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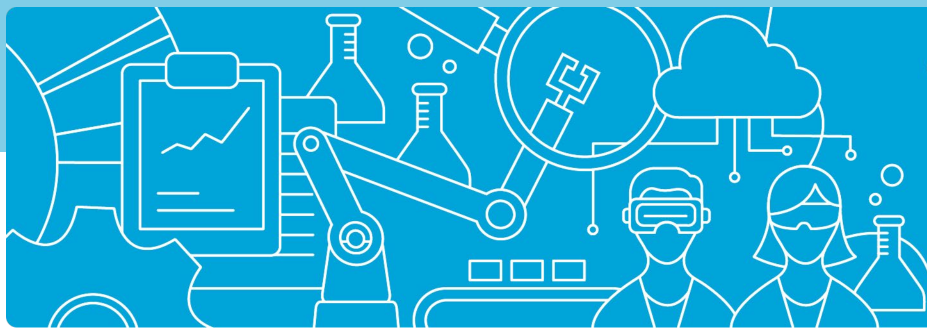

Peter Neuhäusler, Oliver Rothengatter, Alexander Feidenheimer

Patent Applications – Structures, Trends and Recent Developments 2020

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Durchführendes Institut
Fraunhofer Institut für System- und Innovationsforschung (ISI)
Breslauer Straße 48, 76139 Karlsruhe
www.isi.fraunhofer.de

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Expertenkommission Forschung und Innovation (EFI)

Geschäftsstelle
Pariser Platz 6 | 10117 Berlin
www.e-fi.de

Kontakt und weitere Informationen
Dr. Peter Neuhäusler
Fraunhofer Institut für System- und Innovationsforschung (ISI)
Breslauer Straße 48, 76139 Karlsruhe
T + 49 (0) 721 68 09 33 5
M Peter.Neuhaeusler@isi.fraunhofer.de

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0 Summary

Core indicators

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. After 2010, however, the growth resumed with filing numbers in 2010 already being above the pre-crisis level. The largest country at the international level in terms of patent filings is the U.S. where a growth of patent filings could be observed in the recent years. China, which has shown very large growth rates over the last few years is at a slightly higher level than Japan in the number of transnational filings in 2018. However, the growth of Chinese filings has slowed down a bit. Japan, also showing a growth in the number of patent filings lately, scores third followed by Germany, where also an increase in filing figures can be observed after 2015. In 2018, however, the number of filings is at a similar level as in 2017. In terms of patent intensities, smaller countries like Switzerland, Sweden and Finland are at the top of the list. Japan, though outranked by China in absolute terms, scores third in terms of patent intensities, even ahead of Finland. South Korea and Germany are fifth and sixth within the comparison of patent intensities, followed by Denmark and Israel.

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 the same level with France. Denmark, Germany. Japan and Austria 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 2008-2010 and 2016-2018 can be found in "agricultural machinery", "units and equipment for automatic data processing machines", followed by "power generation and distribution", "rubber goods", "communication engineering", "electrical machinery, accessory and facilities" and "optics".

International Co-Patenting Trends

The shares of transnational co-patents in all transnational patents of the respective inventor country is highest in smaller countries which generally tend cooperate more often – for 2017 i.e. Switzerland (35%) as well as Great Britain and Sweden (both 24%). In Germany, this value is around 14%, and in U.S. 13%. Regarding cooperation patterns, the U.S. appears to be the most frequent partner among all countries in comparison. Germany is also a highly significant collaboration partner among all countries as it is ranked second after the U.S. in many cases. In terms of technological areas, western countries tend to cooperate more often in less-R&D intensive technologies, while eastern countries cooperate more often in leading-edge technologies.

Patent Activities of the German Federal States

The largest number of transnational filings within the German comparison can be found in Bavaria, followed by Baden-Württemberg and North Rhine-Westphalia. The three states together are responsible for slightly more than two thirds of all German transnational filings. Since only about half of the German employees are located in these states, the patent intensity there is comparably high. In sum, however, we see a decline in patent filings and consequently also patent intensities across nearly all of the German federal states since 2007. Broken down by NUTS-2 regions it can be found that Oberbayern, followed by Stuttgart, Karlsruhe, Düsseldorf, Darmstadt and Köln are the largest regions in terms of patent filings

When looking at the filing figures of the European regions compared to the German federal states, it is clearly Paris with the largest number of transnational filings, though the figures only grew slightly over the years since 2005. Paris is followed by Southern Netherlands, where - after a sharp decline due to the financial crisis - a major increase can be observed after 2012. The Rhône-Alpes region is the third largest region in our comparison, followed by Lombardy, Flanders and Stockholm.

Patenting Trends in Public Research

The analysis of filings by universities and public research institutes (PROs) shows that the number of transnational patent filings has been stagnating for universities in recent years while it has increased for PROs. This trend is mirrored in the shares of filings by universities and PROs in total filings by German research organizations, i.e. after a convergence of filings in the 2000's the figures now are once again starting to slightly drift apart. Still, nearly 50% of all filings of German research organizations have a university listed as an applicant. The patent intensities for the universities and PROs are lower than in the 2000's, with PROs in sum still being more patent intensive than universities.

When analyzing academic patents, i.e. patents filed by universities plus patents on which university personnel is named as an inventor, the picture slightly changes. Nearly 40% of patents from universities are "hidden" when only taking the applicant perspective into account, while this number is much lower for the PROs (about 8%). This also has an effect on the patent intensities, i.e. the difference between universities and PROs is much smaller when taking academic patents into account. In interesting further effect can be observed when looking at the distribution of applicants of academic patents to see who "owns" an academic patent. For universities, a major shift between the 2000's and the recent years can be observed. The share of single inventors has decreased while the university files a much larger share of patents itself, which can be seen as a result of the abolishment of the "Hochschullehrerprivileg" in the early 2000's. Apart from that, a slight growth in firms being applicants of academic patents can be observed, which is especially true for large enterprises.

Trends in EUIPO trademarks

The general trends in trademark filings show a rather constant increase across the whole time period - except during the financial crisis. The largest group of filings are the marks on goods, followed by mixed goods/services and pure service marks. For non-European countries, the share for product marks is much higher than for European countries (except Italy). This can be attributed to the fact that cross-border trade is less common for services than for goods.

The trademark intensities show that the Scandinavian countries have the highest values (Sweden, Finland and Denmark), followed by Austria. Germany, France and Great Britain. The specialization profiles show that Germany's activities are spread across the whole range of NICE classes. Germany thus shows positive specialization values in most of the fields. However, a rather clear specialization to the fields related to machines and metals as well as rubber goods can be observed. Among the service related classes, Germany is most specialized in "treatment of materials", "building construction" and "telecommunications".

Based on our newly developed bottom-up classification approach, we can investigate trademarks applications even in much more detail comparing to NICE classes. From this perspective, the largest class for Germany is "information technology and audio-visual, multimedia and photographic devices", followed by "Advertising; marketing and promotional services", "IT services" and "Business assistance, management and administrative services".

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 a commonly used tool to assess the technological performance of countries or innovation systems. Patents can thereby be 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 perspective, 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 (Gehrke et al., 2020). 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 1996. For the interpretation, however, 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" and we will analyze patents by German universities and public research institutes to gain insights into the technological performance of the German science system. Finally, as a complementary innovation indicator to patents, we analyze trademark filings in an international comparison.

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 in this report are seen – first and foremost – as an output of R&D processes, using this relation between invention and filing is 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.

For the analyses of community trademarks, the data provided by the EUIPO was used. Based on their flat files, we created an offline SQL database containing registered community trademarks from 1996 onwards. This data allows differentiated analyses of EUIPO trademark filings over time and across countries. However, using the EUIPO data means a slight break in the series as we have used data from the German Patent and Trademark Office in earlier reports. Especially because the EUIPO database does not include all information regarding country codes, which leads to lower filings figures in the country-wise statistics in

1 Revealed Patent Advantage.

general, yet with highly similar trends. In addition to country-wise statistics and international comparisons, trademarks can be differentiated by NICE classes. The NICE classification is an international classification of goods and services that is utilized for the registration of trademarks. It has been established by the Nice Agreement in 1957 and comprises 45 classes. The classes 1 to 34 refer to goods, while classes 35 to 45 are services. The classes define the scope and the context of each trademark filing and are provided by the applicants themselves.

Since several classes are assigned to one trademark, each trademark is counted once for each NICE class it has been assigned to, i.e. the sum of trademarks across NICE classes is larger than the total amount of trademarks filed (whole-count method). Since the applicant provides the classes and has the option of assigning a multitude of classes, the classification, however, only offers limited insight. A description of the content of the trademark, like an abstract, as in the case of patents, is not available.

In order to overcome this issue, we have generated an in-depth classification of trademarks with more than 8.000 classes. It is the result of a matching of the trademark descriptions provided by the applicant upon registration with the pre-defined list of keywords the applicant can choose from the online platform "TMClass". In sum, we were able to assign at least one class to 85% of all EUIPO trademark filings. For more details on the construction of the classification see Neuhäusler et al. (2019).

Table 1: Definition of technology and knowledge-intensive NICE-classes

Nr.	Name	NICE classes
1	Chemistry	1, 2, 3, 4, 13
2	Pharmaceuticals	5
3	Metals	6
4	Machines	7, 8
5	Electronics (components, instruments)	9, 14
6	Medical technologies	10
7	Electronic devices	11
8	Vehicles	12
9	Management	35
10	Finance	36
11	Repair	37
12	Telecommunications	38
13	Transport	39
14	Material treatment	40
15	Entertainment	41
16	Other services	42 (43, 44, 45)

Source: Schmoch and Gauch (2009)

In sum, the differentiation of trademarks across NICE classes has to be made with caution. In addition to the NICE classes and our own in-depth classification, we will further apply a differentiation of product marks, service marks and mixed marks, i.e. marks that are assigned NICE classes referring to goods as well as NICE classes referring to services. In a more finegrained disaggregation, we further resort to the definition of "research-intensive services" with regard to service marks by Schmoch and Gauch (2009), where the classes 35, 36, 38, 41, 42, 43, 44, 45 are regarded as research-intensive services. In the case of products, we will concentrate on eight fields that have been defined as having a high technology relatedness, i.e. they can be seen as potentially research-intensive. The definition of these eight fields can be found in Table 1.

In parallel to the analyses of patent filings, we will calculate not only absolute numbers of trademark filings but also trademark intensities - defined as the number of trademark applications per 1 million labor force - to account for size effects. On the basis of the NICE Classification, also specialization profiles (RPA) for EU trademarks are presented.

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 for 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 activities, 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 enables 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). Filings for which we could not assign 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

We will analyze patents filed by German universities and public research institutes (PRI). In addition, we will look at academic patents, i.e. patents filed by universities and PRI plus university-invented patents.

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 approach for the identification of the whole set of academic patents, including university-invented patents, is based on the examination of name matches of authors of scientific publications from the Scopus database and inventors named on a patent filing. Publications list the authors’ affiliation and enable us to identify academic inventors and the patents they have contributed to. We do not only identify academic patents for universities but also for public research institutes, to find out whether the effect described for universities can also be found for the PROs.

Based on a keyword search and manual correction, the German universities and PROs were identified within Scopus. The author-/inventor names from these two tables were matched and, to ensure a high precision, complemented with additional selection criteria, especially to avoid homonyms, i.e. different persons having identical names. A more detailed description of the name matching and its validation can be found in Dornbusch et al. (2013) .

For the evaluation of the algorithm a *recall* and *precision* analysis has been applied (Baeza-Yates and Ribeiro-Neto, 2011).The recall was estimated using a benchmark (gold standard) set of 200 author/inventor records.[2] The *precision* of the algorithm was validated by an online-survey covering authors for whom academic patents have been identified.[3] Due to the large datasets with imperfect data, 100% for both recall and precision are impossible. However, in order to obtain the best fit between the two, the F-score[4] was calculated, which represents the harmonized mean between recall and precision. However, as a concession to high precision we have to accept a reduced recall, i.e. the retrieved results are likely to underestimate the amount of academic patents and our results so to say are only able to reflect a lower-bound estimate of academic patents.

The number of academic patents cannot easily be compared to the report from earlier series. This has to do with the fact that the most recent version of Scopus (version 2019) was used for the matching, which has a better coverage of scientific journals (across all years) and research organizations in general. In addition, a new regionalization (geocoding) algorithm was used for a better identification of author addresses in Scopus. This has led to slightly lower numbers of academic patents in general, yet with a higher precision of the matching algorithm.

The figures for the patent intensities are calculated as the total number of patent filings per 1,000 employees (full-time equivalents) in the respective universities. The data on university employees were extracted from the German Federal Statistical Office as well as the Federal Report on Research and Innovation 2020. 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 1995. All our analyses were carried out for a selected set of technology-oriented countries[5], 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 USA is the largest technology-providing country at the international level in

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2 Recall: CR/(CR + CM), where CR is Correct Recall and CM is Correct Missing (error type I or false negative); Precision: CR/(CR + IR), where IR is Incorrect Recall (errors type II or false positive).

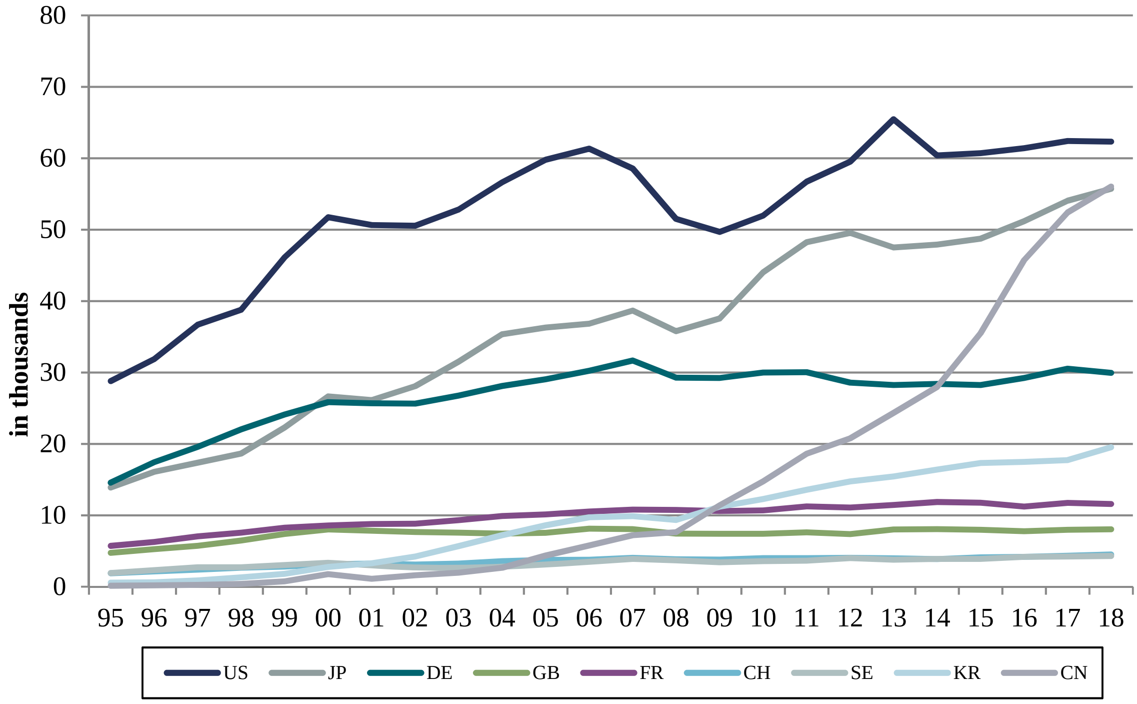
3 The survey addressed 1681 persons with 2782 patent applications at the German patent office. 435 exploitable answers amounting to 678 patents have been received, equaling a response rate of 26%.

4 F-Score: $F\beta = (1+\beta^2)\,(p*r)/(\beta^2*p*r)$; p = precision = tp/(tp+fn) and r = recall = tp/(tp+fp) where tp means true positive, fn false negative and fp false positive.

5 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.

2018, although there has been a slight decline in the last year. China, however, has managed to catch up to the U.S. and has slightly surpassed Japan in terms of absolute number of filings. Yet, a slowdown in the growth of filings in the last two years becomes visible. China is followed by Japan, where a growth in filings can be observed in the recent years, resulting in more than 55,000 transnational patent filings in 2018. Germany follows at rank four, however, with a much smaller number of filings than the U.S., China and Japan. 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 pretty much stagnated 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 with more than 4,000 transnational filings in 2018 and a slight growth in filings over the years.

Figure 1: Absolute number of transnational patent applications for selected countries, 1995-2018



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 2. Here, patent intensities per one million employees are provided, which draws a completely new picture of the country ranks. Although the U.S. is the largest country in absolute terms, it only scores thirteenth in terms of patent intensities. China is located at the nineteenth rank. Smaller countries like Switzerland, Sweden and Finland are at the top of the list of the technology-oriented countries analyzed here. Japan scores third in terms of patent intensities, even ahead of Finland. South Korea and Germany are fifth and sixth within the comparison of patent intensities, followed by Denmark 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 as patents are an important instrument to secure market shares in international technology markets (Frietsch et al., 2014).

Table 2: Patent intensities (patent applications per 1m employees) and shares of technological areas, 2018

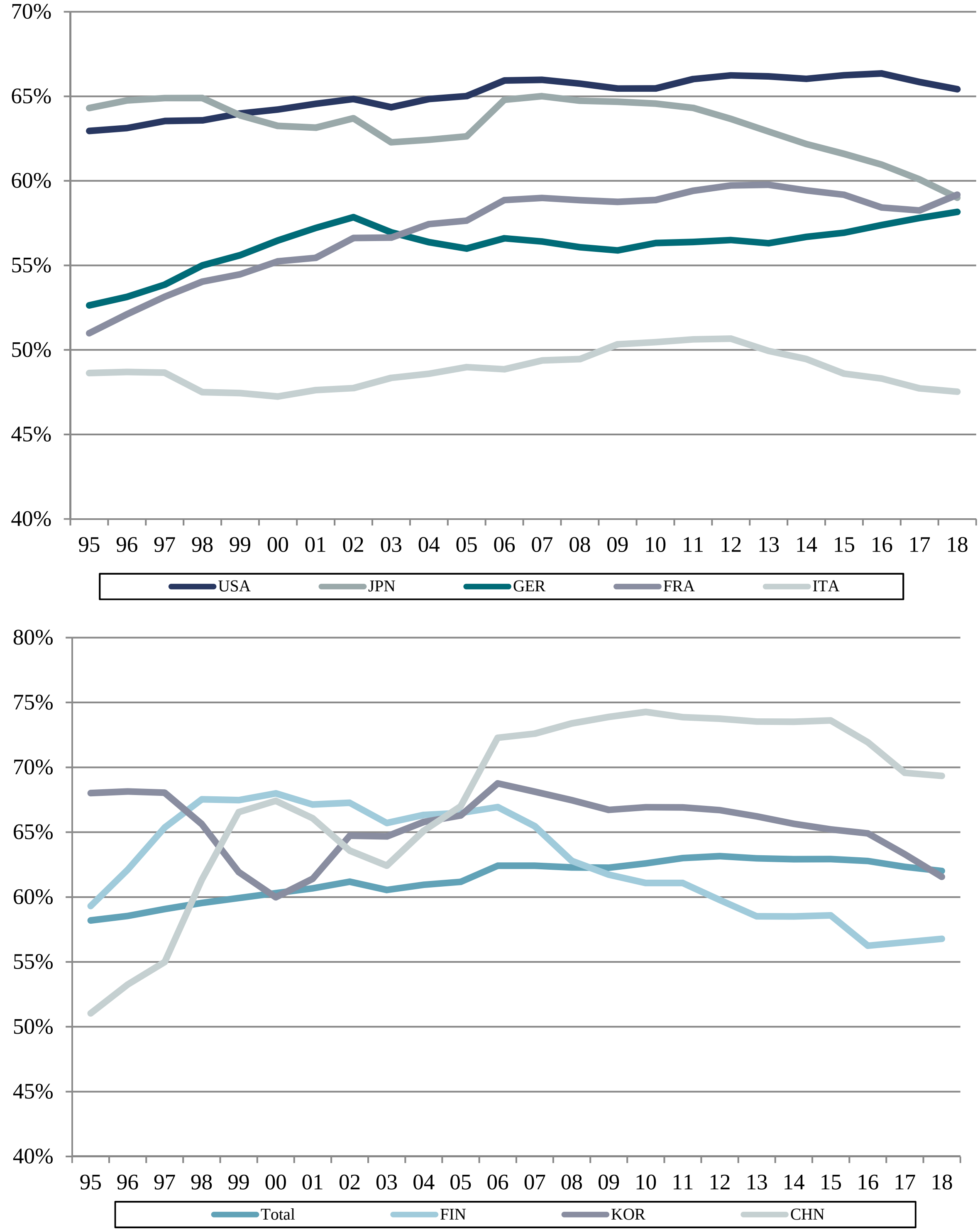
	Total	**Less R&D-intensive**		**High-Tech** of which are:		Leading-edge technologies		High-level technologies	
SUI	966	498	52%	488	51%	167	17%	321	33%
SWE	846	293	35%	572	68%	331	39%	242	29%
JPN	836	363	43%	490	59%	185	22%	305	36%
FIN	772	342	44%	437	57%	263	34%	173	22%
KOR	728	304	42%	445	61%	201	28%	244	33%
GER	715	317	44%	416	58%	141	20%	276	39%
DEK	688	271	39%	430	63%	118	17%	312	45%
ISR	636	241	38%	415	65%	235	37%	180	28%
AUT	619	298	48%	325	53%	106	17%	219	35%
NED	564	273	49%	297	53%	164	29%	132	23%
BEL	431	214	50%	225	52%	87	20%	137	32%
FRA	428	183	43%	255	60%	111	26%	145	34%
USA	400	147	37%	261	65%	134	34%	127	32%
EU-28	356	160	45%	204	57%	82	23%	122	34%
ITA	254	140	55%	121	48%	32	13%	89	35%
GBR	249	109	44%	148	59%	72	29%	76	31%
CAN	196	81	41%	118	60%	65	33%	54	27%
ESP	141	72	51%	72	51%	28	20%	44	31%
CHN	73	25	34%	51	70%	29	40%	21	29%
POL	52	26	49%	27	51%	10	19%	17	33%
RSA	19	12	60%	8	42%	4	18%	4	23%
RUS	17	8	49%	9	51%	4	26%	4	25%
BRA	9	5	56%	4	46%	2	18%	3	28%
IND	7	3	38%	5	64%	3	34%	2	30%

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 2 offers a differentiation of patent intensities by technological areas and displays the respective shares on total patent filings. China, Sweden, the U.S., Israel, India, Denmark, Korea, Canada, and France show the largest shares of patents in high-technology fields. This pattern has already emerged in earlier reports of this series. Regarding Sweden, China, Israel, the U.S., Canada and to a slightly lesser extent also Finland and India, this mostly is the result of large shares of patents in leading-edge technologies. In the case of India and Israel, this can mostly be explained by a high orientation towards the U.S. market. For Denmark, Germany, Japan and Austria, on the other hand, the large shares in high-tech fields are much more an effect of large shares in high-level technologies than in leading-edge technologies. In less R&D intensive fields, the largest shares can be observed for South Africa, followed by Brazil, Italy, Switzerland, Spain Belgium and Poland.

