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Patent Applications – Structures, Trends and Recent Developments 2018

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0 Summary

Transnational Patent Filings

At the international level, the US is and remains the largest technology providing country in absolute terms, followed by Japan and, with a given distance, China and Germany. China still shows large growth rates in international patenting, also in the last two years. In terms of patent intensities, i.e. patent filings per one million employees, however, rather the smaller countries like Switzerland and Sweden are at the top of the list of the analyzed technology-oriented countries. Japan scores third this year, ahead of Finland. Germany ranks fifth. In terms of intensities, the USA is in the midfield, together with France and Great Britain as well as the EU28 on average.

A closer look at high-tech patent filings reveals a rate of about 63% of high-technology patents in total worldwide patenting in the year 2016, with a rather stable trend in the last years. Germany encountered a decrease in high-tech shares between 2002 and 2005 and showed stagnating trends in the following years. Since 2010, however, increasing trends in high technology patenting can be observed. Germany, Japan, Denmark, Italy and Switzerland, but also Brazil and to a certain extent India, are the countries that show the strictest focus on high-level technologies, while most of the other countries are more active in leading-edge technologies.

When looking at Germany's country-specific technology profiles according to the NIW/ISI/ZEW list of research-intensive industries and goods (Gehrke et al., 2013), comparative advantages in three main areas can be found: transport (automobiles and engines as well as rail vehicles), machinery (agricultural machinery, machine tools) and some areas of electrical engineering like power machines and power generation. Positive developments in terms of patent specializations can be found in parts of chemistry (rubber goods, photo chemicals, scents and polish, organic basic materials) as well as medical instruments. Slightly negative trends in specialization, however, can be observed in electronic instruments.

Structures in International Co-Patenting

Over the last twenty years, the shares of international co-patents have constantly increased, implying that the need to cooperate internationally has gained increased importance. From 2007 onwards, however, a stagnation in the share of worldwide co-patents can be observed, which has even led to a decrease in co-patenting shares in many countries. In the last two years, however, co-patenting shares have started to rise again for many of the countries in our comparison. Deviations from this pattern can only be found for the large Asian economies, i.e. China, Japan and Korea, where the shares have been decreasing over the whole time period of the last decade although they already are at a rather low level, at least in Korea and Japan. Switzerland has the largest co-patenting shares among the countries in our comparison with, followed by Great Britain, Sweden and France. Germany follows France but still is ahead of the United States.

For many of the countries in, however, the U.S. is the most important cooperation partner while the U.S. itself cooperates most strongly with China and Germany. Germany is also an important partner for many other countries.

The differentiation by high-tech fields reveals that there are large field-specific idiosyncrasies in co-patenting. The largest specialization in co-patents can be found in chemistry related fields as well as pharmaceuticals. Specializations in co-patents are low in fields regarding machinery and some fields of electronics as well as fields where cooperation is rare as in the case of defense related technologies.

Research Labs and Motives to Internationalize

Patent based indicators can be used to identify labs or research locations of MNEs and with these indicators we can try to empirically differentiate home-base augmenting vs. home-base exploiting motives with the help of field profiles. It could be found that the trend of internationalization of R&D continues. Up to 40% of MNEs patents are invented in locations outside of the MNEs host country. Furthermore, patent filings from research labs are a rising phenomenon. The number of filings from international labs has grown for all three companies in our comparison, i.e. Siemens, BASF and Bosch, since 2000. The largest growth rates can be observed up to 2010. When looking at the similarities of the research labs, the regions in which they are located and the firms as a whole, it can be found that besides the characteristics of the target market and firm capabilities, proximity to the headquarter location seems to influence the motive to internationalize. We have further found the there is a focus on the U.S. when it comes to home-base augmenting strategies.

Patent Activities of the German Federal States

The regionalized patent statistics for the German federal states shows that the two large southern federal states, i.e. Bavaria and Baden-Württemberg, file the largest number of patents at the transnational level. Together with North-Rhine Westphalia, they account for about two thirds of all German transnational filings. Generally, it can be stated that the Southwestern German federal states have larger filing numbers than the Northern and Eastern states. With regard to the growth rates only moderate growth in patent filings can be found between 2005 and 2015. The largest growth rates can be observed for Mecklenburg-West Pomerania, Hamburg and Bavaria, i.e. two Northern German federal states show a large growth in filings. However, seven of the sixteen federal states show negative growth rates since 2005. In terms of internationalization, it can be found that Hesse, Rhineland-Palatinate, Hamburg, Berlin, Brandenburg and North-Rhine Westphalia have the largest internationalization rates while the least internationalized federal states Baden-Württemberg, Saxony, Saxony-Anhalt, Bavaria and Lower-Saxony. The high-tech profiles of the federal states show that the largest share of high-technology patents within the German comparison can be found in Brandenburg, followed by Berlin, Thuringia, Baden-Württemberg and Bavaria.

Patenting Trends in Public Research

The analyses of patent filings by universities and public research organizations (PROs) in Germany shows that patenting has become more and more important for universities and PROs over the last 10 years. However, the analyses of academic patents reveal that at least part of the growth in university filings after the abolishment of the Hochschullehrer-privileg" in 2002 can be attributed to the fact that universities more often show up as patent applicants on patent filings, while the actual research output of universities has not grown exceptionally.

Since 2010, however, declining patent trends by universities and PROs can be observed. This is also reflected in the patent intensities, i.e. the number of transnational patent filings per 1,000 R&D employees, of universities and PROs. Especially in the recent years the patent intensities have been decreasing. Though the patent intensities of universities have risen in the course of the 2000s, PROs still are far more patent intensive than universities are. Among the PROs, the Fraunhofer Society is responsible for the largest share of patent filings, followed by the Helmholtz Association, the Max-Planck Society and the Leibniz Society.

The analyses if high-technology shares show it can that there are no extreme differences in the high-tech shares between universities and the single PROs. Though the universities still show larger high-tech shares than the PROs, this mostly stems from differences in the shares of high-level technologies.

Trademarks

The general trends in trademark filings show an increase in EU trademark filings between 2002 and 2017 with slowdowns visible during the economic crises in 2000/2001 and 2008/2009. Germany is by far the largest trademark applicant at the EUIPO with more than 22,000 filings in 20175, followed by the U.S. and China, which has shown massive growth rates in EU trademark filings in the last few years and thus has managed to catch up with the United States. Overall, non-European countries show a larger share of product marks than their European counterparts. This is most obvious for China and Korea, while the profile is still more balanced for the U.S. and Japan.

In terms of trademark intensities, i.e. trademark filings normalized alongside the workforce within the respective countries, the smaller economies like Austria, Sweden, Finland, Denmark and Germany show the largest values. The differentiation by NICE classes reveals that Germany's large shares in CTMs are not due to major shares in only few classes but are spread across the whole range of NICE classes. Germany thus shows positive specialization values in most of the fields but still a rather clear specialization to the fields related to machines and metals can be observed.

1 Introduction

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

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

This year's report gives a brief overview of the developments of transnational patent applications since 1995. Yet, we especially focus on the recent trends and structures. In this year's report, we will further provide in-depth analyses of international cooperation structures in terms of co-patents including an empirical analysis on the research labs of three large German companies and their motives for internationalization. Moreover, we will provide a 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.

The report is structured as follows. Section 2 presents the data and methods applied for the analyses in the following chapters. Section 3 focuses on transnational patent applications and discusses total trends, growth rates, intensities and specialization indices, which are designed to reflect patent structures beyond size effects of countries and technology fields. Section 4 will provide the analyses on international co-patenting structures and in section 6 we will look at the motives for internationalization. In section 7, we will show the differences in patenting behavior across the German federal states. In section 8, we will take a closer look at patents from German universities and public research institutes. Finally, section 8 presents the analyses on structures and trends in Community Trademark filings.

2 Basic Methodology

The patent data for this study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected more than 80 patent authorities worldwide. The list of research-intensive industries and goods (NIW/ISI/ZEW-Lists 2012) will be 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 therefore also more intuitive.

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

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

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

For the analyses of patents in different technological fields, patent specializations are calculated. For the analysis of specializations, the relative patent share (RPA[1]) is estimated. It indicates in which fields a country is strongly or weakly represented compared to the total patent applications. The RPA is calculated as follows:

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

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

1 Revealed Patent Advantage.

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

3 Trends in Transnational Patent Filings

Within this section, the recent trends of transnational patent filings will be described. The analyses were carried out for a selected set of technology-oriented countries[2], although, for reasons of presentation, not every country is displayed in each figure. Besides a country-specific view, we will provide a distinction between low- and high-technology areas. High-tech is defined as technologies for which usually an average investment in R&D of more than 3% of the turnover is required (Gehrke et al., 2013). High-tech will further be differentiated by high-level and leading-edge technologies. While high-level covers technologies that require R&D expenditures between 3% and 9%, the leading-edge area covers technologies that are beyond 9% investment shares (Gehrke et al., 2013). In section 3.1, we will firstly discuss some broader country as well as technology-specific trends, while the differentiation of national technology profiles of Germany – looking at a list of 38 technology fields – will be presented in section 3.2.

3.1 Country Comparisons

In Figure 1, the absolute number of transnational patent filings by inventor countries is displayed. The USA is the largest technology-providing country with more than 60,000 filings in 2016. Though there has been a decline in the figures between 2013 and 2014, which has to do with the coming into force of the Leahy-Smith America Invents Act (AIA)[3], we can observe a stabilization and even a slight increase in filings in 2015 and 2016. The U.S. is followed by Japan with nearly 50,000 filings in the same year. Since patent filings from the US grew at a quicker pace than the filings originating from Japan, at least until 2013, the distance between the two countries increased in these years. Due to the drop in the U.S. filings after 2013, however, the level for both countries has stabilized once more at a high level. The next country in the ranking is China with a huge growth in filings in the last ten years and more than 40,000 patent filings in 2016. Germany scores fourth in the number of transnational patent filings and has been overhauled by China since 2014.

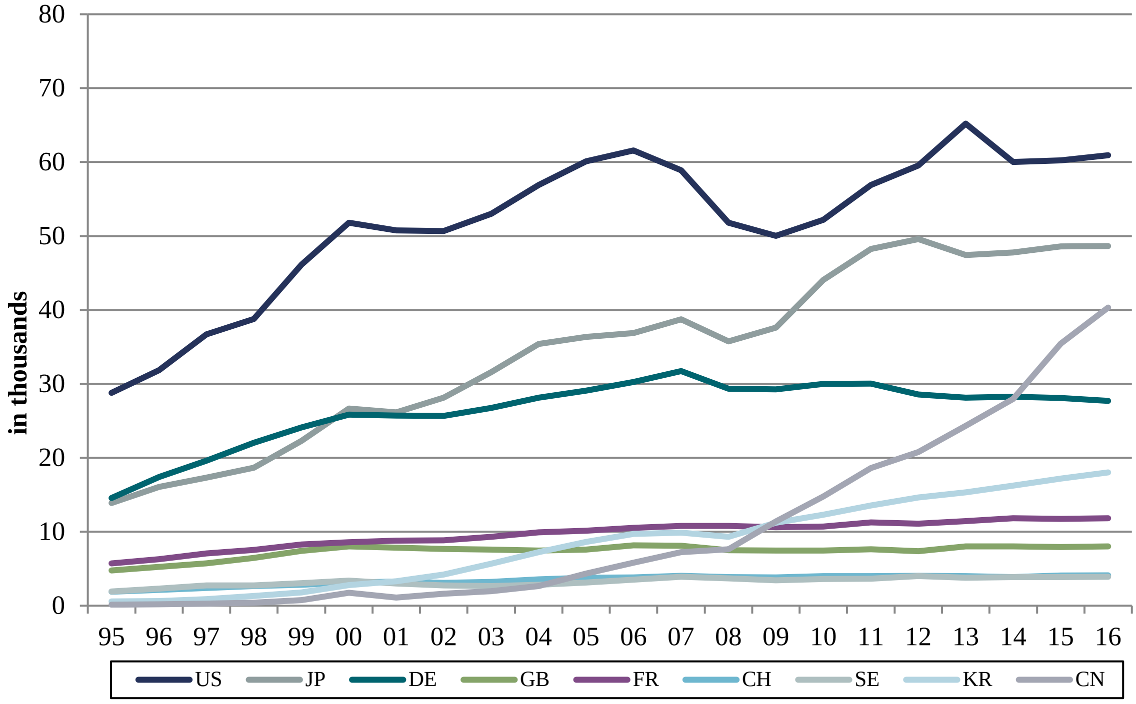
2 These are: Belgium, Denmark, Germany, Finland, France Israel, Italy, Japan, Canada, Korea, The Netherland, Austria, Poland, Sweden, Switzerland, Spain, United Kingdom, USA, Brazil, Russia, India, China, South Africa as well as the group of EU-28 member states.

3 In the run up to the AIA deadline, an unprecedented number of US priority applications were filed since the changes of the AIA were regarded by many as introducing less favorable conditions for applicants. In turn, this lead to a corresponding spike in PCT filings until 12-months later. Consequently, changes in U.S. patent law in contributed to the temporary surge of filings seen in the priority year 2013 WIPO (2016b).

On the one hand, this is a result of the massive growth of filings from China since 2008, but also of a stagnation in German patent filings during the last few years. Following behind these four countries, Korea is the fifth largest country in terms of patent filings. Due to the growth rates in the last years, it has managed to leave behind France with about 11,000 filings and Great Britain with about 8,000 filings. Sweden and Switzerland follow Great Britain with about 4,000 transnational filings in 2016.

With regard to Germany, several effects could serve as an explanation for the stagnation in patent filings, although business R&D expenditures have still been growing in the recent years (Schasse et al., 2018). One of the explanations is that the stagnation in filings is at least partly a stronger concentration of patent filings in large firms, making it harder for SMEs to enter certain markets. Another explanation are shifts in patenting patterns between high- and low-tech sectors in the recent years (Daimer et al., 2017).

Figure 1: Absolute number of transnational patent applications for selected countries, 1995-2016



Source: EPO – PATSTAT; Fraunhofer ISI calculations

Yet, the absolute patenting figures are affected by the size of the country who files the patents effects. To adjust for these size effects, patent intensities, i.e. patents per one million employees, were calculated (Table 1). As can be observed from the table, the size adjustment sheds new light on the country ranks. Though the USA is the largest country in absolute terms, it only scores thirteenth within our country set in terms of patent intensities. It is rather the smaller countries like Switzerland and Sweden that score on top of the list when looking at patent intensities. Japan scores third and is ahead of Finland. It is thus the first among the larger countries in terms of patent intensities, followed by Germany and South Korea. Israel scores seventh between Korea and Germany. The high patent intensities on the one hand resemble a strong technology orientation and technological competitiveness. On the other hand, it is also a sign of a clear and strict international orientation and an outflow of the export activities of these countries as patents can be seen as an important instrument to secure market shares in international technology markets (Frietsch et al. 2014). France, Great Britain and the EU-28 are in the midfield together with the USA, Austria, the Netherlands, Italy and Belgium. The BRICS countries, i.e. China, South Africa, Russia, Brazil and India, score on the lower ranks on this indicator, although China has massively grown in terms of patent filings.

