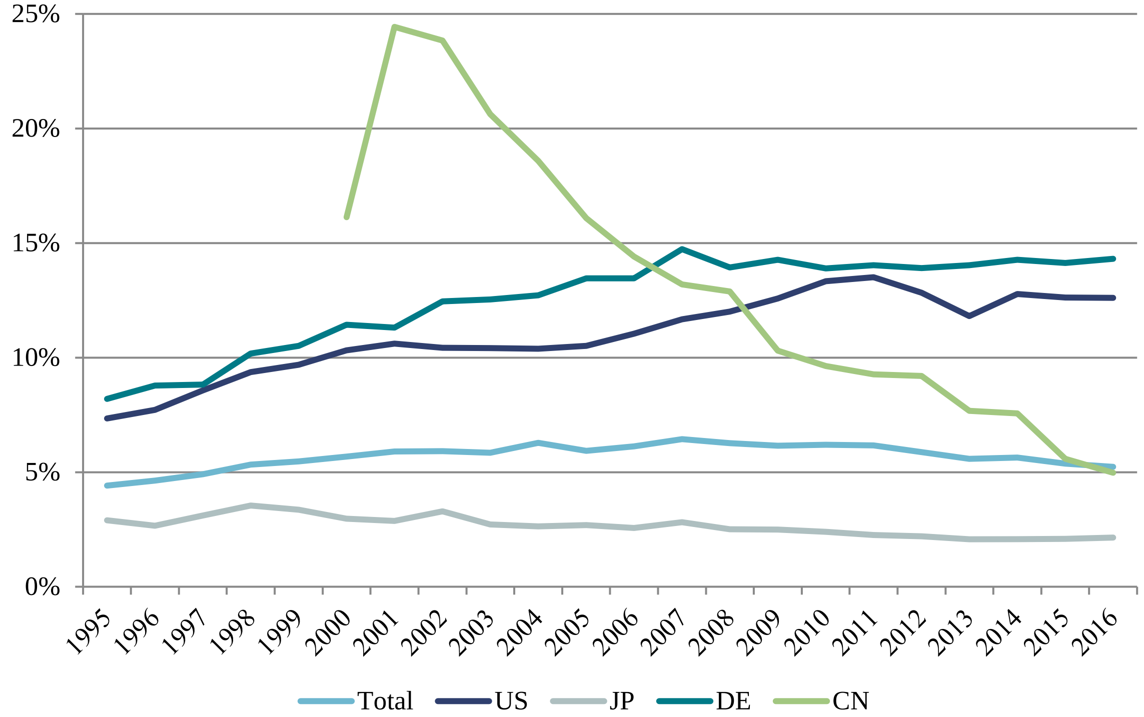
5 International Co-Patenting Trends

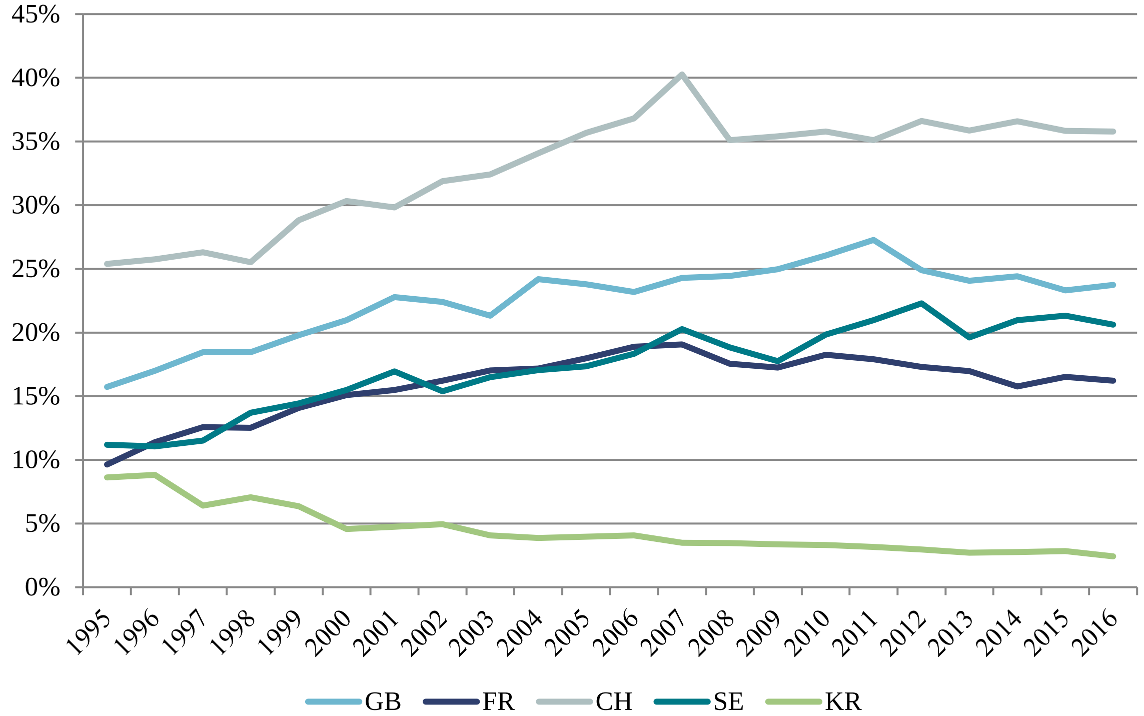
In this section, we will take a closer look at the international co-patenting trends of the countries in our comparison. The shares of transnational co-patents (with OECD countries) in all transnational patent filings of the respective country are depicted in Figure 4. This gives us an idea of the cooperation intensity of the countries, with large shares implying that many inventors from the respective country are cooperating internationally. The top-panel of the figure provides the results for the larger countries in comparison, while the lower-panel shows the results for the smaller countries in terms of patenting activity.