Figure 2: Shares of high-tech patent applications in total patent applications for selected countries, 1995-2018



Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 2 (upper and lower panel) shows the trends in high-tech shares within the national profiles of selected large countries. As can be seen from the picture, the average share of total transnational high-tech patent applications rose from about 58% in 1995 to 62% in 2018. Since 2015, however, the shares have slightly declined. The single countries underwent 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 2006 onwards, we see a slightly rising trend in high-tech shares, with stagnation and even a slight decline after 2015. For China, which now has the largest high-tech shares of the countries in our comparison, 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. Since 2015, however, we see a rather strong decline in the Chinese high-tech shares which continues in 2018. Yet, with 69%, it still has the largest share of high-tech patents in our comparison.

Japan and Korea were the second and third most high-tech active countries in terms of transnational patenting before the shares of China significantly increased. However, both have clearly lost ground compared to the U.S. at the end of the 1990s and beginning of 2000s. Though they have managed to catch up afterwards, a decreasing trend in Japanese high-tech shares after 2011 could be observed, which can also be found for Korea. However, both countries still show comparably large shares in high-tech patents. France was able to increase its high-tech share over the years, although we see a slight decline after 2013, which has become less pronounced in the last two years. 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, a growth can be observed which led to a similar high-tech share as France in 2018. Each year, the high-tech shares of Germany increased up to a level of 58% in 2018. 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. Yet, in the last two years it seems that the Finish high-tech shares stagnated at a lower level.

4.2 Technology Profiles and Specialization Patterns

In this section, we provide a deeper insight into the transnational patent applications by German inventors according to the classification of 38 technology fields of the high-tech sector (Gehrke et al., 2013). The absolute number, specialization and the percentage growth of German transnational patent applications by technology fields are displayed in Table 3. The largest growth rates between the periods 2008-2010 and 2016-2018 can be found in "agricultural machinery", "units and equipment for automatic data processing machines", followed by "power generation and distribution", "rubber goods", "communication engineering", "electrical machinery, accessory and facilities" and "optics". Thus, especially "communication engineering" and "units and equipment for automatic data processing machines" have grown at a quicker pace then in the recent years. The fields that are growing most slowly in Germany are three rather small fields, namely "photo chemicals", "nuclear reactors and radioactive elements", weapons" but also "pesticides, "technical glass/construction glass" and "pharmaceuticals". Here, a declining trend has already been observed in earlier reports of this series.

Table 3: Transnational Patent applications of Germany according by high-technology sectors (absolute, specialization, and growth), 2016-2018

Technology Field	Abs.	RPA	% Growth (08-10=100)
agricultural machinery	980	75	214.6
units and equipment for automatic data processing machines	961	-73	163.5
power generation and distribution	2586	34	140.4
rubber goods	372	13	137.3
communications engineering	5421	-46	134.5
electrical machinery, accessory and facilities	657	12	130.3
optics	693	-44	129.6
mechanical measurement technology	1361	30	124.0
aeronautics	844	-23	114.1
lamps, batteries etc.	1982	-3	113.7
rail vehicles	314	70	112.8
optical and electronic measurement technology	2983	-13	111.6
automobiles and engines	5757	68	110.4
pumps and compressors	785	38	109.3
electrical appliances	698	10	107.9
optical and photooptical devices	73	-82	106.3
machine tools	2627	62	105.4
computer	2028	-63	105.1
medical instruments	2669	-18	103.5
electrical equipment for internal combustion engines and vehicles	1172	60	100.9
air conditioning and filter technology	1922	30	99.9
special purpose machinery	3346	19	93.7
broadcasting engineering	602	-87	92.7
Scents and polish	32	-45	91.7
power machines and engines	3179	55	87.4
electronic medical instruments	876	-54	86.4
other special chemistry	890	1	83.2
electronics	1312	-31	83.1
office machinery	58	-63	82.6
organic basic materials	1364	5	79.0
inorganic basic materials	318	-18	77.4
biotechnolgy and agents	1380	-59	77.3
pharmaceuticals	1055	-49	76.7
technical glass, construction glass	70	-100	71.8
pesticides	395	6	65.0
weapons	184	30	59.0
nuclear reactors and radioactive elements	8	-84	39.2
photo chemicals	0	-98	7.2

Source: EPO – PATSTAT; Fraunhofer ISI calculations

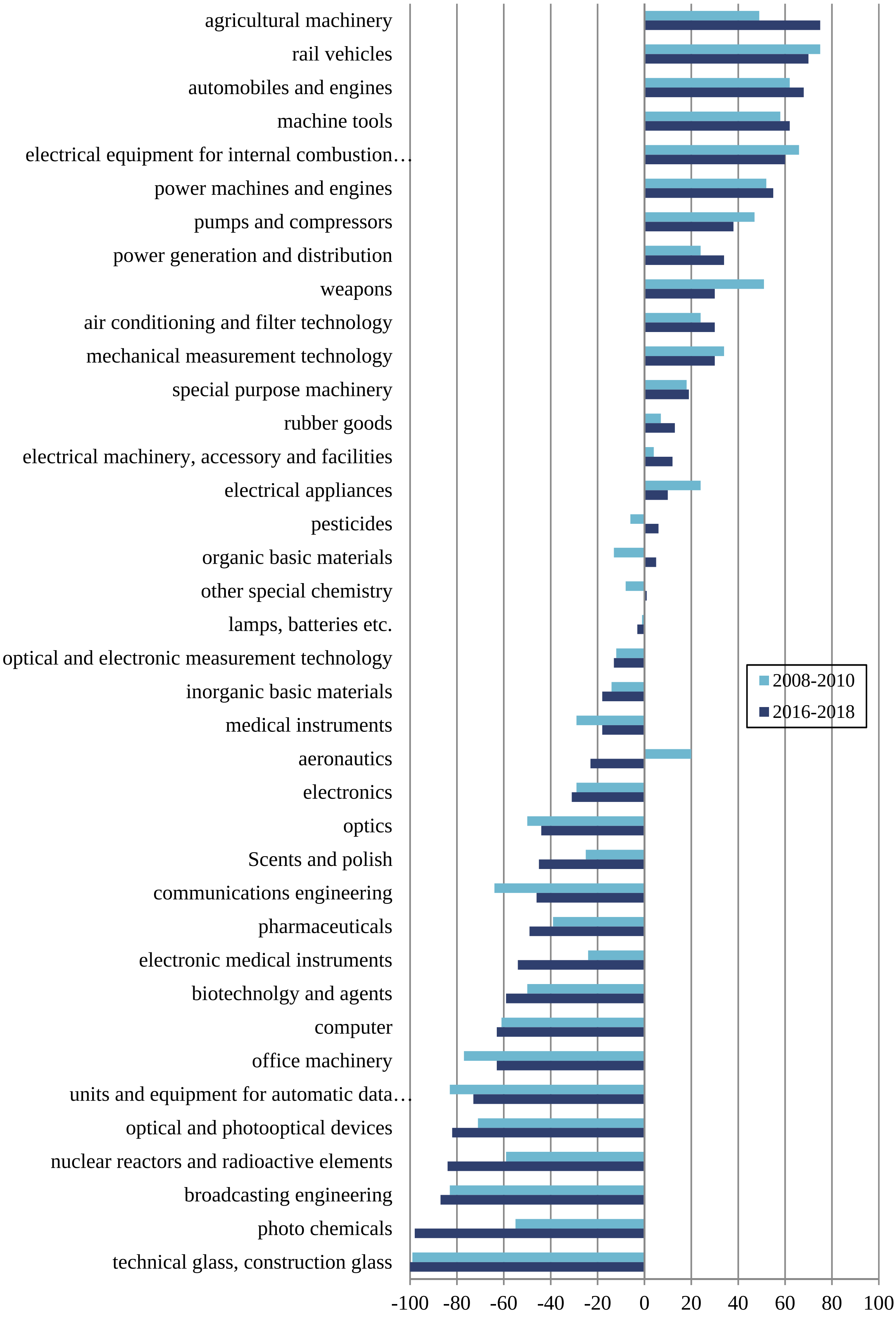
Yet, also further chemistry related fields, e.g. "inorganic basic materials", "biotechnology and agents", "organic basic materials and "other special chemistry", can be seen as comparably slowly growing fields within the German technology profile, followed by the ICT and electrical engineering related fields of "electronics", "power machines and engines", "electronic medical instruments" and "broadcasting engineering".

In general, it can be found that many electronics related fields, certain fields in mechanical engineering (especially agricultural machinery, 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 and certain ICT related fields do not show very high growth rates. In electrical engineering, there seems to be a split as some fields are growing rather strongly while other only show negative 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. In the case of "special purpose machinery" even a decline becomes visible.

The specialization (RPA) of the German technology profile of the years 2008-2010 and 2016-2018 is shown in Figure 3. Germany has positive specialization values 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, which is a trend that already emerged in earlier years.

An average activity rate in patenting can be found in chemistry (organic basic materials, other special chemistry, pesticides), where there has been a positive development in terms of the German technology specialization compared to the 2008-2010 period. Comparative disadvantages, reflected in negative specialization indices, can especially be found in smaller fields like technical glass, photo chemicals, broadcasting engineering, nuclear reactors and optical and photo-optical devices, but also in computers, units and equipment for automatic data processing and office machinery, implying that Germany does not have an outstanding profile in these sectors in international technology markets. Yet, there is still a major growth 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", "power generation and distribution", "rubber goods", "organic basic materials", "pesticides" and "electrical machinery", where Germany has become more specialized, whereas in "aeronautics", "electronic medical instruments", "electrical appliances", "weapons" and "nuclear reactors" and "photo chemicals" Germany has become less specialized.

Figure 3: Germany's technological profile, 2008-2010 vs. 2016-2018



Source: EPO – PATSTAT; Fraunhofer ISI calculations

5 International Co-Patenting Trends

International co-patenting plays a crucial role in analyzing cooperation structures of R&D activities between countries. A cooperative patent application is therefore not only an indication of knowledge exchange about an underlying technology (i.e. patent) but also an indication of general cooperation and knowledge flows on international level.

However, analyzing and – even more importantly – interpreting international co-patents comes with a few pitfalls that need to be considered. First, a co-patent as such is an intermediate outcome of a collaborative R&D activity that captures a specific aspect of it. On the one side, it is only an eventual technological result of a successful inventive process, which does not provide a picture of other beneficial outcomes such as skill improvement and conceptual learning, especially of not very successful collaboration activities. On the other side, it is always unclear which of the partners benefits more from the collaboration, i.e. one cannot estimate the direction and amount of the knowledge flow between two countries. Furthermore, an international co-patent may involve inventors from the same company located around the world across its various branches or subsidiaries (ADL, 2005). Thus, the data may reflect inter- as well as intra-firm international collaboration (Fraunhofer ISI et al., 2009; Guellec and Pluvia Zuniga, 2007).

Another predictive factor of international collaboration is the size of a country. Early studies suggest that smaller countries tend to collaborate comparably more often than bigger countries since the later one have more domestic partners available (Narin et al. 1991; Schubert and Braun 1990; Frame and Carpenter 1979). However, these findings have been discussed quite controversially (Luukkonen et al. 1992; Luukkonen et al. 1993; Narin et al. 1991). Further collaboration influencing factors can be attributed to the overall heterogeneity between countries as e.g. geopolitical, historical and language related factors as well as social, intellectual, cognitive and economic factors (Frame and Carpenter 1979; Glänzel and Schubert 2004; Luukkonen et al. 1992). Beyond these country specific predictors, there are also differences in collaboration patterns that are based on technological profiles. Liu et al. (2012), for example, have shown that there is more international collaboration in basic research compared to applied research. Furthermore, Frietsch (2004) as well as Schmoch (2005; 2006) argue that strategic aspects should also be taken into account, as e.g. obtaining access to privileged research facilities, or unique resources. On the contrary, protective positions might hamper the willingness to cooperate, if a disadvantage is expected from knowledge sharing. Last but not least, the geographic proximity might also determine the extent of collaboration (Katz 1994; Hong and Su 2012). Other studies, however, argue that this factor becomes less important due to prolonged advances in mobility and communication technologies (Hoekman et al. 2010). Especially the latter one might be expedite considerably by the global corona crisis. However, there is no hard evidence in this regard at the moment.

In sum, it can be stated that there is a multitude of collaboration influencing factors and mechanisms. However, the causalities are not always as clear as it is desirable. Thus, evidence of collaborative activities should always be interpreted carefully. Regarding the choice of indicators, it is also crucial to present a preferably balanced picture that sheds light on various aspects instead of focusing on specific measures that might be biased by e.g. country specific characteristics and other influencing factors. Hence, our approach is not only to show the total numbers of international co-patents, but also to relativize them over various aspects by providing shares as well as looking precisely at collaboration patterns between each country in our set.

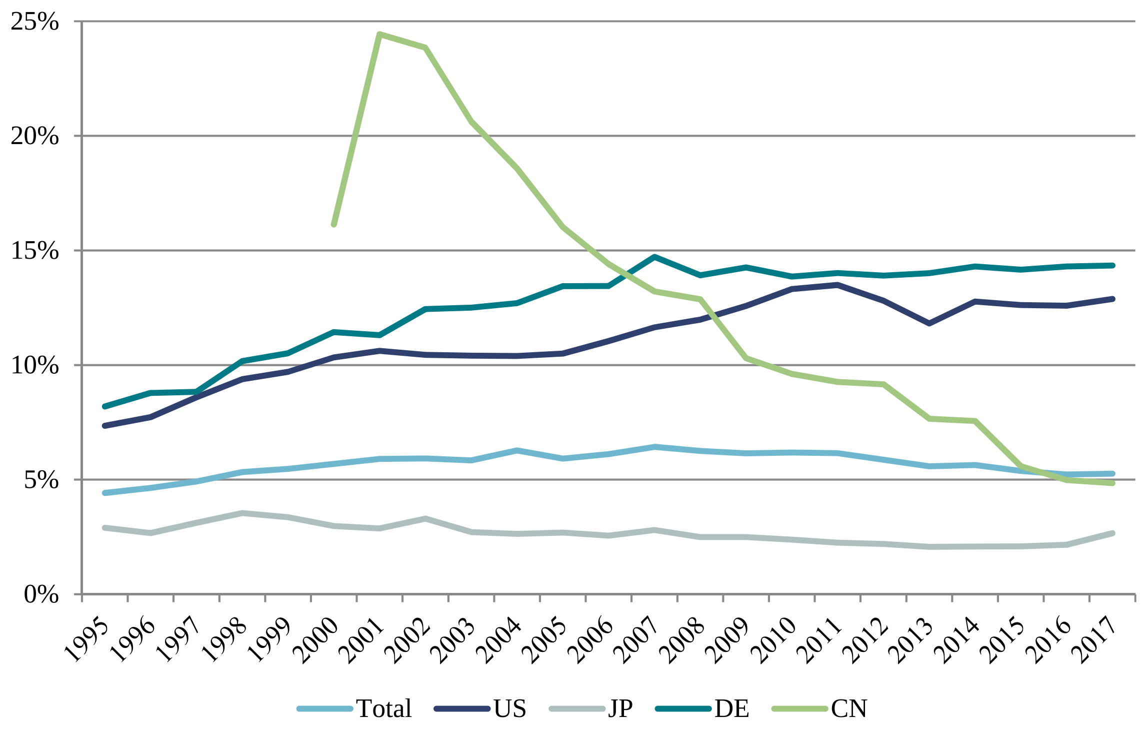
Figure 4 depicts the cooperation intensities of countries presented, i.e. the share of transnational co-patents (with OECD countries) in all transnational patent filings. Large shares on this indicator allude a higher degree of international cooperation efforts of a given country. However, lower shares do not necessarily pinpoint to a lack of effort in cooperating, but it also might reflect a higher availability of national cooperation partners, which renders international collaboration less important. Furthermore, a lower degree of international co-patents can also reflect a highly protective innovation policy in a given country, or a lower number of big international companies with dispersed location of R&D laboratories over the globe. However, it is rather difficult to reflect these kind of causalities reliably based on general numbers. Nevertheless, one have to keep such possibilities in mind while drawing conclusions.

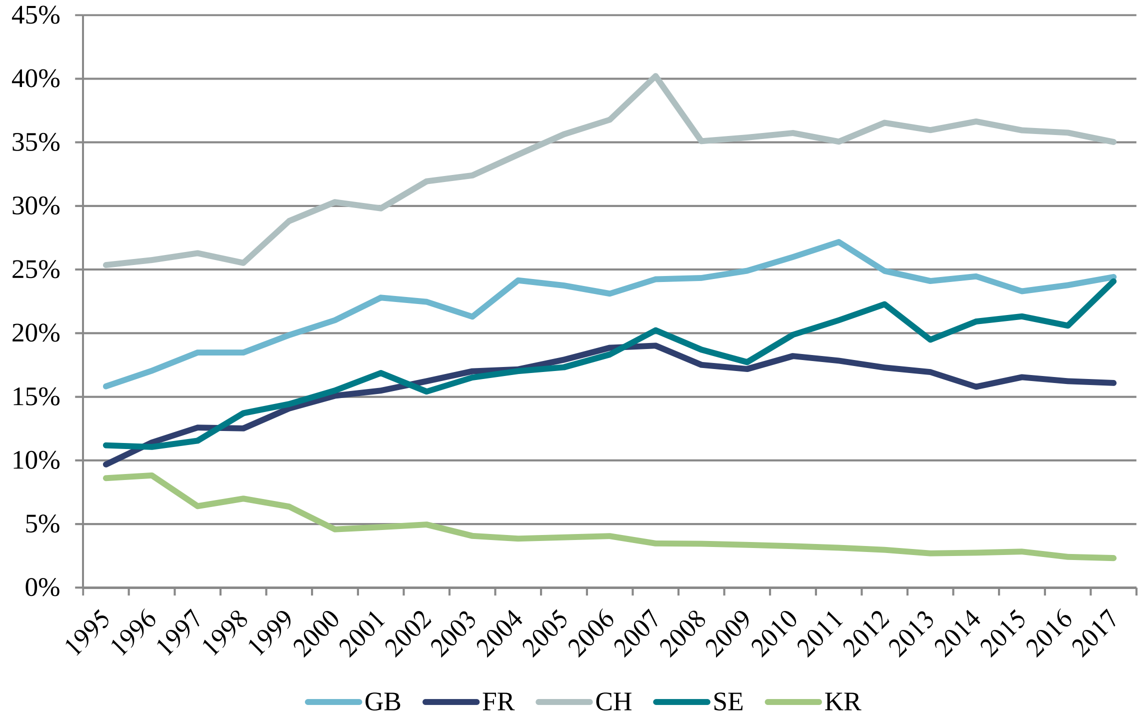
The total share of co-patents in all transnational filings is has been continuously increasing from 4.4% in 1995 to 6.4% in 2007. The total numbers (not shown here) approve that this upwards trend is due to a higher growth rate of transnational co-patents related to all transnational filings, confirming the gain of importance of international collaboration over the years. During the economic crisis between 2007 and 2011, both numbers have dropped drastically while the share was only slightly affected with a decrease down to 6.2%. Afterwards, however, we can observe a more accelerated downwards trend on this indicator until the end of the observation period, not only with respect to the total share, but also in several countries (U.S., Great Britain, France). Looking at total numbers as well as the growth rates again, we can confirm that indeed much less co-patents are filed after the crisis than before, while total transnational filings still increase after 2011, although with a lower growth rate. It is also noteworthy that the economic crisis had different effects on this indicator, if looking at it at the county level. In Germany, for example, we can observe a drop in 2008. However, afterwards the share stabilized and remained at a rather constant level until 2014, where it began to rise again. This is also quite similar to the progress in Switzerland.

In the U.S., on the other hand, the share kept rising fast until 2011 (13.5%), dropped to 11.8% in 2013 and started to rise again afterwards. A similar trend can be observed in Great Britain and – partially – in Sweden. Whereas Asian countries (Korea and Japan) show a prolonged decline over the whole observation period and the economic crisis seem not have affected them as strongly. These kinds of differences are highly likely to be attributable to different technological market positions and focus of the countries, their crisis coping strategies, as well as other determining factors related to the respective innovation policy and system. In general, this resembles their 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, Japanese as well as 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. At least in Japan, the effects of these policy initiatives are slowly begin to be recognizable in 2017.

Furthermore, we can also observe differences in the overall level of the shares on this indicator. As already anticipated above, smaller countries (e.g. Switzerland, Great Britain, and Sweden) – or countries that seek an access to the international market, or resources (e.g. human capital) – tend to have a higher share of co-patents related to overall transnational filings than bigger countries as the U.S., Germany, or Japan. Finally, China constitutes a rather special case. Since 2001, there has been a constant rapid decline in the transnational co-patents' share. However, the total numbers reveal that this is due to the dynamic growth of overall transnational filings that occur after a phase of a more nationally oriented focus in technological innovation, while the growth of transnational co-patents was comparably less steep. However, at the end of the observation period, the value tends to settle at around 5%.

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





Source: EPO – PATSTAT; Fraunhofer ISI calculations

In order to analyze the co-patenting activities in more detail, Table 3 shows the absolute numbers of co-patents between two countries (bottom-left) as well as the shares of co-patents on all transnational filings between two countries (top-right). Additionally, the last column show a countries share of transnational co-patents on all transnational co-patents filed worldwide. Contrasting to the shares discussed above, this value provides a different picture of co-patenting activities that is biased by a country's size. Hence, the highest share can be ascribed to the U.S. (24.1%), followed by Germany (13.7%), Great Britain (7%), France (6.6%), and Switzerland (6%). The lowest shares in this regard can be found in South Africa, Brazil, Poland, Russia, and Ireland. A special case in this picture constitutes Japan with a share of 3.4% while having the second highest number of total transnational filings among the countries in our set. The reluctant co-patenting activities of Japan reflect their comparably isolated technological innovation strategy compared to other countries with a similar amount of transnational patent filings overall, e.g. the U.S. On the contrary, Switzerland has a rather high value that is quiet on the same level as in France or Great Britain, which shows the very high cooperation intensity of the country and thus a comparably open innovation system to knowledge in- and out-flow.

