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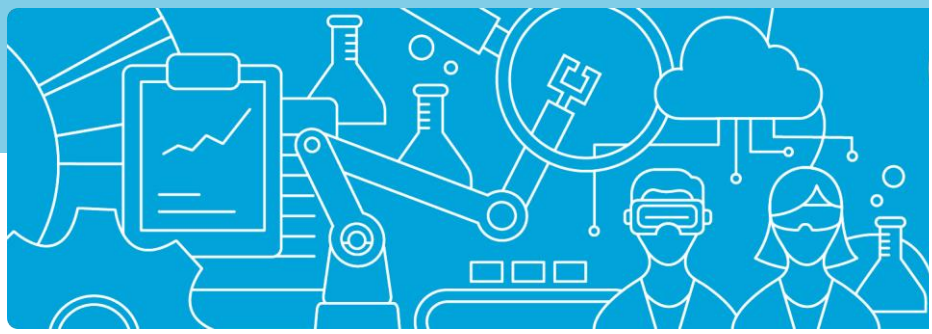

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Patent Applications – Structures, Trends and Recent Developments 2021

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Contents

Figures

Tables

0 Summary

Over the past years, the number of transnational patent filings has been growing steadily - except during the financial crisis, when a considerable drop in the filings figures occurred. The largest technology-providing country at the international level in 2019 is China, followed very closely by the United States, where a growth of the number of patent filings since 2014 can be observed. The USA is followed by Japan, where a drop in filings between 2018 and 2019 has occurred, although the numbers have been growing up to 2018. Germany scores fourth behind China the U.S. and Japan also because the number of filings stayed rather stable since 2012, but a slight decrease can be found in the recent three years. In terms of patent intensities, smaller countries like Switzerland, Sweden and Finland are at the top of the list. Japan and Korea are ranked even before Finland at rank five. Germany sixth within the comparison of patent intensities.

A closer look at high-tech patent filings shows that worldwide 62% of total patents are patents in high-technology. Since 2015, however, the shares have slightly declined. Germany has increased its high-tech shares in recent years and is now at a similar level as France and rather close to Japan Denmark, Germany, Italy, Japan, Austria, 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 profile, the largest growth rates between the periods 2009-2011 and 2017-2019 can be found in "agricultural machinery", "units and equipment for automatic data processing machines", followed by "communication engineering" "power generation and distribution" and "mechanical measurement technology".

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 (35%) in 2018. It is followed by Great Britain (22%), Sweden (21%) and France (17%). With a share of 15%, 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 et al. 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:

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

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.

1 Revealed Patent Advantage.

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.

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 Organizations

Patents filed by universities and public research organizations (PRO) help us to assess the technological output of research organizations in Germany. Patents filed by universities and PRO 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

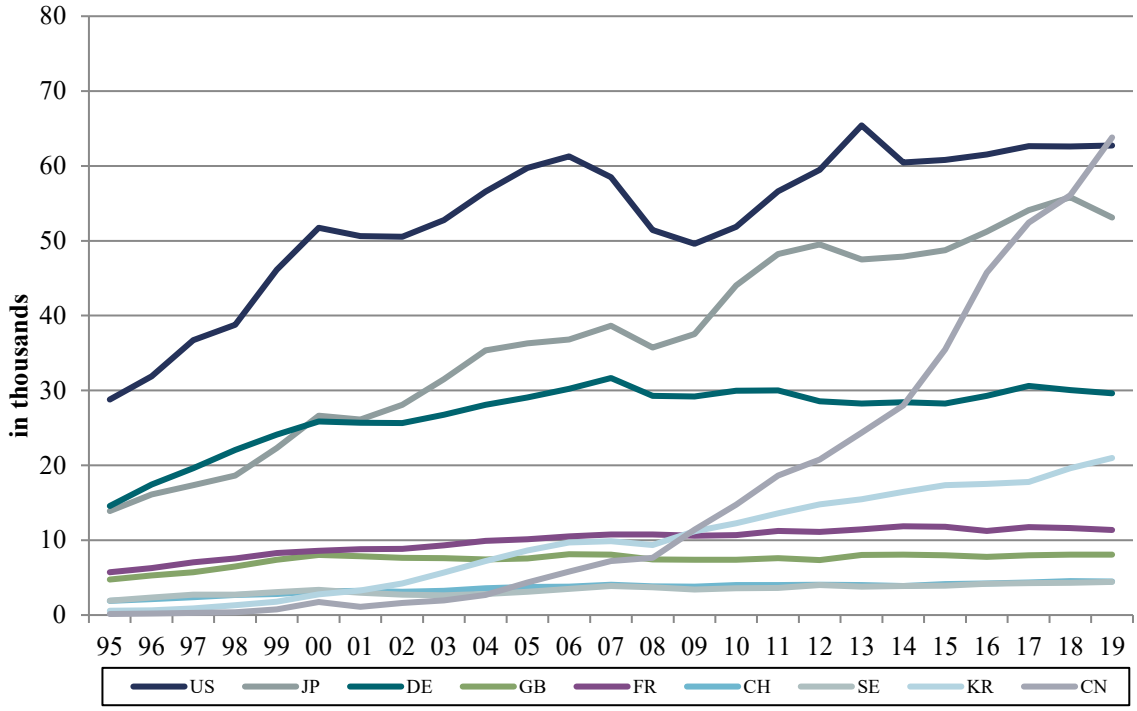
In this section, we will describe the recent trends of transnational patent filings since the mid 1990s. All our analyses were carried out for a selected set of technology-oriented countries[2], although, for reasons of presentation, not every country is displayed in each figure. Besides a country-specific view, we will provide a distinction between low- and 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 2019 is China, followed very closely by the United States, where a growth of the number of patent filings since 2014 can be observed. The USA is followed by Japan, where a drop in filings between 2018 and 2019 has occurred, although the numbers have been growing up to 2018. Germany scores fourth behind China the U.S. and Japan also because the number of filings stayed rather stable since 2012. Between 2015 a slight growth in filings could be observed, but the number are slightly declining afterwards. 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. In addition, quite large growth rates can be found for Koreas filings in the last two years. Sweden and Switzerland follow Great Britain with more than 4,000 transnational filings in 2019 and a slight growth in filings over the years.

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.