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 5.2% in 2016 was reached. Especially since 2011 there seems to be a slightly larger drop. This resembles a more general trend that is visible in a larger number of countries, like the U.S., Japan, Great Britain, France, Korea and Sweden. In 2014, however, the figures started to slightly increase again in the non-Asian countries, i.e. the U.S., Great Britain, France and Sweden. Germany has also been affected by a slight decline since 2007, yet a slow but steady growth can be observed since 2010.

Apart from these trends over time, Switzerland has the largest co-patenting shares with 36% in 2016. It is followed by Great Britain (24%), Sweden (21%) and France (16%). With a share of 14% in 2016, Germany is slightly ahead of the U.S. in terms of co-patent shares with 13%. Between 2011 and 2013, the U.S. shares were declining while the German shares were slightly growing. Since 2014, however, the U.S. shares started growing 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. Currently, only about 5% of all Chinese transnational filings are international co-patents. In comparison with the remaining Asian countries, in this case 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.

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. After 2010, the governments in both countries set up programs to overcome these shortcomings, yet mostly with respect to the public science system. However, effects of these policy initiatives still are not reflected in co-patenting trends.

In sum, 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 allows an assessment of the most important cooperation partners for each of the countries in the 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. This is a different point of view than the one in Figure 4 as size effects do matter here, i.e. larger countries in terms of patenting take advantage over smaller countries. The U.S. has the highest share of co-patents in all transnational co-patents with a value of 24.4%. It is followed by Germany with a share of 13.9%. Great Britain and China score third and fourth with a share of 7.2% and 7.0%, respectively. France is fifth with a comparable share of 6.9%. Although a small country in absolute terms, Switzerland scores sixth and reaches rather high shares in total transnational co-patents (6.1%) as it is very co-operation intensive. It is followed by Canada, India, Japan, Belgium and Sweden, yet with a certain gap and values between 3% and 4%. Although it is the second largest country in terms of transnational patent filings, Japan only reaches a share of 3.1%, which resembles the fact that its innovation system is relatively isolated compared to other innovation systems.

In Table 4, the importance of collaboration partners for each of the countries in our comparison 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 indicate the importance of collaboration partners (by column) for each country from green to red. The most important collaboration partner for Germany, for example, is the U.S. as more than 26% of all German co-patents in the period of 2014 to 2016 are filed in cooperation with a U.S. inventor. The next largest partners are Switzerland, France, Austria and Great Britain (all with values above 5%). To a certain extent, this can be explained by geographical proximity of these countries to Germany, which still is a large factor in international collaborations. When looking at the table is interesting to note, however, that the U.S. is the most important partner for many of the countries in our comparison, while the US itself co-operates most strongly with China, Germany, Great Britain, Canada and India. Germany is also an important partner for many countries, which is also true for China and to a certain extent also Switzerland, which operates collaborations with many partners around the world. China itself is highly oriented towards the U.S. More than 53% of all Chinese co-patents are filed in cooperation with a U.S. inventor, followed by Germany and Japan with 9%, respectively. 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 U.S. is and remains the most important cooperation partners for the countries in comparison, while Germany and China also are often frequented collaboration partners.