The picture of co-patenting activities between two countries is completed by Table 4 where the importance of collaboration partners for each country is shown. This is measured by the share of co-patents with a given partner on all co-patents filed. The colors indicate the importance of collaboration partners (by column) for each country from green (important) to red (less important). Looking at Germany, the most important collaboration partner is the U.S. with a share of 26% on all German co-patents. Other significant partners are Switzerland (13%), France (10%), Austria (8%), and Great Britain (6%). It is quite prominent that the geographic proximity – potentially also the EU membership – as well as a shared language is one of the determining factors of international collaboration. The U.S., however, is in fact a special case as neither of these explanation factors can be applied here. Nevertheless, looking at overall collaboration with the U.S., it is noticeable that for 20 out of 23 countries in comparison it is the most important partner, especially for Brazil, Canada, China, Ireland, Israel, India, and – quite surprisingly – Russia (all above 40%). At least for China, this might partly have to do with research facilities and production sites of foreign companies (Ernst 2006). For the other three countries (Austria, Switzerland, and Poland), Germany is most important partner. Furthermore, Germany also appears to be a highly significant collaboration partner among all countries as it ranks second after the U.S. in many cases. However, this might also be due to the geographic proximity and a slight overrepresentation of EU countries in our set compared to other regions. Nonetheless, for U.S. itself, Germany represents the highest share of co-patents and is thus the most important collaboration partner alongside China and Great Britain. 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 4: Absolute number of transnational co-patents and shares in total transnational co-patents, 2015-2017

	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
AT		0.06%	0.01%	0.02%	0.51%	0.04%	1.14%	0.02%	0.02%	0.13%	0.07%	0.10%	0.01%	0.00%	0.02%	0.09%	0.01%	0.00%	0.05%	0.02%	0.01%	0.11%	0.22%	0.00%	2.65%
BE	69		0.01%	0.04%	0.10%	0.09%	0.46%	0.02%	0.08%	0.03%	0.56%	0.31%	0.03%	0.02%	0.02%	0.09%	0.08%	0.02%	0.28%	0.01%	0.00%	0.04%	0.64%	0.00%	3.01%
BR	9	7		0.01%	0.01%	0.01%	0.06%	0.00%	0.01%	0.00%	0.03%	0.02%	0.00%	0.00%	0.02%	0.02%	0.00%	0.00%	0.01%	0.00%	0.00%	0.03%	0.28%	0.00%	0.56%
CA	17	47	15		0.08%	0.27%	0.17%	0.02%	0.02%	0.02%	0.17%	0.16%	0.02%	0.04%	0.07%	0.04%	0.03%	0.02%	0.03%	0.01%	0.03%	0.13%	2.10%	0.01%	3.50%
CH	552	109	15	82		0.15%	1.80%	0.08%	0.07%	0.04%	0.93%	0.32%	0.02%	0.03%	0.10%	0.32%	0.09%	0.02%	0.12%	0.04%	0.02%	0.15%	0.93%	0.01%	5.95%
CN	39	103	14	290	160		0.68%	0.05%	0.04%	0.17%	0.20%	0.30%	0.02%	0.05%	0.09%	0.06%	0.78%	0.13%	0.05%	0.02%	0.11%	0.33%	3.46%	0.01%	7.11%
DE	1242	505	70	190	1966	741		0.18%	0.32%	0.18%	1.38%	0.85%	0.07%	0.13%	0.36%	0.46%	0.43%	0.11%	0.58%	0.18%	0.10%	0.47%	3.56%	0.02%	13.69%
DK	26	17	4	23	90	59	197		0.03%	0.05%	0.05%	0.12%	0.00%	0.01%	0.05%	0.03%	0.01%	0.00%	0.05%	0.02%	0.00%	0.22%	0.25%	0.00%	1.29%
ES	17	91	13	24	79	46	345	37		0.03%	0.21%	0.22%	0.02%	0.05%	0.03%	0.12%	0.02%	0.00%	0.09%	0.01%	0.00%	0.06%	0.45%	0.00%	1.92%
FI	141	29	0	22	45	190	193	51	29		0.02%	0.08%	0.01%	0.01%	0.04%	0.03%	0.04%	0.01%	0.04%	0.04%	0.01%	0.32%	0.22%	0.00%	1.49%
FR	75	612	38	180	1019	218	1506	53	233	17		0.49%	0.03%	0.04%	0.10%	0.29%	0.14%	0.05%	0.16%	0.08%	0.02%	0.09%	1.44%	0.01%	6.55%
GB	113	341	25	172	353	329	922	134	242	82	531		0.15%	0.08%	0.14%	0.16%	0.17%	0.09%	0.18%	0.05%	0.04%	0.21%	2.77%	0.03%	7.04%
IE	7	31	5	19	25	17	75	3	17	8	35	162		0.01%	0.02%	0.02%	0.00%	0.00%	0.01%	0.00%	0.00%	0.03%	0.38%	0.00%	0.85%
IL	5	19	2	46	33	56	144	6	50	6	46	84	15		0.04%	0.02%	0.01%	0.01%	0.02%	0.01%	0.07%	0.01%	0.97%	0.00%	1.63%
IN	21	21	19	77	105	102	397	58	37	47	112	153	22	45		0.05%	0.07%	0.11%	0.07%	0.02%	0.01%	0.07%	1.85%	0.00%	3.37%
IT	96	95	21	45	354	63	505	28	128	30	319	172	22	24	56		0.03%	0.01%	0.08%	0.02%	0.02%	0.10%	0.54%	0.00%	2.58%
JP	15	91	4	35	100	847	467	15	20	41	150	186	1	14	80	33		0.16%	0.06%	0.00%	0.01%	0.03%	1.24%	0.00%	3.43%
KR	5	22	2	19	20	142	115	3	1	6	58	99	1	7	115	9	179		0.03%	0.01%	0.04%	0.01%	0.57%	0.00%	1.40%
NL	54	310	7	33	126	53	631	59	94	40	174	192	15	24	80	82	68	37		0.01%	0.01%	0.09%	0.80%	0.01%	2.82%
PL	18	11	0	14	39	23	201	25	16	49	83	54	4	6	18	25	3	7	6		0.01%	0.03%	0.16%	0.00%	0.76%
RU	10	3	1	36	27	117	106	5	4	15	22	44	3	77	6	17	7	44	14	10		0.00%	0.43%	0.00%	0.95%
SE	116	42	32	137	162	357	508	240	69	346	96	232	28	11	79	108	29	9	96	34	3		0.72%	0.00%	3.23%
US	237	702	303	2286	1018	3777	3885	276	496	242	1566	3017	410	1058	2020	584	1354	627	872	178	467	787		0.06%	24.05%
ZA	3	4	5	11	8	6	21	0	3	1	6	36	1	4	4	1	0	0	7	1	1	3	64		0.17%
Total	2887	3281	611	3820	6487	7749	14932	1409	2091	1630	7149	7675	926	1782	3674	2817	3739	1527	3074	825	1039	3524	26226	190	100.00%

Source: EPO – PATSTAT; Fraunhofer ISI calculations

Table 5: Share of co-patenting partners within the transnational co-patenting portfolio of a given country, 2015-2017

	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%	0%	9%	1%	8%	2%	1%	9%	1%	1%	1%	0%	1%	3%	0%	0%	2%	2%	1%	3%	1%	2%
BE	2%		1%	1%	2%	1%	3%	1%	4%	2%	9%	4%	3%	1%	1%	3%	2%	1%	10%	1%	0%	1%	3%	2%
BR	0%	0%		0%	0%	0%	0%	0%	1%	0%	1%	0%	1%	0%	1%	1%	0%	0%	0%	0%	0%	1%	1%	3%
CA	1%	1%	2%		1%	4%	1%	2%	1%	1%	3%	2%	2%	3%	2%	2%	1%	1%	1%	2%	3%	4%	9%	6%
CH	19%	3%	2%	2%		2%	13%	6%	4%	3%	14%	5%	3%	2%	3%	13%	3%	1%	4%	5%	3%	5%	4%	4%
CN	1%	3%	2%	8%	2%		5%	4%	2%	12%	3%	4%	2%	3%	3%	2%	23%	9%	2%	3%	11%	10%	14%	3%
DE	43%	15%	11%	5%	30%	10%		14%	16%	12%	21%	12%	8%	8%	11%	18%	12%	8%	21%	24%	10%	14%	15%	11%
DK	1%	1%	1%	1%	1%	1%	1%		2%	3%	1%	2%	0%	0%	2%	1%	0%	0%	2%	3%	0%	7%	1%	0%
ES	1%	3%	2%	1%	1%	1%	2%	3%		2%	3%	3%	2%	3%	1%	5%	1%	0%	3%	2%	0%	2%	2%	2%
FI	5%	1%	0%	1%	1%	2%	1%	4%	1%		0%	1%	1%	0%	1%	1%	1%	0%	1%	6%	1%	10%	1%	1%
FR	3%	19%	6%	5%	16%	3%	10%	4%	11%	1%		7%	4%	3%	3%	11%	4%	4%	6%	10%	2%	3%	6%	3%
GB	4%	10%	4%	5%	5%	4%	6%	10%	12%	5%	7%		17%	5%	4%	6%	5%	6%	6%	7%	4%	7%	12%	19%
IE	0%	1%	1%	0%	0%	0%	1%	0%	1%	0%	0%	2%		1%	1%	1%	0%	0%	0%	0%	0%	1%	2%	1%
IL	0%	1%	0%	1%	1%	1%	1%	0%	2%	0%	1%	1%	2%		1%	1%	0%	0%	1%	1%	7%	0%	4%	2%
IN	1%	1%	3%	2%	2%	1%	3%	4%	2%	3%	2%	2%	2%	3%		2%	2%	8%	3%	2%	1%	2%	8%	2%
IT	3%	3%	3%	1%	5%	1%	3%	2%	6%	2%	4%	2%	2%	1%	2%		1%	1%	3%	3%	2%	3%	2%	1%
JP	1%	3%	1%	1%	2%	11%	3%	1%	1%	3%	2%	2%	0%	1%	2%	1%		12%	2%	0%	1%	1%	5%	0%
KR	0%	1%	0%	0%	0%	2%	1%	0%	0%	0%	1%	1%	0%	0%	3%	0%	5%		1%	1%	4%	0%	2%	0%
NL	2%	9%	1%	1%	2%	1%	4%	4%	4%	2%	2%	3%	2%	1%	2%	3%	2%	2%		1%	1%	3%	3%	4%
PL	1%	0%	0%	0%	1%	0%	1%	2%	1%	3%	1%	1%	0%	0%	0%	1%	0%	0%	0%		1%	1%	1%	1%
RU	0%	0%	0%	1%	0%	2%	1%	0%	0%	1%	0%	1%	0%	4%	0%	1%	0%	3%	0%	1%		0%	2%	1%
SE	4%	1%	5%	4%	2%	5%	3%	17%	3%	21%	1%	3%	3%	1%	2%	4%	1%	1%	3%	4%	0%		3%	2%
US	8%	21%	50%	60%	16%	49%	26%	20%	24%	15%	22%	39%	44%	59%	55%	21%	36%	41%	28%	22%	45%	22%		34%
ZA	0%	0%	1%	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%

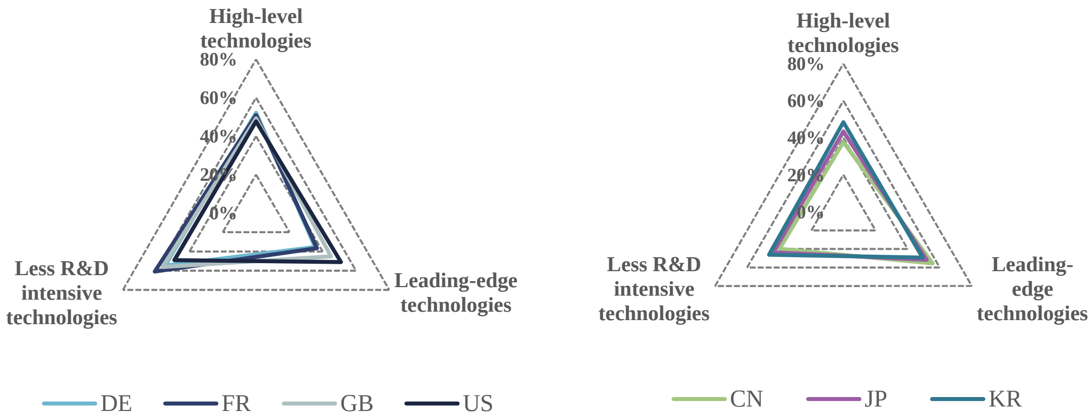
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

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.

Our last picture with regard to co-patenting activities (Figure 5) shows a breakdown of co-patents by technological areas – i.e. less R&D intensive, high-level, and leading-edge technologies – as a share on all transnational co-patents filed by a country. It compares several high performing western countries (on the left side) with high performing eastern countries (on the right side). Furthermore, it has to be noted that the sum of the shares exceeds 100% due to double counts resulting from IPC-based multiple assignment of a single patent to a technological area. However, the overall picture and the tendencies are still reliable. Looking at western countries, the average level of high-level technology related patents is about 50%. In terms of less R&D intensive technologies, the value is around 55% and for leading-edge technologies it is 42%. Thus, western countries cooperate more frequently in less R&D intensive technologies. In case of the U.S., however, the distribution of filings among technological areas is rather evenly spread compared to other countries (Germany, France, and Great Britain), where there is a clear tendency towards less R&D intensive technologies – especially in France. In eastern countries, on the other side, the focus lies on international cooperation in leading-edge technologies (52% on average), while the other two areas are addressed more or less equally with a value of 43% each. Particularly in China, this amplitude can clearly be observed. Hence, eastern countries use international cooperation strategically to catch up with, or even get ahead of the global technological progress.

In sum, Figure 5 shows that western and eastern countries have different technological development strategies while cooperating internationally. While European countries tend to cooperate preferably on less-R&D intensive technologies, the eastern countries focus more on leading-edge technologies. On the one hand, this could be a sign of a different technological level of both regions, or the structure of the domestic innovation system. On the other hand, this might also be due to different strategical means. However, a clear statement in this regard cannot be made based on this broad picture.

Figure 5: Transnational co-patents in technological areas as a share on all transnational co-patents of respective country, 2015-2017



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Note: In some 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 exceed 100%.

6 Patent Activities of the German Federal States

In this section, we will take a look at the patent activities of the German federal states. A regionalized patent statistic allows taking a closer look at the structural composition of the German innovation landscape, which enables us to identify regional technology trends as an important precondition for the composition and framing of regional innovation policies in Germany. Therefore, we will first provide some general trends in regionalized patent activity in Germany, including an analysis of patenting at the NUTS-2 level ("Regierungsbezirke") to get some further information on what is happening within the federal states. In addition, we have included twelve European regions for comparison with the trends in Germany. Among them are cities like London, Paris or Stockholm, but also larger regions like Catalonia or South Netherlands. In a final step, we have conducted an analysis of high-technology shares in the German federal states compared to the European regions.

The absolute numbers of transnational patent filings based on inventor addresses are displayed in Figure 6.[6] Up to the year 2007, the number of transnational patent filings was rising for nearly all of the German federal states. After 2007, a decrease of filings in many of the federal states due to the economic crisis can be found, which is most strongly visible for Bavaria and Baden-Württemberg. After the crisis, the filings figures started to increase again for most of the countries. However, we can observe a stagnation and in some cases, e.g. Baden-Württemberg, North Rhine-Westphalia or Hesse, also a decrease in the recent years. In 2016 and 2017, the filings figures seem to start growing again for most of the federal states.

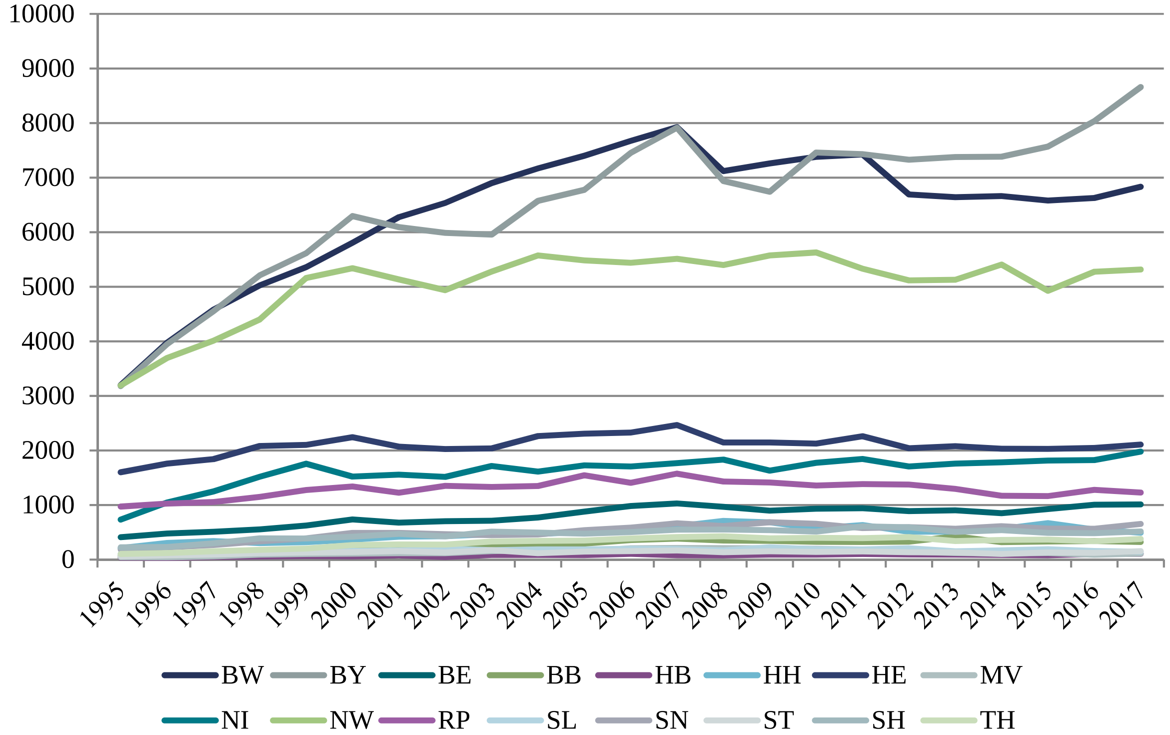
The largest number of transnational filings within the German comparison can be found in Bavaria with nearly 8,700 filings in 2017. Baden-Württemberg is the second largest state in terms of patent filings (about 6,800 filings in 2017), followed by North Rhine-Westphalia (about 5,315filings in 2017). Large parts of the German industry are located in these three countries, so they are responsible for slightly more than 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 an increase in the last two years can be found. Berlin is the final state with more than 1,000 filings in 2017, all other federal states are at a level of around 500 or less filings per year.

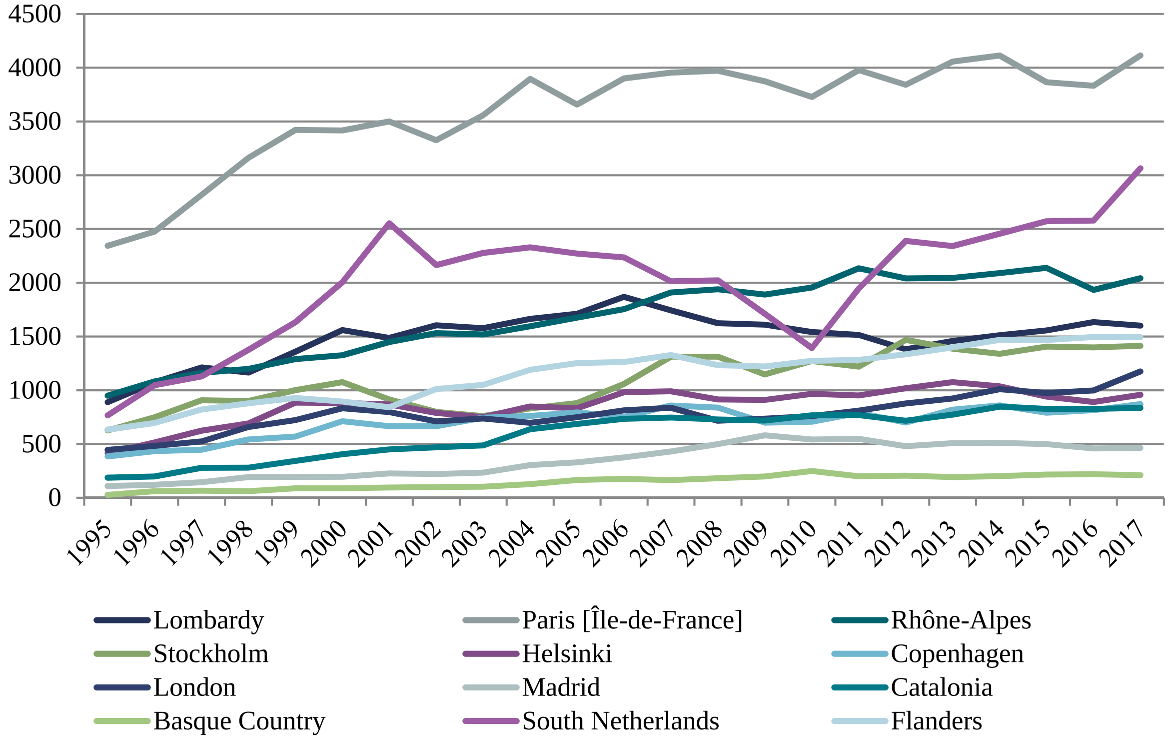
When looking at the filing figures of the European regions, it is clearly Paris with the largest number of transnational filings, though the figures only grew slightly over the years since 2005. Still, however, with about 4,100 filings Paris has half of the filing figures of Bavaria, which is a large number for a city-state (Berlin, in comparison, only has ~1,000 filings in 2017). Paris is followed by Southern Netherlands, where – after a sharp decline due to the

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

financial crisis – a major increase can be observed after 2012. The Rhône-Alpes region is the third largest region in our comparison, followed by Lombardy, Flanders and Stockholm.