Table 1: Patent intensities (patent applications per 1m employees) and shares of technological areas, 2016

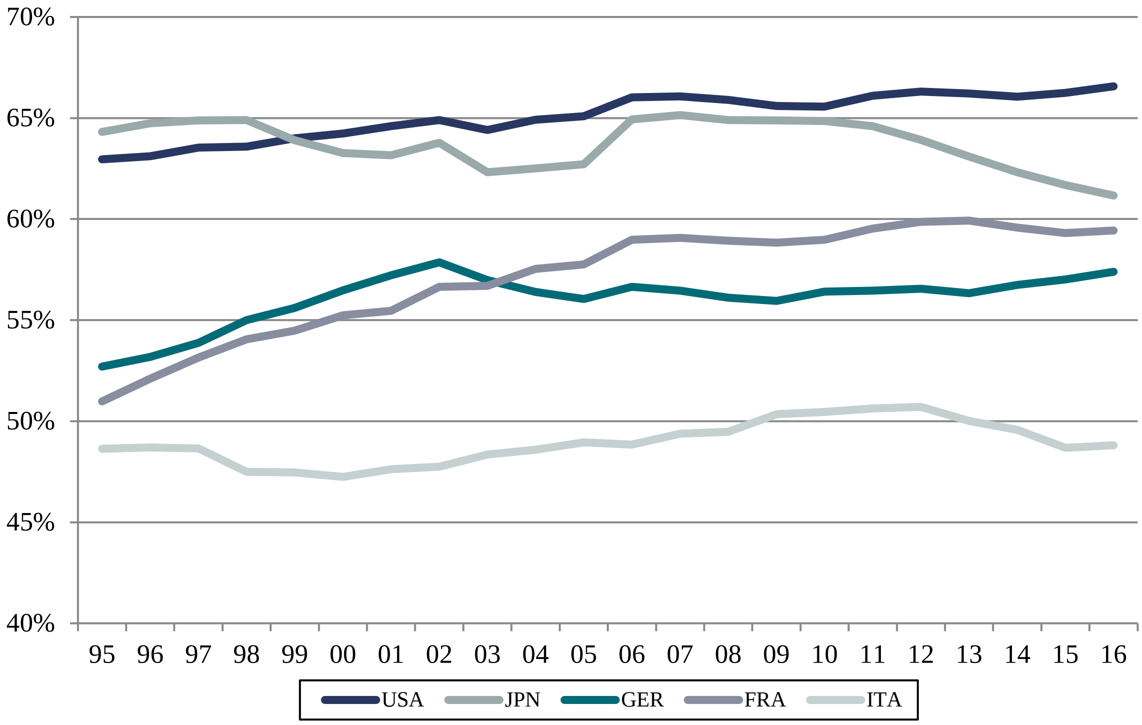
		Total	**Less R&D-intensive**		**High-Tech** of which are:		Leading-edge technologies		High-level technologies	
1	SUI	892	439	49%	494	55%	171	19%	323	36%
2	SWE	799	256	32%	565	71%	334	42%	230	29%
3	JPN	753	313	42%	459	61%	168	22%	292	39%
4	FIN	724	309	43%	428	59%	244	34%	185	26%
5	KOR	683	257	38%	444	65%	213	31%	232	34%
6	ISR	682	231	34%	472	69%	271	40%	201	29%
7	GER	672	302	45%	386	57%	126	19%	259	39%
8	DEK	597	248	41%	363	61%	129	22%	234	39%
9	AUT	580	297	51%	299	52%	112	19%	187	32%
10	NED	558	268	48%	303	54%	160	29%	143	26%
11	FRA	445	192	43%	265	60%	115	26%	150	34%
12	BEL	435	205	47%	246	56%	110	25%	135	31%
13	USA	402	143	35%	268	67%	139	35%	129	32%
14	EU-28	338	153	45%	193	57%	78	23%	116	34%
15	GBR	253	112	44%	148	58%	70	28%	77	30%
16	ITA	250	138	55%	122	49%	31	12%	91	36%
17	CAN	187	71	38%	121	64%	67	36%	54	29%
18	ESP	135	68	51%	71	52%	28	21%	43	32%
19	POL	67	32	47%	37	56%	15	22%	23	34%
20	CHN	53	16	30%	40	75%	24	45%	16	30%
21	RSA	20	12	59%	8	43%	4	18%	5	25%
22	RUS	14	6	42%	9	61%	5	34%	4	27%
23	BRA	8	4	54%	4	49%	1	18%	2	30%
24	IND	6	2	34%	4	69%	2	34%	2	35%

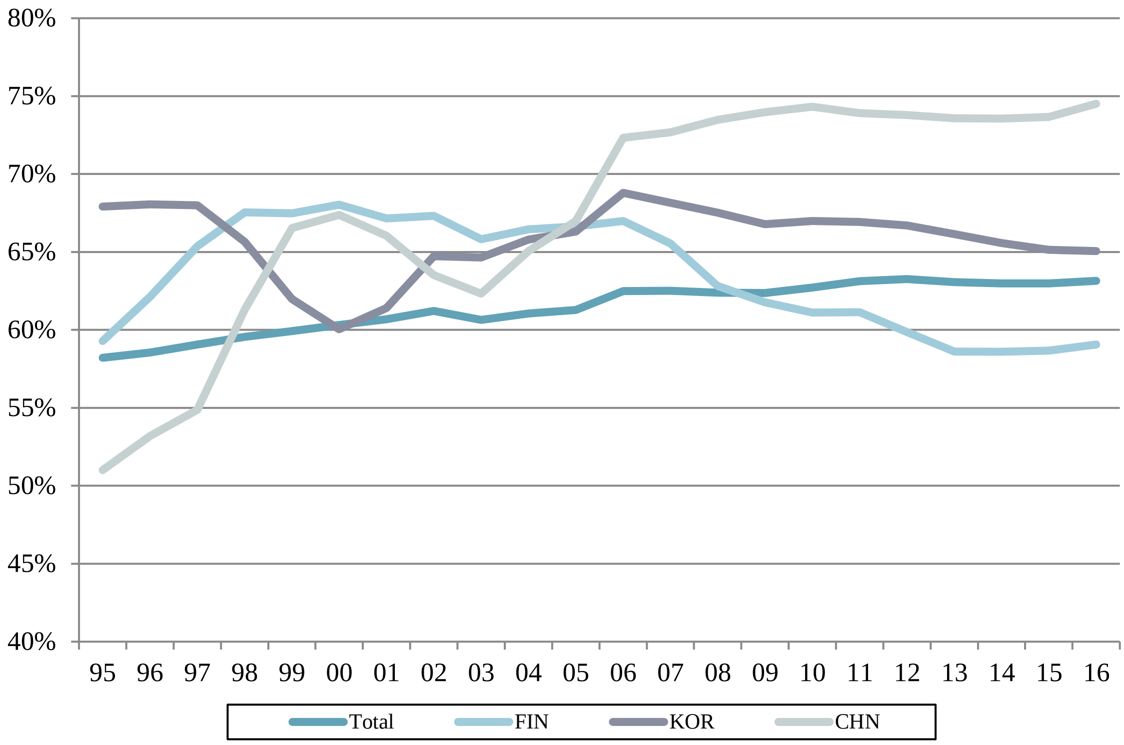
Source: EPO – PATSTAT; OECD, The World Bank, Fraunhofer ISI calculations

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

In addition to the patent intensities at a general level, Table 1 provides a differentiation of patent intensities by technological areas and displays the respective shares of low- and high-tech patents on total patent filings. Interestingly Switzerland shows rather high activities in less R&D intensive fields, which is also Italy, the Netherlands, Spain and Austria. The BRICS countries Brazil and South Africa also are very active in fields with a low R&D intensity. China and India deviate from this pattern with a comparably small share of patents in less R&D-intensive fields. Small shares less R&D intensive fields can also be found in Sweden, Korea, Israel, the USA and Canada. With regard to high-technology shares, the largest values can be observed for China and Sweden, where the shares exceed 70%. Shares above 65% can be found in the cases of the USA, Korea, India and Israel. In the case of India and Israel, however, this can at least partly be explained by a high orientation towards the US market, which is the most important national market for high-tech products. A similar argument can be made for Canada, which also shows high-tech shares of 64%.

Figure 2: Shares of high-tech patent applications in total patent applications for selected countries, 1995-2016





Source: EPO – PATSTAT; Fraunhofer ISI calculations

The differentiation by leading-edge and high-level areas further qualifies these findings. Especially China files a large proportion of its patents in leading-edge technologies. The same is true for Sweden and Israel, where the shares are above 40% in all patent filings of these countries. Finland, the USA and Canada also display comparably high shares, which is also true for Russia and India. In consequence, these countries reach comparably low shares in high-level technologies compared to the other countries. Germany, Japan, Denmark, Italy and Switzerland are focused on high-level technologies, but reach comparably low shares in leading-edge areas.

Figure 2 provides more detail on the development of the high-tech shares over time. The average share of total transnational high-tech patent applications rose slightly from about 58% in 1995 to 63% in 2016, while there has been a stagnation in this share since 2011. Yet, some countries underwent a considerable change of their patenting patterns in high-tech areas over the years. China is at the top of the countries under analysis in this graph with a high-tech share of 75% in 2016, followed by the USA and Korea with a value of 67% and 66%, respectively. The Chinese high-tech shares grew quickly between 2003 and 2006 after China joined the WTO and the TRIPS agreement in 2001. Since 2010, there has been a stagnating trend, yet at a very high level. The high-tech shares of Korea have been decreasing since 2006, although the absolute number of filings from Korea increased considerably. This implies that the growth in Korean filings are mostly related to a growth of filings in less R&D intensive areas, which can be confirmed when looking at the trend of low-tech filings from Korea over the last years (not shown). The USA displays slight but constant increasing shares in high-tech patents over the years. There has been a stagnation period between 2011 and 2014. In 2015 and 2016, however, the figures have started to increase again. Japan is the fourth most high-technology active country in terms of transnational patenting in the year 2016, at least for this selected country set. Japan, which had clearly lost ground and had lower shares of patenting activities in high-tech areas between 2003 and 2005, had managed to catch up with the USA until 2011. From 2011 onwards, however, a decrease in high-tech shares can be observed, which goes along with an increase in low-tech patents. It thus follows a similar trend as Korea. France was able to increase its high-tech shares up to 2006, yet the share remained mostly stable from this year onwards until 2010, where another growth period can be observed. In the recent two years, however, the figures have slightly declined. Italy had encountered an increase in high-tech shares until 2012, so the gap to the other large innovation-oriented countries has became smaller. In the recent years, however, Italy's high-tech shares have decreased so the gap started to enlarge. Germany encountered a decrease in high-tech shares between 2002 and 2005 and showed stagnating trends in the following years. Since 2010, however, increasing trends in high technology patenting can be observed.

3.2 Technology Profiles and Specialization Patterns

In this section, we will take a closer look at the field specific patterns in high-technology patenting in Germany. For this, we will resort to the classification of 38 technology fields of the high-tech sector (Gehrke et al. 2013). The absolute number, specialization and the percentage growth of German transnational patent applications by technology fields are displayed in Table 2. The largest growth rates between the periods 2006-2008 and 2014-2016 can be observed in the fields of "rubber goods", "agricultural machinery", "aeronautics", "power generation and distribution", "scents and polish ", and " electrical machinery, accessory and facilities".

Table 2: Transnational patent applications of Germany by high-technology sectors (absolute, specialization, and growth), 2012-2014

Technology Field	Abs.	RPA	% Growth (06-08=100)
rubber goods	428	26	174.8
agricultural machinery	691	61	165.4
aeronautics	936	8	153.1
power generation and distribution	2115	23	130.6
Scents and polish	51	-6	130.5
electrical machinery, accessory and facilities	515	-4	129.6
units and equipment for automatic data processing machines	729	-83	119.1
medical instruments	2785	-11	114.3
rail vehicles	270	72	114.1
air conditioning and filter technology	1979	31	110.0
pumps and compressors	782	42	107.6
electrical appliances	657	15	106.5
electrical equipment for internal combustion engines and vehicles	1341	67	104.3
optics	589	-43	103.5
optical and photooptical devices	69	-78	102.8
lamps, batteries etc.	1555	-7	102.4
mechanical measurement technology	1158	33	98.0
machine tools	2445	61	97.3
power machines and engines	3383	53	92.9
optical and electronic measurement technology	2606	-20	92.4
automobiles and engines	5527	68	92.1
inorganic basic materials	358	-8	90.9
communications engineering	4106	-62	90.6
electronics	1274	-21	90.2
special purpose machinery	3170	23	80.4
weapons	234	48	79.4
technical glass, construction glass	76	-100	79.4
computer	1725	-74	78.7
biotechnolgy and agents	1512	-47	73.1
organic basic materials	1409	3	72.2
broadcasting engineering	514	-89	71.4
other special chemistry	861	1	70.7
pharmaceuticals	1024	-45	70.5
photo chemicals	5	-18	63.2
electronic medical instruments	656	-66	60.1
pesticides	398	-4	56.3
nuclear reactors and radioactive elements	6	-89	37.5
office machinery	31	-86	26.6

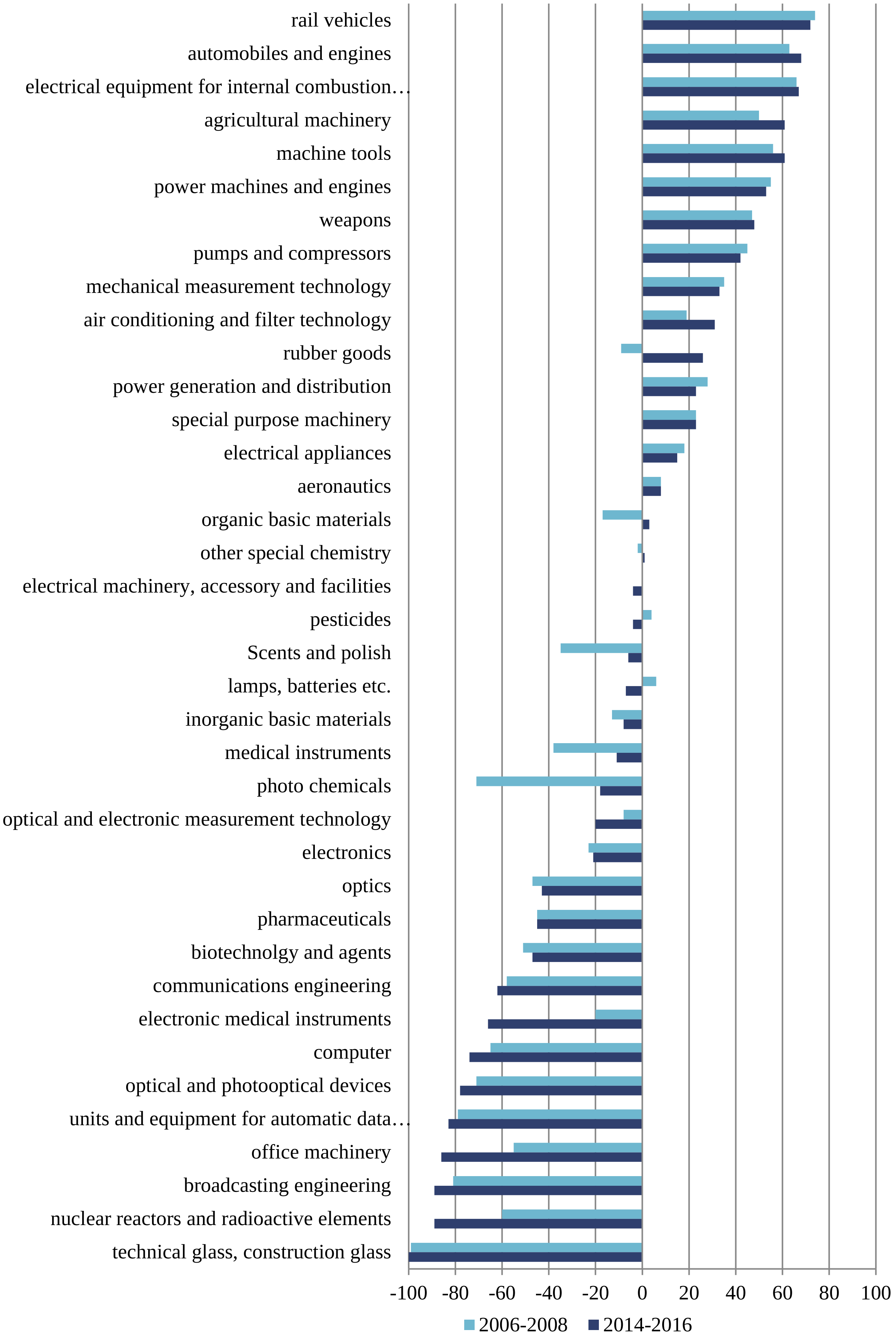
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Among the fields that are growing most slowly in Germany are three rather small fields, namely "office machinery", "nuclear reactors and radioactive elements" as well as "photo chemicals" but also two larger fields, namely "pesticides " and "electronic medical instruments". All in all, many chemistry related fields besides pesticides, i.e. "pharmaceuticals", "other special chemistry", "organic basic materials" and biotechnology and agents" can be seen as comparably slowly growing fields within the German technology profile. They are followed by the ICT related fields of "broadcasting engineering", "computers" and "communications engineering", which also show declining figures in the last years.

This also confirms the results from last year's study. Some electronics related fields like " units and equipment for automatic data processing machines", " electrical machinery, accessory and facilities", "electrical appliances" and "electrical equipment for internal combustion engines and vehicles" are growing rather strongly, whereas chemistry and pharmaceuticals as well as ICT related fields do not show very high growth rates. The fields related to the mechanical engineering sector, where Germany has its particular technological strengths, e.g. "machine tools", "automobiles and engines" or "special purpose machinery", show moderate to low growth rates in recent years, which also resembles the trends that have been found in earlier studies of this series.