Table 3: Absolute number of transnational co-patents and shares in total transnational co-patents, 2014-2016

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA	Share in total trans. co-patents
AT		0,07%	0,01%	0,02%	0,46%	0,03%	1,16%	0,02%	0,02%	0,13%	0,08%	0,08%	0,00%	0,02%	0,11%	0,02%	0,00%	0,04%	0,01%	0,01%	0,09%	0,19%	0,00%	2,57%
BE	73		0,01%	0,04%	0,09%	0,10%	0,51%	0,01%	0,08%	0,02%	0,59%	0,31%	0,01%	0,02%	0,09%	0,09%	0,02%	0,31%	0,01%	0,00%	0,05%	0,64%	0,00%	3,08%
BR	11	8		0,01%	0,02%	0,01%	0,06%	0,01%	0,01%	0,00%	0,04%	0,03%	0,01%	0,01%	0,02%	0,00%	0,00%	0,01%	0,00%	0,00%	0,02%	0,29%	0,00%	0,59%
CA	16	46	15		0,07%	0,23%	0,19%	0,02%	0,02%	0,02%	0,16%	0,19%	0,04%	0,07%	0,04%	0,03%	0,02%	0,04%	0,01%	0,03%	0,14%	2,25%	0,01%	3,64%
CH	478	92	23	75		0,15%	1,88%	0,09%	0,09%	0,06%	1,05%	0,27%	0,03%	0,08%	0,34%	0,07%	0,02%	0,12%	0,04%	0,03%	0,17%	0,96%	0,01%	6,08%
CN	31	101	15	236	154		0,65%	0,05%	0,04%	0,14%	0,18%	0,32%	0,04%	0,10%	0,06%	0,60%	0,14%	0,05%	0,02%	0,07%	0,28%	3,69%	0,00%	6,96%
DE	1197	525	65	195	1944	674		0,19%	0,28%	0,20%	1,45%	0,93%	0,14%	0,30%	0,48%	0,40%	0,10%	0,66%	0,18%	0,11%	0,43%	3,60%	0,03%	13,93%
DK	19	15	7	18	89	49	199		0,03%	0,05%	0,06%	0,12%	0,00%	0,05%	0,03%	0,01%	0,00%	0,05%	0,03%	0,00%	0,21%	0,27%	0,00%	1,29%
ES	24	85	15	18	91	38	291	33		0,02%	0,25%	0,25%	0,05%	0,03%	0,10%	0,02%	0,00%	0,10%	0,01%	0,01%	0,05%	0,44%	0,00%	1,89%
FI	133	17	1	22	57	140	210	55	23		0,01%	0,09%	0,01%	0,05%	0,03%	0,03%	0,00%	0,03%	0,04%	0,01%	0,24%	0,22%	0,00%	1,41%
FR	80	608	40	168	1088	189	1501	63	261	14		0,49%	0,05%	0,10%	0,28%	0,14%	0,05%	0,17%	0,08%	0,03%	0,09%	1,50%	0,01%	6,86%
GB	82	326	26	196	276	332	967	128	254	90	508		0,08%	0,14%	0,15%	0,17%	0,10%	0,21%	0,04%	0,05%	0,24%	2,91%	0,03%	7,19%
IL	3	15	7	41	28	41	141	2	52	9	56	83		0,03%	0,03%	0,01%	0,01%	0,02%	0,00%	0,05%	0,01%	0,96%	0,00%	1,58%
IN	19	23	11	73	85	103	314	51	29	55	106	147	34		0,04%	0,09%	0,12%	0,09%	0,03%	0,01%	0,08%	1,93%	0,01%	3,40%
IT	109	89	19	38	352	58	495	27	99	34	287	152	26	46		0,03%	0,00%	0,09%	0,03%	0,01%	0,11%	0,54%	0,00%	2,59%
JP	18	91	4	26	76	626	415	10	21	34	143	175	8	91	36		0,18%	0,05%	0,00%	0,01%	0,03%	1,16%	0,00%	3,15%
KR	5	18	2	21	23	150	105	1	1	4	49	101	10	122	5	190		0,04%	0,00%	0,04%	0,01%	0,62%	0,00%	1,50%
NL	42	323	10	37	124	53	679	51	100	30	179	215	20	90	90	52	44		0,01%	0,01%	0,07%	0,87%	0,01%	3,04%
PL	14	14	0	7	39	21	187	26	8	39	80	39	5	28	28	3	5	10		0,02%	0,03%	0,17%	0,00%	0,75%
RU	8	1	3	31	26	75	109	2	7	10	26	48	52	6	15	9	38	11	18		0,00%	0,39%	0,00%	0,88%
SE	92	51	23	141	181	290	444	220	51	253	96	249	8	84	110	33	11	75	27	3		0,70%	0,00%	3,06%
US	201	663	302	2333	992	3824	3732	275	452	225	1555	3016	993	2002	561	1201	647	901	174	408	724		0,06%	24,38%
ZA	2	3	5	12	8	4	35	0	2	1	8	32	4	6	2	0	0	14	1	1	4	65		0,20%
Total	2657	3187	612	3765	6301	7204	14424	1340	1955	1456	7105	7442	1638	3525	2678	3262	1552	3150	773	907	3170	25246	209	100,00%