Figure 6: Number of transnational filings by German federal states (upper panel) and European regions (lower panel)



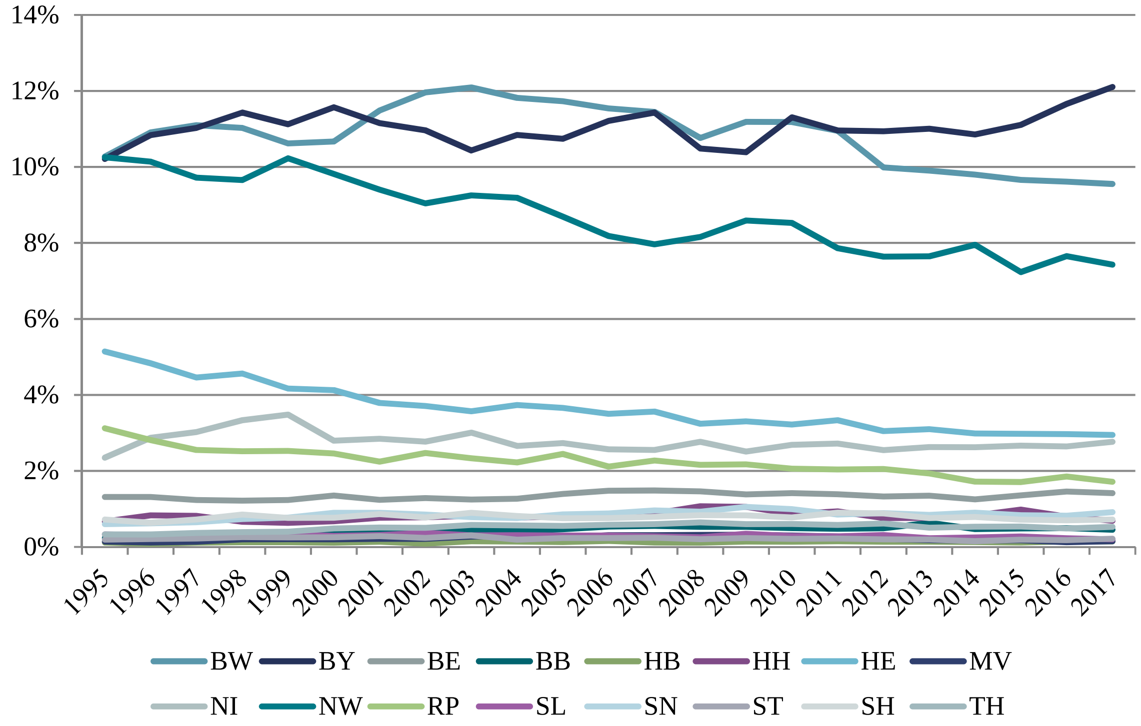


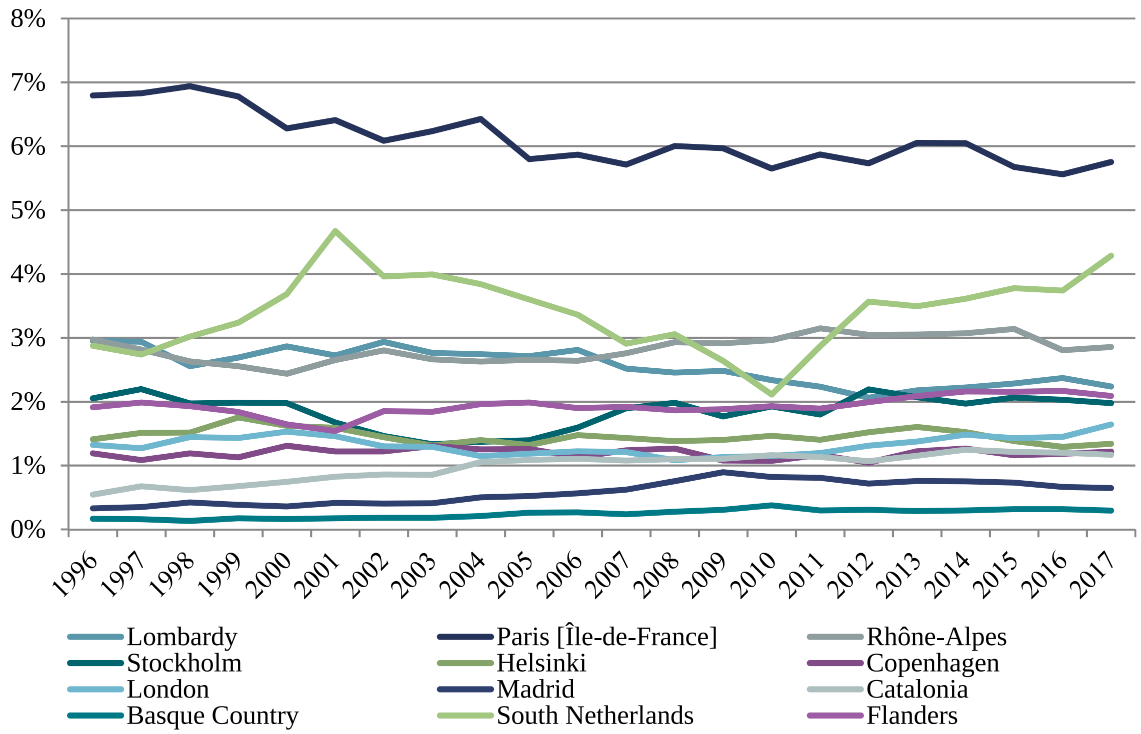
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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

The trends depicted in Figure 6 are mirrored in the shares of transnational filings, which are provided in Figure 7. For better comparability of the German federal states and the European regions, the figures are calculated as the shares of the respective state/region in total EU27 filings. Bavaria and Baden-Württemberg have the largest shares in transnational filings among the states and regions in our comparison.

Figure 7: Shares of transnational filings by federal states

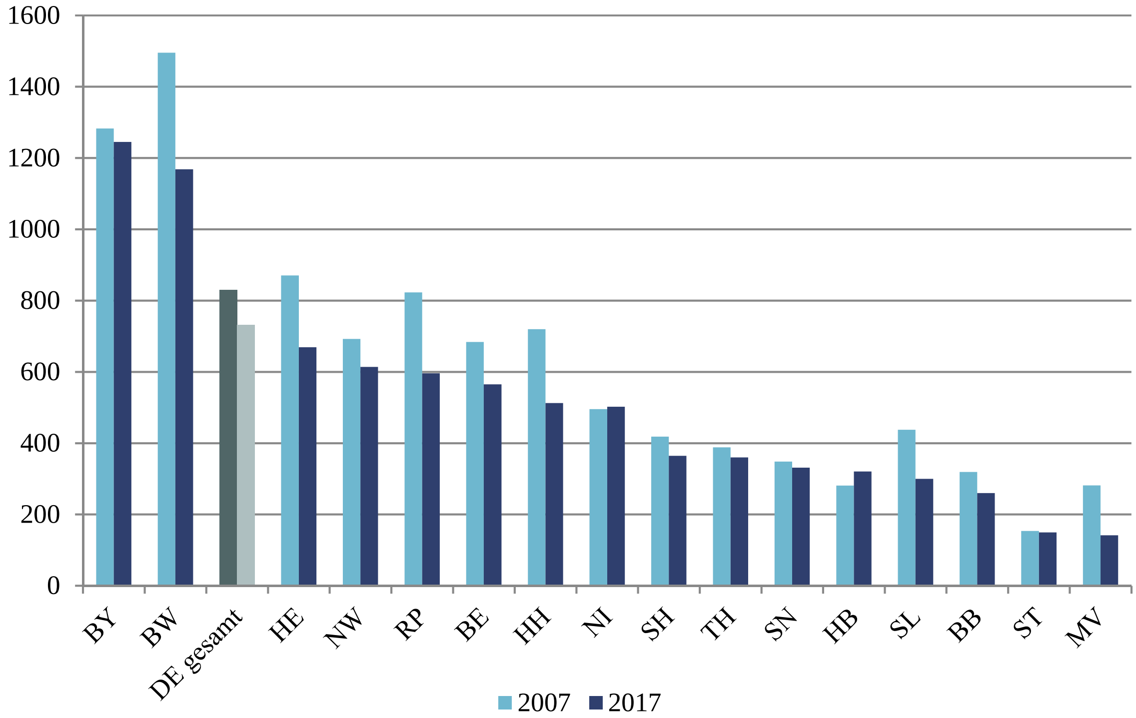




Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Bavaria accounts for 12% in all transnational filings of the EU-27 while this share lies at 10% for Baden-Württemberg. After 2010, we see rising shares of Bavaria, while the shares were slightly declining for Baden-Württemberg and North Rhine-Westphalia, which is a trend that still continues in 2017. As for the European regions, Paris reaches the largest shares with 6%, which has been rather stable since 2005. Rising shares can especially be observed for Southern Netherlands, which is a trend that has already been observed in the absolute numbers.

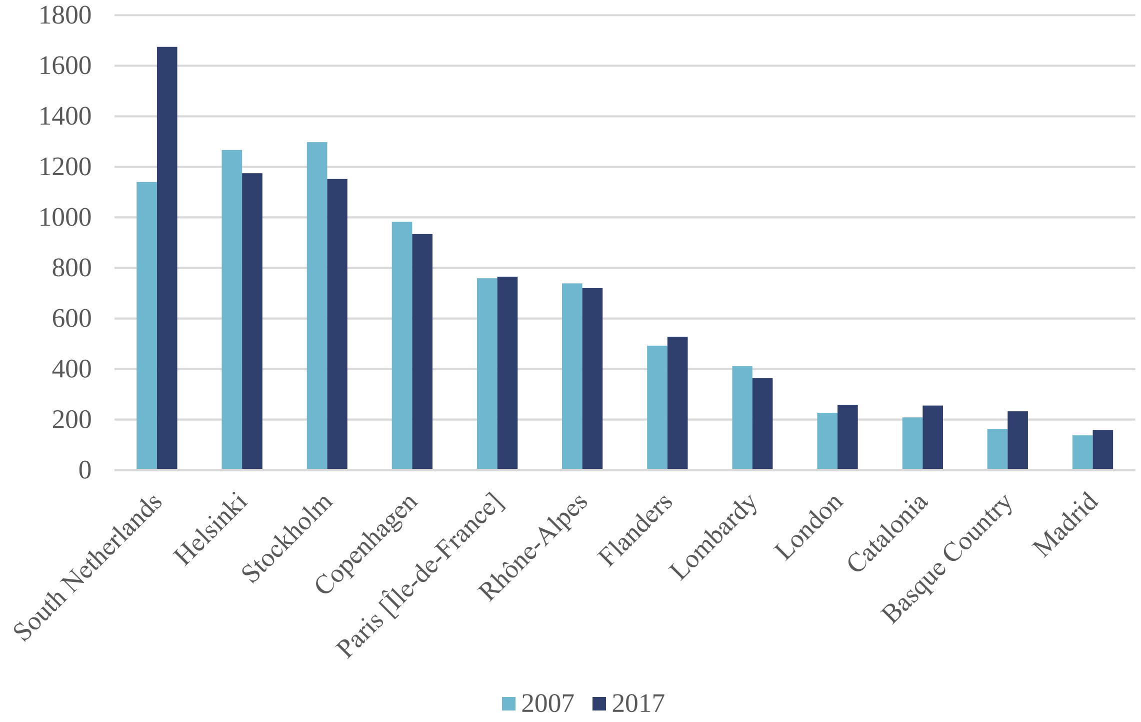
Figure 8: Patent intensities of the German federal states (per 1 million employees)



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

Figure 8 shows the patent intensities, calculated as the number of patent filings by federal state or European region, respectively, divided by the number of employees (in millions) in the respective state/region. Bavaria and Baden-Württemberg also score first in the Germany comparison, though a decrease in the patent intensity since 2007 becomes visible especially for Baden-Württemberg. This leads to the fact that Bavaria has a larger patent intensity than Baden-Württemberg in 2017, which was not the case in 2016 (see last years report in this series). North-Rhine Westphalia, which scored third in absolute terms, scores only fourth within this comparison, after Hesse on the third rank. North-Rhine Westphalia is followed by Rhineland-Palatinate, Berlin and Hamburg. In sum, however, we see a decline in patent intensities across nearly all of the German federal states since 2007.

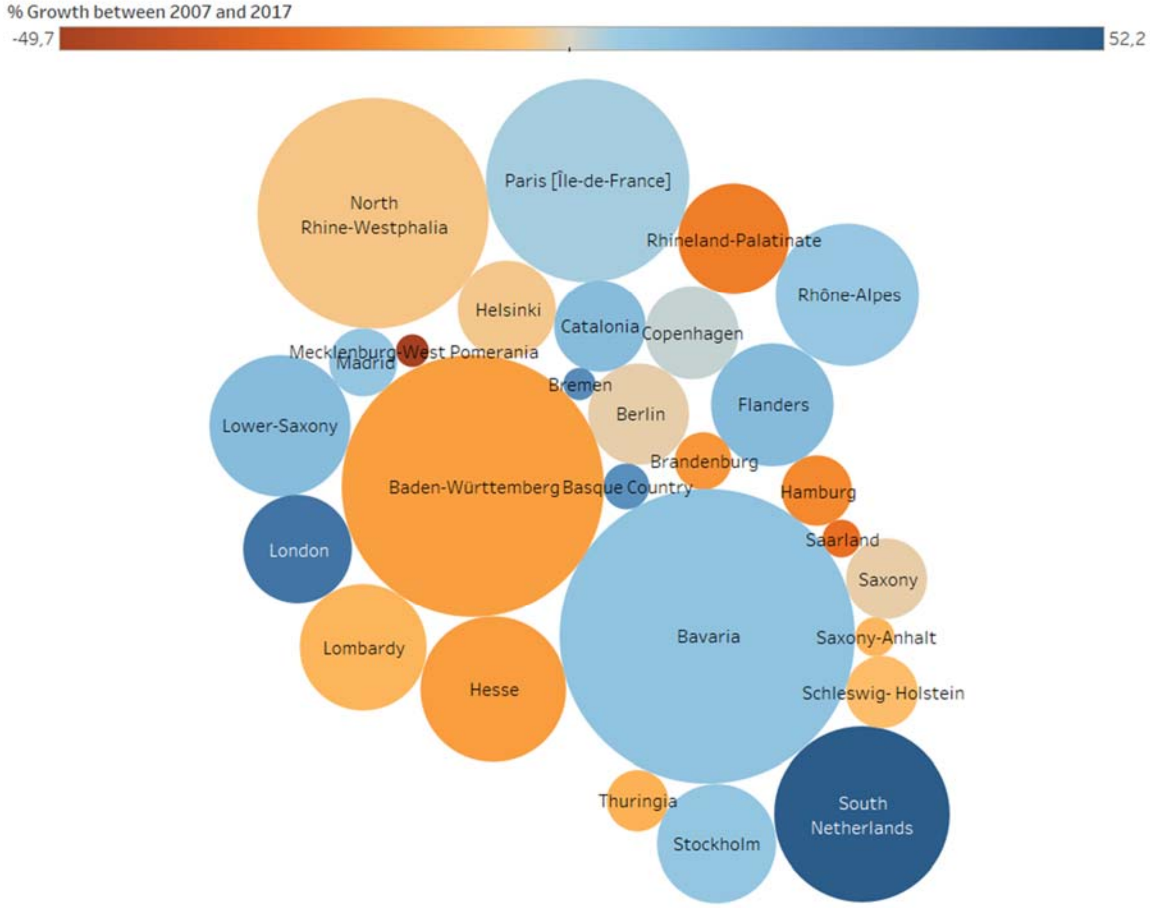
A closer look at the European regions reveals that especially city states score high in terms of patent intensities. The largest and most quickly growing patent intensity could be found for the South Netherlands, which is the largest among all regions in our comparison. It is followed by the Northern cities Helsinki, Stockholm and Copenhagen, which all have encountered slight decreases in patent intensities since 2007. The Spanish regions Catalonia, the Basque Country and Madrid score last in terms of patent intensities among the regions in this comparison.



Source: EPO – PATSTAT; Eurostat, calculations by Fraunhofer ISI

For a better comparison of the German and the European regions, Figure 9 once again provides the patent shares in all EU-27 filings for all regions. In addition, the figure shows the growth rates of filings between 2007 and 2017. Once again, it can be found that Bavaria and Baden-Württemberg have the largest filing shares but Baden-Württemberg shows negative growth trends since 2007. As we have seen before, South Netherlands – though still not the largest region in terms of patent shares – shows the largest growth rates in our comparison. All in all, there seems to be more or less growth in the European regions while the shares have – at least slightly – declined in many of the German federal states.

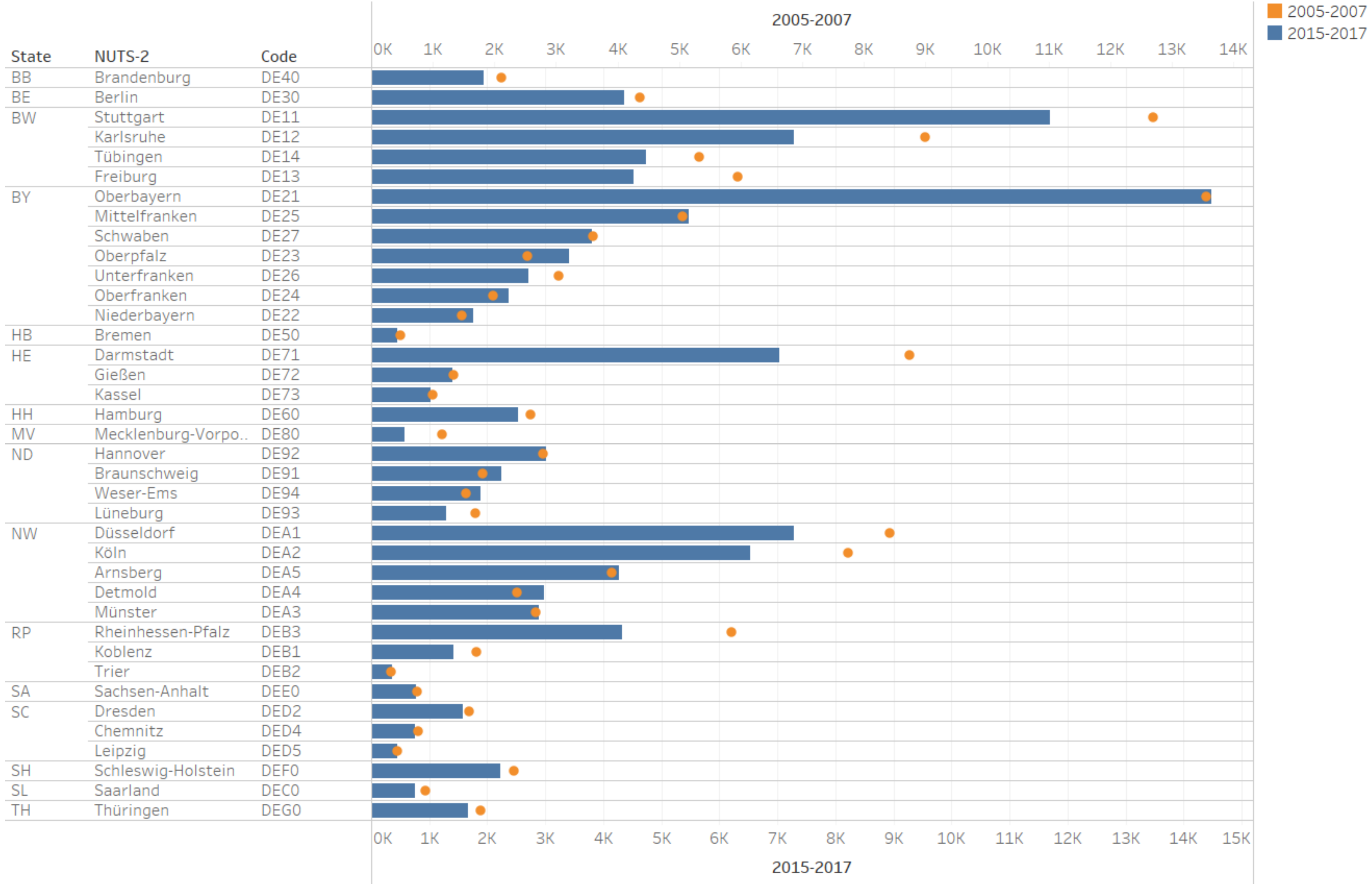
Figure 9: Patent shares and growth rates of the German federal states and European regions, 2017



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

In Figure 10, we drill down the regional filings of the German federal states by NUTS-2 regions. The filing figures are presented for the years 2015-2017 (aggregate) compared to 2005-2007 (aggregate). The largest German NUTS-2 region is Oberbayern, followed by Stuttgart, Karlsruhe, Düsseldorf, Darmstadt and Köln. Once again, we observe a decline in the filing figures compared to the 2005-2007 time window, except for the Bavarian regions where the figures have slightly increased.

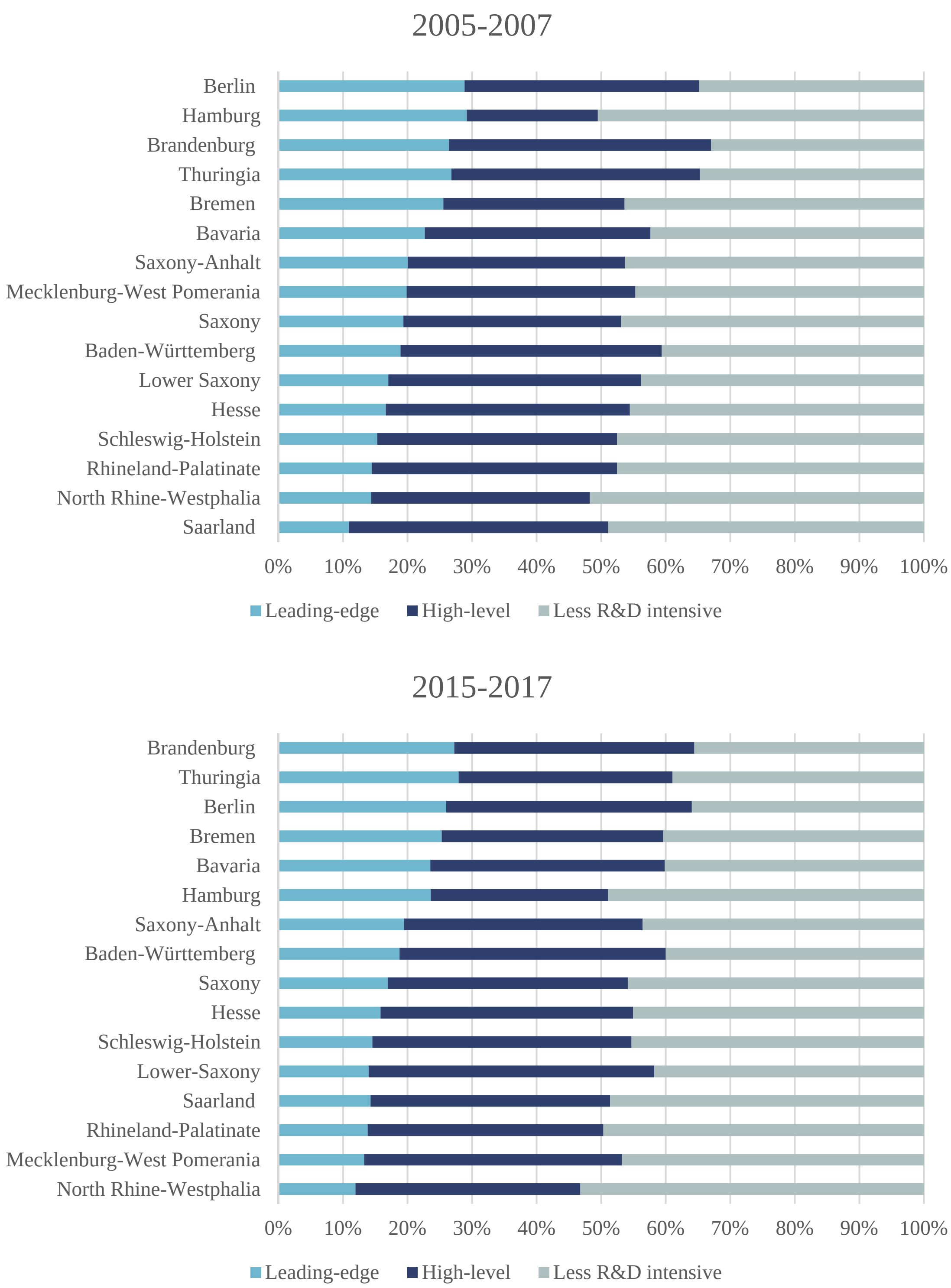
Figure 10: Number of transnational patent filings by NUTS-2 regions in Germany, 2005-2007 and 2015-2017



Source: EPO – PATSTAT, calculations by Fraunhofer ISI

In a final step, we will take a closer look at the regional filings by technology domains, i.e. leading-edge and high-level technologies – which together form the high-tech sector – and less R&D intensive technologies. As can be seen from Figure 11, the largest shares in leading-edge patents can be found in Brandenburg, Thuringia, Berlin, Bremen and Bavaria.