The specialization (RPA) of the German technology profile of the years 2006-2008 and 2014-2016 is displayed in Figure 3. Germany is specialized and thus has comparative advantages in three main areas: transport (automobiles and engines, rail vehicles), machinery (agricultural machinery, machine tools) and some areas of electrical engineering like power machines and power generation. Germany also has a very strong specialization within the field of "electrical equipment for internal combustion engines and vehicles". An average activity rate in patenting can be found in chemistry and related fields ("organic basic materials", "inorganic basic materials", "pesticides", "other special chemistry"). Due to the rather large growth rates over the years, however, Germany shows a more an more positive specialization in rubber goods. Comparative disadvantages, reflected in negative specialization indices, can be found in ICT related fields, e.g. " broadcasting engineering", "units and equipment for automatic data processing machines", "office machinery" and "computers" as well as in some chemistry related fields like "pharmaceuticals" and "biotechnology and agents", implying that Germany does not have particular strengths in these sectors in international technology markets. All of these trends can be found in both time periods, i.e. the specialization profile of Germany is rather stable over time. The largest differences over the years can be found in the already mentioned field of "rubber goods". A further positive development can be observed in "photo chemicals", "medical instruments", "scents and polish" and "organic basic materials". We thus can see a general positive trend in chemistry. More negative values than in 2006-2008 can be observed in "optical and electronic measurement technology", "electronic medical instruments", "office machinery" and "nuclear reactors and radioactive elements". There thus seems to be a slightly negative trend in electronic instruments when it comes to comparative advantages in patenting.

Figure 3: Germany's technological profile, 2006-2008 vs. 2014-2016



Source: EPO – PATSTAT; Fraunhofer ISI calculations

4 Structures in International Co-Patenting

The internationalization of R&D activities can be analyzed with the help of cooperation structures in international patenting. In this vein, co-patents can be applied as an instrument to indicate the extent to which countries are cooperating with each other. Since a cooperative patent application is associated with the exchange of knowledge about the patented invention, the analysis of co-patenting further allows us to draw conclusions about international knowledge flows.

However, there also are downsides to applying patent indicators for the identification of international knowledge flows. The first issue with patent indicators is that they are only one of many outcomes of international collaborations. Patents, however, can only give us information on the collaborations that have actually led to the respective patented invention. Furthermore, the direction and amount of the knowledge flow is cannot easily be identified, i.e. it is hard to say which country benefits most from the exchanged knowledge. Third, it is important to stress that the analysis of patent filings only gives us information on the location of the inventor (or the applicant) but not on his or her nationality. Finally, an international co-patent may involve inventors from the same company located around the world across its various branches or subsidiaries (ADL, 2005). The data thus reflects inter- as well as intra-firm international collaboration (Fraunhofer ISI et al., 2009; Guellec and Pluvia Zuniga, 2007). Still, it can be assumed that co-patent data is not systematically biased, which is why they can serve as an indicator of international knowledge exchange, especially in relative terms (Fraunhofer ISI et al., 2009).

For this report, the concept of co-invention, i.e. two or more inventors from different countries are named on a patent application - is used to analyze international co-patents. This clearly indicates that the innovative endeavors resulting in an international co-patent have been carried out by people living in two different countries (although it might take place within the same company).

In sum, we will focus on the transnational co-patent filings of the countries under analysis in the previous chapters. We will apply the whole count method to analyze the co-patents by countries. This due to the fact that the shares of co-patents cannot be easily assigned to an inventor from one or another country as the real contribution of an inventor is unknown.

4.1 A brief literature review

Several characteristics that can foster or hamper international cooperation have been named in the literature (for an extended overview see Fraunhofer ISI et al. 2009). First of all, the size of a country influences its propensity to collaborate internationally (Frame and Carpenter 1979), i.e. inventors from smaller countries collaborate more than inventors from large countries since there are fewer domestic partners to collaborate with (Narin et al. 1991; Schubert and Braun 1990). However, conflicting statements on this topic can be found in the literature. Evidence on the degree and direction of this relationship thus remains rather vague (Luukkonen et al. 1992; Luukkonen et al. 1993; Narin et al. 1991).

Besides country size, there still is considerable heterogeneity between countries in their propensity to collaborate, which can be attributed to a multitude of different factors (Hoekman et al. 2010). Mainly geopolitical, historical and language related factors are predominant, but also social, intellectual, cognitive and economic factors seem to be relevant (Frame and Carpenter 1979; Glänzel and Schubert 2004; Luukkonen et al. 1992).

Differences in the propensity to collaborate not only occur between countries but also between fields. In basic disciplines there is a higher propensity to collaborate internationally than in applied disciplines (Liu et al. 2012). Frietsch (2004) as well as Schmoch (2005; 2006) show that strategic aspects should also be taken into account. Getting access to certain data or research facilities might build an incentive to collaborate internationally. In addition, one might willingly choose not to cooperate in a given field in order to protect proprietary knowledge, especially when the need to cooperate is low.

In addition to country- and field-specific differences, Katz (1994) found that collaboration intensity decreases with increasing distance between partners, which has also been found by Hong and Su (2012) regarding university-industry collaborations. Glänzel and Schubert (2004) added the argument that mobility and migration are also relevant. More recent findings by Hoekman et al. (2010) suggest that the geographical distance between collaborating partners became less important in the recent years, due to regular airplane connections and modern communication means. Mattson et al. (2008) provide a summary on the above mentioned motives by introducing four categories: financial reasons (e.g. funding access, facilities sharing), social factors (networking, acknowledgements from the scientific community, preference for teamwork), knowledge improvement, and political factors (including framework programs and others to facilitate collaboration).

In sum, it can be stated that analyzing and interpreting international collaborations should be done with care, having in mind that there are several mutually dependent factors that can influence patterns of collaboration. This also affects the choice and interpretation of the indicators that are able to evaluate the degree of collaboration on an international scale, implying that absolute as well as relative measures should be taken into account (Fraunhofer ISI et al. 2009).

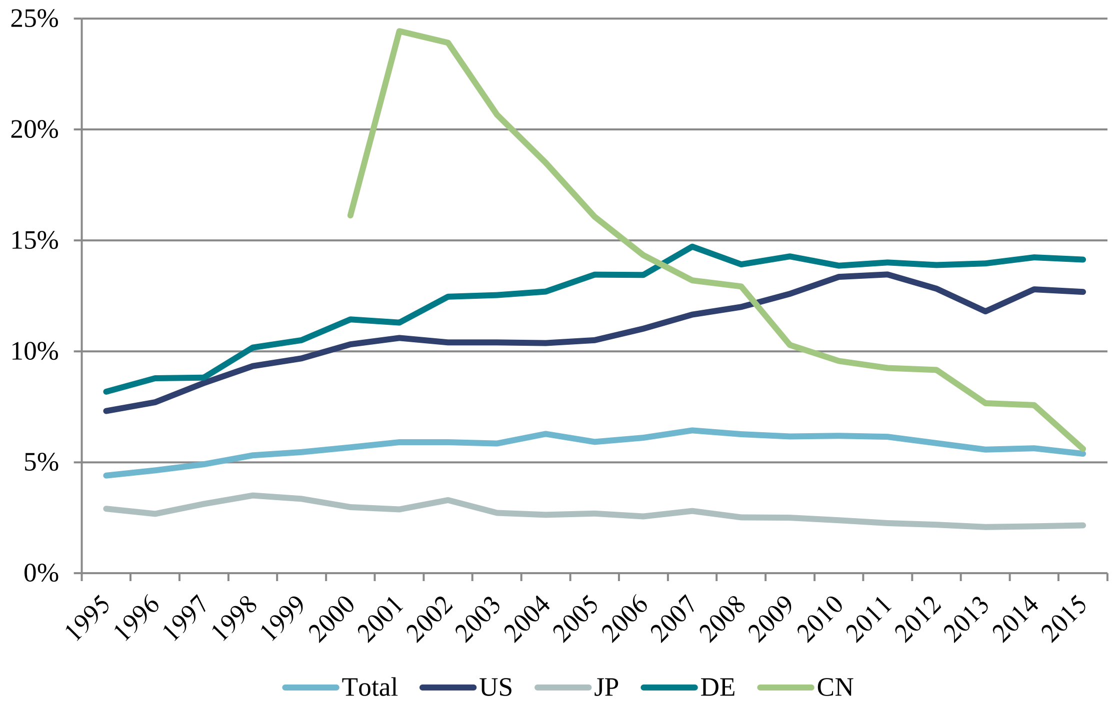
4.2 International Co-Patenting Trends

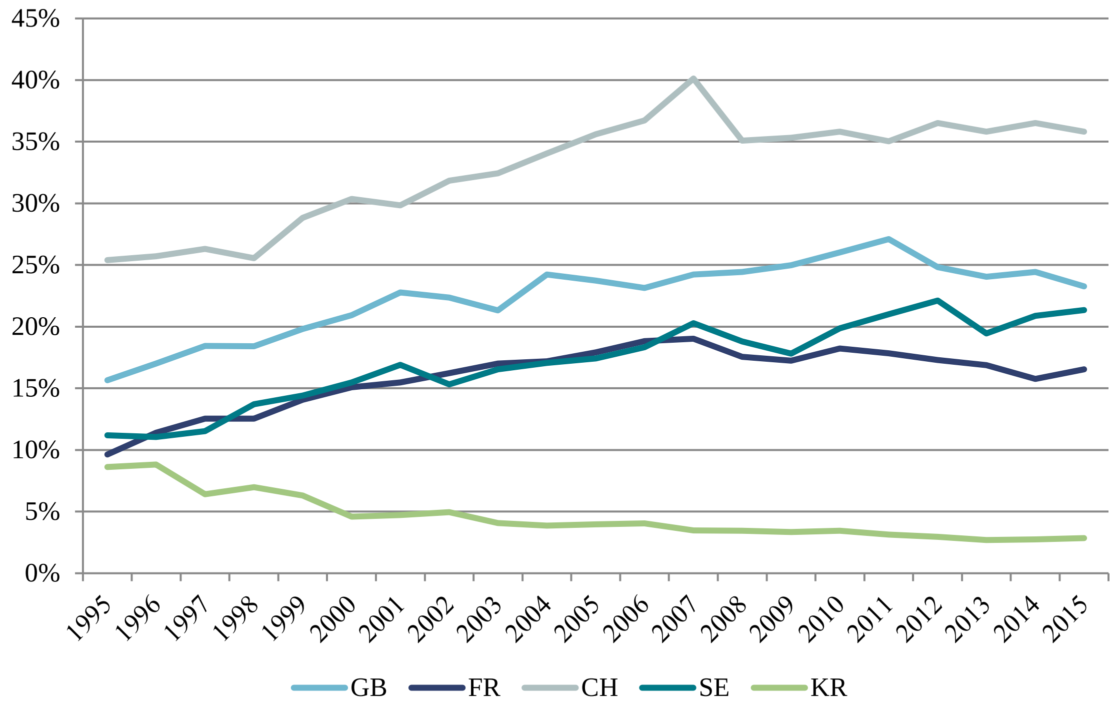
The co-patenting trends by countries are depicted in Figure 4. Here, the shares of transnational co-patents (with OECD countries) in all transnational patent filings of the respective country are shown, which gives us an impression on the cooperation intensity of the countries. Large shares imply that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

The total share of co-patents in all filings has constantly been increasing over the years until 2007. In 1995, about 4.4% of all transnational filings were international co-patents. In 2007, this share has reached a peak of 6.4%, implying that cooperation has gained importance over the years. From 2007 onwards, however, the share started to slightly decline until a share of 5.4% in 2015 was reached. This trend is influenced especially by China's but also by Korea's and Japan's declining shares of co-patents over the years. The drop in the last few years, however, also is a result of declining figures for other countries like the U.S., Germany, France and Great Britain. However, in the last two seems there once again seems to be a rising trend, at least for Germany, France and the United States.

Although the figures stagnated in the last few years, Switzerland has the largest co-patenting shares among the countries in our comparison with 36% in 2015. It is followed by Great Britain (23%), Sweden (21%) and France (17%), although declines in co-patenting shares are visible especially for Britain. With a share of 14% in 2015, Germany still is ahead of the US with 13%. These two countries followed a similar trend across the whole time period. Germany, however, was less affected by the decline after 2010. The Chinese co-patenting shares started from a very high level, but then the rates constantly decreased since 2003. In 2015, only about 6% of all Chinese transnational filings are international co-patents. In comparison with the remaining Asian countries, here Japan and Korea, however, this share still is comparably high. Japan shows a more or less constant co-patenting rate of 2% to 3% over the years, although a slight decline becomes visible over the years. Similar values can be observed for Korea, at least since the year 2000, but at a slightly higher level of co-patenting shares between 3% and 5% over the years.

Figure 4: Shares of transnational co-patents in all transnational patents of the respective country, selected countries, 1995-2015





Source: EPO – PATSTAT; Fraunhofer ISI calculations

For these two Asian countries, this resembles their general underrepresentation in international science and innovation collaborations (Schubert et al., 2013; Weissenberger-Eibl et al., 2011). This is associated with their industry structure that is dominated by very large firms. Furthermore, the Japanese and also the Korean large enterprises were hardly conducting any R&D abroad. The governments in both countries set up programs to overcome these shortcomings, especially with respect to the public science system. They also realized that international collaboration is a crucial factor in nowadays innovation activities. Apart from Korea, however, it becomes evident that most of the smaller countries have higher co-patenting rates than their large counterparts, which corroborates the arguments made in the literature section.

Table 3 provides more detail on the international co-patenting structures by showing the country-to-country co-patents for each of the countries under analysis. In the area below the diagonal line, the absolute numbers of co-patent filings between two countries is depicted. The values above the diagonal in the table show the share of co-patents between the respective countries in all transnational co-patents. In the last column, the share of a country's total co-patents in all transnational co-patents worldwide is provided.

With a value of 24.6%, the US has the largest share of co-patents in all transnational co-patents. However, this share is affected by the size of a country, i.e. larger countries in terms of patenting have an advantage over smaller countries. The U.S. is followed by Germany with a share of nearly 14%. Great Britain and France score third and fourth with a share of about 7.3% and 7.1%, respectively. Although a small country in absolute terms, Switzerland reaches rather high shares in total transnational co-patents (6.1%) as it is comparably cooperation intensive. China, though much more patent-intensive in absolute terms scores a share of 6.7% and scores fifth while Switzerland scores sixth. Japan is the second largest country in terms of transnational patent filings, yet only reaches a share of about 3.2%. Japan thus has a comparably low level of internationalization of R&D activities, at least as measured in terms of co-patents, implying that its innovation system is relatively isolated compared to the German or the US innovation system for example. This is similar for South Korea, which also shows rather low shares of co-patents in all transnational co-patents (1.5%).

The importance of collaboration partners for each of the countries becomes more clearly visible when looking at the share of cooperation partners within the transnational co-patenting portfolio of a given country, which is presented in Table 4. The colors in the table indicate the importance of collaboration partners for each country from green to red. The most important collaboration partner for Germany, for example, is the US as 26% of all German co-patents are filed in cooperation with a US inventor. The next largest partners are Switzerland, France, Austria and Great Britain, which at least to a certain extent has to do with geographical proximity of these countries to Germany. All in all, it can be found that the US is the most important partner for many countries in our comparison, while the US itself cooperates most strongly with China - which has a larger share than Germany for the first time in this year's comparison - Germany, Great Britain and Canada. Germany, is an important partner for many countries, closely followed by other European countries like France, Switzerland and Great Britain. Outside of Europe, China is in important partner besides the United States. China itself is highly oriented towards cooperating with US inventors. More than 54% of all Chinese co-patents are filed in cooperation with a US inventor. This concentration has even increased over the years (not shown). Yet, this might at least partly also have to do with research facilities and production sites of foreign companies in China (Ernst, 2006). Germany is the next largest partner with 9%, followed by Japan with 7% and Great Britain with 5%. In sum, the US, and to a certain extent also Germany (yet with smaller shares), are the most important cooperation partners for the countries in comparison.

Another interesting fact that becomes obvious when looking at the table - which could also be shown in earlier reports of this series - is the different motivations to collaborate. Many of the countries in our comparison, on the one hand, show a large tendency to cooperate with partners that are geographically close. On the other hand, they seem to seek access to markets, e.g. the US or China, and/or to certain data or research facilities that are not locally available. This leads to the fact that there is a quite multifaceted motivation to collaborate, which can be summarized as "collaborating local", "collaborating with the best" and "collaborating for market access".