Source: EPO – PATSTAT; Fraunhofer ISI calculations

Table 4: Share of co-patenting partners within the transnational co-patenting portfolio of a given country, 2014-2016

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA
AT		2%	2%	0%	8%	0%	8%	1%	1%	9%	1%	1%	0%	1%	4%	1%	0%	1%	2%	1%	3%	1%	1%
BE	3%		1%	1%	1%	1%	4%	1%	4%	1%	9%	4%	1%	1%	3%	3%	1%	10%	2%	0%	2%	3%	1%
BR	0%	0%		0%	0%	0%	0%	1%	1%	0%	1%	0%	0%	0%	1%	0%	0%	0%	0%	0%	1%	1%	2%
CA	1%	1%	2%		1%	3%	1%	1%	1%	2%	2%	3%	3%	2%	1%	1%	1%	1%	1%	3%	4%	9%	6%
CH	18%	3%	4%	2%		2%	13%	7%	5%	4%	15%	4%	2%	2%	13%	2%	1%	4%	5%	3%	6%	4%	4%
CN	1%	3%	2%	6%	2%		5%	4%	2%	10%	3%	4%	3%	3%	2%	19%	10%	2%	3%	8%	9%	15%	2%
DE	45%	16%	11%	5%	31%	9%		15%	15%	14%	21%	13%	9%	9%	18%	13%	7%	22%	24%	12%	14%	15%	17%
DK	1%	0%	1%	0%	1%	1%	1%		2%	4%	1%	2%	0%	1%	1%	0%	0%	2%	3%	0%	7%	1%	0%
ES	1%	3%	2%	0%	1%	1%	2%	2%		2%	4%	3%	3%	1%	4%	1%	0%	3%	1%	1%	2%	2%	1%
FI	5%	1%	0%	1%	1%	2%	1%	4%	1%		0%	1%	1%	2%	1%	1%	0%	1%	5%	1%	8%	1%	0%
FR	3%	19%	7%	4%	17%	3%	10%	5%	13%	1%		7%	3%	3%	11%	4%	3%	6%	10%	3%	3%	6%	4%
GB	3%	10%	4%	5%	4%	5%	7%	10%	13%	6%	7%		5%	4%	6%	5%	7%	7%	5%	5%	8%	12%	15%
IL	0%	0%	1%	1%	0%	1%	1%	0%	3%	1%	1%	1%		1%	1%	0%	1%	1%	1%	6%	0%	4%	2%
IN	1%	1%	2%	2%	1%	1%	2%	4%	1%	4%	1%	2%	2%		2%	3%	8%	3%	4%	1%	3%	8%	3%
IT	4%	3%	3%	1%	6%	1%	3%	2%	5%	2%	4%	2%	2%	1%		1%	0%	3%	4%	2%	3%	2%	1%
JP	1%	3%	1%	1%	1%	9%	3%	1%	1%	2%	2%	2%	0%	3%	1%		12%	2%	0%	1%	1%	5%	0%
KR	0%	1%	0%	1%	0%	2%	1%	0%	0%	0%	1%	1%	1%	3%	0%	6%		1%	1%	4%	0%	3%	0%
NL	2%	10%	2%	1%	2%	1%	5%	4%	5%	2%	3%	3%	1%	3%	3%	2%	3%		1%	1%	2%	4%	7%
PL	1%	0%	0%	0%	1%	0%	1%	2%	0%	3%	1%	1%	0%	1%	1%	0%	0%	0%		2%	1%	1%	0%
RU	0%	0%	0%	1%	0%	1%	1%	0%	0%	1%	0%	1%	3%	0%	1%	0%	2%	0%	2%		0%	2%	0%
SE	3%	2%	4%	4%	3%	4%	3%	16%	3%	17%	1%	3%	0%	2%	4%	1%	1%	2%	3%	0%		3%	2%
US	8%	21%	49%	62%	16%	53%	26%	21%	23%	15%	22%	41%	61%	57%	21%	37%	42%	29%	23%	45%	23%		31%
ZA	0%	0%	1%	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.