Figure 11: Shares of patents by technology domains in German federal states, 2005-2007 vs. 2015-2017

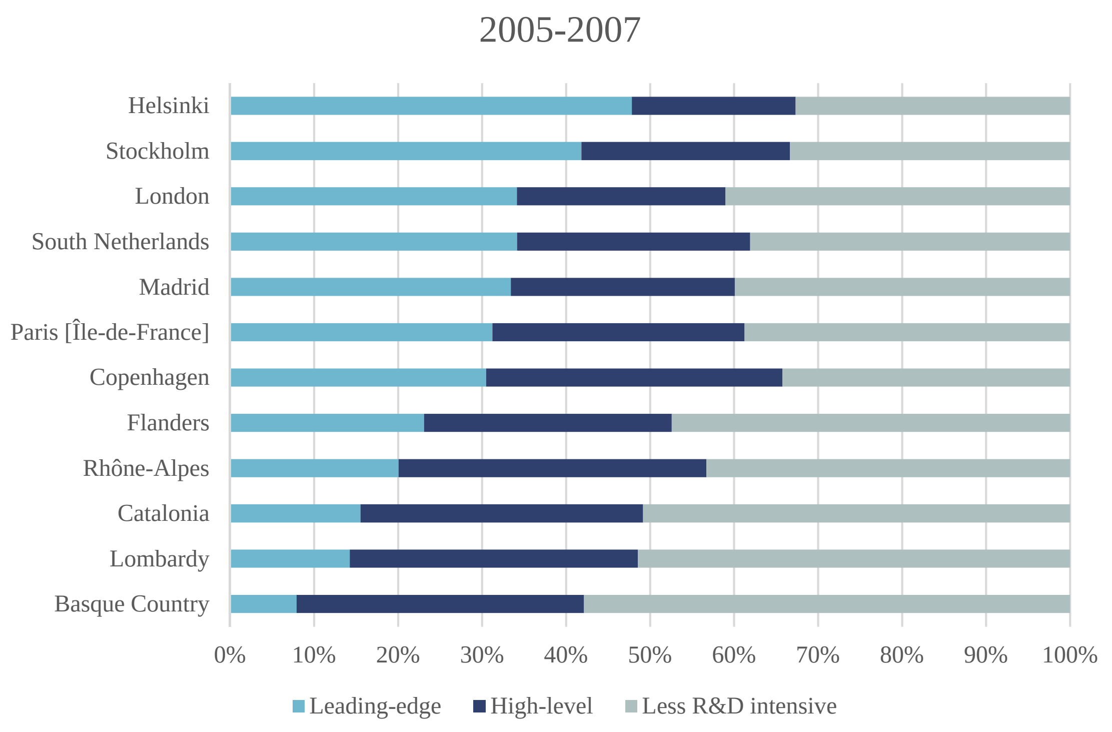


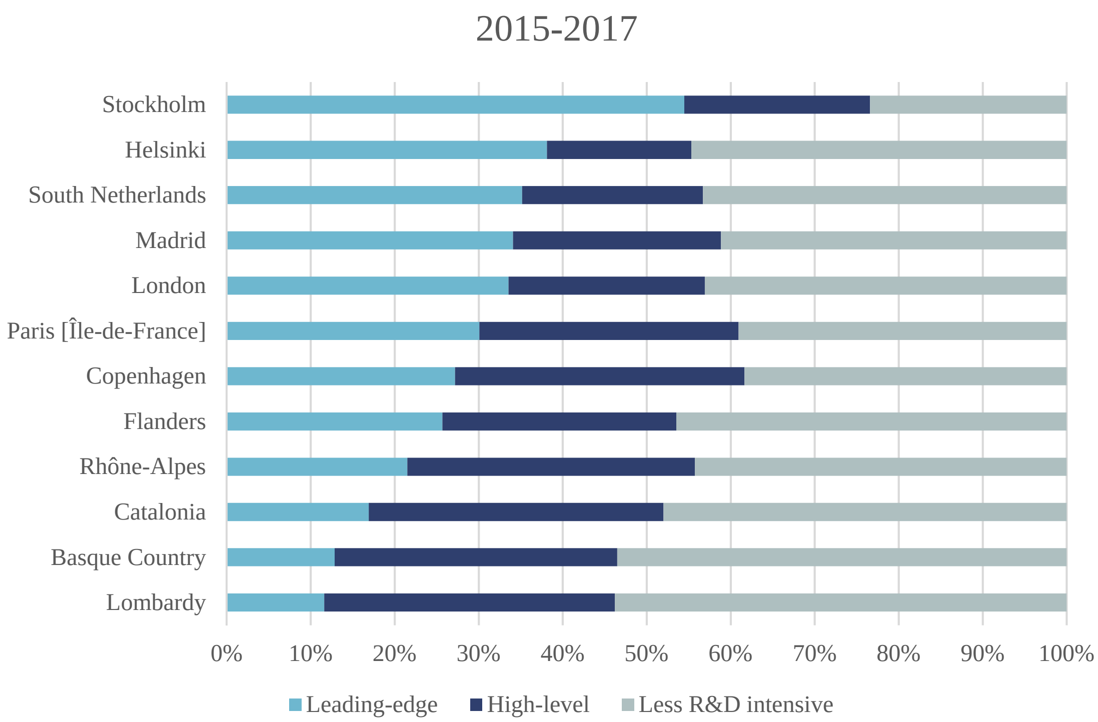
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

In sum, especially Berlin and Brandenburg have the largest shares of patents in high-tech sectors. Since we look at the patents from an inventor's point of view it can be assumed that a certain share of inventors from Brandenburg commutes to work to Berlin, which can serve as an explanation for the large shares of Brandenburg. The largest shares in less R&D-intensive technologies can be observed in North-Rhine Westphalia, Hamburg and Rhineland-Palatinate. In sum, nearly all of the states have high-tech shares above 50% and there seems to be a tendency of a slight shift towards more high-tech patent filings between 2005-2007 and 2015-2017.

The same analysis can be performed for the European regions (Figure 12). The largest leading-edge shares can be found in Helsinki, followed by Stockholm and London. Helsinki and Stockholm also have large high-tech shares, as well as Copenhagen, although in Copenhagen especially the high-level technologies are responsible for this trend. The largest shares in less R&D-intensive technologies can be observed in the Basque Country, the Lombardy and Catalonia.

Figure 12: Shares of patents by technology domains in European regions, 2005-2007 vs. 2015-2017





Source: EPO – PATSTAT; calculations by Fraunhofer ISI

7 Patenting Trends in Public Research

Scientific achievements most commonly are published in journals, which enables other researchers to access and eventually cite them in their own research (Michels et al., 2013). In addition to scientific publications, also patent filings can be regarded as an output of R&D activities of research organizations. Since patents indicate an interest in the commercial exploitation of a new finding or a new technology (Schmoch, 1997), they are more strongly focused on measuring an orientation towards the technological application of a given invention compared to the publication of scientific results in journals. Employing patent statistics to assess the performance of German universities and public research organizations (PROs) thus enables us to draw conclusions about their technology-oriented research output.

Despite quite extensive policy action, 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), a large share of patent filings from universities is still registered by companies. In this case, the university staff often only appears as an inventor but the university does not show up as a patent applicant. This might happen in cases where external R&D of companies is carried out by universities or in the case of university-industry collaborations. However, it implies that analyzing patents filed by universities falls short of capturing the "real" share of patents of universities.

Several approaches to solve this problem haven been applied, e.g. by searching for academic titles (PROF, etc.) on patents Schmoch (2007) or using staff lists of universities and match them with the names of inventors listed on patents (Lissoni et al., 2008; Thursby et al., 2009).

The approach applied here follows the idea of checking the names of scientific authors, thus research-active university staff, and inventors named on patents. This way, it is ensured that patents on which the university staff is only named as inventors are counted as patents from academia.

In this section, we will take a closer look at both, patents filed by universities and PROs and what has become known as "academic patents", i.e. patents where universities/PROs are listed as applicants plus patents that mention university/PRO staff on their inventor lists. The first dimension gives us an idea about how many patented inventions are owned by public research. Academic patents provide a more complete picture of the actual trends of patenting in academia.

7.1 The Applicant Perspective

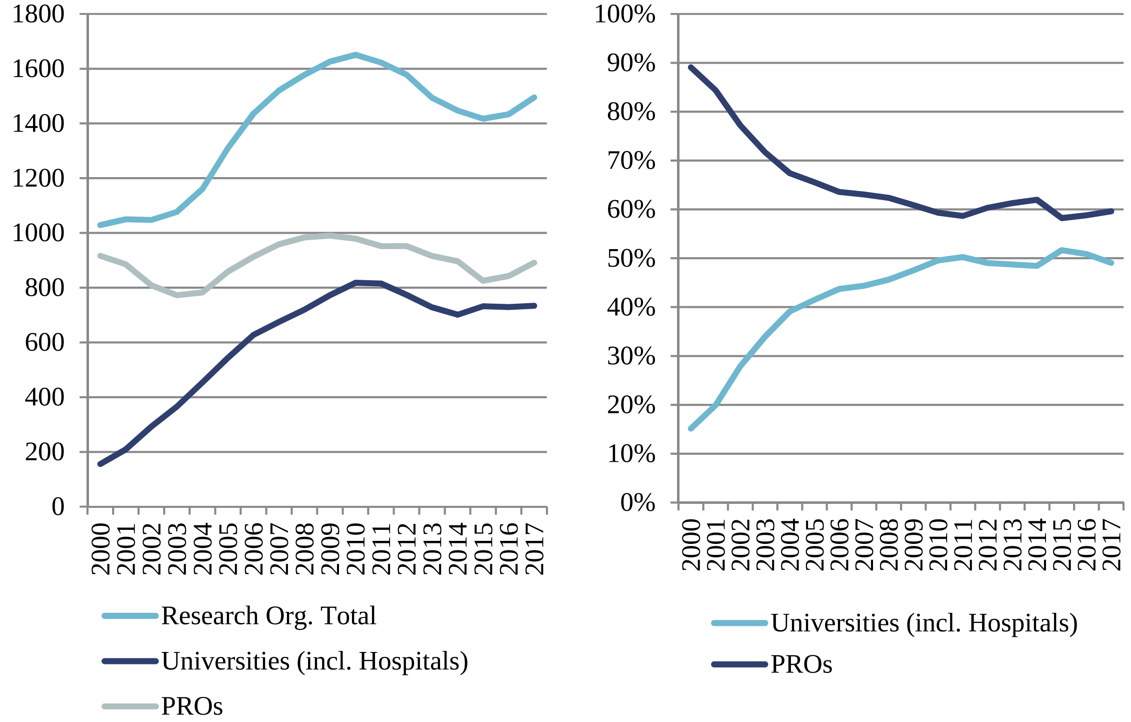
In Figure 13, the total number of patents filed by German research organizations is depicted. In addition, the figure shows the number of filings differentiated by universities and public research organizations (PRO) as well as the shares of universities and PROs in the total number of filings by research 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.

Up to the year 2010, we can observe a large increase in the filing figures of universities, implying that patenting has become a more and more important instrument over the years. A similar, yet less strongly pronounced, effect can also be found for PROs. The larger growth rates of patents filed by universities can at least partly be attributed to the abolishment of the Hochschullehrerprivileg in 2002. Consequently, the number of filings from PROs and universities have converged up to 2010.

Between 2010 and 2015, a decline in the number of filings of German research organizations (universities plus PROs) becomes visible. This is at least partly an effect of the financial crisis, which has also been found to affect patent filings from industry. The number of filings by universities and PROs started to rise again after 2015. In the recent years, however, the university filings have stagnated while the PRO filings once again started to increase.

The trend in absolute filings figures is mirrored in the shares of filings by universities and PROs in total filings by German research organizations (right panel of Figure 13). We find a strong convergence of filing figures at least until 2010, with the financial crisis having some differentiated effects between 2010 and 2015. Due to the stagnation in university filings and a growth of PRO filings in the recent years, the shares of universities have started to decrease, once again leading to a divergence of university and PRO filings. Still, however, nearly 50% of all filings of German research organizations have a university listed as an applicant. This share goes up to 60% for PROs. These shares exceed 100% due to co-patents that list a university as well as a PRO on certain filings.

Figure 13: Number of transnational filings by German research organizations and shares of universities and PROs

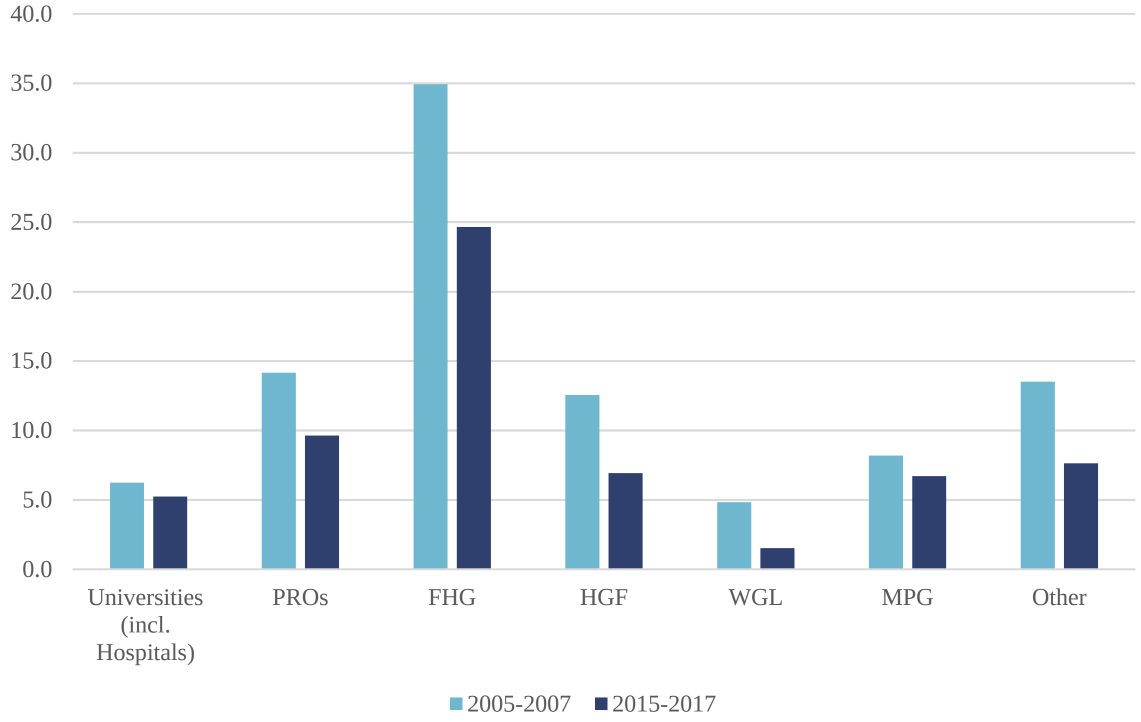


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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

The patent intensities (Figure 14), i.e. the number of transnational patent filings per 1,000 R&D employees (full-time equivalents), of universities and PROs are also affected by these trends. In the 2015-2017 period, the patent intensities for all PROs are lower than in the 2005-2007 period, which is due to the fact that patent filings have stayed comparably stable or only grew slightly, while the number of R&D employees has continuously increased (though employment growth was also a bit slower in the recent years). The patent intensities of universities have only slightly decreased compared to 2005-2007. However, PROs (in sum) are still far more patent intensive due to the lower number of R&D employees. In PROs, on average ten patents are filed per 1,000 R&D employees, while this figure only lies at five for the universities. Yet, this is mostly driven by the fact that PROs, especially the Fraunhofer Society, but to a certain extent also the Helmholtz Association are more focused on applied research, which explains the high patent intensity compared to universities.

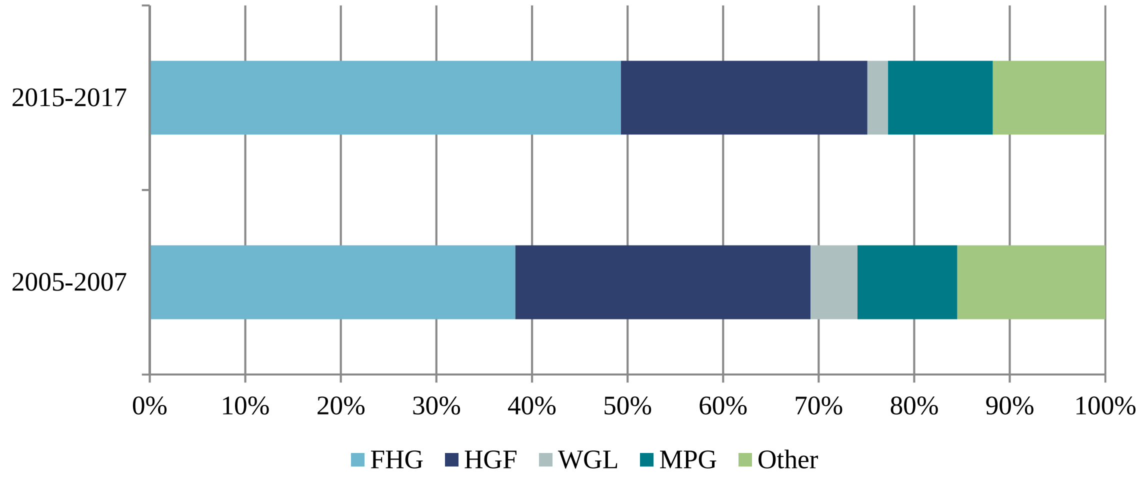
Figure 14: Patent intensities (patents per 1,000 R&D employees, full-time equivalents) by German research organizations (3-years moving average)



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

The shares of patents by the individual public research organizations in all PROs is depicted in Figure 15. The Fraunhofer Society – with its focus on applied research – is responsible for the largest share of patent filings within the comparison of the public research institutes with increasing shares over the years, though the patent intensity has decreased. This has to do with the fact, that the number of patent filings for all PROs has declined over the years. However, the decline has been less severe for the Fraunhofer Society than for the other PROs. The second largest PRO in terms of patent filings is the Helmholtz Association, whose role is to pursue more long-term oriented research. The shares of the Max-Planck Society, which is rather strongly focused on basic science within Germany, has stayed constant at 11% compared to the period 2005-2007. Finally, the Leibniz Association is smallest in terms of patent filings and is in the recent years only responsible for 2% of the patent filings by PROs.

Figure 15: Shares of filings by public research organizations in all PRO filings (3-years moving average)



Source: EPO – PATSTAT; calculations by Fraunhofer ISI.

Besides the single PROs, we also take a closer look at the patent filing figures and intensities of the single universities. Their filing figures are provided in Table 6. The Technical University of Munich files the largest number of patents between 2015 and 2017, followed by the University of Erlangen-Nürnberg, the Karlsruhe Institute of Technology (KIT), the Technical University of Dresden, the University of Heidelberg and the Medizinische Hochschule Hannover.

Table 6: Patent filings and patent intensities by university applicants

University	Transnational Filings		Intensities (per 100 scientific personnel, FTE)	
	2005-2007	2015-2017	2005-2007	2015-2017
Technische Universitaet Muenchen	63	210	0,40	0,84
Universitaet Erlangen-Nuernberg	69	191	0,46	0,85
Karlsruher Institut fuer Technologie	134	137	1,47	1,14
Technische Universitaet Dresden	53	114	0,35	0,55
Universitaet Heidelberg	53	92	0,28	0,32
Medizinische Hochschule Hannover	46	85	1,06	1,16
Universitaet Stuttgart	31	74	0,28	0,52
LMU Muenchen	71	72	0,37	0,24
Universitaet Jena	17	71	0,17	0,50
Technische Universitaet Berlin	48	70	0,42	0,49
Universitaet Freiburg (i.Br.)	133	58	0,86	0,24
Charite - Universitaetsmedizin Berlin	168	56	1,25	0,41
Universitaet Mainz	73	56	0,60	0,31
Universitaet Hamburg	50	48	0,31	0,22
Universitaet Hannover	21	46	0,26	0,42
Universitaet Tuebingen	63	45	0,50	0,23
Universitaet Wuerzburg	34	45	0,28	0,25
RWTH Aachen	60	42	0,61	0,28
Universitaet des Saarlandes	19	39	0,20	0,41
Universitaet Kiel	16	37	0,13	0,22
Universitaet Frankfurt a.M.	26	36	0,23	0,24
Freie Universitaet Berlin	49	32	0,42	0,26
Universitaet Giessen	20	32	0,17	0,23
Universitaet Duisburg-Essen	36	28	0,41	0,17
Universitaet Kassel	22	26	0,38	0,30
Universitaet Rostock	40	26	0,64	0,31
Universitaet Regensburg	21	25	0,22	0,18
Universitaet Bonn	31	24	0,25	0,13
Universitaet Koeln	20	22	0,18	0,09
Technische Universitaet Braunschweig	40	20	0,51	0,25
Technische Universitaet Ilmenau	27	20	1,09	0,62

University	Transnational Filings		Intensities (per 100 scientific personnel, FTE)	
	2005-2007	2015-2017	2005-2007	2015-2017
Universitaet Bielefeld	9	20	0,16	0,23
TU Bergakademie Freiberg	14	19	0,62	0,46
Ruhr-Universitaet Bochum	11	18	0,07	0,08
Humboldt Universitaet Berlin	28	17	0,32	0,16
Universitaet Goettingen	38	17	0,36	0,11
Universitaet Magdeburg	10	17	0,16	0,22
Universitaet Bremen	30	16	0,50	0,21
Universitaet der Bundeswehr Muenchen	0	15	0,00	0,54
Universitaet Leipzig	19	15	0,16	0,09
Universitaet Greifswald	12	14	0,25	0,22
Universitaet Marburg	33	14	0,60	0,19
Universitaet Dortmund	13	12	0,19	0,12
Universitaet Duesseldorf	16	12	0,17	0,09
Universitaet Luebeck	9	12	1,52	1,32
Universitaet Ulm	10	12	0,15	0,13
Technische Universitaet Darmstadt	20	11	0,29	0,11
Universitaet Oldenburg	7	10	0,19	0,15
Universitaet Paderborn	8	10	0,21	0,14
Technische Universitaet Kaiserslautern	12	9	0,34	0,13
Universitaet Bayreuth	8	9	0,19	0,16
Universitaet der Bundeswehr Hamburg	3	9	0,35	0,50
Universitaet Konstanz	17	9	0,40	0,12
Technische Universitaet Chemnitz	9	7	0,24	0,10
Universitaet Mannheim	2	7	0,05	0,12
Universitaet Muenster	34	7	0,22	0,04
Universitaet Siegen	6	6	0,15	0,10
Universitaet Augsburg	3	5	0,08	0,07
Universitaet Halle	3	5	0,04	0,05
Brandenburgische TU Cottbus	18	4	0,84	0,08
Technische Universitaet Clausthal	13	4	0,74	0,20
Universitaet Potsdam	11	4	0,20	0,04
Universitaet Hohenheim	3	3	0,10	0,08
Universitaet Wuppertal	1	3	0,03	0,04
Universitaet Koblenz-Landau	2	2	0,07	0,05
Universitaet Lueneburg	0	2	0,00	0,06
Technische Universitaet Hamburg-Harburg	13	1	0,67	0,03
Universitaet Osnabrueck	4	1	0,11	0,02
Universitaet Witten/Herdecke	0	1	0,00	0,06
Bauhaus Universitaet Weimar	3	0	0,17	0,00
Eichstätt-Ingolstadt, Kath. U	0	0	0,00	0,00
Euro.-Uni. Viadrina Frankfurt (Oder) (Priv)	0	0	0,00	0,00
FernUniversitaet Hagen	0	0	0,00	0,00
Universitaet Bamberg	1	0	0,04	0,00
Universitaet Hildesheim	0	0	0,00	0,00
Universitaet Passau	0	0	0,00	0,00
Universitaet Trier	0	0	0,00	0,00
Universität Erfurt	0	0	0,00	0,00
Universität Flensburg	0	0	0,00	0,00
Universität Vechta	0	0	0,00	0,00

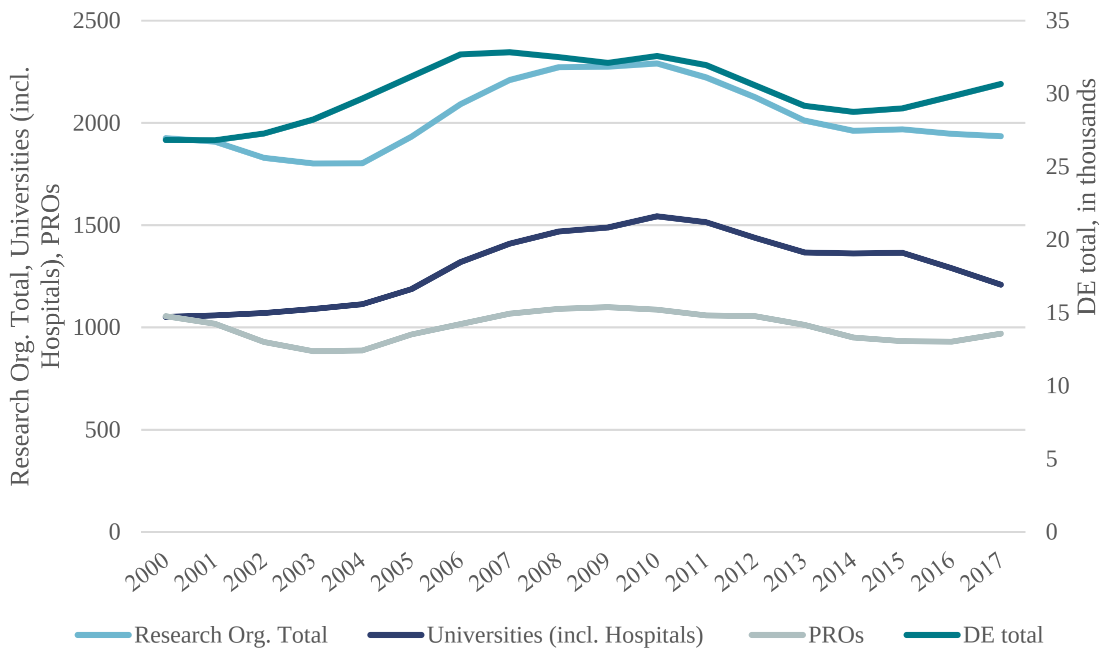
Source: EPO – PATSTAT; Statistisches Bundesamt, Fachserie 11, Reihe 4.4, calculations by Fraunhofer ISI

In terms of patent intensities, the universities with the largest values are the University of Lübeck, the Medizinische Hochschule Hannover, the KIT, the University of Erlangen-Nürnberg, the Technical University of Munich, the Technical University of Ilmenau and the Technical University of Dresden, implying that the universities with large filing figures also tend to have rather large patent intensities. However, also some smaller universities – in terms of the number of patent filings – like the University of Lübeck or the TU Ilmenau show up in this list.