Table 3: Absolute number of transnational co-patents and shares in total transnational co-patents, 2013-2015

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA	Share in total transnational co-patents
AT		0.06%	0.01%	0.03%	0.45%	0.02%	1.11%	0.01%	0.02%	0.13%	0.07%	0.08%	0.00%	0.01%	0.10%	0.01%	0.00%	0.04%	0.02%	0.01%	0.06%	0.20%	0.00%	2.44%
BE	59		0.01%	0.03%	0.08%	0.10%	0.47%	0.01%	0.08%	0.01%	0.58%	0.26%	0.01%	0.03%	0.09%	0.06%	0.02%	0.33%	0.01%	0.00%	0.05%	0.65%	0.00%	2.95%
BR	8	8		0.02%	0.02%	0.01%	0.07%	0.01%	0.02%	0.00%	0.05%	0.04%	0.01%	0.01%	0.02%	0.00%	0.00%	0.02%	0.00%	0.00%	0.02%	0.29%	0.00%	0.63%
CA	29	35	18		0.07%	0.17%	0.21%	0.02%	0.02%	0.02%	0.16%	0.23%	0.04%	0.07%	0.03%	0.03%	0.02%	0.05%	0.01%	0.03%	0.13%	2.46%	0.01%	3.88%
CH	454	86	25	73		0.14%	1.91%	0.07%	0.08%	0.05%	1.10%	0.26%	0.02%	0.08%	0.34%	0.08%	0.02%	0.11%	0.05%	0.03%	0.15%	0.93%	0.01%	6.06%
CN	19	104	11	173	147		0.60%	0.05%	0.04%	0.16%	0.21%	0.32%	0.04%	0.10%	0.05%	0.50%	0.13%	0.06%	0.03%	0.06%	0.27%	3.62%	0.00%	6.67%
DE	1135	478	68	210	1941	606		0.20%	0.23%	0.25%	1.46%	0.96%	0.12%	0.27%	0.48%	0.39%	0.10%	0.68%	0.17%	0.11%	0.41%	3.56%	0.03%	13.80%
DK	13	14	9	21	74	48	204		0.02%	0.06%	0.06%	0.14%	0.00%	0.05%	0.02%	0.01%	0.00%	0.04%	0.02%	0.00%	0.20%	0.28%	0.00%	1.29%
ES	18	84	16	22	80	40	232	21		0.01%	0.24%	0.21%	0.04%	0.03%	0.09%	0.02%	0.00%	0.08%	0.01%	0.01%	0.06%	0.40%	0.00%	1.69%
FI	133	12	3	21	54	158	252	60	10		0.02%	0.09%	0.01%	0.06%	0.04%	0.04%	0.00%	0.03%	0.04%	0.01%	0.22%	0.21%	0.00%	1.45%
FR	75	586	51	164	1121	211	1490	58	240	17		0.53%	0.06%	0.11%	0.29%	0.16%	0.04%	0.16%	0.07%	0.03%	0.10%	1.61%	0.01%	7.10%
GB	78	266	36	238	268	329	980	141	218	88	535		0.08%	0.18%	0.16%	0.19%	0.09%	0.25%	0.04%	0.05%	0.23%	2.91%	0.02%	7.32%
IL	0	8	9	37	24	43	126	3	42	7	59	85		0.03%	0.02%	0.01%	0.01%	0.02%	0.00%	0.02%	0.01%	0.96%	0.00%	1.52%
IN	15	29	14	74	85	101	279	48	31	65	109	181	27		0.04%	0.08%	0.15%	0.10%	0.03%	0.01%	0.07%	1.91%	0.00%	3.43%
IT	103	87	19	35	350	49	491	24	91	37	293	163	25	38		0.04%	0.01%	0.07%	0.04%	0.02%	0.09%	0.56%	0.00%	2.62%
JP	9	64	3	34	77	506	396	8	21	36	160	194	8	83	41		0.19%	0.04%	0.00%	0.01%	0.03%	1.29%	0.00%	3.17%
KR	3	22	1	24	17	128	106	3	1	2	37	89	10	149	14	196		0.04%	0.00%	0.04%	0.01%	0.60%	0.00%	1.48%
NL	43	333	17	51	109	65	697	44	84	27	161	257	18	99	73	39	45		0.01%	0.01%	0.06%	0.94%	0.01%	3.16%
PL	16	12	1	8	49	27	174	22	6	40	75	39	4	33	38	3	3	13		0.02%	0.03%	0.16%	0.00%	0.76%
RU	8	0	4	32	26	58	115	3	6	15	30	49	21	7	19	12	41	11	21		0.01%	0.38%	0.00%	0.86%
SE	63	51	25	133	156	278	417	207	57	226	106	231	12	76	96	32	9	62	34	7		0.66%	0.00%	2.90%
US	201	665	294	2508	942	3682	3625	286	405	218	1642	2965	976	1940	573	1309	610	957	159	392	675		0.06%	24.64%
ZA	1	3	5	6	8	4	34	0	0	0	8	23	3	5	4	0	0	12	0	2	4	63		0.18%
Total	2483	3006	645	3946	6166	6787	14056	1311	1725	1481	7228	7453	1547	3488	2663	3231	1510	3217	777	879	2957	25087	185	100.00%

Source: EPO – PATSTAT; Fraunhofer ISI calculations

Table 4: Share of co-patenting partners within the transnational co-patenting portfolio of a given country, 2011-2013

	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	FR	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA
AT		2%	1%	1%	7%	0%	8%	1%	1%	9%	1%	1%	0%	0%	4%	0%	0%	1%	2%	1%	2%	1%	1%
BE	2%		1%	1%	1%	2%	3%	1%	5%	1%	8%	4%	1%	1%	3%	2%	1%	10%	2%	0%	2%	3%	2%
BR	0%	0%		0%	0%	0%	0%	1%	1%	0%	1%	0%	1%	0%	1%	0%	0%	1%	0%	0%	1%	1%	3%
CA	1%	1%	3%		1%	3%	1%	2%	1%	1%	2%	3%	2%	2%	1%	1%	2%	2%	1%	4%	4%	10%	3%
CH	18%	3%	4%	2%		2%	14%	6%	5%	4%	16%	4%	2%	2%	13%	2%	1%	3%	6%	3%	5%	4%	4%
CN	1%	3%	2%	4%	2%		4%	4%	2%	11%	3%	4%	3%	3%	2%	16%	8%	2%	3%	7%	9%	15%	2%
DE	46%	16%	11%	5%	31%	9%		16%	13%	17%	21%	13%	8%	8%	18%	12%	7%	22%	22%	13%	14%	14%	18%
DK	1%	0%	1%	1%	1%	1%	1%		1%	4%	1%	2%	0%	1%	1%	0%	0%	1%	3%	0%	7%	1%	0%
ES	1%	3%	2%	1%	1%	1%	2%	2%		1%	3%	3%	3%	1%	3%	1%	0%	3%	1%	1%	2%	2%	0%
FI	5%	0%	0%	1%	1%	2%	2%	5%	1%		0%	1%	0%	2%	1%	1%	0%	1%	5%	2%	8%	1%	0%
FR	3%	19%	8%	4%	18%	3%	11%	4%	14%	1%		7%	4%	3%	11%	5%	2%	5%	10%	3%	4%	7%	4%
GB	3%	9%	6%	6%	4%	5%	7%	11%	13%	6%	7%		5%	5%	6%	6%	6%	8%	5%	6%	8%	12%	12%
IL	0%	0%	1%	1%	0%	1%	1%	0%	2%	0%	1%	1%		1%	1%	0%	1%	1%	1%	2%	0%	4%	2%
IN	1%	1%	2%	2%	1%	1%	2%	4%	2%	4%	2%	2%	2%		1%	3%	10%	3%	4%	1%	3%	8%	3%
IT	4%	3%	3%	1%	6%	1%	3%	2%	5%	2%	4%	2%	2%	1%		1%	1%	2%	5%	2%	3%	2%	2%
JP	0%	2%	0%	1%	1%	7%	3%	1%	1%	2%	2%	3%	1%	2%	2%		13%	1%	0%	1%	1%	5%	0%
KR	0%	1%	0%	1%	0%	2%	1%	0%	0%	0%	1%	1%	1%	4%	1%	6%		1%	0%	5%	0%	2%	0%
NL	2%	11%	3%	1%	2%	1%	5%	3%	5%	2%	2%	3%	1%	3%	3%	1%	3%		2%	1%	2%	4%	6%
PL	1%	0%	0%	0%	1%	0%	1%	2%	0%	3%	1%	1%	0%	1%	1%	0%	0%	0%		2%	1%	1%	0%
RU	0%	0%	1%	1%	0%	1%	1%	0%	0%	1%	0%	1%	1%	0%	1%	0%	3%	0%	3%		0%	2%	1%
SE	3%	2%	4%	3%	3%	4%	3%	16%	3%	15%	1%	3%	1%	2%	4%	1%	1%	2%	4%	1%		3%	2%
US	8%	22%	46%	64%	15%	54%	26%	22%	23%	15%	23%	40%	63%	56%	22%	41%	40%	30%	20%	45%	23%		34%
ZA	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

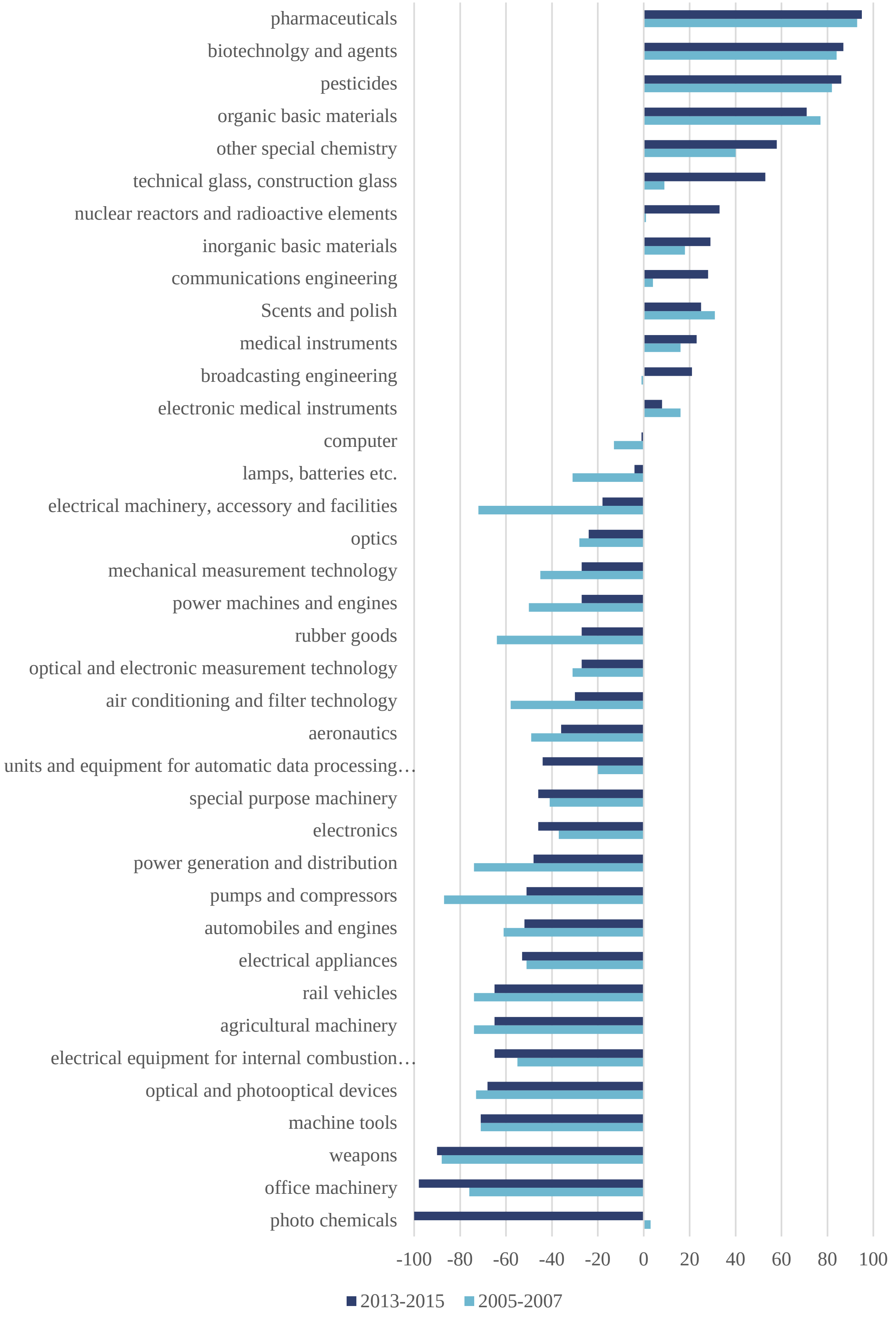
Source: EPO – PATSTAT; Fraunhofer ISI calculations.
Note: The colors in the table indicate the importance of collaboration partners for a given country (vertically). Green resembles the most important partners (largest share of co-patents in a country's total co-patents), red resembles the least important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

Up to now, we have only taken into account country-specific differences in international co-patenting. However, there are also field specific differences that influence co-patenting structures between countries. In this year's report, we will focus on the differences between high-technology and less R&D-intensive fields. This will not only be done for the co-patenting trends but also for the regionalization of patents and the patenting trends in public research   to get a more complete picture of high-tech patenting trends. The differentiation of the co-patenting specializations (RPAs) by the list of 38 high-tech fields for the countries with the largest shares in total transnational co-patents, i.e. Germany, the U.S., Switzerland, China and Great Britain is provided in Figure 5 to Figure 9.

The RPA values for the co-patents of Germany are plotted in Figure 5. In terms of co-patents, Germany is specialized in pharmaceuticals, followed by biotechnology and agents, pesticides and organic basic materials. The fields with the smallest specialization in co-patenting are office machinery, weapons, machine tools, optical and photo-optical devices, electrical equipment for internal combustion engines and vehicles as well as agricultural machinery. The fields with the largest change over the years are electrical machinery, accessory and facilities, technical glass, construction glass, rubber goods, nuclear reactors and radioactive elements as well as photo chemicals, although the latter two fields are very small in terms of absolute patenting and co-patenting. In sum, we thus see a large specialization in chemistry, pharmaceuticals and related fields and a lower specialization in fields regarding machinery (as well as fields where cooperation is rare as in the case of defense related technologies).

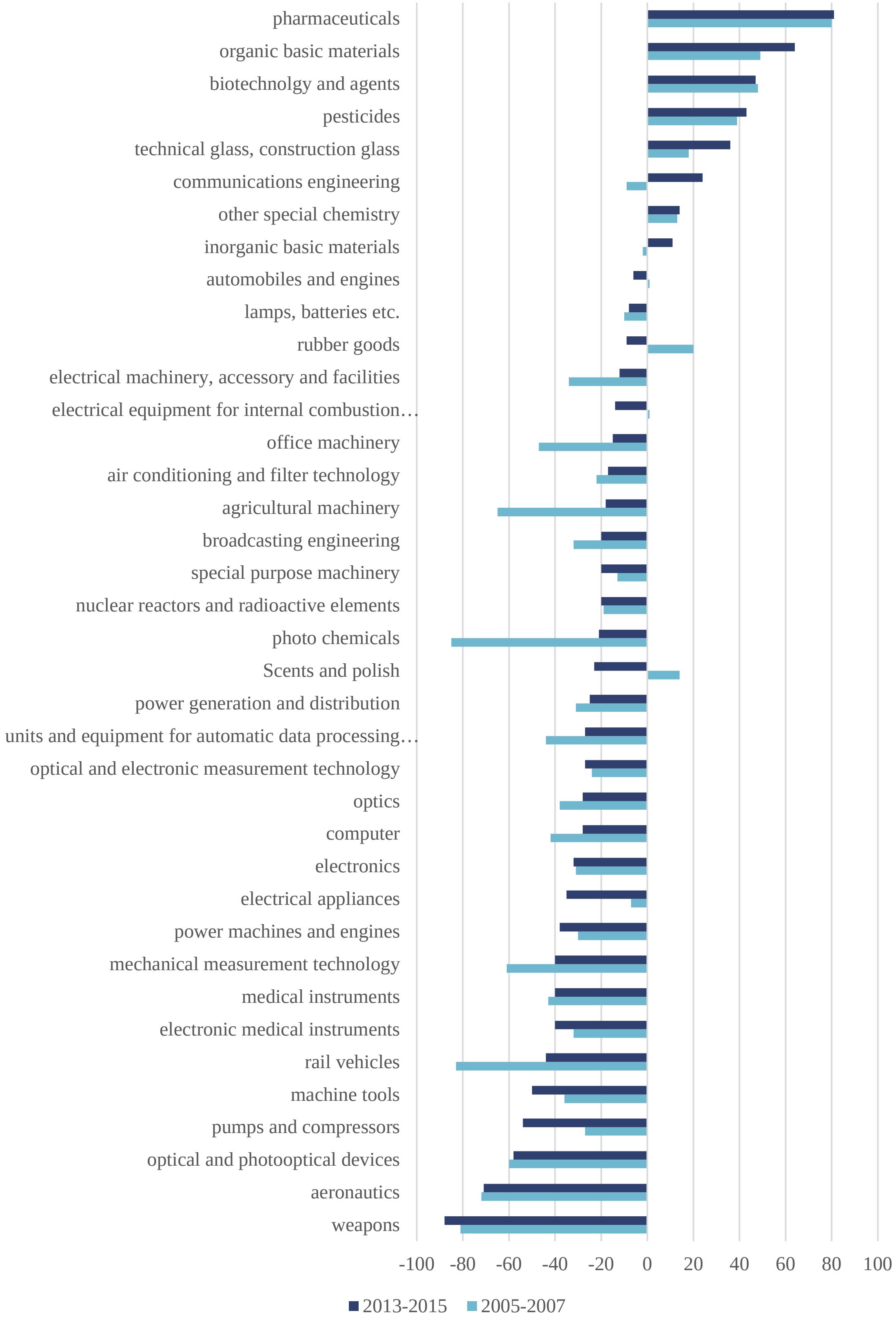
In the other countries the picture is very similar to the one found in Germany. For the United States, the co-patenting specialization is largest in pharmaceuticals, organic basic materials, biotechnology and agents and pesticides, while the smallest values can be found in weapons, aeronautics, optical and photooptical devices as well as other machinery and electronics related fields. The largest changes in the profiles across the years can be observed in photo chemicals, agricultural machinery, rail vehicles, office machinery and electrical machinery, accessory and facilities. The trends in the most and least specialized fields continue throughout the whole country-set, with pharmaceuticals, organic basic materials, biotechnology and agents and pesticides being the most highly-specialized fields while weapons, office machinery, agricultural machinery, machine tools, aeronautics, optical and photooptical devices and nuclear reactors and radioactive elements are the least specialized fields in terms of co-patents. Besides country idiosyncrasies there thus are large field-specific idiosyncrasies in co-patenting.