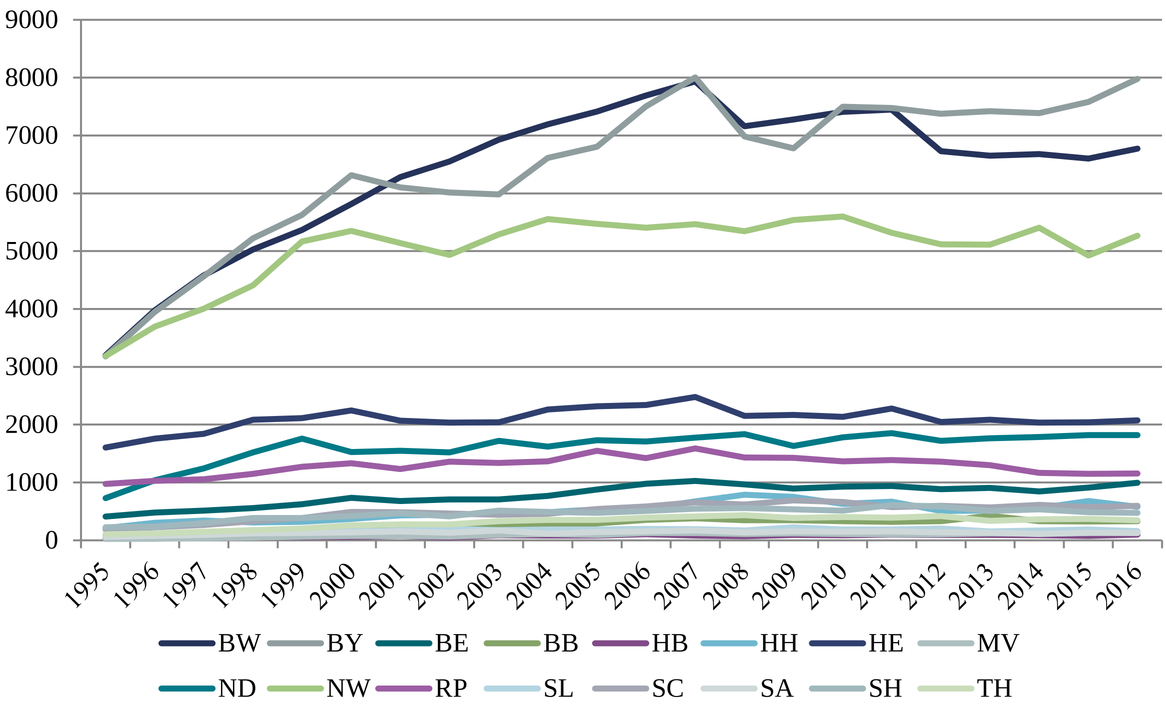
Note: The colors in the table indicate the importance of collaboration partners for a given country (vertically). Green resembles the most important partners (largest share of co-patents in a country's total co-patents), red resembles the least important partners.

6 Patent Activities of the German Federal States

The absolute numbers of transnational patent filings based on inventor addresses are plotted in Figure 5.[3] Between the years 1995 and 2007, the number of filings were increasing for nearly all of the German federal states. After that, we can observe slight decrease to a larger or lesser extent for many of the federal states due to the economic crisis. After the crisis, the filings figures increased for most of the countries, yet we can observe decreases in the recent years, for example in Baden-Württemberg, North Rhine-Westphalia and Hesse.

The largest number of transnational filings within the German comparison can be found in the south part. Bavaria ranks first, with nearly 8,000 filings in 2016, followed by Baden-Württemberg (about 6,800 filings in 2016) and North Rhine-Westphalia at a slightly lower level (about 5,300 filings in 2016). Large parts of the German industry are located in these three countries, which is why it is 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, who both reach similar levels in terms of patenting, and Rhineland-Palatinate, where a decrease in filings in the last years can be observed. The remainder of the federal states is at a similar level with 1,000 filings or less per year.