Figure 1: Absolute number of transnational patent applications for selected countries, 1995-2019



Source: EPO – PATSTAT; Fraunhofer ISI calculations

The absolute filing figures we have seen so far are 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 China is the largest country in terms of absolute filing figures, it only scores nineteenth in terms of patent intensities. A similar effect can be observed for the U.S. It is the second largest country in terms of absolute filing figures, but only scores thirteenth in terms of patent intensities (just ahead of the EU-28 as a whole)

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 while Korea ranks fourth, even ahead of Finland. Germany is ranked sixth within the comparison of patent intensities, followed by Denmark, Austria and Israel. 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, 2019

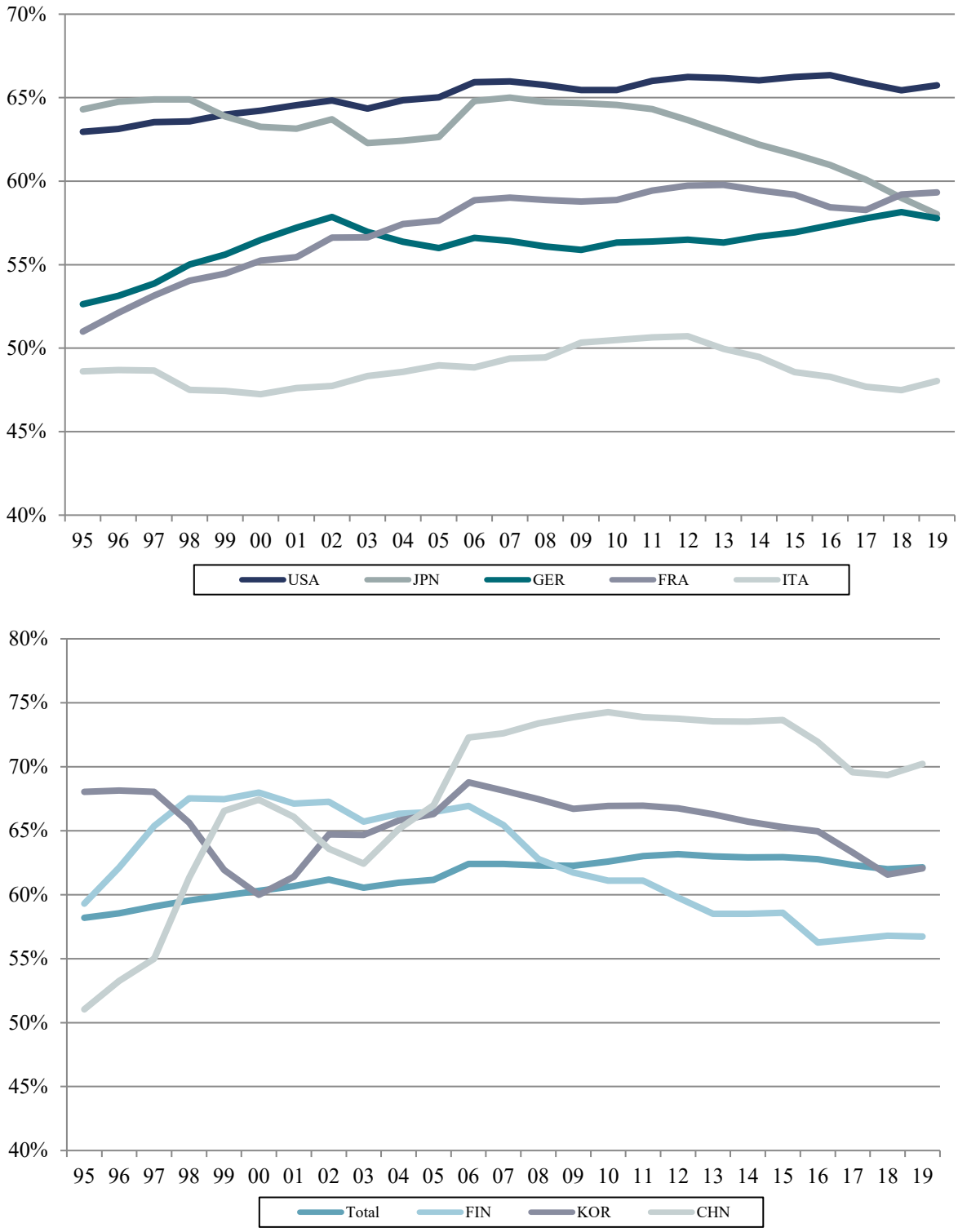
	Total	Less R&D-intensive		High-Tech		of which are: Leading-edge technologies		High-level technologies	
SUI	950	499	53%	472	50%	176	19%	296	31%
SWE	863	299	35%	593	69%	339	39%	253	29%
JPN	790	351	44%	456	58%	179	23%	277	35%
KOR	774	310	40%	484	63%	233	30%	251	32%
FIN	738	323	44%	419	57%	260	35%	160	22%
GER	698	314	45%	402	58%	141	20%	261	37%
DEK	675	265	39%	416	62%	143	21%	274	41%
AUT	624	312	50%	318	51%	107	17%	211	34%
ISR	623	232	37%	404	65%	225	36%	179	29%
NED	557	280	50%	286	51%	155	28%	131	24%
FRA	418	183	44%	247	59%	108	26%	139	33%
BEL	413	206	50%	215	52%	94	23%	121	29%
USA	398	144	36%	263	66%	140	35%	123	31%
EU-28	348	159	46%	197	57%	81	23%	117	33%
ITA	258	142	55%	125	48%	34	13%	90	35%
GBR	247	113	46%	141	57%	68	28%	73	30%
CAN	190	76	40%	119	63%	66	35%	54	28%
ESP	139	71	51%	71	51%	28	20%	43	31%
CHN	83	28	34%	59	71%	34	41%	25	29%
POL	48	26	53%	23	48%	10	21%	13	27%
RUS	17	8	49%	9	52%	4	26%	4	26%
RSA	15	10	62%	6	38%	2	14%	4	24%
BRA	9	5	54%	4	48%	2	17%	3	31%
IND	7	3	39%	4	63%	2	32%	2	31%

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, Poland and Switzerland. China, Sweden, the U.S., Israel, India, Canada, Korea, Denmark, France 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, Israel, India, the U.S. and Canada, this mostly is the result of large shares of patents in leading-edge technologies, while for Denmark, Japan and Korea 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, Italy, Japan, Austria, France and Korea.