7.2 Academic Patents

Academic patents provide a more complete picture of the trends in patenting by universities and PROs. A rather large share of patents from universities is registered by companies and the university staff only appears as an inventor. Counting only filings that states the name of the university/PRO as an applicant thus underestimates the actual share of patents from academia. In this section, we will therefore focus on the extended perspective of "academic patents", which also takes university inventors into account.

Figure 16: Number of academic patents by German research organizations (3-years moving average), transnational



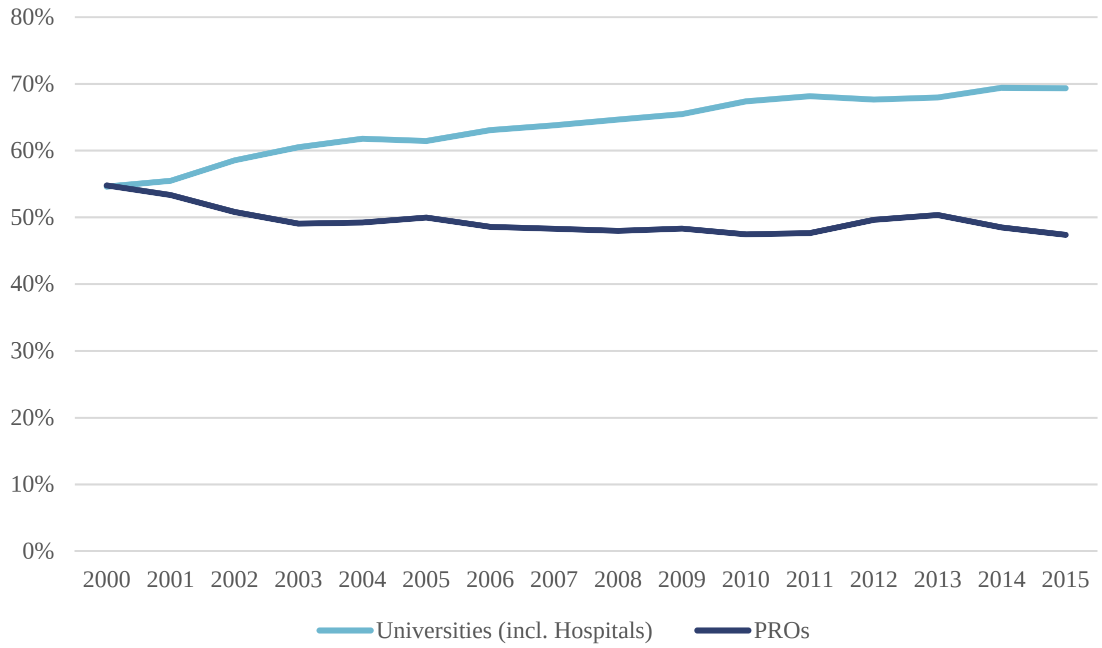
Source: EPO – PATSTAT; Scopus; calculations by Fraunhofer ISI

The number of academic patents by universities and PROs is depicted in Figure 16. As we can see from the figure, slightly more than 1.200 academic patents were filed in 2017. When comparing this to the 734 patents filed by universities with universities named as applicants (Figure 13), it becomes obvious that nearly 40% of patents from universities are "hidden" when only taking the applicant perspective into account. For PROs, on the other hand, this share is much smaller. Only about 8% of patents state inventors from PROs on patents where the PRO is not named as an applicant itself, i.e. we are dealing with an effect that is more deeply associated with universities than PROs.

Consequently, the time trend for academic PRO patents looks similar to the trend of patents filed by PROs (Figure 13). However, this is different for universities. Although there is a growth in academic patents between 2000 and 2010, it is far less pronounced than in the case of patents filed by universities. It thus seems that the abolishment of the "Hochschullehrerprivileg" in 2002 has not led to more patenting by universities per se but only a shift to more patents that are owned by the universities, i.e. they are now stated more often as applicants.

Consequently, these figures consequently are also resembled in the shares of academic patents by universities and PROs in all filings by German research organizations (Figure 17). For universities, a clear increase in these shares can be observed over the years, while the trend has stagnated for PROs. In 2017, 69% of all academic patents come from universities, while 47% originate from public research.[7]

Figure 17: Shares of academic patents by universities and public research institutes in all filings by research organizations (3-years moving average)



Source: EPO – PATSTAT; Scopus; calculations by Fraunhofer ISI

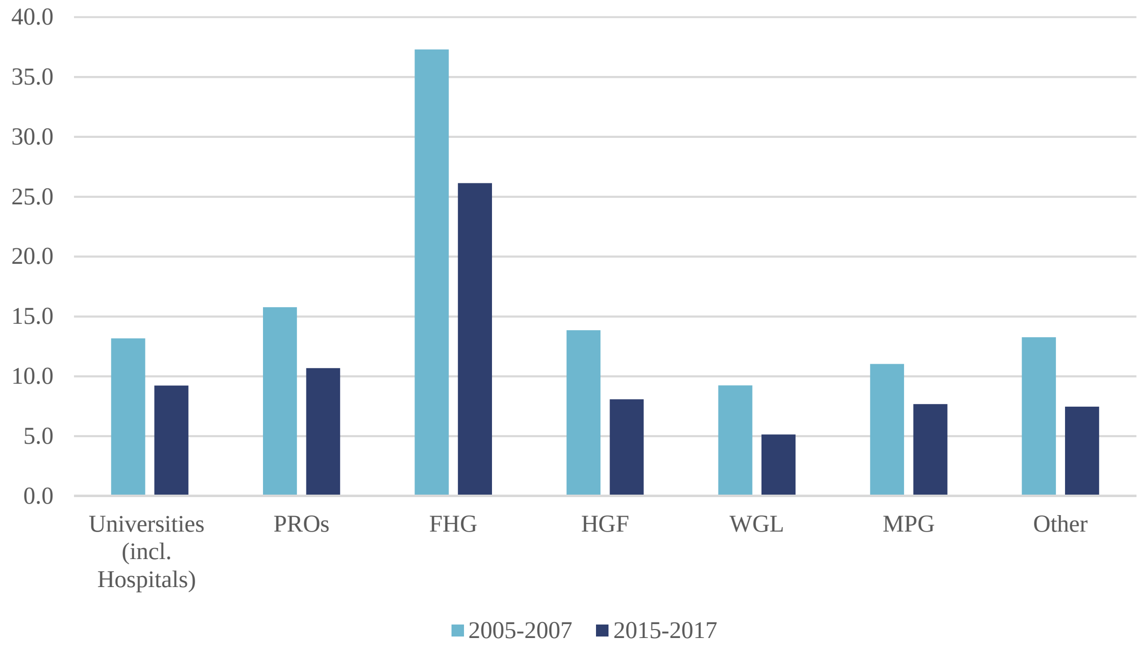
In Figure 18, the patent intensities – per 1,000 R&D employees – for academic patents are provided. What has been observed for the applicant perspective, i.e. a decrease in the patent intensity for universities and PROs, can also be found for academic patents. The difference in the patent intensity between universities and PROs, however, is much smaller in the comparison of the academic patents than when looking at the applicant perspective only. This is due to the fact that university filings are more affected by including the inventors into the picture than PROs. Therefore, in this comparison, the patent intensities for PROs are very similar to the patent intensity by universities, especially in the 2015-2017 period. Regarding the single PROs, the picture resembles the one we have found for patents where the PRO is named as an applicant (as shown in Figure 14). The Fraunhofer Society has the largest patent intensity, followed by the Max-Planck Society, the Helmholtz Association and the Leibniz Association.

The shares by single PROs (Figure 19) make this picture even clearer. Fraunhofer has the largest shares of academic patents, which has even increased over the years. It is followed by the Helmholtz Association, where the shares have slightly declined across time periods. The same is true for the Max-Planck Society, which scores third in terms of academic patent

7 The shares exceed 100% due to co-patents between PROs and universities.

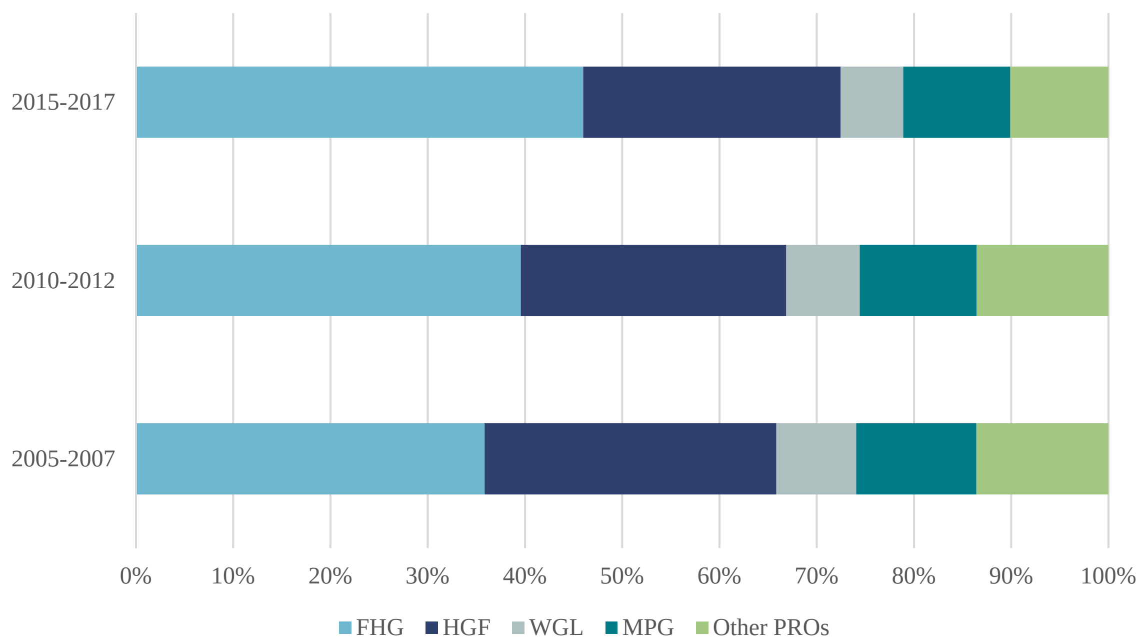
shares. The Leibniz Association has the smallest share of patent filings within the comparison of the large German public research organizations.

Figure 18: Patent intensities (patents per 1,000 R&D employees, full-time equivalents) by German research organizations for academic patents (3-years moving average)



Source: EPO – PATSTAT; Scopus; BMBF Datenportal Table 1.7.6 and 1.7.9, calculations by Fraunhofer ISI

Figure 19: Shares of academic patents from public research organizations in all academic patents by PRO (3-years moving average)



Source: EPO – PATSTAT; Scopus; calculations by Fraunhofer ISI.

In Table 7, we take a closer look at the academic patents of single universities. Their absolute number as well as patent intensities are provided in Table 7. The Technical University of

Munich has the largest number of academic patents between 2015 and 20017 followed by the University of Jena, the University of Erlangen-Nürnberg, the RWTH Aachen, the Technical University of Dresden, the KIT and the Charité in Berlin. In terms of patent intensities, smaller universities, e.g. the University of Lübeck, the Medizinische Hochschule Hannover, the Helmut Schmidt University and the University of Jena are on top of the list. However, also some larger universities like the KIT or the TU Munich show up in the top 10 of patenting universities in terms of intensities.

Table 7: Number of academic patents and patent intensities by universities

University	Transnational Filings		Intensities (per 100 scientific personnel, FTE)	
	2005-2007	2015-2017	2005-2007	2015-2017
Technische Universitaet Muenchen	203	362	1.30	1.45
Universitaet Jena	201	268	1.96	1.87
Universitaet Erlangen-Nuernberg	138	253	0.91	1.12
RWTH Aachen	146	200	0.99	0.91
Technische Universitaet Dresden	173	194	1.14	0.94
Karlsruher Institut fuer Technologie	156	190	1.71	1.58
Charite - Universitaetsmedizin Berlin	315	174	2.34	1.29
Medizinische Hochschule Hannover	117	155	2.69	2.12
LMU Muenchen	178	149	0.93	0.50
Universitaet Hannover	66	149	0.80	1.36
Freie Universitaet Berlin	290	141	2.47	1.12
Technische Universitaet Berlin	144	139	1.27	0.98
Humboldt Universitaet Berlin	256	129	2.95	1.25
Universitaet Heidelberg	116	129	0.61	0.45
Universitaet Mainz	128	114	1.06	0.64
Universitaet Stuttgart	83	103	0.76	0.72
Universitaet Freiburg (i.Br.)	173	94	1.12	0.39
Universitaet Hamburg	96	93	0.60	0.42
Universitaet des Saarlandes	61	84	0.66	0.89
Universitaet Tuebingen	134	74	1.06	0.38
Universitaet Regensburg	53	60	0.56	0.44
Ruhr-Universitaet Bochum	50	51	0.51	0.34
Universitaet Wuerzburg	60	51	0.49	0.28
Universitaet Dortmund	47	49	0.70	0.47
Universitaet Giessen	33	48	0.29	0.35
Universitaet Bayreuth	29	46	0.70	0.81
Universitaet Magdeburg	21	46	0.34	0.58
Universitaet Rostock	54	46	0.86	0.55
Technische Universitaet Bergakademie Freiberg	28	44	1.23	1.06
Universitaet Kiel	49	44	0.39	0.26
Universitaet Frankfurt a.M.	67	42	0.60	0.28
Technische Universitaet Darmstadt	84	41	1.20	0.42
Universitaet Ulm	52	41	0.78	0.45
Universitaet Duisburg-Essen	62	39	0.70	0.24
Universitaet Koeln	49	39	0.43	0.16
Universitaet der Bundeswehr Hamburg	16	36	1.85	1.99
Technische Universitaet Ilmenau	39	34	1.57	1.05
Technische Universitaet Braunschweig	62	32	0.79	0.39
Universitaet Bremen	49	27	0.81	0.36
Universitaet Bonn	40	26	0.33	0.14
Universitaet Kassel	29	26	0.50	0.30
Universitaet Bielefeld	12	25	0.22	0.29
Universitaet Goettingen	78	25	0.73	0.17
Universitaet Muenster	62	25	0.41	0.13
Universitaet Luebeck	37	22	6.26	2.42
Universitaet Paderborn	16	22	0.42	0.31
Universitaet Greifswald	36	21	0.75	0.33
Technische Universitaet Hamburg-Harburg	37	20	1.91	0.55
Universitaet Duesseldorf	58	19	0.63	0.15
Universitaet Leipzig	38	18	0.32	0.10
Universitaet Marburg	84	18	1.53	0.24
Technische Universitaet Kaiserslautern	20	17	0.57	0.25
Universitaet der Bundeswehr Muenchen	3	17	0.16	0.62
Technische Universitaet Clausthal	27	16	1.54	0.82
Brandenburgische Technische Universitaet Cottbus	20	12	0.93	0.25
Universitaet Augsburg	5	12	0.14	0.18
Universitaet Osnabrueck	15	11	0.41	0.24

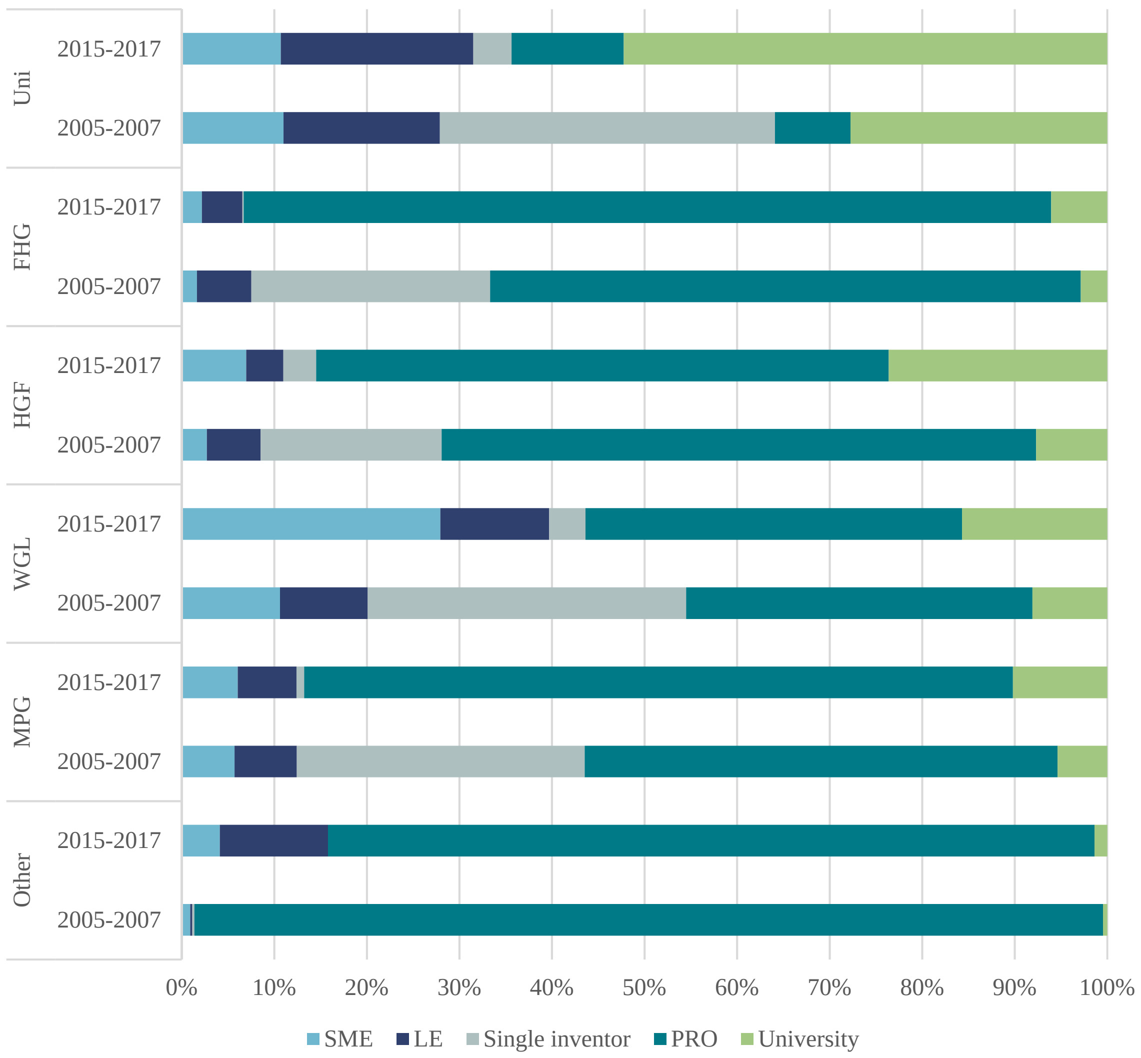
Universitaet Konstanz	45	10	1.06	0.14
Universitaet Oldenburg	7	10	0.19	0.15
Technische Universitaet Chemnitz	26	9	0.68	0.13
Universitaet Siegen	20	9	0.49	0.15
Universitaet Mannheim	10	7	0.26	0.12
Universitaet Potsdam	20	7	0.37	0.07
Universitaet Halle	3	5	0.04	0.05
Universitaet Hohenheim	8	5	0.27	0.13
Universitaet Wuppertal	3	5	0.08	0.07
Bauhaus Universitaet Weimar	4	4	0.22	0.16
Universitaet Witten/Herdecke	25	4	3.88	0.36
Universitaet Koblenz Landau	2	2	0.07	0.05
Universitaet Lueneburg	0	2	0.00	0.06
Universitaet Passau	0	1	0.00	0.03
Katholische Universitaet Eichstaett Ingolstadt	3	0	0.17	0.00
Europa-Universitaet Viadrina Frankfurt (Oder) (Priv)	0	0	0.00	0.00
FernUniversitaet Hagen	0	0	0.00	0.00
Universitaet Bamberg	1	0	0.04	0.00
Universitaet Hildesheim	0	0	0.00	0.00
Universitaet Trier	2	0	0.06	0.00
Universitaet Erfurt	0	0	0.00	0.00
Universitaet Flensburg	0	0	0.00	0.00
Universitaet Vechta	0	0	0.00	0.00

Source: EPO – PATSTAT; Scopus; Statistisches Bundesamt, Fachserie 11, Reihe 4.4, calculations by Fraunhofer ISI

In a final step, we will take a look at the distribution of the applicants of academic patents. We do this by combining the two perspectives, i.e. patent applicants and academic patents, and can thus analyze who "owns" an academic patent. The shares of academic patents by type of patent applicant are plotted in Figure 20. For universities, a major shift between the periods 2005-2007 and 2015-2017 can be observed. The share of single inventors has decreased while the university files a much larger share of patents itself. This can be interpreted as a direct effect of the 2002 legislation change and can be found for universities as well as for PROs, yet to a lesser extent. In sum, however, filings of academic patents by single inventors have become rather uncommon in recent years.