Figure 5: Number of transnational filings by federal states

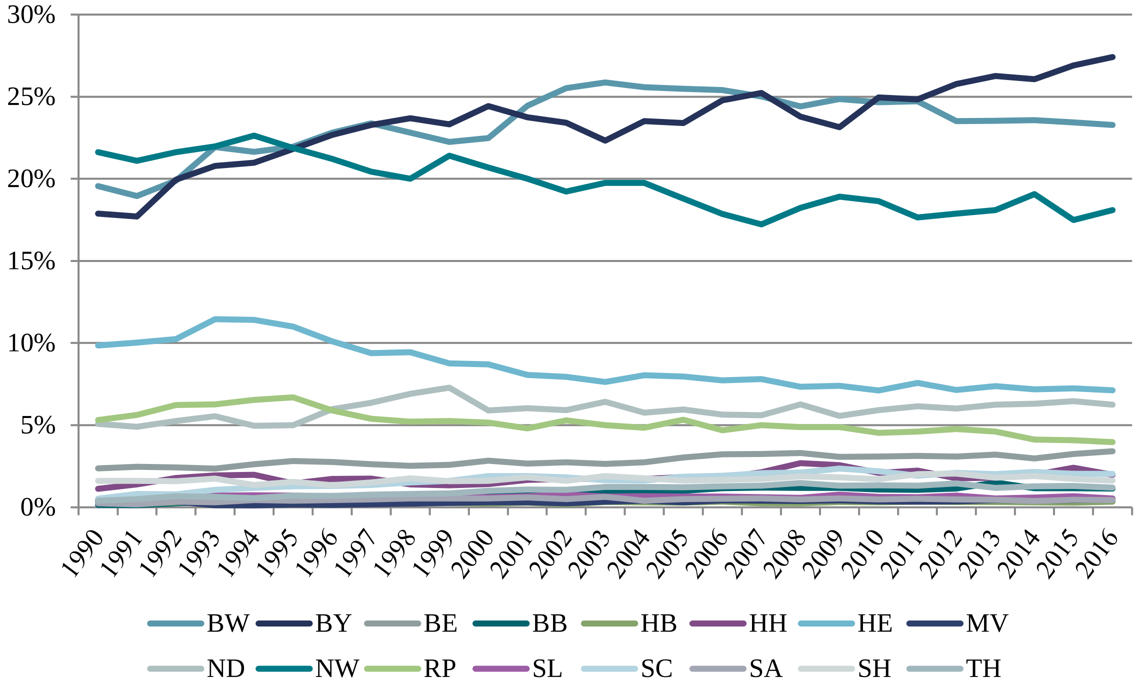


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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. .

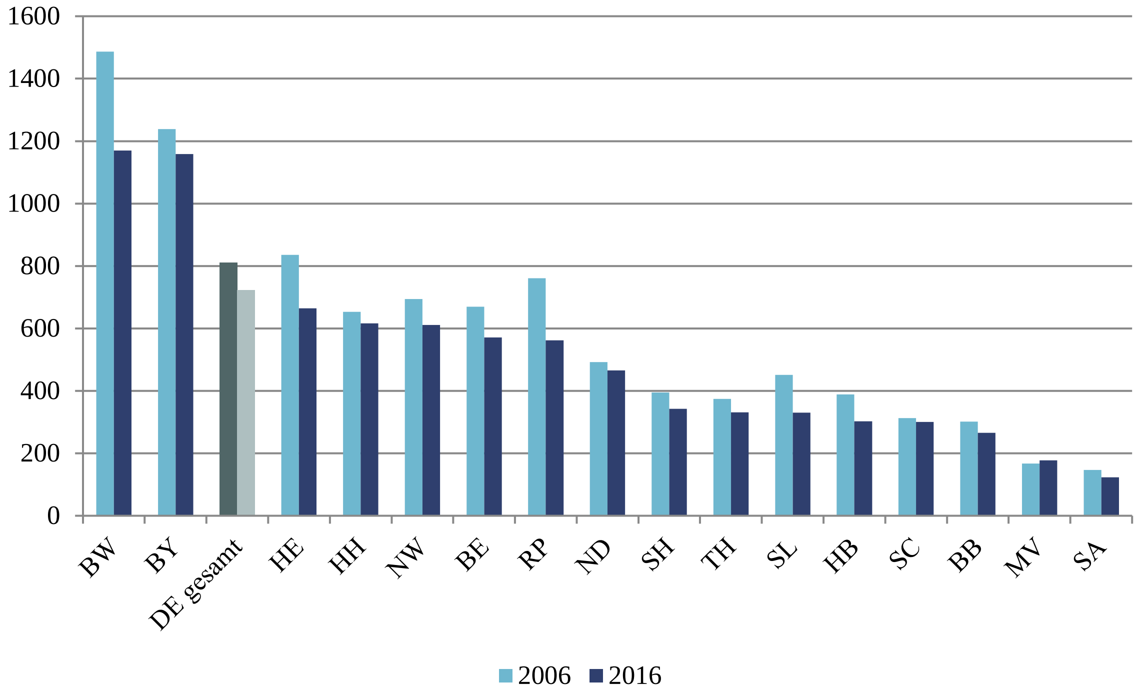
Note: BW=Baden-Württemberg, BY=Bavaria, BE=Berlin, BB=Brandenburg, HB=Bremen, HH=Hamburg, HE=Hesse, MV=Mecklenburg-West Pomerania, ND=Lower-Saxony, NW=North Rhine-Westphalia, RP=Rhineland-Palatinate, SL=Saarland, SC=Saxony, SA=Saxony-Anhalt, SH=Schleswig-Holstein, TH=Thuringia.