Figure 2: Shares of high-tech patent applications in total patent applications for selected countries, 1995-2019



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 2019, but has stagnated since 2011 and even slightly decreased in the recent years. 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, a rather stable stagnating trend at a high level with some decreases during the financial crisis and a slight rise after 2010 could be observed. Since 2016, a decrease in high-tech shares can be found, but there seems to be a rising trend in 2019.

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 becomes visible, 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 the recent three year, 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, and we once again can observe a growth in 2019.

France was able to increase its high-tech share over the years, although we see a slight decline after 2013. Since 2018, however, the shares have started to increase again. 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 2018. However, a slight decline can be found in 2019. 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 has continued until 2016. Since, then, the numbers seem to have stabilized at a lower level.

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 2009-2011 and 2017-2019 can be found in "agricultural machinery", "units and equipment for automatic data processing machines" and "communication engineering". Among the fields that are growing most slowly in Germany are three rather small fields, namely "photo chemicals", "nuclear reactors and radioactive elements" "technical glass/construction glass". The chemistry related fields, e.g. "organic basic materials", "phar-

maceuticals", "biotechnology and agents" and "inorganic basic materials", can be seen as comparably slowly growing fields within the German technology profile, followed by "electronics".

Table 2: Transnational Patent applications of Germany according by high-technology sectors (absolute, specialization, and growth), 2017-2019

Technology Field	Abs.	RPA	% Growth (09-11=100)
agricultural machinery	1024	75	191.7
units and equipment for automatic data processing machines	1049	-69	157.9
communications engineering	5695	-44	146.1
power generation and distribution	2665	37	132.9
mechanical measurement technology	1404	32	124.1
rubber goods	363	17	121.4
computer	2219	-59	120.4
optics	679	-48	118.9
optical and electronic measurement technology	3135	-8	115.1
aeronautics	849	-20	110.3
machine tools	2726	63	108.7
lamps, batteries etc.	2033	-2	107.3
automobiles and engines	5649	69	105.4
electrical machinery, accessory and facilities	647	11	103.8
electronic medical instruments	926	-49	102.8
Scents and polish	39	-33	101.8
electrical appliances	688	13	100.8
pumps and compressors	747	38	98.6
office machinery	51	-68	98.6
rail vehicles	285	68	98.4
broadcasting engineering	684	-85	98.3
air conditioning and filter technology	1907	30	96.2
medical instruments	2672	-17	95.9
optical and photooptical devices	68	-83	94.8
special purpose machinery	3297	20	94.6
electrical equipment for internal combustion engines and vehicles	1039	56	88.8
other special chemistry	871	2	82.3
biotechnolgy and agents	1375	-61	80.5
electronics	1289	-36	79.9
pharmaceuticals	1044	-51	79.3
organic basic materials	1309	1	79.2
power machines and engines	2862	54	76.3
inorganic basic materials	318	-16	75.2
pesticides	374	3	71.1
weapons	194	36	64.8
technical glass, construction glass	72	-100	60.7
nuclear reactors and radioactive elements	9	-77	46.3
photo chemicals	1	-81	37.4

Source: EPO – PATSTAT; Fraunhofer ISI calculations

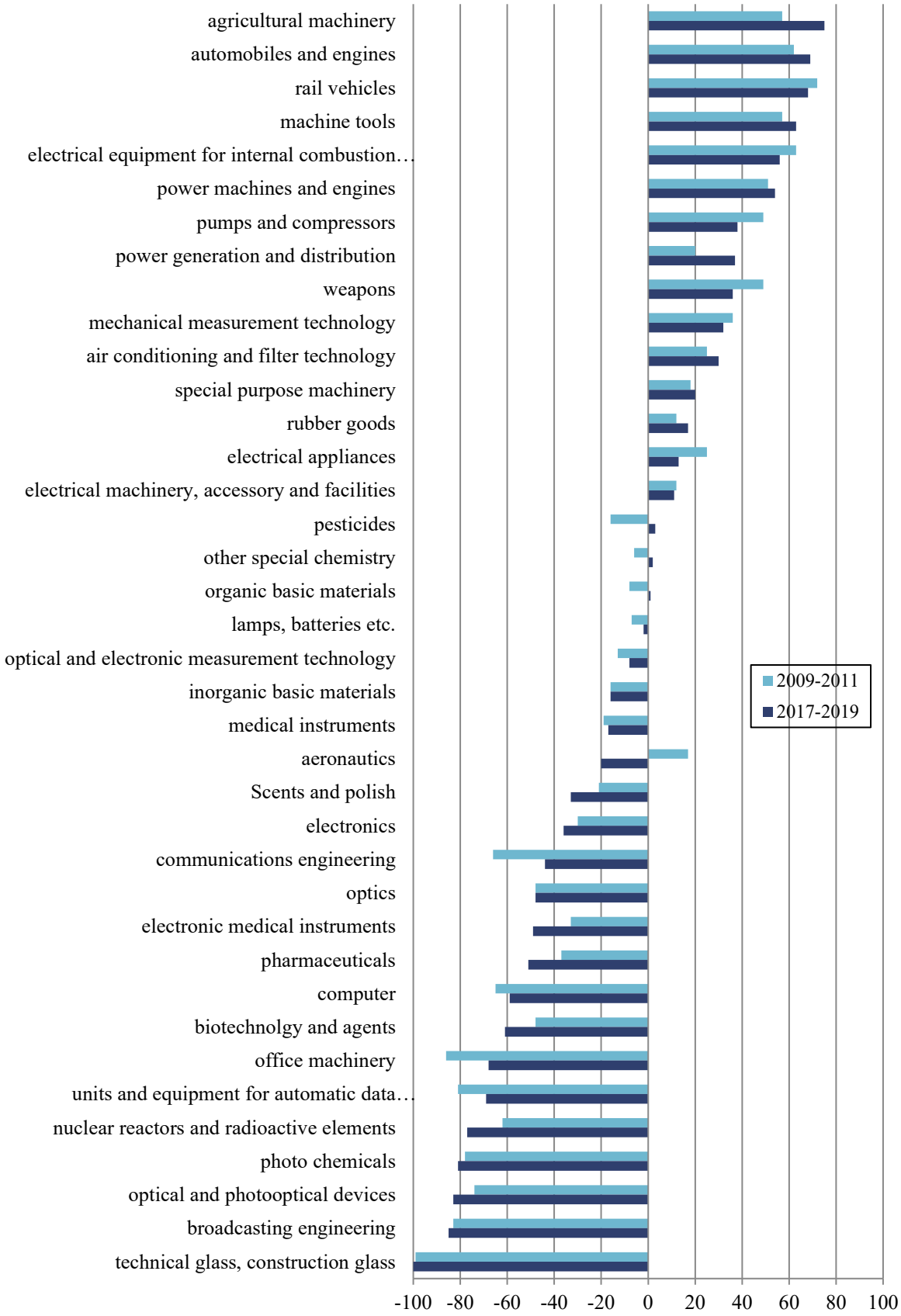
In general, it can be found that most electronics related fields, certain fields in mechanical engineering (especially electrical machinery as well as units and equipment for automatic data processing machines and power generation and distribution) as well as mechanical measurement technology, aeronautics 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 2009-2011 and 2017-2019 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). Comparative disadvantages, reflected in negative specialization indices, can be observed in smaller fields like technical glass, broadcasting engineering, photo chemicals, optical and photooptical devices, nuclear reactors, but also in computers, office machinery. units and equipment for automatic data processing (though growth rates are high), 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 "agricultural machinery" and "power generation and distribution", where Germany has become more specialized in and in "aeronautics", "electrical appliances" and "communications engineering", where Germany has become less specialized in.