Apart from that, we can also observe a slight growth in firms being applicants of academic patents, especially large firms. In case of universities, 32% of their academic patents are filed/owned by companies. This share was at 28% in the 2005-2007 period. For Fraunhofer patents, the share of firm applicants has remained rather low over time, implying that most of academic patents are filed by Fraunhofer itself. The same is true for the Max-Planck Society. Hence, the Fraunhofer Society and the Max-Planck Society show the largest shares of self-owned patents, 87% and 77%, respectively. For the Leibniz Association, the Helmholtz Association and especially the "other" PROs the share of filings by firms has clearly increased over the years.

Figure 20: Academic patents by type of patent applicant



Source: EPO – PATSTAT; Scopus; calculations by Fraunhofer ISI

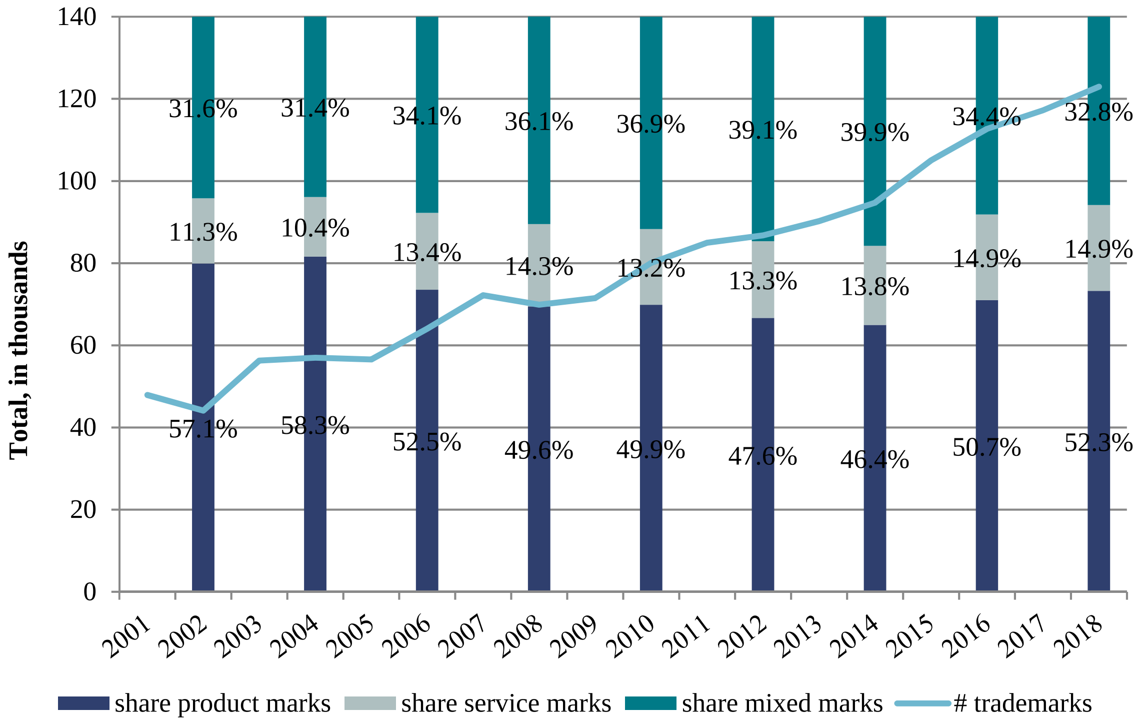
8 Trends in EUIPO trademarks

In this section, we will analyze basic structures of innovation in services and product-related services across industrialized countries with the help of trademark filings at the EUIPO. Patents only provide a limited picture of innovation activities in services. Here, trademarks have established themselves as a prominent indicator for the measurement of innovative activities (Gauch, 2007; Sandner and Block, 2011; Schmoch, 2014). In particular at the micro level, the relationship between trademarks and innovation has been well established (Greenhalgh and Rogers, 2006; Sandner and Block, 2011). Although trademarks can also be filed for products like technical equipment or technical procedures, services are eligible for protection within the system of trademark rights. Trademarks can thus be used as a complementary and relatively "close to the market" indicator for new products and innovation activities in the service sector (Gauch, 2007; Mendonca et al., 2004; Schmoch, 2014). Especially in the case of knowledge-intensive business services trademarks have shown to be well applicable (Schmoch and Gauch, 2009).

In this analysis, we focus on trademarks registered in the form of an EU trademark (former Community Trademark (CTM)) at the EUIPO (European Union Intellectual Property Office), which is valid across the EU.

The general trends show a rather constant rise in trademark filings since 2002, where about 44,000 CTMs were filed (Figure 21). In 2018, nearly 123,000 trademarks were filed at the EUIPO, implying a major growth across the years. Slight declines are only visible during the financial crisis periods between 2000 and 2002 and between 2008 and 2009. Besides the absolute numbers in trademark filings, the figure also provides information on the shares of trademark filings by types (biannually). It can be found that the distribution of filings across type of trademarks has only changed slightly over the years. The largest group of filings are the marks on goods with a share of 52% in 2018. The mixed goods/services marks, i.e. marks the have a NICE code from goods and one from services, are the second largest group of filings with a share of nearly 33%. The pure services marks have the lowest shares with 15%.

Figure 21: Absolute number of EU trademark filings and shares by trademark types, 2000-2018

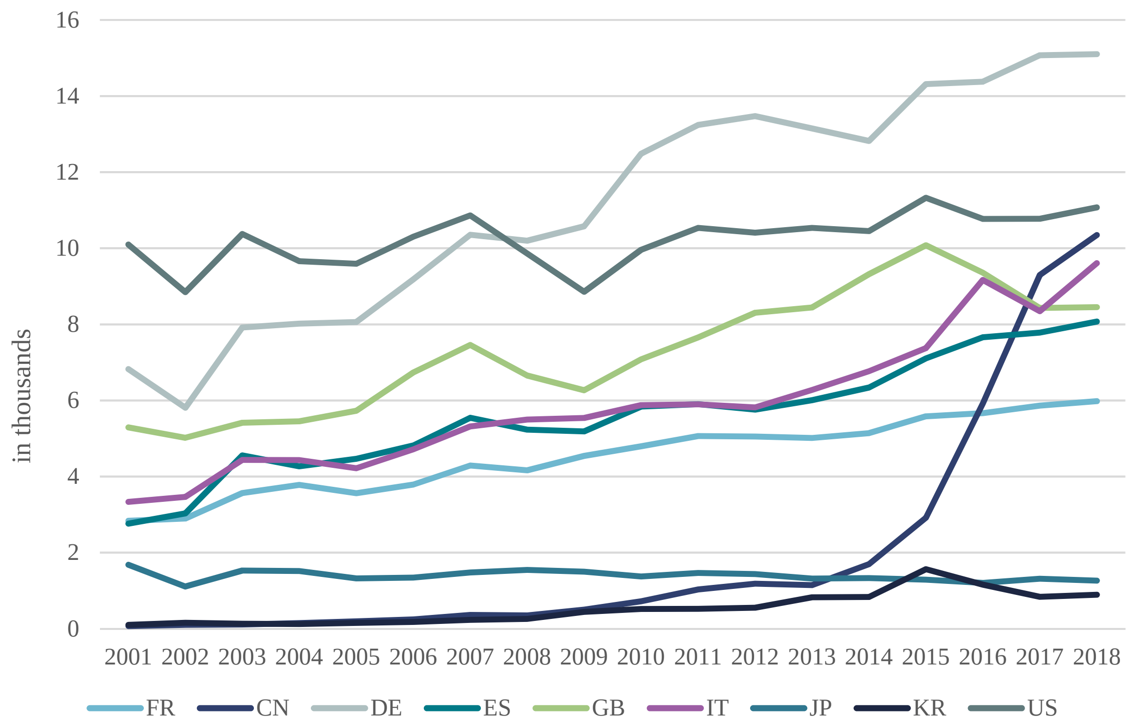


Source: EUIPO; calculations by Fraunhofer ISI

Mixed marks can mostly be regarded as "product-related", meaning that the product is in the foreground, which is also the reason why the share of product marks has more strongly risen than the share of service marks. Oftentimes, however, applicants file a service mark in addition to the product mark representing a product related service, which have gained increased importance within the manufacturing sectors over the last decade (Schmoch, 2003).

There has been a slight shift towards that structure over the years, i.e. there has been a trend towards more mixed marks and less product marks up o 2014. From then on, however, the trend has reversed in favor of the share of product marks and, though to a lesser extent, also the share of service marks. This is most likely an outcome of the changes of the fee structure at the EUIPO (only one class now allowed without additional fees as opposed to three before). In total, 54.7% of the trademarks filed in 2017 are product marks, whereas 31.6% are mixed product/service marks and the remaining 13.7% are pure service marks.

Figure 22: Absolute number of EU trademark filings for selected countries, 2000-2018

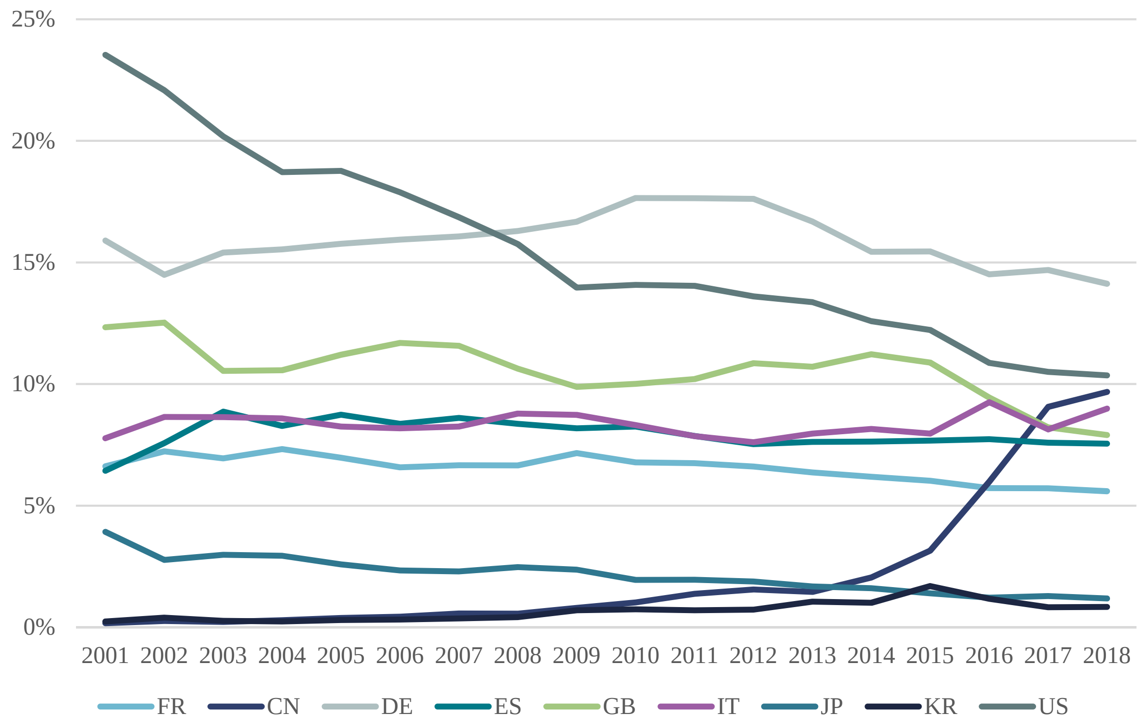


Source: EUIPO; calculations by Fraunhofer ISI

Differentiating the absolute number of EU trademark filings by countries provides more information about the largest trademark applicants at the EUIPO (Figure 22). Germany is the largest trademark applicant with more than 15,000 filings in 2018. Since the year 2000, the trademark filings by German applicants have grown quite constantly, although there have been slight decreases between 2012 and 2014. The second largest applicant is the United States[8], which had rather constant filings figures up to 2009 but a sharp decline during the economic crisis. Afterwards, a slight growth can once again be observed but to a lesser extent than the German filings figures. The number of Chinese filings has massively increased after 2013. Thus, China ranks third directly following the United States in terms of absolute filing figures. Following China is Great Britain, Italy, Spain and France.

8 This lower number of the USA is a direct effect of the fact that we are only able to analyze trademark filings at the OHIM, while the alternative/competing filing procedure via the WIPO is not taken into account due to missing data availability.

Figure 23: Shares in EU trademark filings for selected countries, 2000-2018



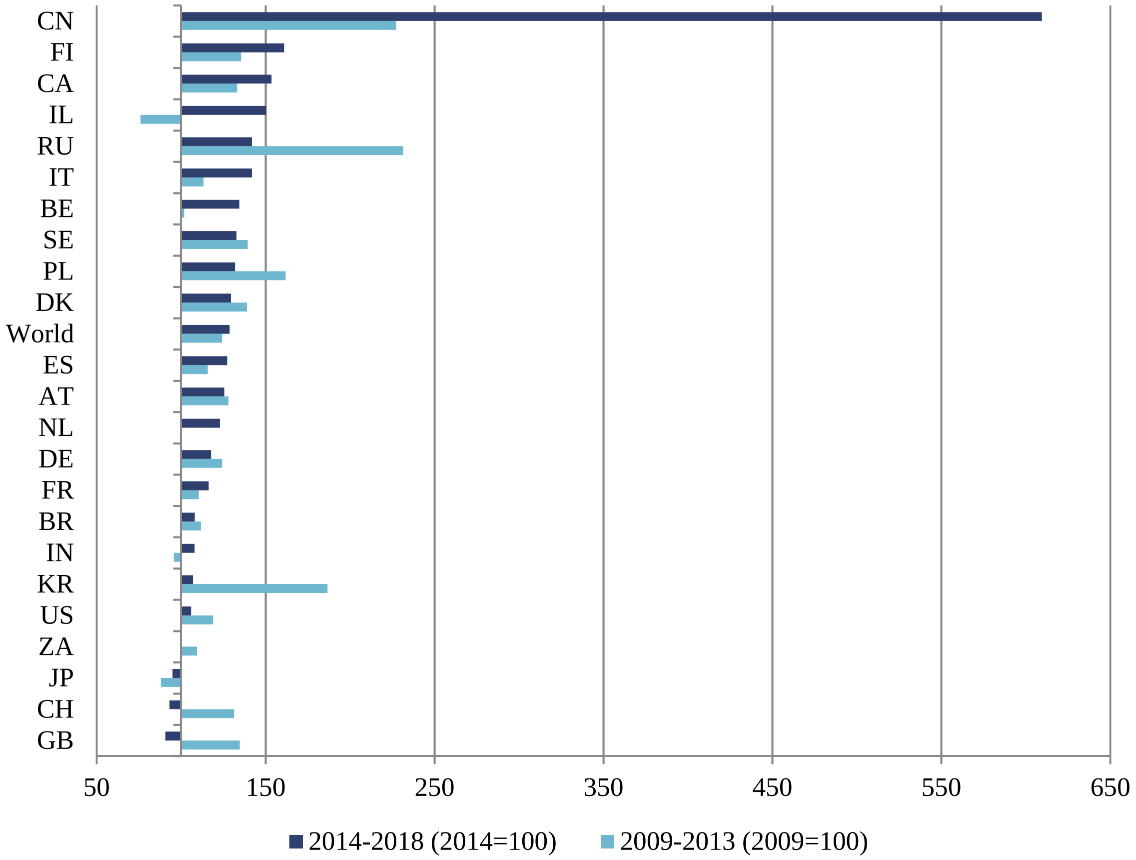
Source: EUIPO; calculations by Fraunhofer ISI

In addition to the absolute figures, the country-specific shares in global EU trademark filings are plotted in Figure 23. Germany is responsible for 14% of all EU trademark filings. Though the German shares were rising between 2004 and 2010, we see a decrease of shares in recent years, which is an effect of the massive growth of Chinese trademark filings. This is not only visible for Germany, but to an even larger extent also for the U.S., where the shares have decreased over the whole time period. Sill, the U.S. have the second largest trademark shares at the EUIPO, followed by China, Italy, Great Britain and Spain.

The strong increase in Chinese trademark filings becomes even more visible when looking at the growth statistics (Figure 24). There already was a rather strong increase in Chinese filings in the 2009 to 2013 period, but growth more than tripled in the 2014 to 2018 period.

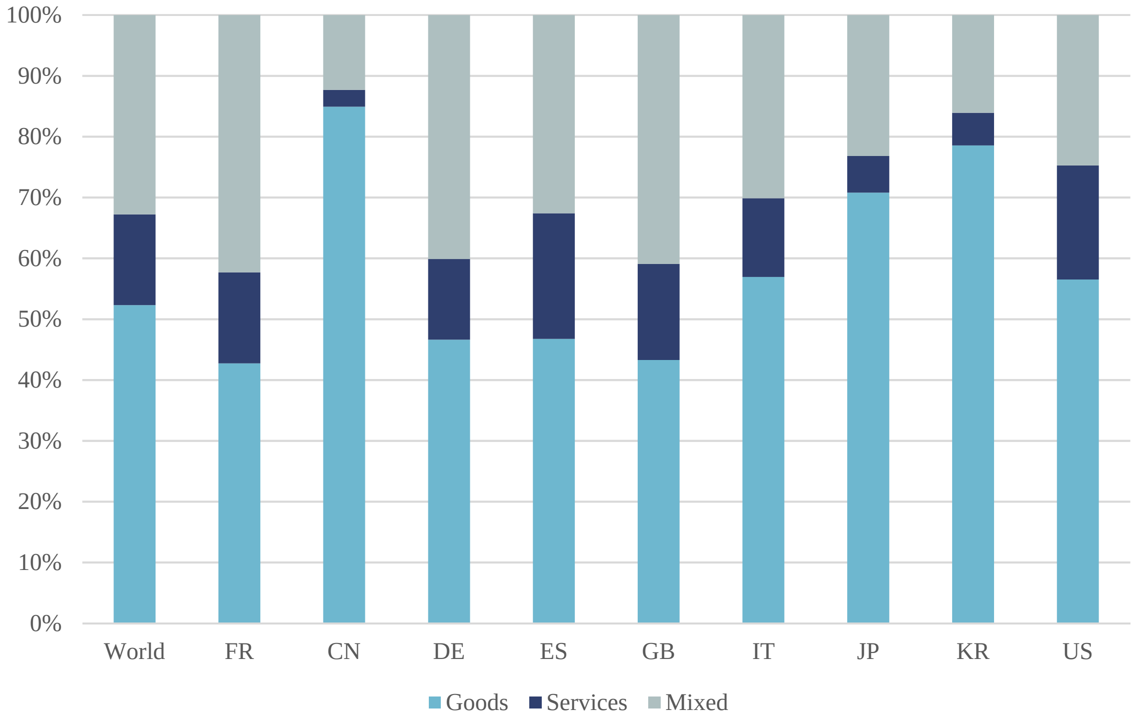
The second largest growth in EU trademark filings between 2014 and 2018 can be observed for applicants from Finland, Canada, Israel and Russia.

Figure 24: Growth in EU trademark filings for selected countries between 2009-2013 and 2014-2018



Source: EUIPO; calculations by Fraunhofer ISI

Figure 25: Shares of trademark types within the countries' portfolios, 2018



Source: EUIPO; calculations by Fraunhofer ISI

A country-specific view on EU trademark filings by trademark type in 2018 is plotted in Figure 25. Here, differences in the trademark portfolios of the analyzed countries can be observed. The world shares are included as a reference as these figures have already been discussed in Figure 21. The German profile is highly similar to the worldwide shares, though mixed trademarks make up for a larger share than in the world average. Similar shares can also be observed for France, Spain and Great Britain, i.e. most of the European countries have a similar profile. An exception is Italy, which has a much larger share in pure goods trademarks than the other countries. It thus more closely resembles the profile of the U.S., although it still has a larger share of mixed marks than the U.S., where a larger share of pure service marks can be found.

Table 8: Trademark intensities (EU trademark filings per 1m employment) and shares of trademarks by types, 2018

Country	Total	Goods		Services		Mixed	
SE	608	270	44%	101	17%	237	39%
FI	577	232	40%	72	12%	272	47%
DK	547	264	48%	63	12%	220	40%
AT	517	201	39%	96	19%	220	43%
CH	425	235	55%	55	13%	136	32%
NL	423	190	45%	71	17%	163	38%
ES	418	195	47%	86	21%	136	33%
IT	414	236	57%	54	13%	125	30%
BE	396	180	45%	73	18%	144	36%
DE	360	168	47%	48	13%	145	40%
GB	261	113	43%	41	16%	107	41%
FR	221	94	43%	33	15%	94	42%
PL	170	87	51%	25	15%	58	34%
CA	76	37	49%	10	14%	29	38%
IL	71	34	48%	15	21%	23	32%
US	71	40	57%	13	19%	18	25%
KR	33	26	79%	2	5%	5	16%
JP	19	13	71%	1	6%	4	23%
CN	13	11	85%	0	3%	2	12%
ZA	10	7	73%	1	9%	2	18%
BR	3	1	48%	1	23%	1	29%
RU	1	1	59%	0	6%	0	35%
IN	0	0	n.a.	0	n.a.	0	n.a.

Source: EUIPO; calculations by Fraunhofer ISI

The largest shares of pure product marks can be observed for the Asian countries, i.e. Japan, Korea and especially China, with a share of product marks of 85%. Pure service marks are rather uncommon and most of the remaining marks are mixed marks. In sum, the share of product marks is much larger for the non-European countries than for the European countries, with the exception of Italy. These trends can be attributed to the fact that cross-border trade with services is much less common than with products. Since we have a very strong focus to the European market when looking at trademark filings at the EUIPO, this at least partly explains the low shares of service marks for non-European countries.