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)



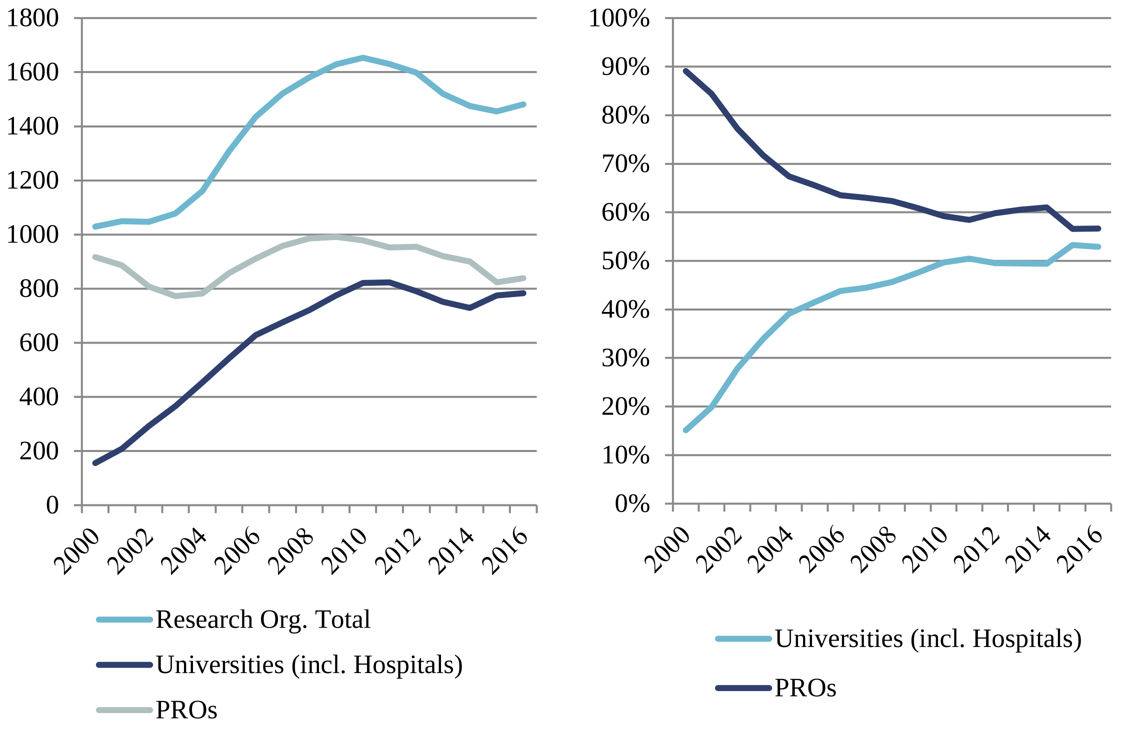
Source: EPO – PATSTAT; Statistisches Bundesamt, calculations by Fraunhofer ISI

The trends depicted in Figure 5 are also resembled in the share of transnational filings by federal states, which are provided in 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 federal state divided by the number of employees (in millions) in the respective state. Baden-Württemberg and Bavaria also score first by this indicator, though their intensities have decreased compared to 2006. Although Baden-Württemberg has lost ground compared to Bavaria in terms of absolute filing figures, it still has the largest patent intensity, though the difference between the two federal states has become much smaller compared to 2006. North-Rhine Westphalia, on the other hand, which scored third in absolute terms, loses ground and scores only fifth within this comparison, after Hamburg and Hesse.

7 Patents filed by Universities and Public Research Institutes

In Figure 8, the total number of patents filed by German research organizations are depicted. In addition, the figure depicts the number of filings differentiated by universities and public research organizations (PRO) as well as the shares of universities and PROs in the total number of filings by research organizations (right panel of the figure). Here, we only look at filings where the university was named as a patent applicant on the patent filing.