Figure 3: Germany's technological profile, 2009-2011 vs. 2017-2019



Source: EPO – PATSTAT; Fraunhofer ISI calculations

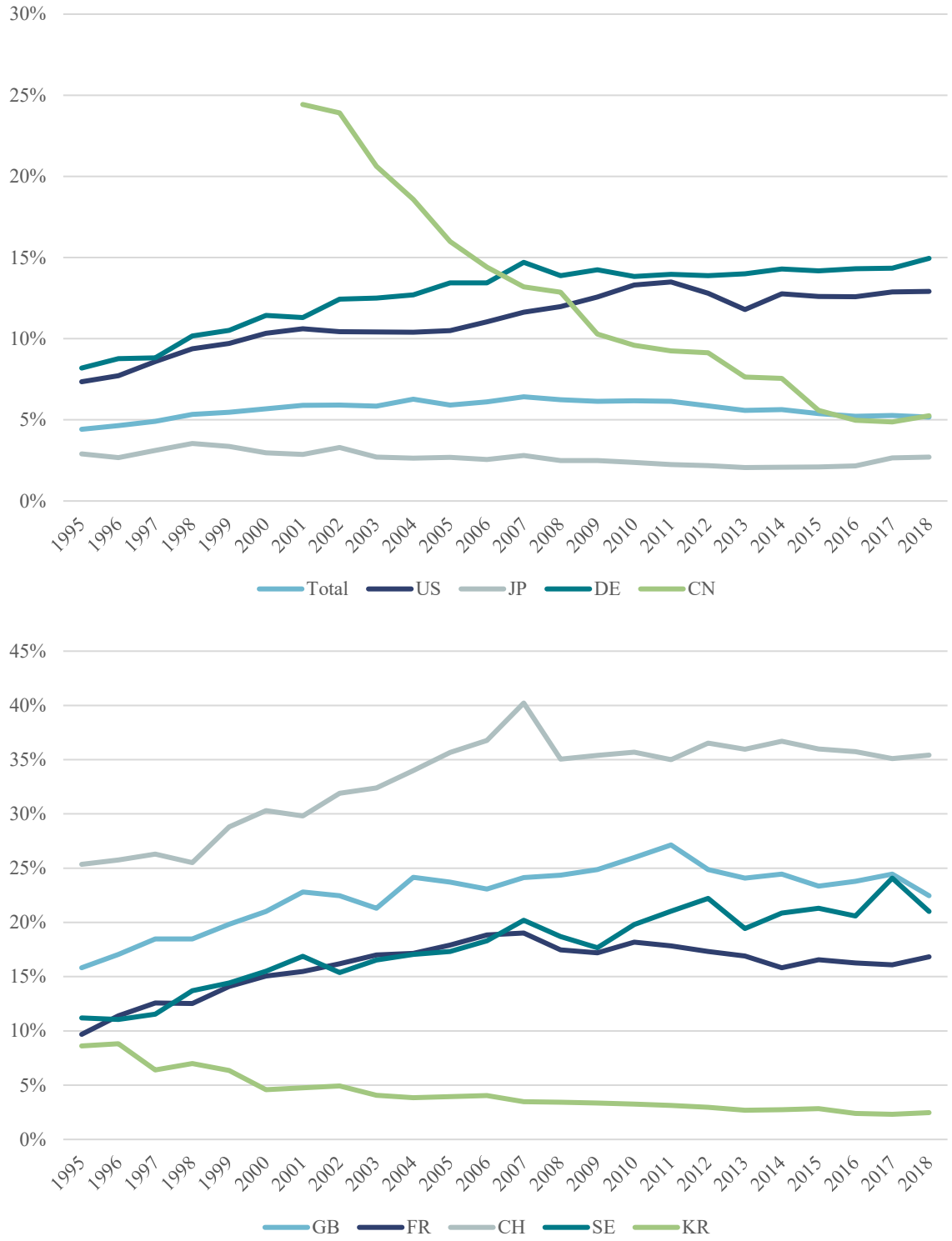
5 International Co-Patenting Trends

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 was lying 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 2018 was reached. Especially since 2011/2012 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.

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 (35%) in 2018. It is followed by Great Britain (22%), Sweden (21%) and France (17%). With a share of 15%, Germany is slightly ahead of the US in terms of co-patent shares with 13%. Apart from these trends over time, Switzerland has the largest co-patenting shares with 35% in 2018. It is followed by Great Britain (22%), Sweden (21%) and France (17%). With a share of nearly 15% in 2018, 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 rather high level, the co-patenting rates have constantly decreased since 2001. 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, yet slightly higher level at least in the early 2000s.