Figure 5: Germany's co-patenting profile, 2005-2007 vs. 2013-2015



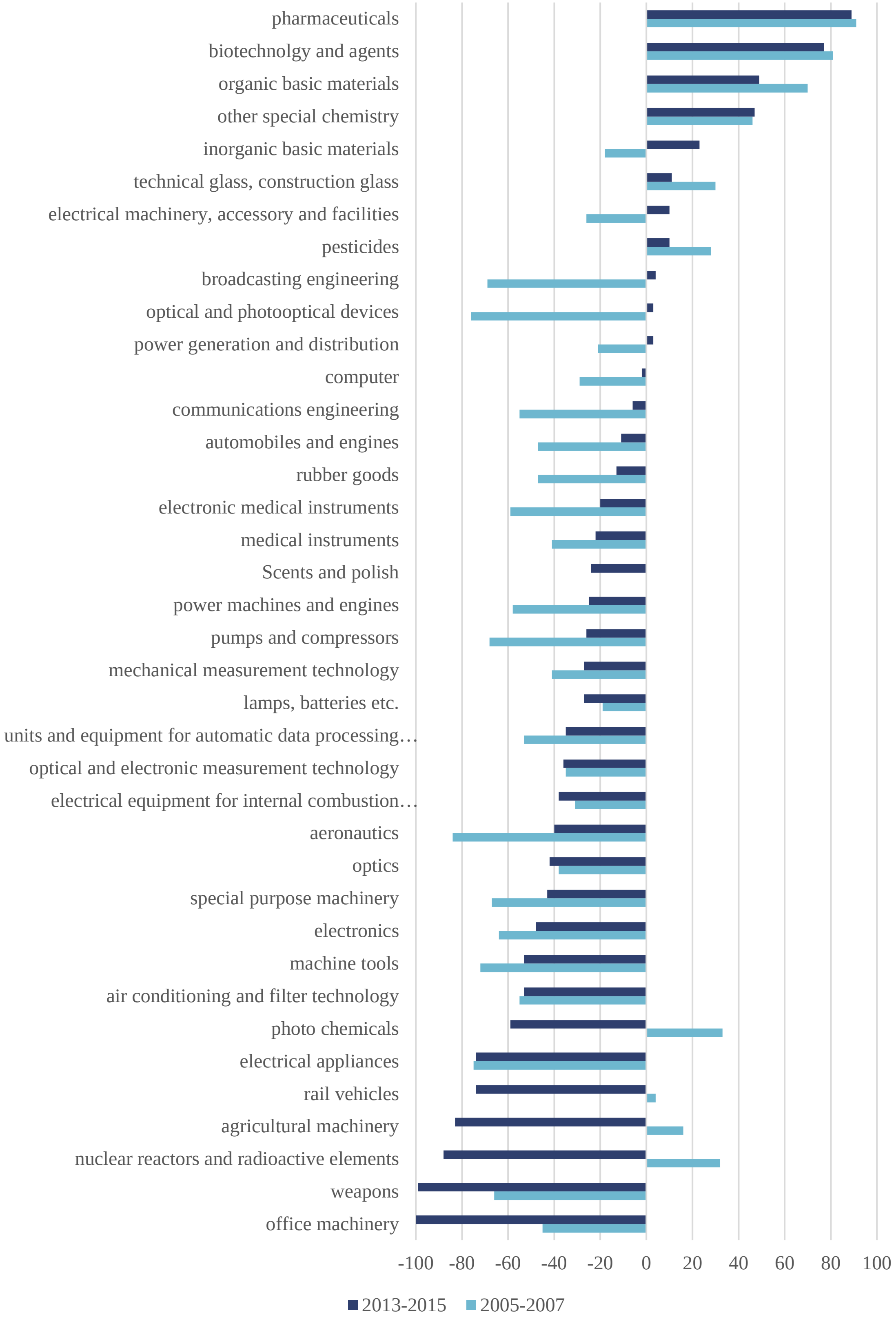
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 6: The United States co-patenting profile, 2005-2007 vs. 2013-2015



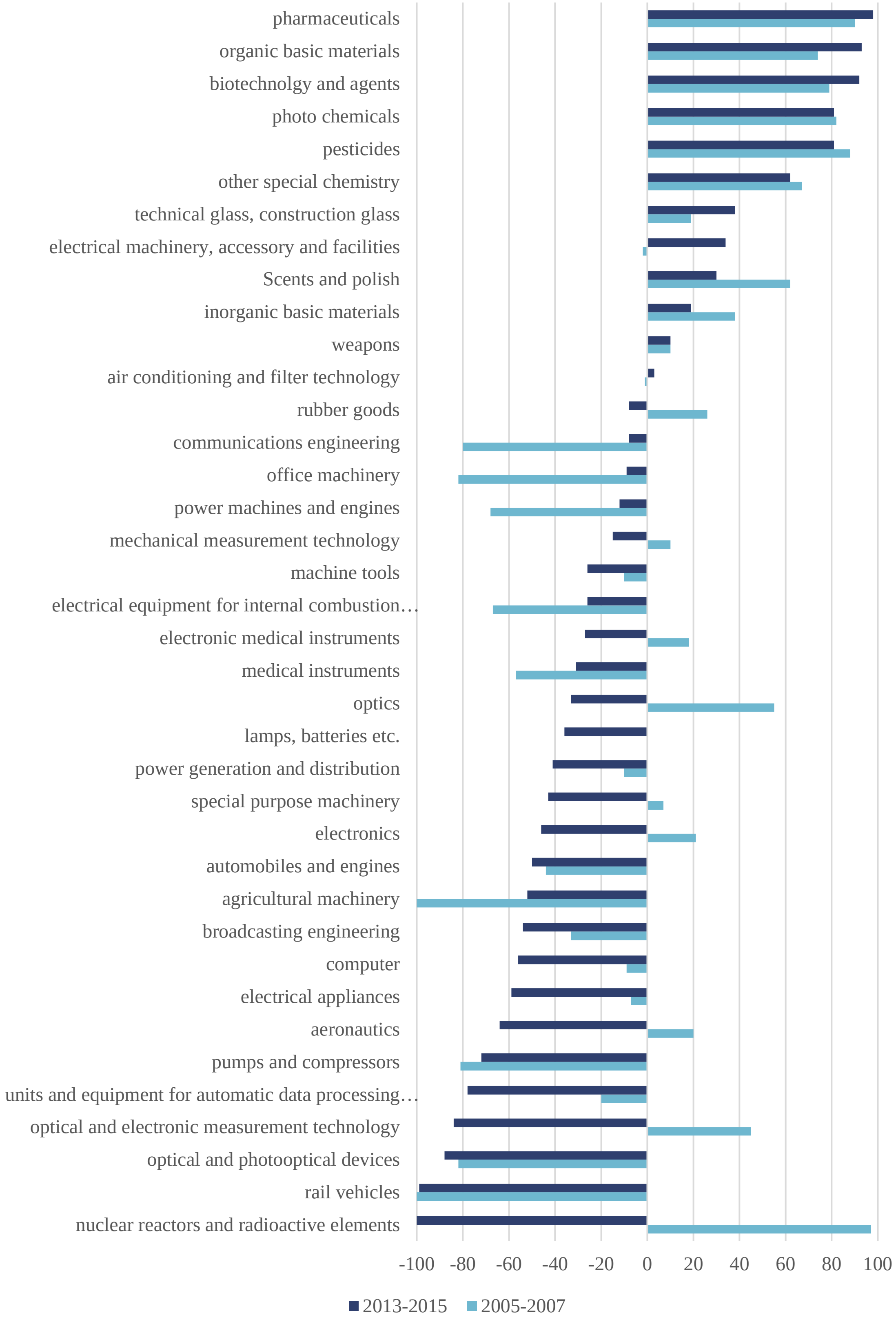
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 7: Switzerland's co-patenting profile, 2005-2007 vs. 2013-2015



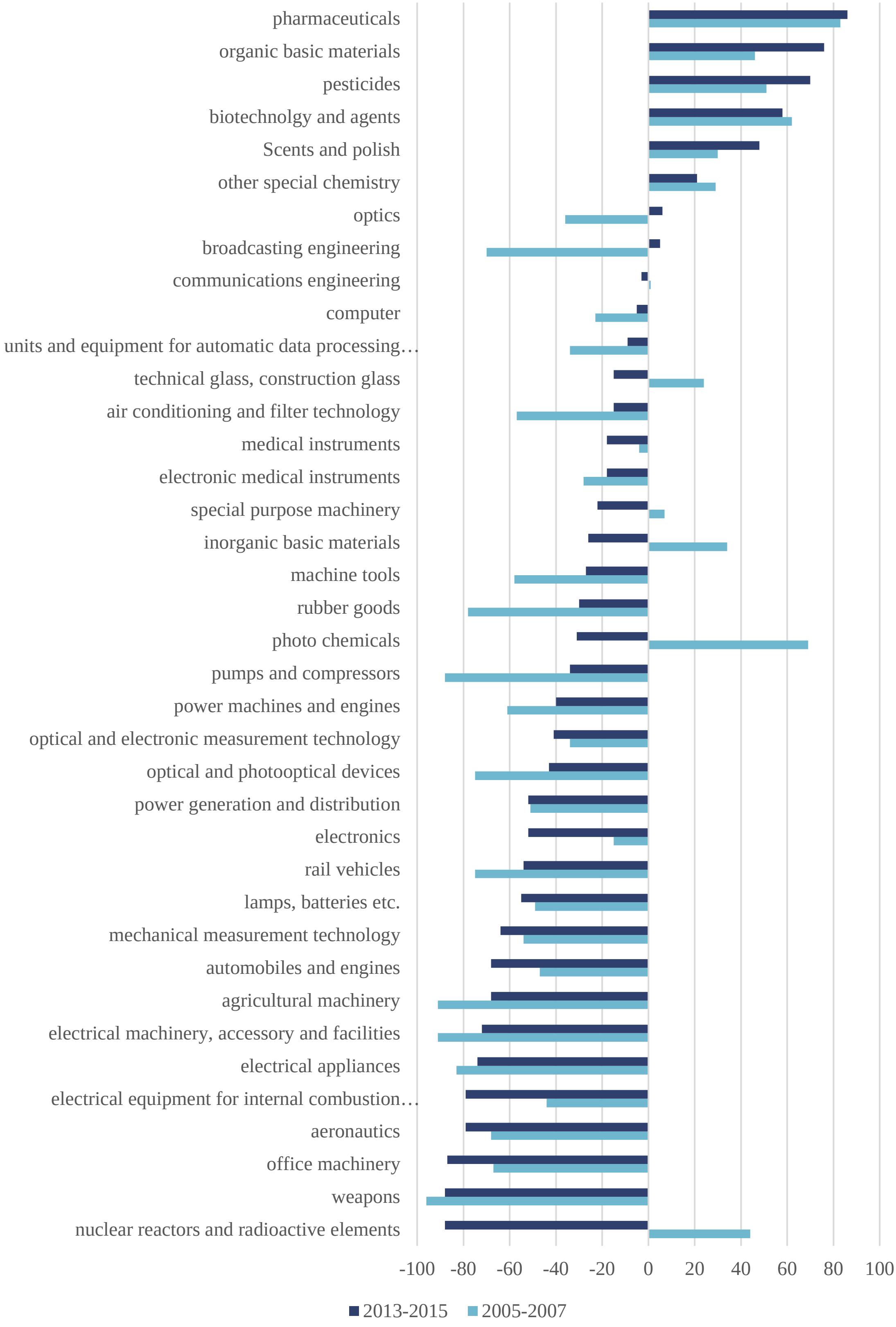
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 8: China's co-patenting profile, 2005-2007 vs. 2013-2015



Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 9: Great Britain's co-patenting profile, 2005-2007 vs. 2013-2015



Source: EPO – PATSTAT; Fraunhofer ISI calculations

4.3 Conclusions

Over the last twenty years, the shares of international co-patents have constantly increased, implying that the need to cooperate internationally has gained increased importance. In 1995, about 4.4% of all transnational filings were international co-patents. In 2007, however, this share has reached a peak of 6.4%. From then onwards, stagnation in the share of worldwide co-patents can be observed, which has even led to a decrease in co-patenting shares in many countries. In the last two years, however, co-patenting shares have started to rise again for many of the countries in our comparison. Deviations from this pattern can only be found for the large Asian economies, i.e. China, Japan and Korea, where the shares have been decreasing over the whole time period of the last decade although they already are at a rather low level, at least in Korea and Japan.

Switzerland has the largest co-patenting shares among the countries in our comparison with 36% in 2015. It is followed by Great Britain (23%), Sweden (21%) and France (17%), although declines in co-patenting shares are visible especially for Britain. With a share of 14% in 2015, Germany still is ahead of the US with 13%.

The country-by-country trends reveal that the U.S. is the most important partner for many countries in our comparison while the U.S. itself cooperates most strongly with China and Germany. Germany is also an important partner for many other countries, which is also true for France, Switzerland, Great Britain and China. The most important partners for Germany are the U.S., Switzerland, France, Austria and Great Britain.

The differentiation by high-tech fields reveals that there are large field-specific idiosyncrasies in co-patenting. The trends in the most and least specialized fields continue throughout the whole country-set, with pharmaceuticals, organic basic materials, biotechnology and agents and pesticides being the fields where most countries have a large specialization in terms of co-patents, while weapons, office machinery, agricultural machinery, machine tools, aeronautics, optical and photooptical devices and nuclear reactors and radioactive elements are the least specialized fields. Specializations in co-patents thus are low in fields regarding machinery and some fields of electronics as well as fields where cooperation is rare as in the case of defense related technologies.

5 Research Labs and Motives to Internationalize

Within this section, we aim to further understand the role of international research laboratories within the internationalization strategies of large multinational enterprises (MNEs). The internationalization of research and development is an important factor in the technological performance of a company, as it facilitates access to international markets and resources, but also serves to exchange knowledge across national borders.

The economic literature on internationalization suggests that there are basically two different motivations for companies to undertake parts of research and development abroad:

namely market access or access to resources (Belitz et al., 2006; Cantwell and Janne, 1999; Dalton and Serapio, 1999; Kuemmerle, 1997; Patel and Vega, 1999; UNCTAD, 2005). Market access implies a clear commercialization strategy whereby companies access the market not only externally but also internally. Besides commercialization, market-specific R&D is carried out abroad, with products often adapted or tailored to the national market. Thus, the focus is often on development rather than research activities. Market access strategies have also been coined as home-base exploiting strategies because they utilize the firm's already developed assets (Danguy, 2016; Kuemmerle, 1997). Access to resources on the other hand implies that the host country offers unique knowledge or competences that can be incorporated into the company's innovation chain (including special pricing or administrative rules exist in the host country). Special infrastructures, such as certain research or testing facilities or natural resources, may also encourage multinationals to transfer R&D activities to the host country. These motives are also summed up as home-base augmenting strategies in the literature (Kuemmerle, 1997).

There are arguments in the literature which state that the motives are dependent on the target country, i.e. it has been found that companies rather seek complementary knowledge in developed countries and more often conduct home-base exploiting activities in countries with growing markets (compare for example Dachs, 2014; Edler, 2003; Kuemmerle, 1998; Thursby and Thursby, 2006). Patel and Vega (1999), on the other side, conclude that companies internationalize in the areas of their individual strengths rather than their weaknesses. The firms' motives thus seem also seem to be dependent its own capabilities in a given technology field (Kafouros et al., 2008).

The empirical differentiation of these motives for internationalization, however, can be seen as a challenge in the empirical literature. Danguy (2016) provides general evidence that internationalization of research is driven more by home-base augmenting motives than by home-base exploitation. A method to identify the motives at a large scale, however, is still missing.