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

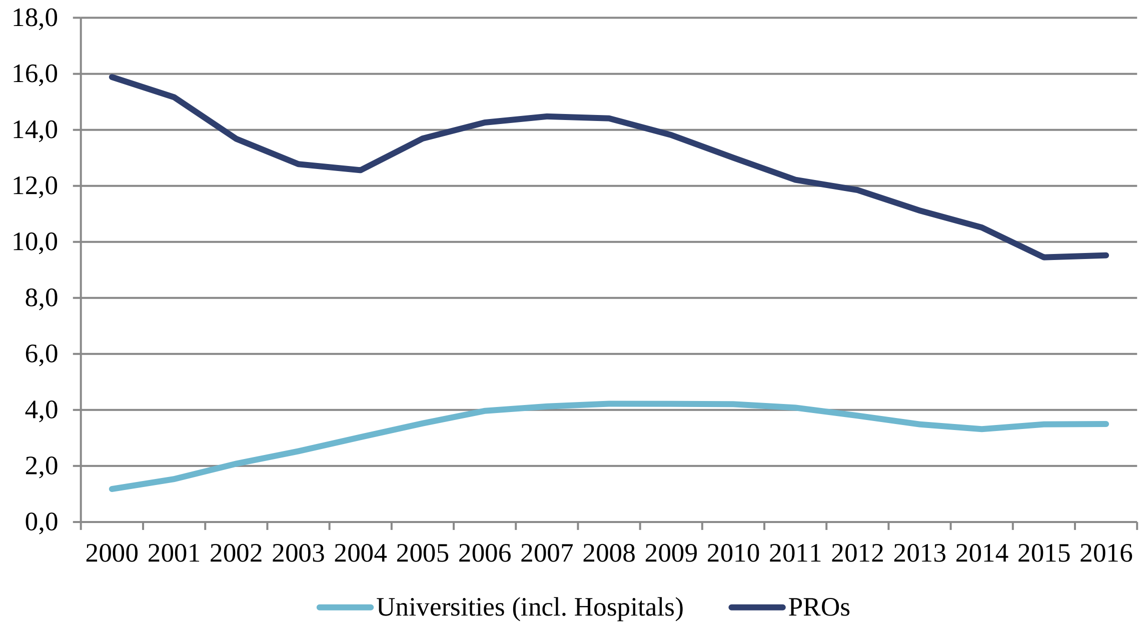


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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.

As we can see from the figure, the number of filings especially by universities but also by PROs has increased in the 2000s, indicating that patenting has become more and more important for German research organizations in this decade. However, this 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). Since 2010, however, the patenting figures for German research organizations have declined. This can partly be explained by the general trend of a stagnation in the growth of filings by German inventors in general. Yet, this also has to do with the fact that we are looking at international filing figures here. 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 filed less of their patents internationally and focused more on national filings only. The reasons could be cost savings or limited expectations for exploitation opportunities and thereby limited expectations of financial inflows. Since 2015, however, a slight growth in the number of transnational filings can once again be found for universities as well as PROs, implying that also international filings have once again gained importance for the German research organizations.

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 2016, research organizations (in total) were responsible for about 1,480 transnational patent filings. About 780 of those were filed by universities, while about 840 were filed by PROs. When looking at the development of the shares across universities and PROs, it can be found that the shares of university filings and PRO filings in all filings by German research organizations nearly converged in 2010. After that, we saw the shares slightly drifting apart again due to a stronger decline in universities filings than PRO filings. As the number of filings for both, universities and PROs, rose after 2015, we once again see ac convergence in the filing shares of universities and PROs in the German research landscape.

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, shows 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 three 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. Up to 2015, we also saw declining patent intensities for universities as well as PROs. The growth of filing numbers in the last two years, however, has led to a slight growth also in the patent intensities of universities and PROs.

8 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 on Education and Research, 2018. Federal Report on Research and Innovation 2018, 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 8-2013, 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. Patent Applications - Structures, Trends and Recent Developments 2013 4-2014.

Pavitt, K., 1982. R&D, patenting and innovative activities: A statistical exploration. Research Policy 11 (1), 33–51.

Polanyi, M., 1985. Implizites Wissen. Suhrkamp, Frankfurt am Main.

Schasse, U., Gehrke, B., Stenke, G., 2018. Forschung und Entwicklung in Staat und Wirtschaft – Deutschland im internationalen Vergleich. Studien zum deutschen Innovationssystem, Nr. 2-2018. EFI, Berlin, 131 pp. Accessed 19 September 2018.

Schmoch, U., 2007. Patentanmeldungen aus deutschen Hochschulen. Studien zum deutschen Innovationssystem Nr. 10-2007. Expertenkommission Forschung und Innovation, 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, 2017. Personal an Hochschulen, Fachserie 11, Reihe 4.4, Wiesbaden.