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 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 23.9%. It is followed by Germany with a share of 13.7%. China scores third and with a share of 7.9%. Great Britain and France score fourth and fifth with a share of 6.7% and 6.3%, respectively. Although a small country in absolute terms, Switzerland scores sixth and reaches rather high shares in total transnational co-patents (5.9%) as it is very cooperation intensive. It is followed by Japan, Canada, India, Sweden and Belgium, 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 3.8%, 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 26% of all German co-patents in the period of 2016 to 2018 are filed in cooperation with a U.S. inventor. The next largest partners are Switzerland, France, Austria, Great Britain and China (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 cooperates most strongly with China, Germany, Great Britain, Canada, India and France. Germany is also an important partner for many countries, which is also true for China and for example for Switzerland, which operates collaborations with many partners around the world. China itself is highly oriented towards the U.S. About 47% of all Chinese co-patents are filed in cooperation with a U.S. inventor, followed by Japan and Germany with 12% and 10%, 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, 2016-2018

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IE	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA	Share in total transnational co-patents
AT		0.05%	0.01%	0.02%	0.50%	0.06%	1.15%	0.02%	0.02%	0.14%	0.05%	0.09%	0.00%	0.01%	0.01%	0.08%	0.02%	0.00%	0.05%	0.02%	0.01%	0.12%	0.22%	0.00%	2.65%
BE	58		0.01%	0.05%	0.10%	0.10%	0.50%	0.02%	0.08%	0.03%	0.51%	0.25%	0.02%	0.02%	0.01%	0.09%	0.08%	0.01%	0.28%	0.01%	0.01%	0.03%	0.59%	0.00%	2.85%
BR	7	8		0.02%	0.01%	0.02%	0.06%	0.01%	0.01%	0.00%	0.04%	0.02%	0.01%	0.00%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.26%	0.00%	0.54%
CA	20	59	18		0.06%	0.26%	0.18%	0.02%	0.03%	0.03%	0.18%	0.16%	0.02%	0.04%	0.07%	0.05%	0.05%	0.02%	0.02%	0.01%	0.02%	0.14%	2.03%	0.01%	3.50%
CH	562	112	16	71		0.17%	1.73%	0.07%	0.07%	0.04%	0.92%	0.32%	0.03%	0.04%	0.11%	0.34%	0.10%	0.02%	0.12%	0.04%	0.02%	0.11%	0.93%	0.01%	5.89%
CN	64	108	17	298	196		0.75%	0.07%	0.05%	0.21%	0.23%	0.33%	0.03%	0.05%	0.13%	0.07%	0.93%	0.13%	0.04%	0.03%	0.11%	0.37%	3.71%	0.01%	7.85%
DE	1297	559	70	204	1950	841		0.21%	0.32%	0.19%	1.29%	0.81%	0.08%	0.12%	0.44%	0.48%	0.45%	0.13%	0.55%	0.19%	0.09%	0.51%	3.51%	0.02%	13.74%
DK	23	17	9	26	81	74	232		0.03%	0.03%	0.05%	0.13%	0.00%	0.01%	0.05%	0.02%	0.02%	0.00%	0.06%	0.02%	0.00%	0.20%	0.27%	0.00%	1.30%
ES	27	86	13	36	83	52	363	36		0.03%	0.20%	0.17%	0.03%	0.04%	0.03%	0.12%	0.02%	0.00%	0.08%	0.03%	0.01%	0.07%	0.45%	0.00%	1.89%
FI	156	39	4	32	50	236	214	36	36		0.02%	0.08%	0.01%	0.01%	0.04%	0.03%	0.05%	0.01%	0.03%	0.06%	0.02%	0.34%	0.21%	0.00%	1.61%
FR	61	580	47	206	1037	261	1458	61	220	20		0.45%	0.03%	0.06%	0.08%	0.27%	0.14%	0.05%	0.15%	0.06%	0.01%	0.08%	1.40%	0.00%	6.30%
GB	103	281	23	180	366	373	911	149	192	90	510		0.12%	0.07%	0.16%	0.15%	0.15%	0.08%	0.19%	0.05%	0.03%	0.20%	2.65%	0.03%	6.70%
IE	3	27	7	17	30	32	89	2	31	10	32	138		0.02%	0.03%	0.02%	0.01%	0.00%	0.01%	0.00%	0.00%	0.02%	0.37%	0.00%	0.86%
IL	7	21	2	50	50	62	135	12	48	7	63	74	20		0.04%	0.02%	0.02%	0.01%	0.02%	0.01%	0.06%	0.01%	0.93%	0.00%	1.61%
IN	12	16	19	75	126	143	493	52	31	45	95	182	30	41		0.06%	0.08%	0.10%	0.06%	0.01%	0.00%	0.07%	1.79%	0.00%	3.39%
IT	90	102	15	51	384	79	537	23	136	35	307	164	25	20	64		0.03%	0.01%	0.08%	0.02%	0.01%	0.09%	0.52%	0.00%	2.56%
JP	21	90	5	55	115	1054	511	17	24	51	155	171	7	21	88	36		0.14%	0.06%	0.00%	0.01%	0.04%	1.38%	0.00%	3.78%
KR	4	16	4	24	24	152	142	3	3	9	62	90	0	14	113	9	163		0.03%	0.00%	0.04%	0.01%	0.54%	0.00%	1.36%
NL	60	311	3	27	135	44	624	63	87	35	172	212	13	25	69	92	67	32		0.01%	0.01%	0.07%	0.76%	0.01%	2.69%
PL	19	11	0	14	43	31	210	23	30	68	71	56	4	6	15	24	3	5	8		0.01%	0.03%	0.17%	0.00%	0.77%
RU	14	7	1	18	21	126	101	4	6	19	12	35	2	72	4	9	8	44	11	6		0.00%	0.42%	0.00%	0.88%
SE	134	39	35	156	128	412	574	222	79	380	92	228	27	10	82	106	45	9	84	29	4		0.70%	0.00%	3.25%
US	249	664	289	2293	1051	4187	3961	301	506	241	1577	2991	422	1052	2019	582	1555	613	852	187	472	785		0.05%	23.87%
ZA	2	2	1	11	7	8	18	0	3	1	5	35	0	2	4	1	0	0	7	1	1	2	60		0.15%
Total	2993	3213	613	3941	6638	8850	15494	1466	2128	1814	7104	7554	968	1814	3818	2891	4262	1535	3033	864	997	3662	26909	171	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, 2016-2018