In sum, however, the motives to internationalize seem to be a) dependent on the target market and b) dependent on the firm’s own capabilities. A combination of these two dimensions therefore allows us to create a method for the identification of the respective motive by comparing the technological portfolio of the research lab with the portfolio of the region where the lab is located comparing the technological portfolio of the research lab with the company's overall patent portfolio. A fit between the technology profiles of the research lab, the firm and the region thus points to a home-base exploiting strategy. If the profiles do not fit, we assume a home-base augmenting strategy (due to the search for complementary assets within the region).

In this section, we will thus first of all present a method to identify international research labs of three large German firms, namely the Siemens AG, the BASF SE and the Bosch GmbH. We will then proceed to some analyses regarding the differentiation of their motives to internationalize.

5.1 The Identification of Research Labs

The data we use for the analyses were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT). As in the other sections, we focus on transnational patents for our analyses. The regionalization of patent filings is based on the OECD-REGPAT database, complemented with address information from the German Patent and Trademark Office. We further filled in addresses applying information from other patent family members which resembles the approach described in from address information is further filled with a similar approach as de Rassenfosse et al. (2013). For the current analysis, we focus on Siemens, BASF and Bosch. These three companies were chosen to provide a mix of large companies across sectors and technology fields. The name harmonization is based on the EEE-PPAT table provided by the K.U. Leuven including some manual adjustments (Du Plessis et al., 2009; Magerman et al., 2009; Peeters et al., 2009).

In order to identify the international research labs of those companies, we apply a stepwise approach. First, we demarcate the enterprises with the help of the EEE-PPAT table in PATSTAT and identify all their inventors from abroad by IDs (person_ID in PATSTAT). In a second step, we exclude inventors that also occur on patents of other applicants than the focal enterprise to eliminate the fact that inventors from partner institutions (e.g. through co-patents) are counted as inventors located in actual research labs of the focal company. We then clean the addresses of the inventors and assign them inventors to a lab, i.e. agglomerations of inventor locations are seen as labs. We hereby apply NUTS-2 codes for Europe and the federal states for other countries. We also checked randomly with real locations of these MNEs on the Internet to validate our method. In a third and final step, we use all identified inventor IDs to assign all patents of an enterprise to a particular lab. From there, we can analyze the patent profile of the lab and compare it to regional and firm profile.

To compare the profiles, we calculate specialization index (RPA) of the lab across 35 WIPO fields (Schmoch 2008) and repeat this calculation for the region the lab is located in as well as the focal company as a whole. In a final step, we compare the two indices (lab/region, lab/firm) with the help of a cosine similarity of the vectors of RPA values across technology fields. The cosine similarity measures the "angle" between two vectors, here the distribution across WIPO35 fields. An angle of zero degrees means that the cosine similarity is one, i.e. the vectors would point in the same directions (if plotted in a coordinate system). An angle of 90 degrees means that the variables are perpendicular, resulting in a cosine similarity of zero. The cosine similarity for two vectors is calculated as follows.

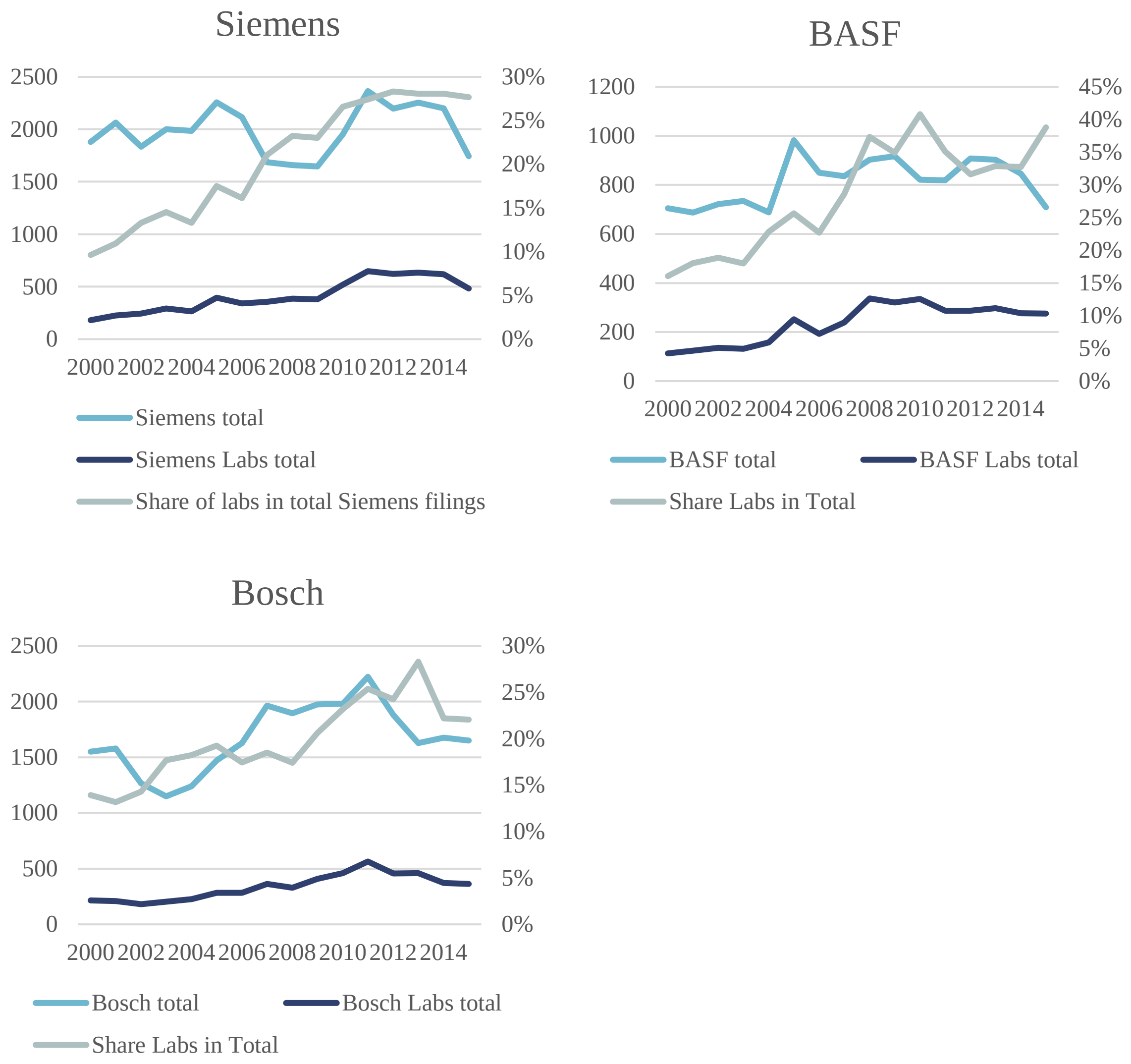
$$\text{Cosine Similarity} = \frac{\sum_{i=1}^{n} x_i y_i}{\sqrt{\sum_{i=1}^{n} x_i^2}\sqrt{\sum_{i=1}^{n} y_i^2}}$$

As a general rule, the smaller the angle between the two vectors, the larger their similarity and consequently the larger cosine value and vice versa.

5.2 Results

After having identified the research labs as inventor agglomerations abroad of Siemens, BASF and Bosch, we can first of all provide some basic trends in patent filings of these locations. In Figure 10, this is plotted for all three companies in our comparison. As can be seen from the figure, there is quite a share of filings of these three MNEs that is made from research labs abroad. In the case of Bosch, 22% of all of the company's filings are made from researchers in international research labs. For Siemens, this share is with 28% even higher. For the BASF it even reaches 40% in 2015. We can also see that patent filings from research labs are a rising phenomenon. The number of filings from international labs has grown for all three companies since 2000. The largest growth rates can be observed up to 2010. Afterwards, following the general trend of declining patent numbers in Germany, patenting from research labs has decreased or at least stagnated as in the case of Siemens. For the BASF, we can observe a rise again between 2014 and 2015.

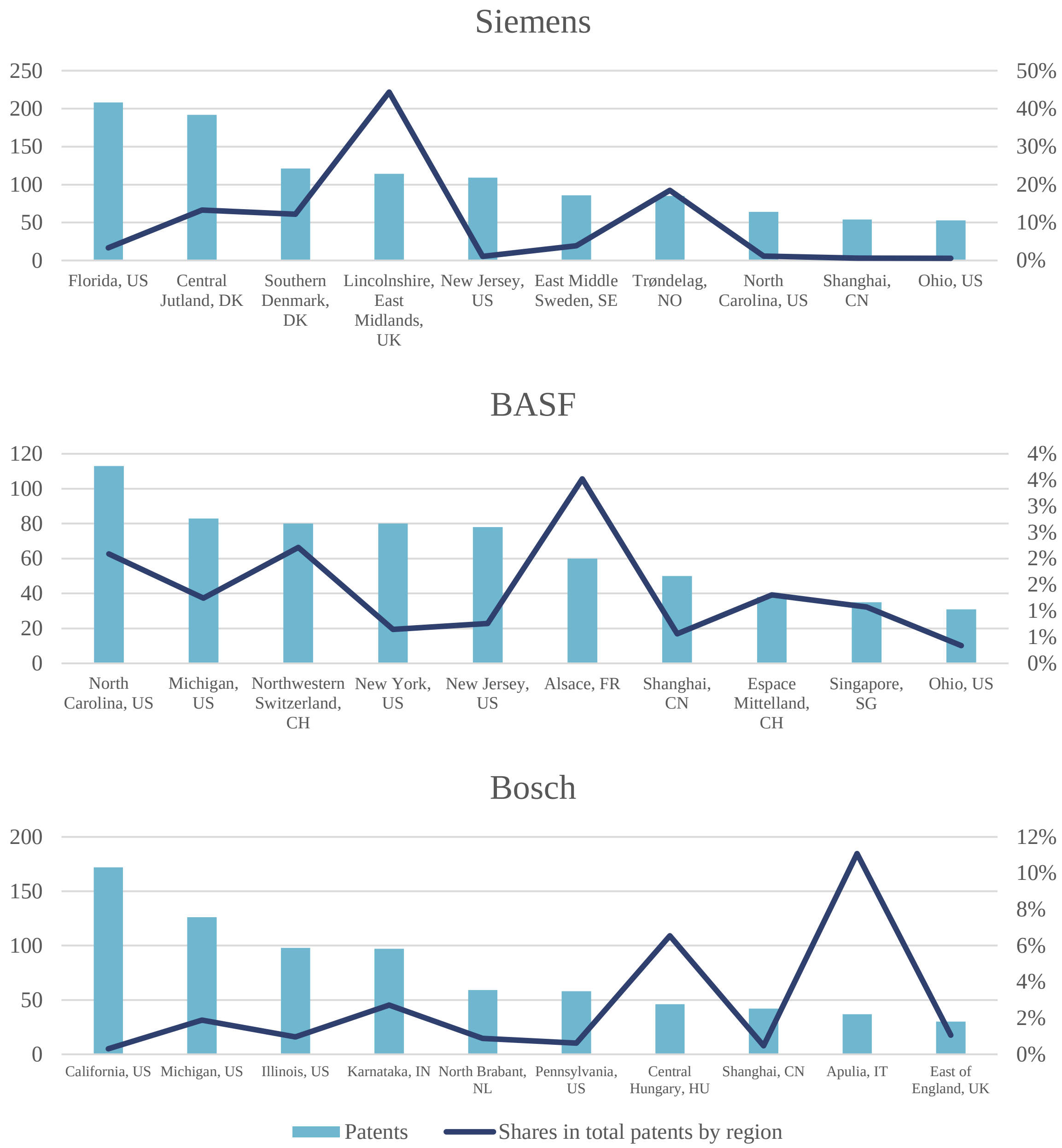
Figure 10: Patent activities of Siemens, BASF and Bosch and its international research labs



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Several other interesting facts can be revealed when looking at the regional distribution of the research labs of the single companies (Figure 11). As we can see from the figure, the largest international research location of Siemens is Florida, followed by Central Jutland (Denmark) and Southern Denmark, Lincolnshire in the UK and New Jersey. Within Europe, the largest Siemens labs thus are located in Scandinavia and the UK. Outside Europe, there is a large focus on the U.S. as well as China (Shanghai). As we can also see from the figure, the contribution of the research lab to the patent portfolio of the region can be substantial, especially for smaller regions in terms of patent filings. In Lincolnshire, for example, the Siemens lab alone s responsible for 44% of the region's total patent filings. In Shanghai or in the U.S. locations, however, this share is considerably smaller. For the BASF it can be shown that within Europe, it operates the largest labs in Switzerland and France. Outside Europe, the main focus is the U.S., but also in China (Shanghai) and Singapore. Bosch on the other hand, has the most geographically diverse set of research labs. The largest R&D labs are in the U.S., but also in India and China labs are operated. Within Europe, the largest labs are in the Netherlands and the UK but also in Italy and Hungary.

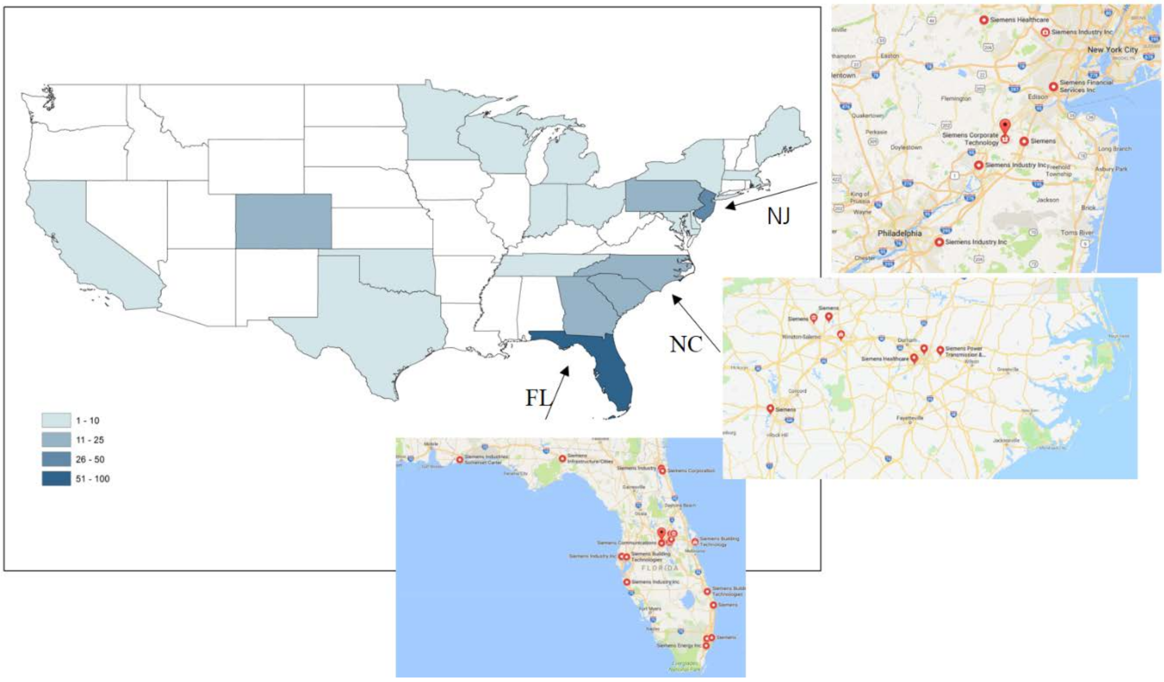
Figure 11: Patent activities of Siemens, BASF and Bosch and its international research labs



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

In order to make sure that the agglomerations of researchers of the focal firms actually resemble international research labs of the companies, manual checks were made with the help of Google Maps. A graphical representation of Siemens' activities in the U.S. including an overlay of Google Maps for the largest research locations is provided in Figure 12. Here we can see that the method of identifying research labs seems to work. In the case of the largest research locations of Siemens in the U.S., i.e. in Florida, North Carolina and New Jersey, locations of the Siemens AG can be found on Google Maps.

Figure 12: Siemens in the USA: transnational patents by lab locations 2013-2015



Source: EPO – PATSTAT; Google Maps; calculations by Fraunhofer ISI

In a final step, we will take a closer look the the cosine similarities of the technology portfolio of the research labs, the international regions in which they are located, and the focal firm as a whole. This is provided for the three firms in our comparison in Figure 13. In the case of Siemens it can be found that the similarity of the lab, the region and the firm is larger within closer range to the firm headquarters. This is true for Central Jutland, Southern Denmark, Lincolnshire, East Middle Sweden and Trondelag in Norway. The internationalization strategy within the direct neighbourhood of Siemens, e.g. in locations within Europe, seems to be home-base exploiting. In the case of Florida, North Carolina, Ohio, and Shanghai, we see a much smaller overlap between the research lab and the patents of the region, although the overlap with Siemens as a whole is rather large. This is not true for New Jersey, where not only the overlap with the region but also the overlap with Siemens as a whole is relatively small. At least for Siemens it can thus be stated that in less proximate locations, i.e. the U.S. and China, home-base augmenting strategies seem to be more prominent. All in all, it thus seems to be the case that not only characteristics of the target market as well as the firm's own capabilities seem to matter when it comes to the motives for internationalization but also proximity to the headquarter locations seems to influence the motive to internationalize.