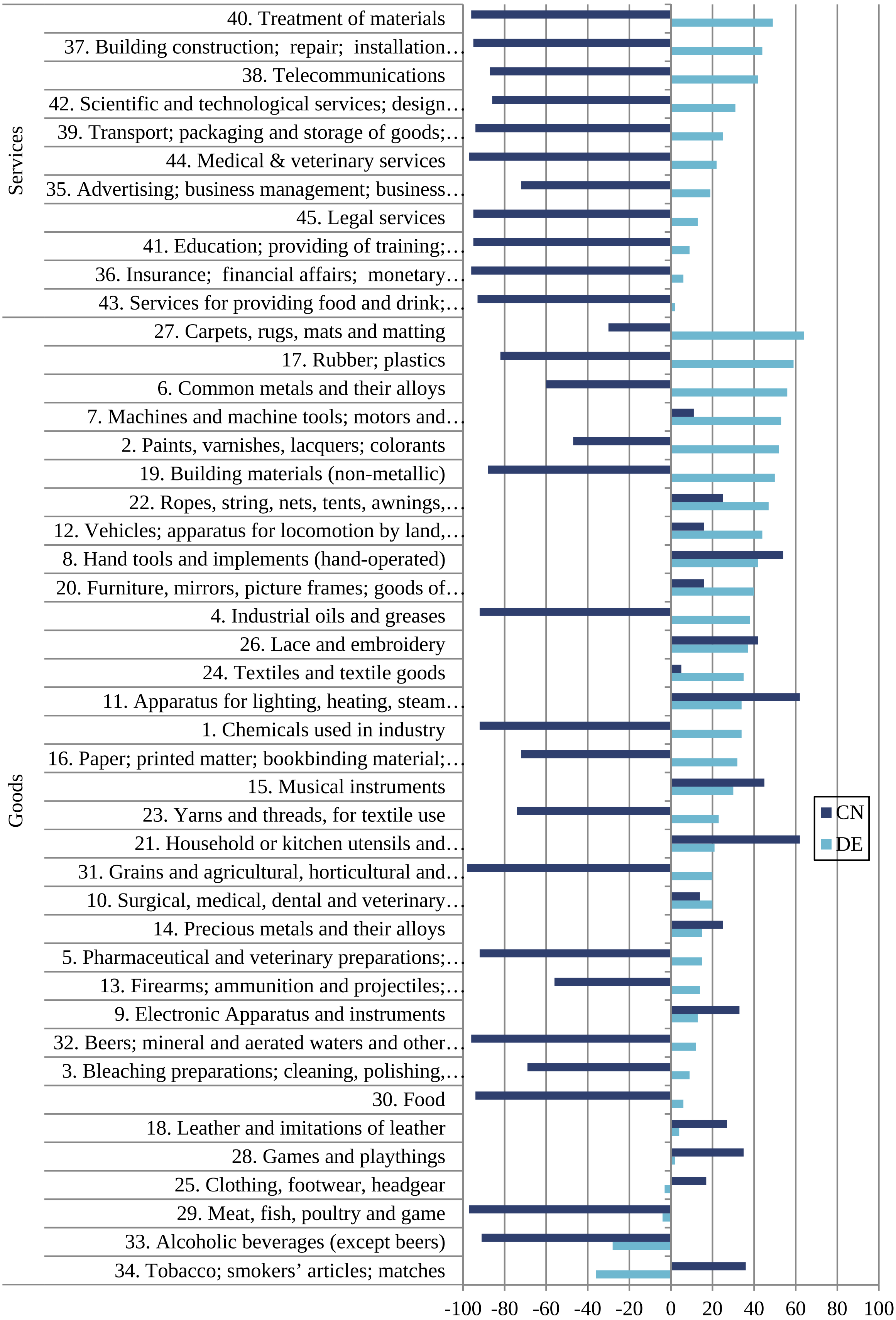
Further interesting trends are revealed by looking at the trademark intensities differentiated by trademark types for the year 2018 in Table 8. As with patents, the number of trademark filings is normalized alongside the workforce within the respective country (per 1 million labor force). This provides a picture of the trademark landscape independent of size effects. From the table it can be seen that the Scandinavian countries have the highest patent intensities (Sweden, Finland and Denmark), followed by Austria on the fourth rank. The large European countries in absolute terms, i.e. Germany, France and Great Britain are ranked tenth, eleventh and twelfth, while Spain and Italy, who also showed comparably large filing figures score sixth and seventh. The international countries, i.e. the U.S. and the Asian countries but also Canada and Israel score at the lower ranks. This, however, is not surprising as we have a focus on the European market by analyzing EUIPO filings.

In a final step, we have calculated the specialization indices for the trademark portfolios of Germany, China and the U.S. in comparison, to find out in which NICE class a country is strongly or weakly represented compared to the total EU trademark filings. The specialization indices were calculated in the same way as for the patenting profiles, i.e. positive signs mean that a NICE field has a higher weight within the country than in the world, negative values imply a below average specialization. The specialization indices of Germany compared to China are depicted in Figure 26.

Germany shows a positive specialization in most of the NICE classes in goods as well as services. The largest values can be found in "carpets, rugs, mats and matting", "rubber goods", " common metals and their alloys" as well as "machines and machine tools". Among the service related classes Germany is most specialized in "treatment of materials", "building construction" and "telecommunications". The picture for China looks completely different. Although its filings figures massively increased in the recent years, specialization took place in only a few classes, i.e. positive values can only be found in 17 of 45 NICE classes. The top three are "apparatus for lighting, heating", "household or kitchen utensils" and "hand tools and implements". Among these, only "apparatus for lighting, heating" is a technology-intensive class as defined by Schmoch and Gauch (2009). Among the technology-intensive classes in Germany, the most highly specialized are "common metals and their alloys" and "machines and machine tools. The most specialized knowledge-intensive service classes are "treatment of materials" and "building construction".

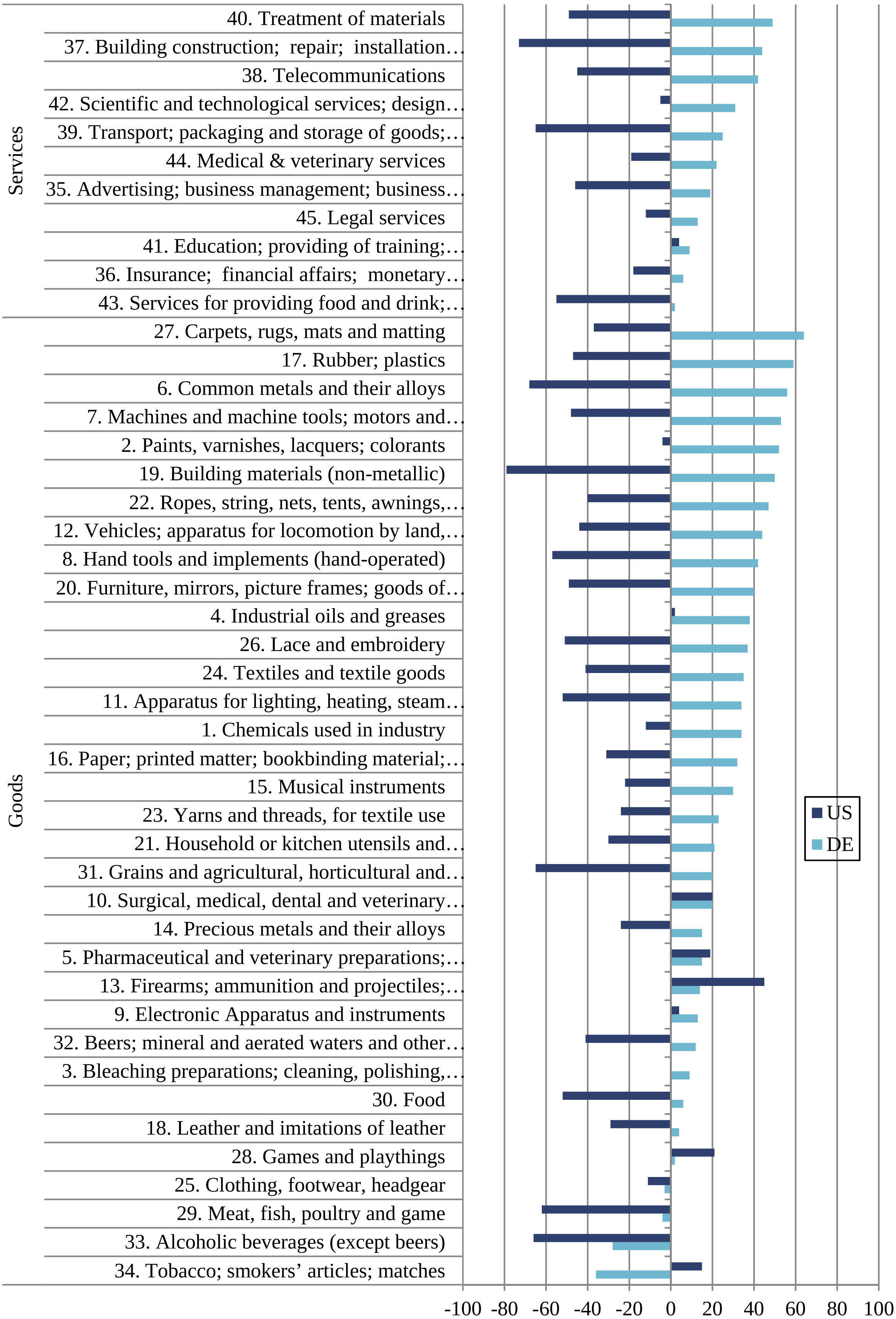
In Figure 27, the comparison of the German specialization profile to the profile of the U.S. is depicted. The U.S. shows even fewer fields with positive specialization values. There are only eight fields with a positive specialization: "furniture", "tobacco", "leather", "firearms", "industrial oils and gases", "rubber and plastics", "pharmaceuticals", "vehicles" and "apparatus for lighting, heating".

Figure 26: EU trademark related profiles Germany and China, 2018



Source: EUIPO; calculations by Fraunhofer ISI

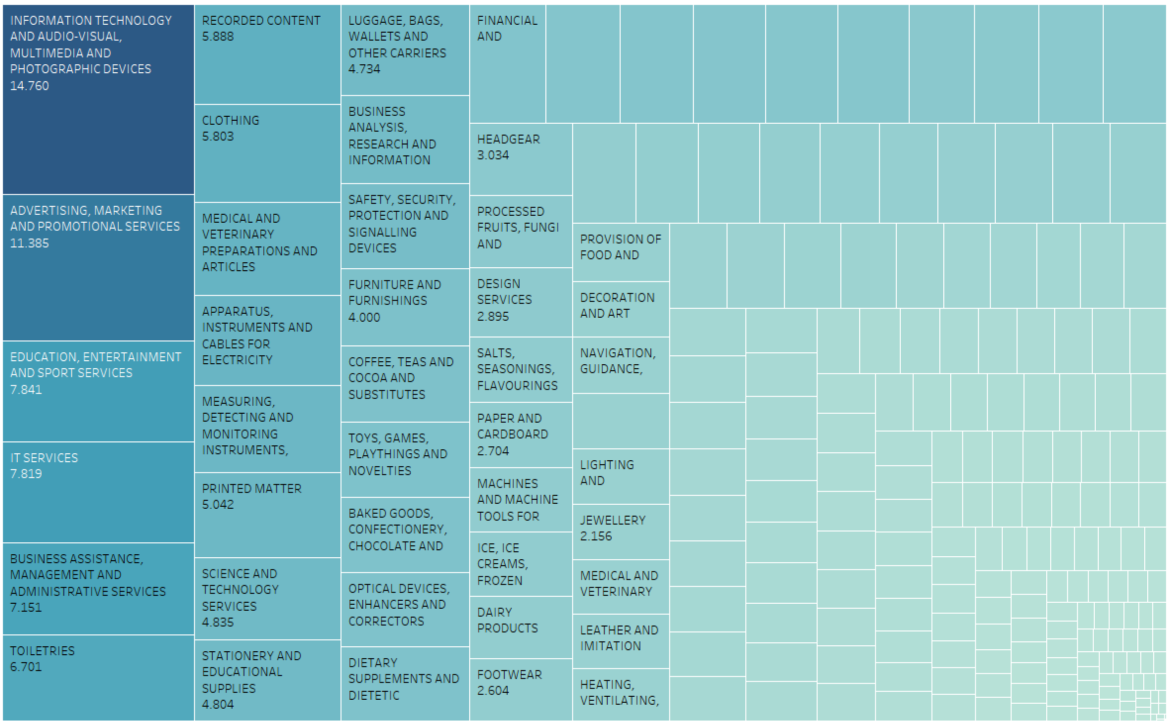
Figure 27: EU trademark related profiles Germany and the U.S., 2018



Source: EUIPO; calculations by Fraunhofer ISI

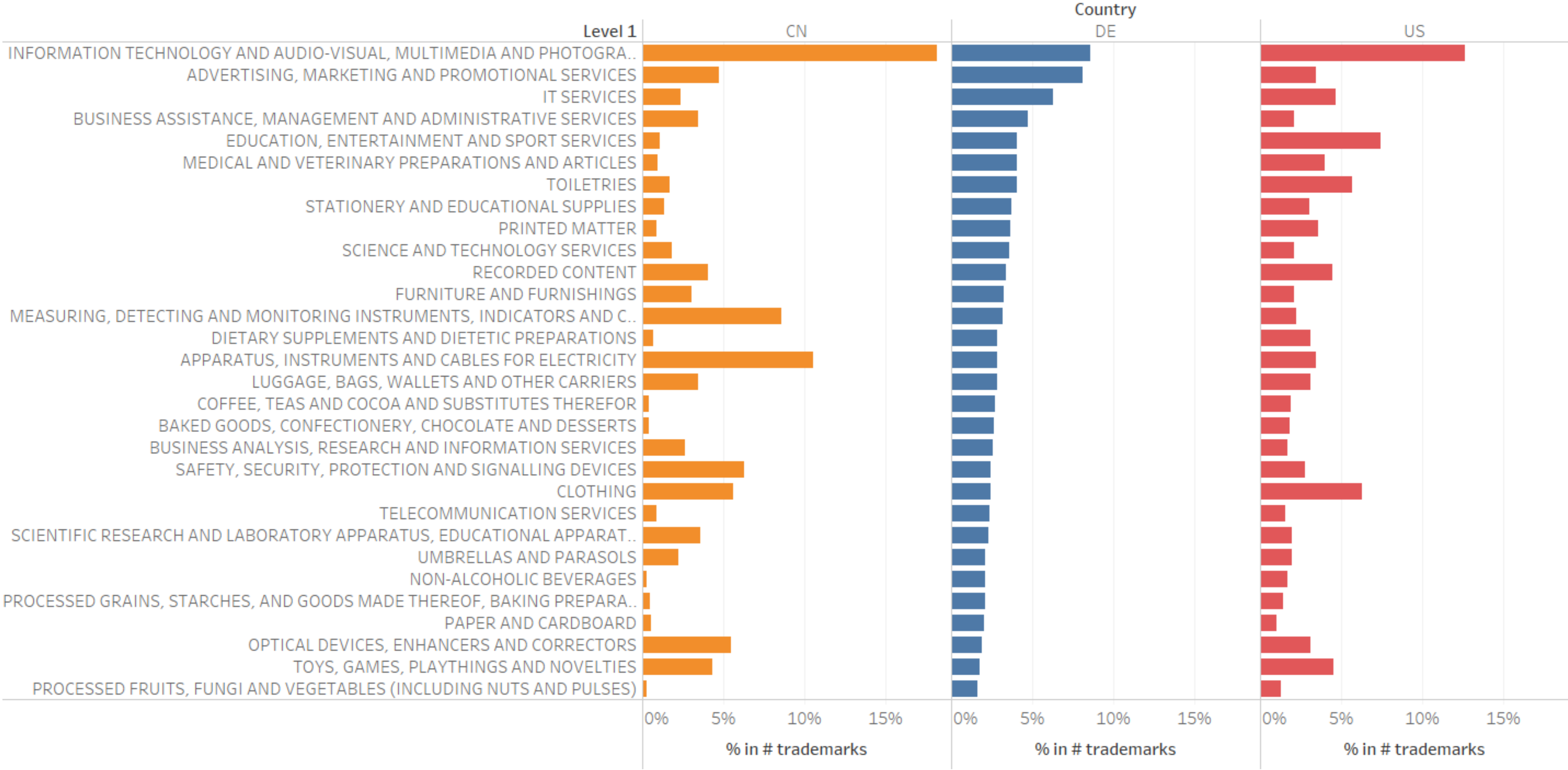
With the help of our newly generated classification (for details please refer to the methodology Section 2), we can now look into much more detail than the NICE classes would allow us. The classification is, similar to the IPC, hierarchical with the NICE classes being the top-level. Below these are five more layers, ranging from the most aggregated "Level I" classes (234) to the most disaggregated "Level V" classes (~8,600). The level I classes by size (absolute numbers) for the complete EUIPO trademark landscape in 2018 (worldwide) is plotted in Figure 28. As can be seen from the figure, the largest level I class is "information technology and audio-visual, multimedia and photographic devices", a subclass of NICE class 9, "electronics (incl. computers)", followed by "advertising, marketing and promotional services", a subclass of NICE class 35 "Advertising; business management". The next largest level I classes are "education, entertainment and sports services", "IT services", "Business assistance, management and administrative services" and "toiletries".

Figure 28: Trademark classification at Level I, World, 2018, absolute numbers



Source: EUIPO; calculations by Fraunhofer ISI

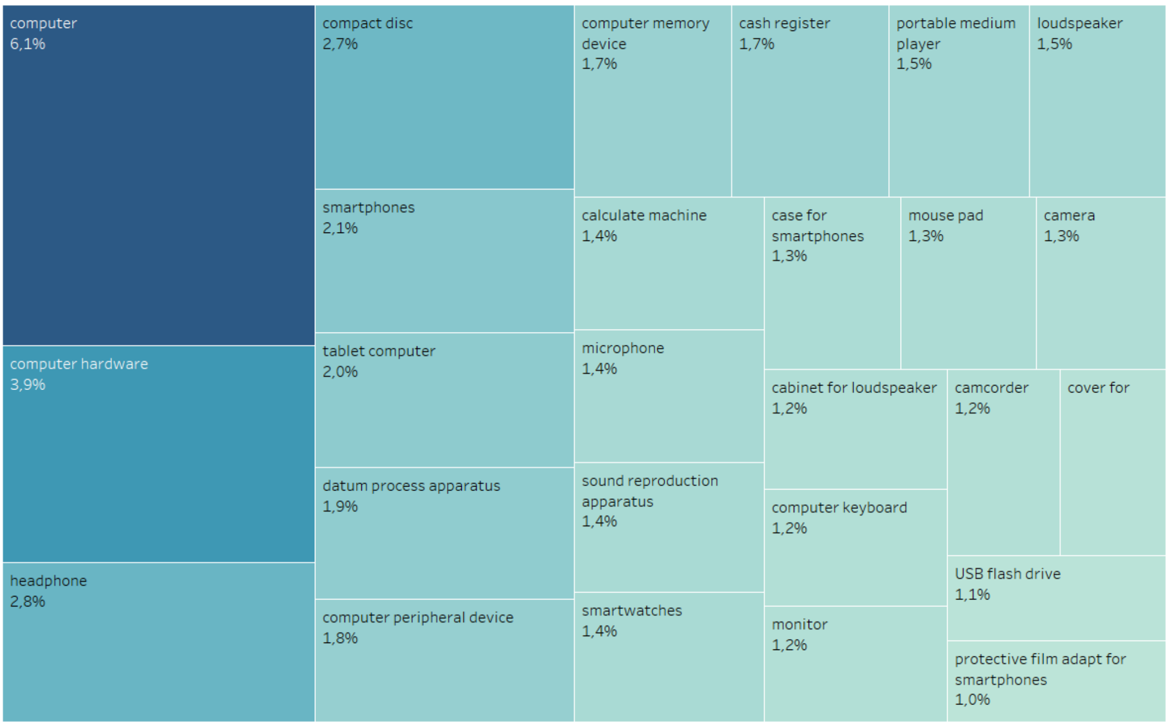
Figure 29: Shares of trademarks in total trademarks at classification level I, China, Germany and the U.S., 2018



Source: EUIPO; calculations by Fraunhofer ISI

This rather aggregated view can also be differentiated by country, which is shown in Figure 29. The figure shows the top thirty classes for Germany (as shares of total German filings) in comparison to the U.S. and China. As in the worldwide average, the largest level I class for all of the three countries is "information technology and audio-visual, multimedia and photographic devices". The next largest level I classes in Germany are "Advertising; marketing and promotional services", "IT services" and "Business assistance, management and administrative services". These classes have a much smaller weight in China, where especially "Apparatus, Instruments and Cables for Electricity", "Measuring, detecting and monitoring services", "safety, security, protection and signaling devices", "clothing" and "optical devices" have a much larger weight, once again showing that the Chinese trademark profile is more product than service oriented. For the U.S. the second largest level I class is "education and sports services", followed by "clothing", "toiletries" and "toys and games", i.e. classes that are more oriented to the consumer market than the "business market".

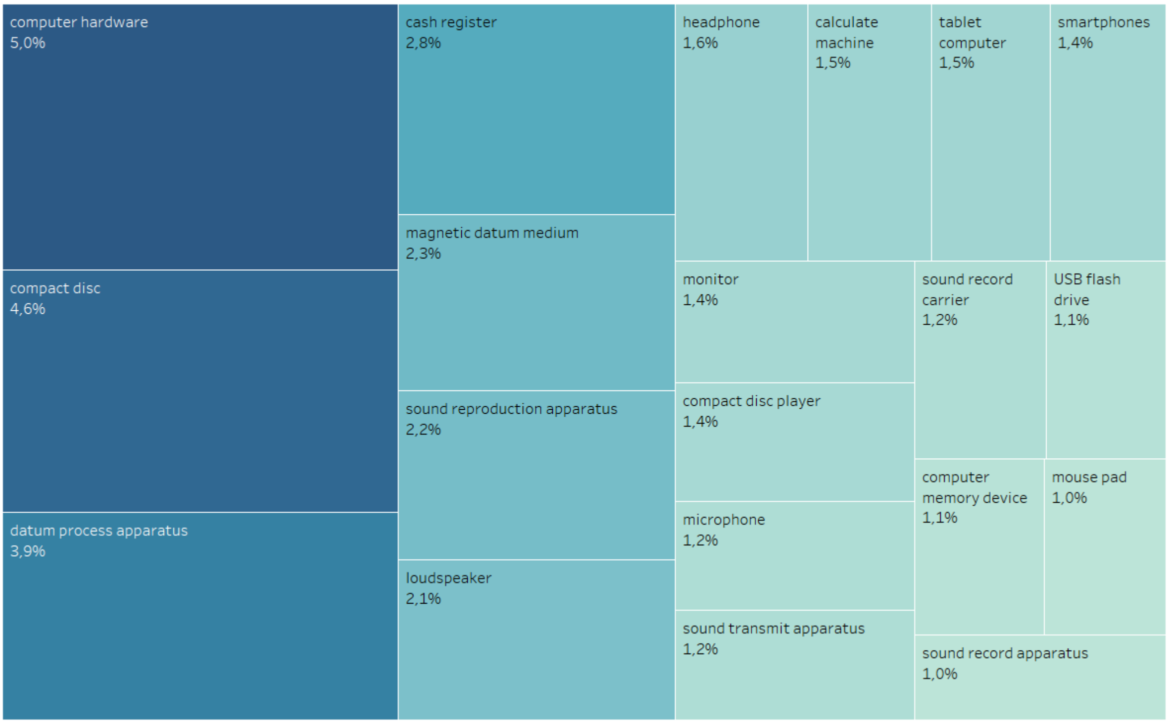
Figure 30: Shares of trademarks within level I class "information technology and audio-visual, multimedia and photographic devices" at level 5, world, 2018



Source: EUIPO; calculations by Fraunhofer ISI

For the largest level I class, namely "information technology and audio-visual, multimedia and photographic devices" we have further generated an overview of the level 5 classes for the world (Figure 30) as well as Germany (Figure 31) in comparison. For the world, it can be found that the largest level 5 class in level I subclass "information technology and audio-visual, multimedia and photographic devices" is "computers", followed by "computer hardware", "headphones", "compact discs", "smartphones" and "tablet computers"

Figure 31: Shares of trademarks within level I class "information technology and audio-visual, multimedia and photographic devices" at level 5, Germany, 2018



Source: EUIPO; calculations by Fraunhofer ISI

For Germany (Figure 31), in comparison, the largest level 5 classes in "information technology and audio-visual, multimedia and photographic devices" are "computer hardware", "compact disc", "datum process apparatus", "cash register", magnetic datum medium", "sound production apparatus" and "loudspeaker". This is a very good example of what differences can be found below the surface of the NICE classes and even below the level I subclasses as Germany shows a rather different picture than the world when it comes to this IT related level I subclass.

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