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IE	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA
AT		2%	1%	1%	8%	1%	8%	2%	1%	9%	1%	1%	0%	0%	0%	3%	0%	0%	2%	2%	1%	4%	1%	1%
BE	2%		1%	1%	2%	1%	4%	1%	4%	2%	8%	4%	3%	1%	0%	4%	2%	1%	10%	1%	1%	1%	2%	1%
BR	0%	0%		0%	0%	0%	0%	1%	1%	0%	1%	0%	1%	0%	0%	1%	0%	0%	0%	0%	0%	1%	1%	1%
CA	1%	2%	3%		1%	3%	1%	2%	2%	2%	3%	2%	2%	3%	2%	2%	1%	2%	1%	2%	2%	4%	9%	6%
CH	19%	3%	3%	2%		2%	13%	6%	4%	3%	15%	5%	3%	3%	3%	13%	3%	2%	4%	5%	2%	3%	4%	4%
CN	2%	3%	3%	8%	3%		5%	5%	2%	13%	4%	5%	3%	3%	4%	3%	25%	10%	1%	4%	13%	11%	16%	5%
DE	43%	17%	11%	5%	29%	10%		16%	17%	12%	21%	12%	9%	7%	13%	19%	12%	9%	21%	24%	10%	16%	15%	11%
DK	1%	1%	1%	1%	1%	1%	1%		2%	2%	1%	2%	0%	1%	1%	1%	0%	0%	2%	3%	0%	6%	1%	0%
ES	1%	3%	2%	1%	1%	1%	2%	2%		2%	3%	3%	3%	3%	1%	5%	1%	0%	3%	3%	1%	2%	2%	2%
FI	5%	1%	1%	1%	1%	3%	1%	2%	2%		0%	1%	1%	0%	1%	1%	1%	1%	1%	8%	2%	10%	1%	1%
FR	2%	18%	8%	5%	16%	3%	9%	4%	10%	1%		7%	3%	3%	2%	11%	4%	4%	6%	8%	1%	3%	6%	3%
GB	3%	9%	4%	5%	6%	4%	6%	10%	9%	5%	7%		14%	4%	5%	6%	4%	6%	7%	6%	4%	6%	11%	20%
IE	0%	1%	1%	0%	0%	0%	1%	0%	1%	1%	0%	2%		1%	1%	1%	0%	0%	0%	0%	0%	1%	2%	0%
IL	0%	1%	0%	1%	1%	1%	1%	1%	2%	0%	1%	1%	2%		1%	1%	0%	1%	1%	1%	7%	0%	4%	1%
IN	0%	0%	3%	2%	2%	2%	3%	4%	1%	2%	1%	2%	3%	2%		2%	2%	7%	2%	2%	0%	2%	8%	2%
IT	3%	3%	2%	1%	6%	1%	3%	2%	6%	2%	4%	2%	3%	1%	2%		1%	1%	3%	3%	1%	3%	2%	1%
JP	1%	3%	1%	1%	2%	12%	3%	1%	1%	3%	2%	2%	1%	1%	2%	1%		11%	2%	0%	1%	1%	6%	0%
KR	0%	0%	1%	1%	0%	2%	1%	0%	0%	0%	1%	1%	0%	1%	3%	0%	4%		1%	1%	4%	0%	2%	0%
NL	2%	10%	0%	1%	2%	0%	4%	4%	4%	2%	2%	3%	1%	1%	2%	3%	2%	2%		1%	1%	2%	3%	4%
PL	1%	0%	0%	0%	1%	0%	1%	2%	1%	4%	1%	1%	0%	0%	0%	1%	0%	0%	0%		1%	1%	1%	1%
RU	0%	0%	0%	0%	0%	1%	1%	0%	0%	1%	0%	0%	0%	4%	0%	0%	0%	3%	0%	1%		0%	2%	1%
SE	4%	1%	6%	4%	2%	5%	4%	15%	4%	21%	1%	3%	3%	1%	2%	4%	1%	1%	3%	3%	0%		3%	1%
US	8%	21%	47%	58%	16%	47%	26%	21%	24%	13%	22%	40%	44%	58%	53%	20%	36%	40%	28%	22%	47%	21%		35%
ZA	0%	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%	100%

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

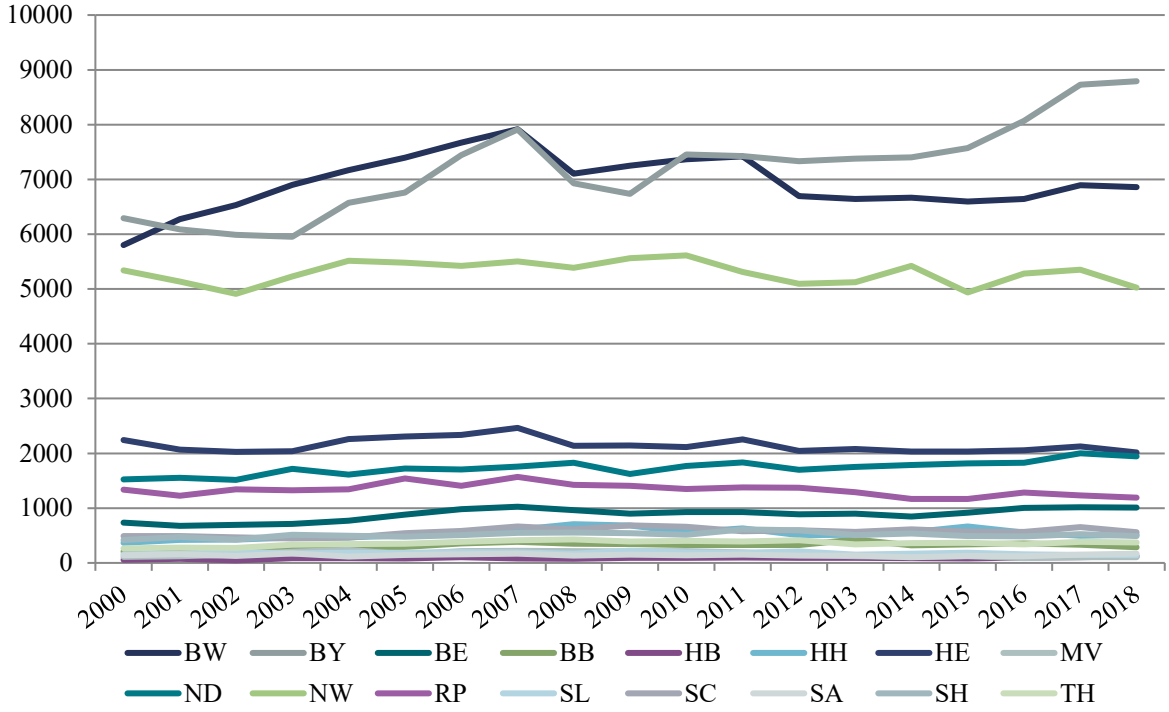
Note: The colors in the table indicate the importance of collaboration partners for a given country (vertically). Green resembles the most important partners (largest share of co-patents in a country's total co-patents), red resembles the least important partners.