Figure 13: (Cosine) Similarity of the lab profile with the region and the firm as a whole

Source: EPO – PATSTAT; calculations by Fraunhofer ISI

For the BASF, proximity to the headquarter location also seems to be a factor, yet not as strongly pronounced as for Siemens. In general, we find a large similarity of the research lab and the regional profile (except for New Jersey) but no clear regional distribution can be found. The BASF thus generally seems to be more home-base exploiting, with own firm capabilities influencing the motive to internationalize. For Bosch, it can be found that it has a strong focus towards the U.S. regarding home-base augmenting strategies (except Illinois), i.e. the similarity is small especially with regard to U.S. locations. However, the remainder of the profile is highly mixed across countries. Again, no clear regional distribution can be found but the similarities to the region are much lower than in the case of BASF, which could be interpreted as market access strategies for non-U.S. locations. Here, it thus seems that market specifities influence the motive. In the U.S., home-base augmenting motives are in the focus, while in other countries market access seems to be the most prominent motive for internationalization.

5.3 Conclusions

In this section, we have taken a closer look at international research laboratories and their fit within the internationalization strategies of MNEs. We have found that patent based indicators can be used to identify labs or research locations of MNEs and with these indicators we can try to empirically differentiate home-base augmenting vs. home-base exploiting motives with the help of field profiles.

Apart from that, we can conclude that the trend of internationalization of R&D continues. Up to 40% of MNEs patents are invented in locations outside of the MNEs host country. Furthermore, patent filings from research labs are a rising phenomenon. The number of filings from international labs has grown for all three companies in our comparison, i.e. Siemens, BASF and Bosch, since 2000. The largest growth rates can be observed up to 2010. When looking at the similarities of the research labs, the regions in which they are located and the firms as a whole, it can be found that besides the characteristics of the target market and firm capabilities, proximity to the headquarter location seems to influence the motive to internationalize. We have further found the there is a focus on the U.S. when it comes to home-base augmenting strategies. At least for the German firms in our sample we can thus state that home-base augmenting strategies are most prominent in close proximity to the headquarter as well as in the United States. In other countries, like for example China or Singapore, home-base exploiting strategies seem to be more prominent.

6 Patent Activities of the German Federal States

In the previous sections, we have discussed several patent related indicators at the international level. In this section, we will take a look at the German patent filings at the level of the German federal states (Bundesländer). We thereby aim to answer the question, which of the federal states contribute most strongly to the patent activities of Germany as a whole. In addition, we will take a closer look at high technology patenting within the German federal states.

A regionalized patent statistic therefore allows us to take a closer look at the structural composition of the German innovation landscape. A further differentiation by high technology vs. less R&D-intensive technologies further enables the identification of high-tech hot spots in Germany and shed more light on the technological strengths and weaknesses of the federal states. This, in turn, allows identifying regional technology trends, which is an important precondition for the composition and framing of regional innovation policies in Germany.

Analogous to the analyses at the international level, we will count transnational patent filings by federal states based on the inventor's address, i.e. a patent application is assigned to the federal state of the inventor.[4] We further apply fractional counting, so each federal state is only assigned a fraction of a patent in case inventors from other federal states are listed. For the identification of the German federal states in patent filings, we use the NUTS-code information available in the OECD REGPAT database, complemented with address information obtained from the German Patent and Trademark Office (DPMA). For filings that could not be assigned a NUTS code with the help of these two data sources, we resorted to the patent family information within the PATSTAT database. In the case that address information could be obtained from any other than the transnational filing, this address information was assigned to the transnational filing.

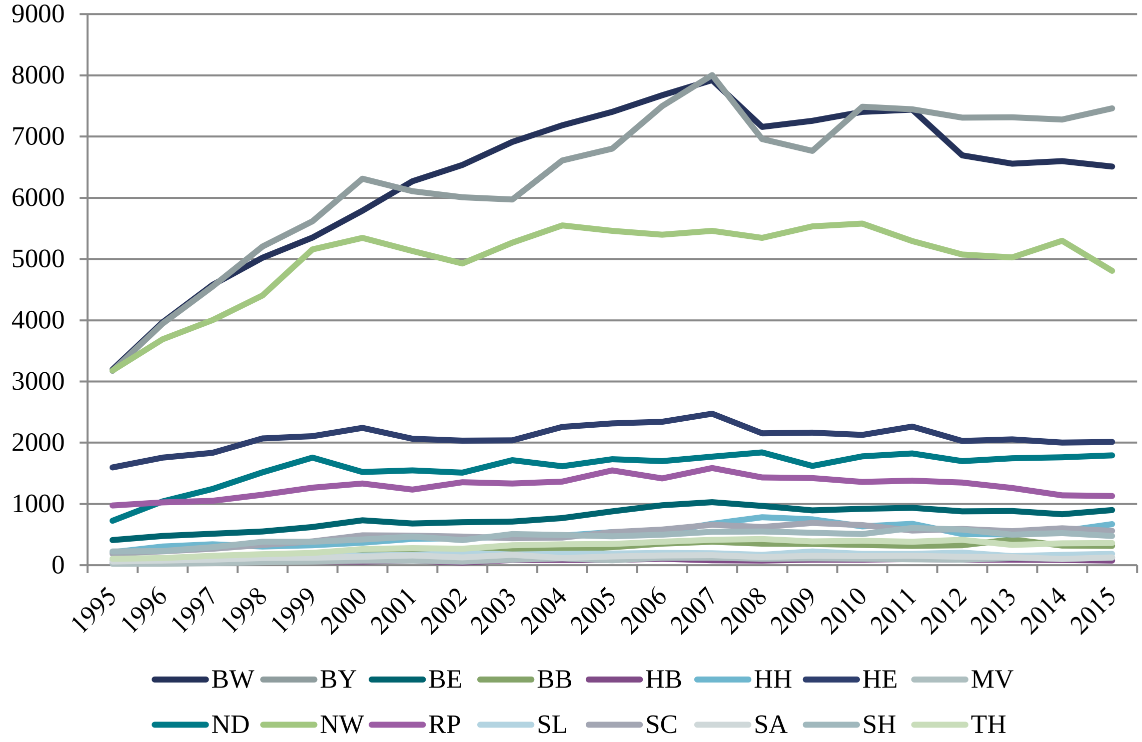
6.1 Results

6.1.1 Structures and Trends

In Figure 14, the absolute numbers of transnational patent filings by federal state are plotted. Until 2007/2008, the number of filings is increasing for all German federal states. At the latest since 2010, however, i.e. after the financial crisis, the number of filings has stagnated, or even decreased as for example in the case of North Rhine-Westphalia or Baden-Württemberg. In sum, however, it can be stated that the south of Germany has the largest number of transnational filings within the German comparison. Bavaria ranks first, with nearly 7,500 filings in 2015, followed by Baden-Württemberg (about 6,500 filings in 2015) and North Rhine-Westphalia at a slightly lower level (about 4,800 filings in 2015). These three federal states together are responsible for 67% of all German transnational filings. However, large parts of the German industry are located in these three federal states and about 51% of the German workforce is located there. At the fourth rank, with about 2,000 filings in 2015, is Hesse, followed by Lower-Saxony and Rhineland-Palatinate. The remainder of the federal states is at a similar level with less than 1,000 filings per year.

4 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 in earlier reports of this series Neuhäusler et al. (2014).

Figure 14: Number of transnational filings by federal states



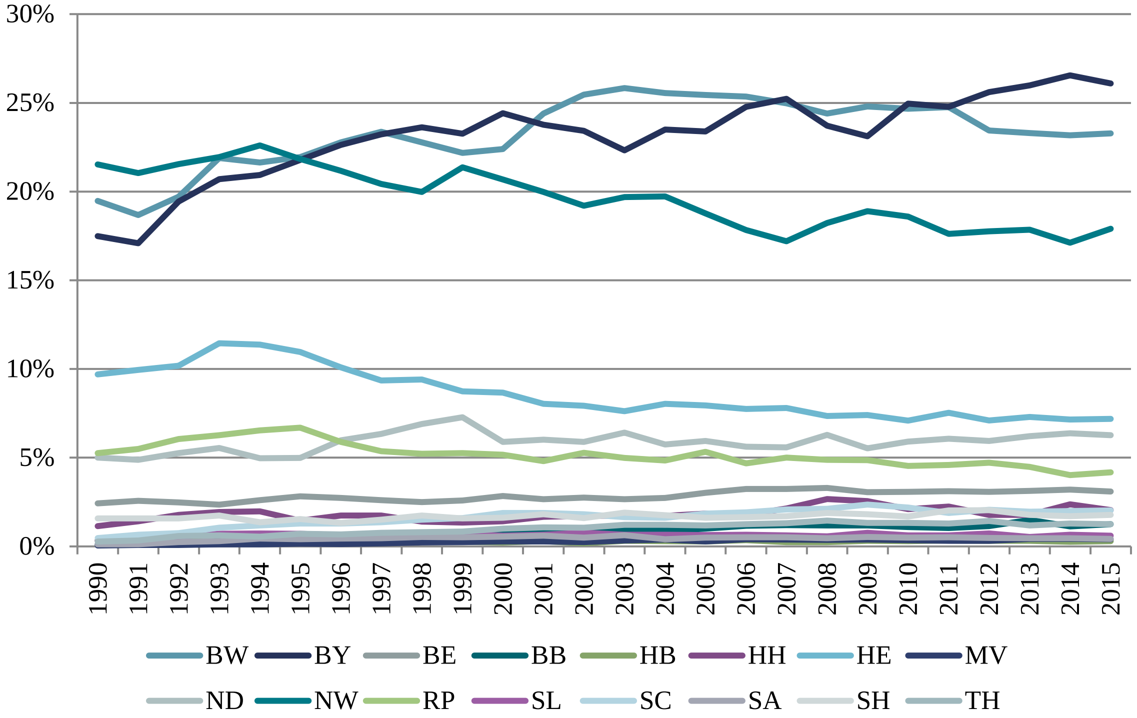
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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

Figure 15 shows the share of regional filings in total German filings. Here, it becomes even clearer how Baden-Württemberg, Bavaria and North-Rhine Westphalia dominate the number of filings within Germany. We can further observe that most Northern and Eastern German states score at the lower ranks when looking at absolute and proportionate number of filings. Yet, it can be found that although Bavaria has increased its filing shares over the years, the shares of Baden-Württemberg have decreased. A similar effect can be observed for North Rhine-Westphalia, Hesse and to a certain extent also Rhineland-Palatinate, where the shares are mostly decreasing over the years. In Lower-Saxony, on the other hand, we see an increase since 2009.

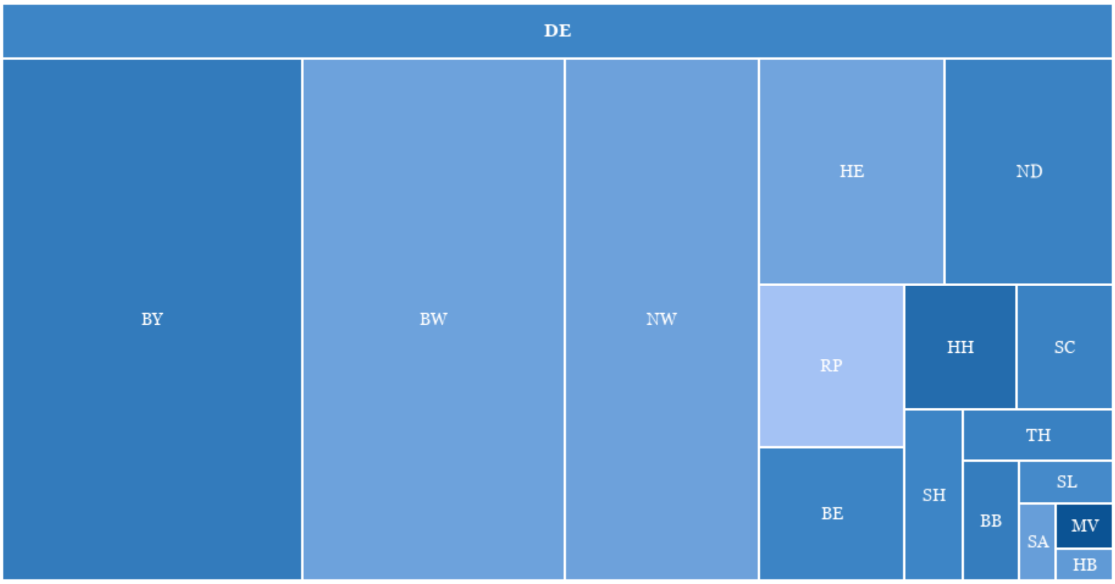
This might become clearer when looking at Figure 16, where the shares and growth rates of the filings of the German federal states are depicted in a tree map. The size of the boxes within the figures indicate the share of the respective federal states, the color indicates the growth rate between 2005 and 2015. Especially the growth rates reveal several interesting results. It can be found that there is only moderate growth for most of the federal states. The largest growth rates can be observed for Mecklenburg-West Pomerania, Hamburg and Bavaria. It is thus two of the Northeastern countries that have managed to increase their amount of filings in the last decade. However, the growth rates are negative in a number of countries, e.g. Rhineland-Palatinate, Hesse, Baden-Württemberg, Bremen and Saarland.

Figure 15: Share of regional filings in total German transnational filings



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

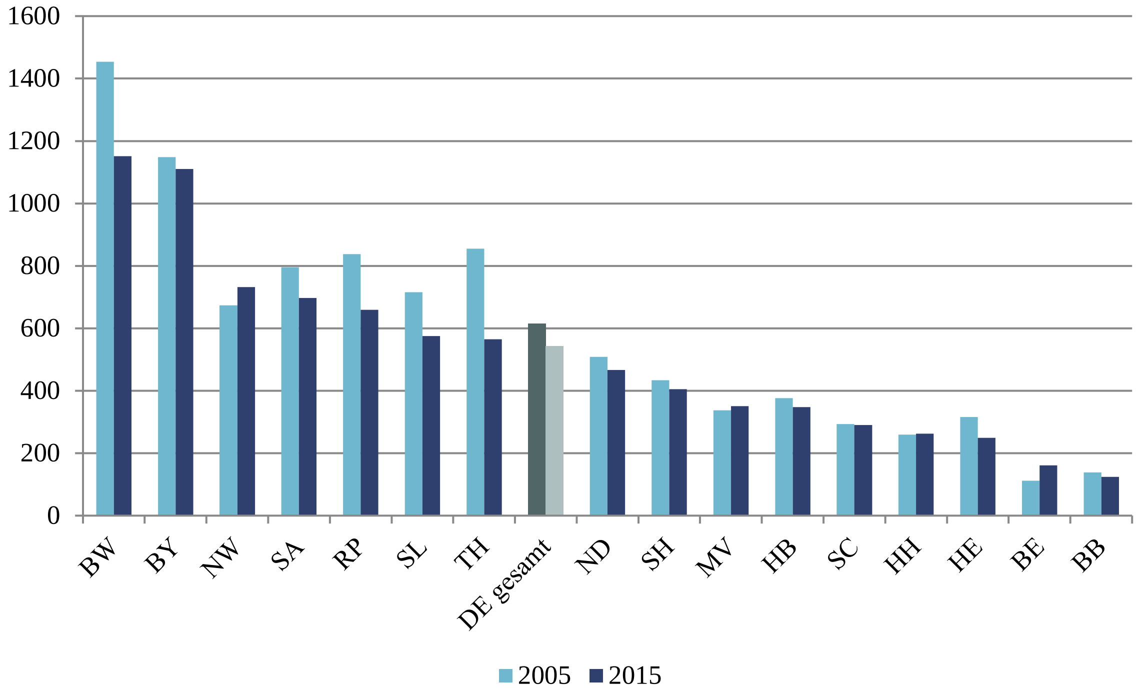
Figure 16: Tree map for the shares (in total German filings) and growth of regional filings, inventor principle, 2015



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Note: The size of the fields resembles the shares of a region in relation to total German transnational filings. The color (from light to dark) indicates the growth in the number of filings between 2005 and 2015.