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. Between 2008 and 2010, we can observe decreases to a larger or lesser extent for many of the federal states due to the economic crisis. In the recent years, the figures have slightly increased for Bavarian, Baden-Württemberg and North Rhine-Westphalia.

The largest number of transnational filings within the German comparison can be found in the southern part. Bavaria ranks first, with nearly 9,000 filings in 2018, followed by Baden-Württemberg (about 6,900 filings in 2019) and North Rhine-Westphalia at a slightly lower level (about 5,000 filings in 2018). 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, closely 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. Berlin follows after Rhineland-Palatinate, with slightly more than 1,000 filings in 2018. 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

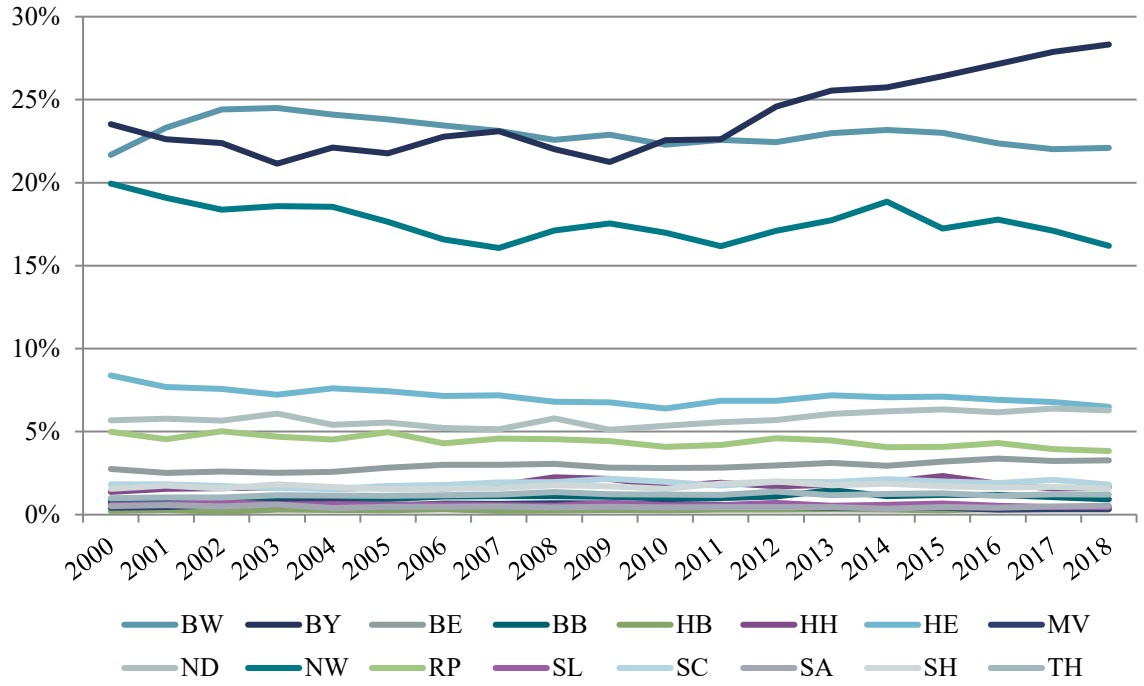


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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.).

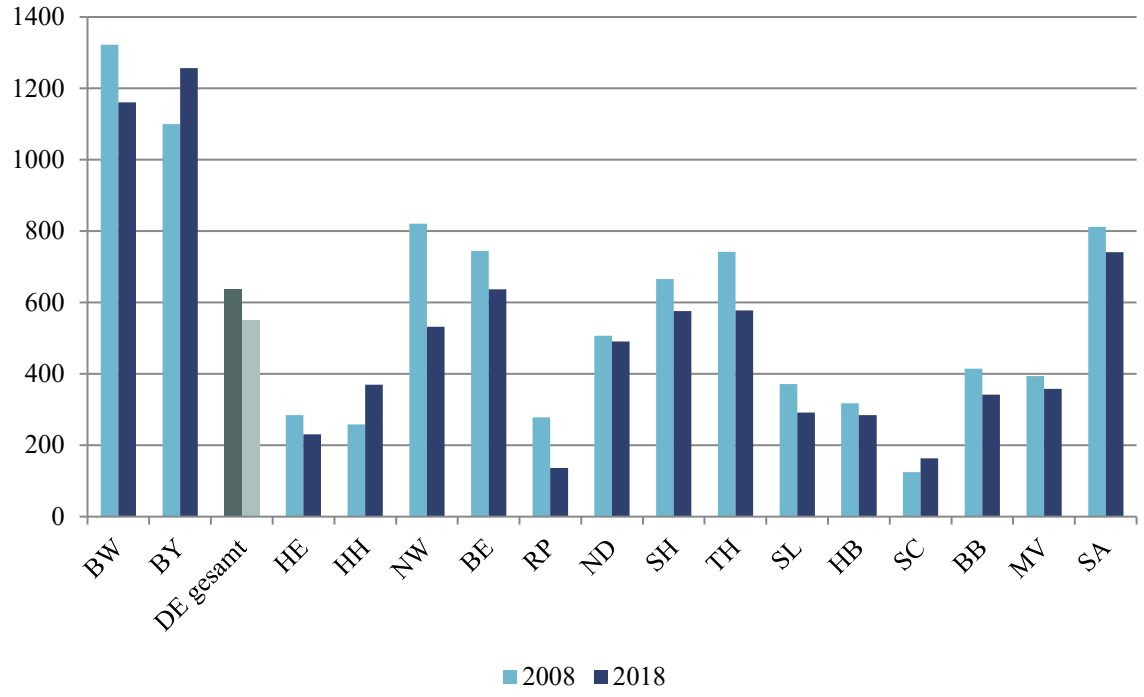
Note: BW=Baden-Württemberg, BY=Bavaria, BE=Berlin, BB=Brandenburg, HB=Bremen, HH=Hamburg, HE=Hesse, MV=Mecklenburg-West Pomerania, ND=Lower-Saxony, NW=North Rhine-Westphalia, RP=Rhineland-Palatinate, SL=Saarland, SC=Saxony, SA=Saxony-Anhalt, SH=Schleswig-Holstein, TH=Thuringia.

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)



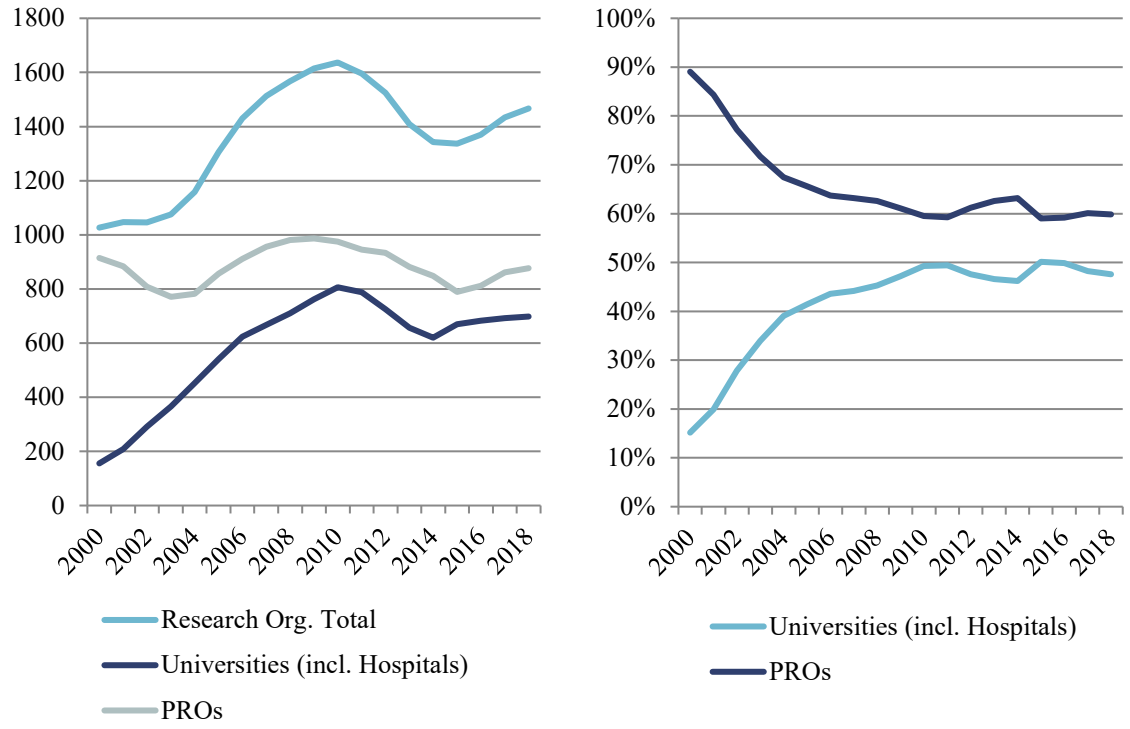
Source: EPO – PATSTAT; Statistisches Bundesamt, calculations by Fraunhofer ISI

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. Baden-Württemberg's intensity has decreased since 2008, while Bavaria's intensity has increased between 2008 and 2018. North-Rhine Westphalia, on the other hand, which scored third in absolute terms, loses ground and scores in the mid-field within this comparison.

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



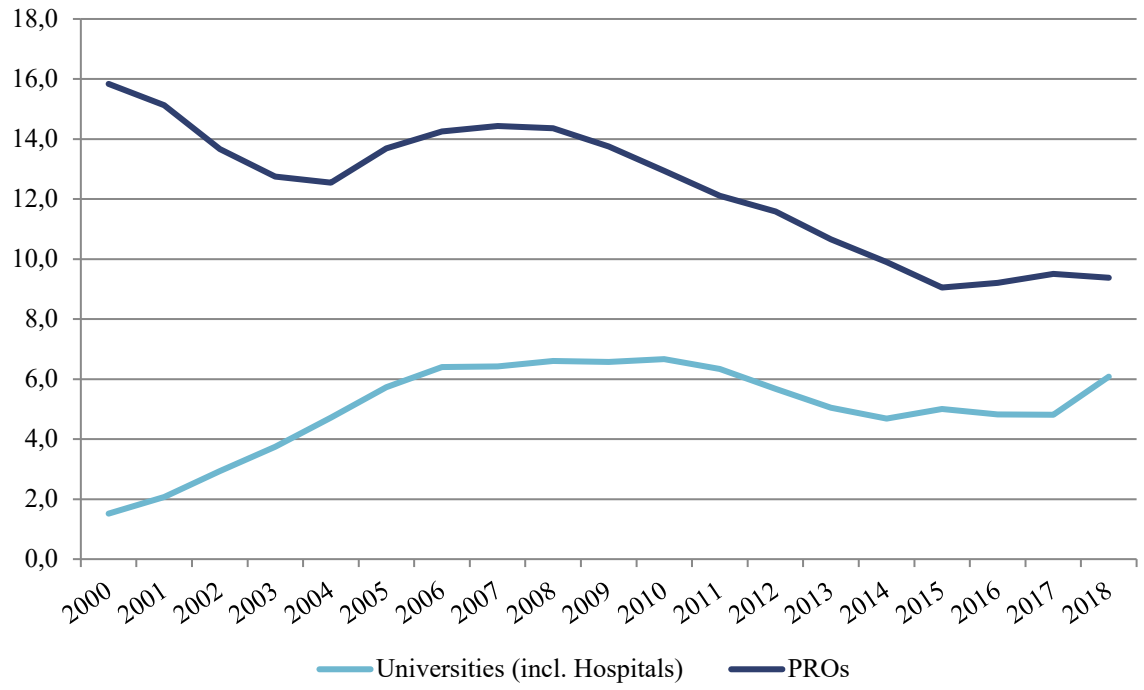
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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 et al. 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 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 2018, research organizations (in total) were responsible for 1,466 transnational patent filings. About 700 of those were filed by universities, while about 880 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 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 lower than for PROs. The intensity of PRO is nearly two 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.

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