Figure 17: Patent intensities per 1 million employees



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

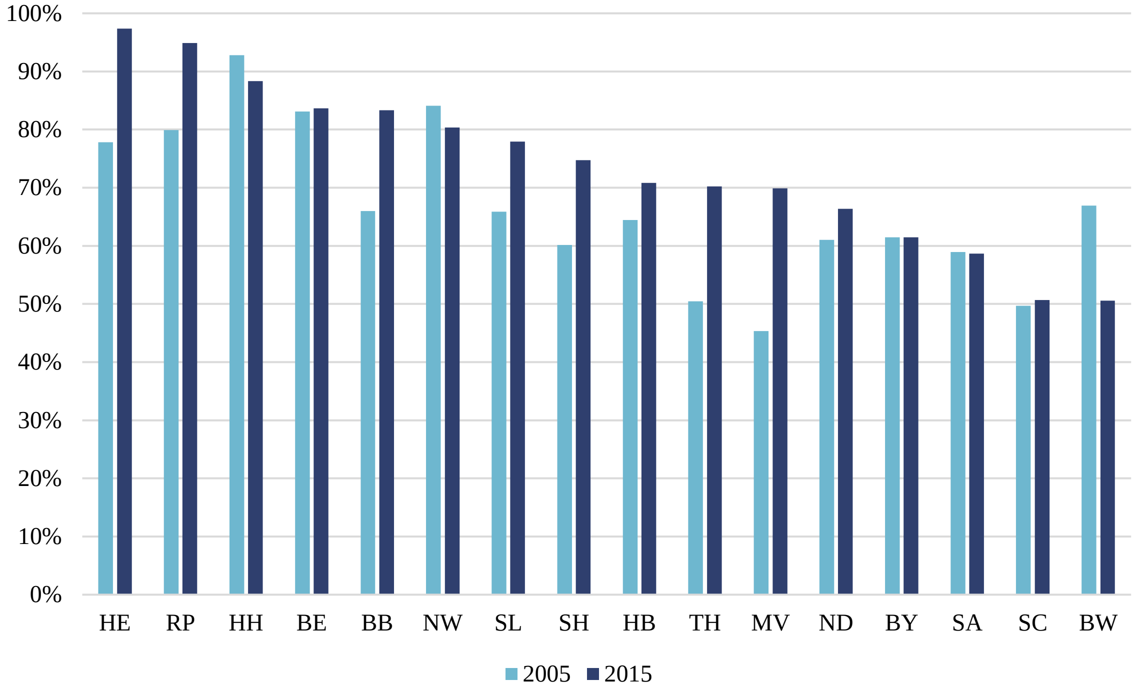
The patent intensities, i.e. the number of patent filings by a federal state divided by the number of employees in the respective state, are plotted in Figure 17. They show that that Baden-Württemberg and Bavaria are not only the largest patenting countries in absolute terms but also in patents per capita. However, both countries have lost some ground on this indicator since 2005, which is even truer for Baden-Württemberg than for Bavaria due to the decrease in the absolute number of filings. North-Rhine Westphalia scores third in terms of patent intensities. This is due to the growth of filings from North-Rhine Westphalia in 2015 but also due to the decreasing patent intensities of other federal states like Thuringia, Rhineland-Palatinate, Saxony-Anhalt and the Saarland. All these countries, however, score above the patent intensity of Germany as a whole. The other federal states score below the German average within this comparison.

In a final step, we take a closer look at the internationalization rates of the German federal states. The internationalization rate is calculated by dividing the number transnational filings by the number of filings that are supposed to target the German market (either via PCT, the EPO or via a direct filing at the German Patent and Trademark Office[5]). It therefore provides the information which share of patents targeting the German Patent and Trademark Office is also filed internationally. These shares are plotted by federal state in

5 This is based on the assumption that all filings by German inventors at the EPO or via PCT name the German Patent and Trademark Office as a designated patent office for their filing, which is true for more than 90% of the cases.

Figure 18. We can see that the highest internationalization are reached by Hesse, Rhineland-Palatinate, Hamburg, Berlin, Brandenburg and North-Rhine Westphalia. The least internationalized federal states in terms of patenting are Baden-Württemberg, Saxony, Saxony-Anhalt, Bavaria and Lower-Saxony.

Figure 18: Internationalization rate of the German federal states



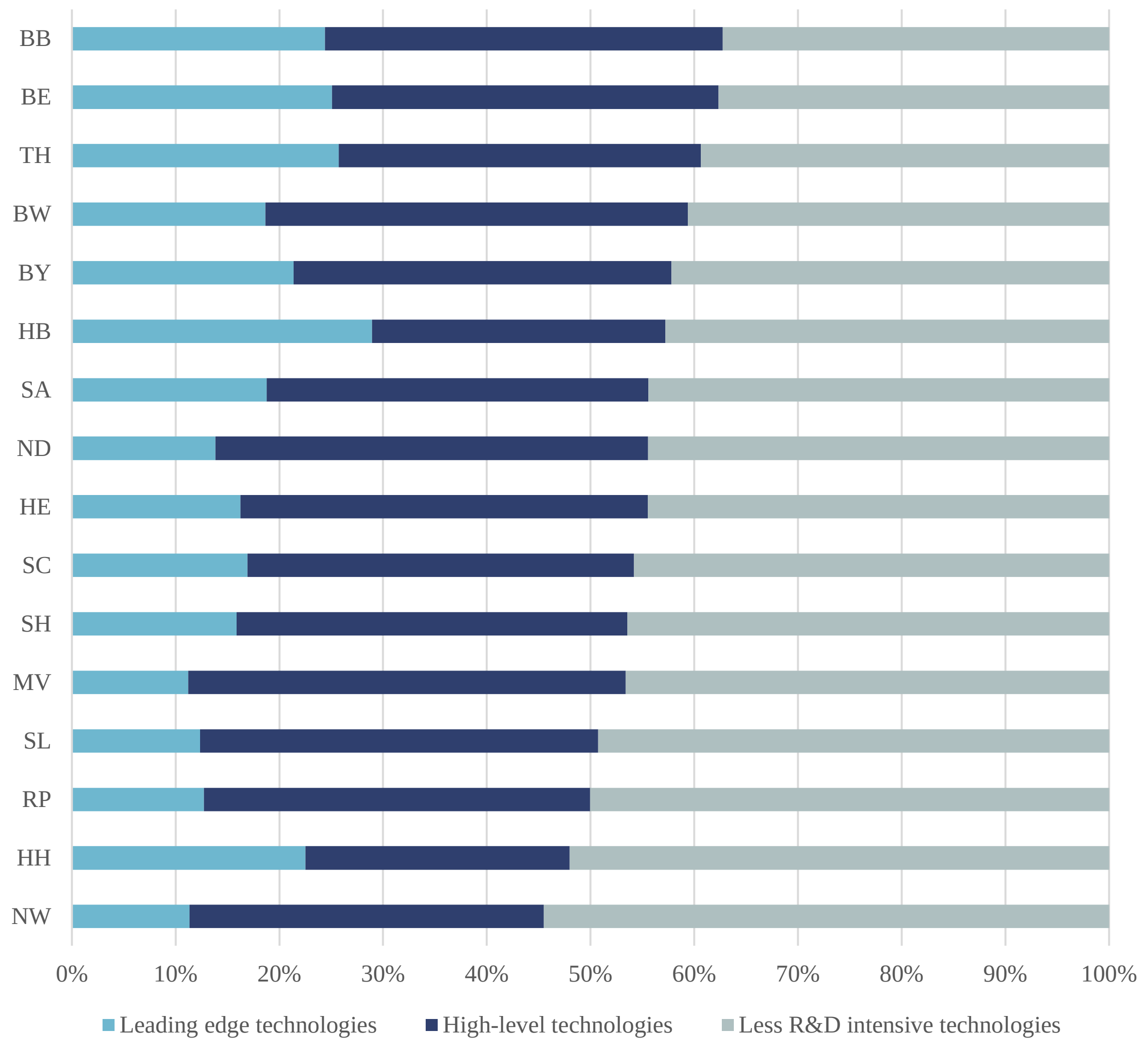
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

6.1.2 High-technology profiles of the German federal states

Within this subsection, the high-techprofiles of the German federal states are presented. They are calculated as shares in total patent filings. The distinction between low- and high-technology areas runs analogue to the analyses at the international level, i.e. high-tech is defined as technologies with an average investment in R&D of more than 3% of the turnover is required. It is composed of high-level technologies (between 3% and 9% of R&D in turnover) and leading-edge technologies (above 9% investment shares) (Gehrke et al., 2013).

The high-tech profiles of the federal states are presented in Figure 19. It can be observed that Brandenburg has the largest share of high-technology patents within the German comparison, followed by Berlin, Thuringia, Baden-Württemberg and Bavaria. The countries with the lowest shares in high-tech patents are North Rhine-Westphalia, Hamburg, Rhineland-Palatinate, the Saarland and Mecklenburg-West Pomerania. Also for the federal states the differentiation by leading-edge and high-level technologies delivers interesting insights. The largest shares of leading-edge technologies within high-tech can be observed in Bremen. This makes sense, as major parts of the German aeronautics and aerospace industry are located in Bremen. Besides being the companies like Airbus or the OHB SE that are located in Bremen, the city hosts an aerospace cluster where companies closely work together with the University of Bremen. The second largest leading-edge technology shares can be found in Thuringia, closely followed by Berlin and Brandenburg as well as Hamburg. In the case of Thuringia, this can be explained by the leading-edge cluster photovoltaics ("Solarvalley Mitteldeutschland"), which is located in Thuringia, Saxony and Saxony-Anhalt. A similar argument can be brought forward for Hamburg, where the aeronautics leading-edge cluster "Hamburg Aviation" is located. In the case of Berlin and Brandenburg the large shares in leading-edge technologies can be explained by the large number of ICT firms that are located in Berlin and surrounding areas. Since we apply the inventor principle here, this also explains the large leading-edge shares in Brandenburg since many people living in Brandenburg commute to work in Berlin. The highest shares in leading-edge technologies in the comparison of the German federal states can be found in Lower-Saxony, Mecklenburg-West Pomerania, Baden-Württemberg and Saarland.

Figure 19: High-technology profiles of the federal states, 2013-2015



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

6.2 Conclusions

In this section, we have provided regionalized patent statistics for the German federal states. Especially the two large southern federal states, i.e. Bavaria and Baden-Württemberg, file the largest number of patents at the transnational level. Together with North-Rhine Westphalia these three federal states account for two thirds of the German transnational filings, while accounting only about the half of the employees in Germany are located within these countries. Baden-Württemberg and Bavaria also show the highest patent intensities within Germany, while the Northern and Eastern German states score at the lower ranks. Yet, especially for Baden-Württemberg, a drop in the patenting shares as well as patent intensities can be observed in the recent years, which is a result of decreasing absolute filings figures. In Bavaria, also a slight drop in intensities can be observed, although the absolute figures have grown recently. A similar effect can be observed for North-Rhine Westphalia, where the filing figures have grown especially in 2015.

This is also resembled in the growth rates of the respective countries. It can be found that there is only moderate growth between 2005 and 2015 for most of the federal states. The largest growth rates can be observed for Mecklenburg-West Pomerania, Hamburg and Bavaria, i.e. two Northern German federal states show a large growth in filings. However, seven of the sixteen federal states show negative growth rates since 2005.

In terms of internationalization, it can be found that Hesse, Rhineland-Palatinate, Hamburg, Berlin, Brandenburg and North-Rhine Westphalia have the largest internationalization rates while the least internationalized federal states Baden-Württemberg, Saxony, Saxony-Anhalt, Bavaria and Lower-Saxony. Within this subsection, the high-techprofiles of the German federal states are presented. They are calculated as shares in total patent filings. The distinction between low- and high-technology areas runs analogue to the analyses at the international level, i.e. high-tech is defined as technologies with an average investment in R&D of more than 3% of the turnover is required. It is composed of high-level technologies (between 3% and 9% of R&D in turnover) and leading-edge technologies (above 9% investment shares) (Gehrke et al., 2013).

The high-tech profiles of the federal states show that the largest share of high-technology patents within the German comparison can be found in Brandenburg, followed by Berlin, Thuringia, Baden-Württemberg and Bavaria. The largest shares of leading-edge technologies within high-tech can be observed in Bremen, with its strenghths in aerospace technologies. A similar effect can be found for Hamburg, where the leading-edge cluster "Hamburg Aviation" is located as well as Thuringia with the leading-edge cluster "Solarvalley Mitteldeutschland". In the case of Berlin and Brandenburg the large shares in leading-edge technologies can be explained by the large number of ICT firms that are located in Berlin and surrounding areas.

7 Patenting Trends in Public Research

Scientific achievements are most commonly published in journals, which enables other researchers to access and eventually cite them if they deem them appropriate for their own research (Michels et al., 2013). Besides scientific publications, however, patent filings can also be seen 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 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. In the last years, 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.

Within this section, we will take a closer look at the trends in patent filings by public research in Germany. Hereby, we will first of all only use the applicant's perspective and analyze trends in patents filed by universities as well as the four large public research institutes in Germany, i.e. the Max Planck Society, the Fraunhofer Society, the Helmholtz Association and the Leibniz Institutes. This gives us an idea about how many patented inventions are owned by public research. These patents were identified within the PATSTAT database with the help of a keyword search, including the names of the universities and PROs with different spelling variations and languages as well as a search for the names of the respective cities, also including spelling variations and languages. In the case of the Technical University of Munich, for example, patents are filed under the names "TECHNICAL UNIVERSITY OF MUNICH", "TECHNISCHE UNIVERSITAET MUENCHEN", or "TU MUENCHEN".

In the second part of the analysis, we will take a closer look at "academic patents" to provide a more complete picture of the trends in academic patenting. We will therefore apply the extended perspective of "academic patents", which – besides the patents where universities are named as patent applicants – also takes university inventors into account, even in the case a patent was filed by a company.

7.1 Academic patents: Methodology

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 the 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.[6] The *precision* of the algorithm was validated by an online-survey covering authors for whom academic patents have been identified.[7] 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[8] 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 last year's series. This has to do with the fact that the most recent version of Scopus (version 2017) was used for the matching, which has a better coverage of scientific journals (across all years) and research organizations in general.

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6 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).

7 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%.

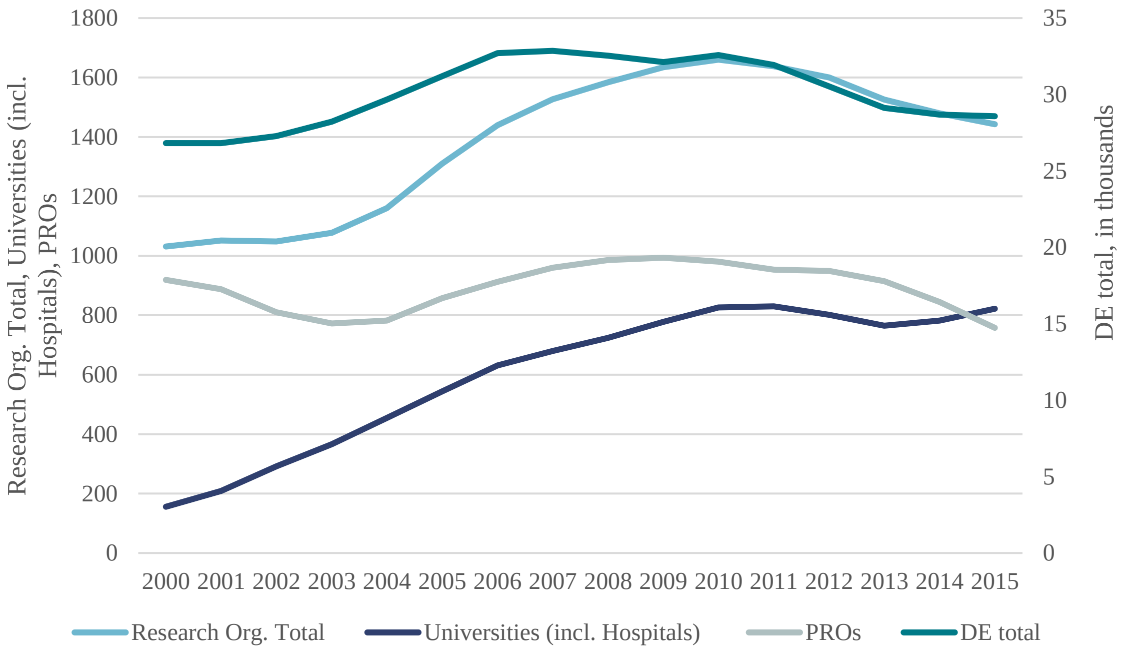
8 F-Score: $F_ß = (1+ß^2)\ (p*r)/(ß^2*p*r)$; p = precision = tp/(tp+fn) and r = recall = tp/(tp+fp) where tp means true positive, fn false negative and fp false positive.

7.2 Results

7.2.1 The Applicant Perspective

In Figure 20, the number of patents filed by research organizations in total (universities + PROs), as well as differentiated by universities and public research organizations, is depicted. Up to the year 2010, the filings number of PROs and especially universities have increased, which implies that patenting has become a more and more important instrument for universities and PROs. The larger growth rates of patents filed by universities can at least partly be attributed to the abolishment of the Hochschullehrerprivileg in 2002, which has led to a convergence in the number of filings from PROs and universities in the last few years.

Figure 20: Number of transnational filings by German research organizations (3-years moving average)

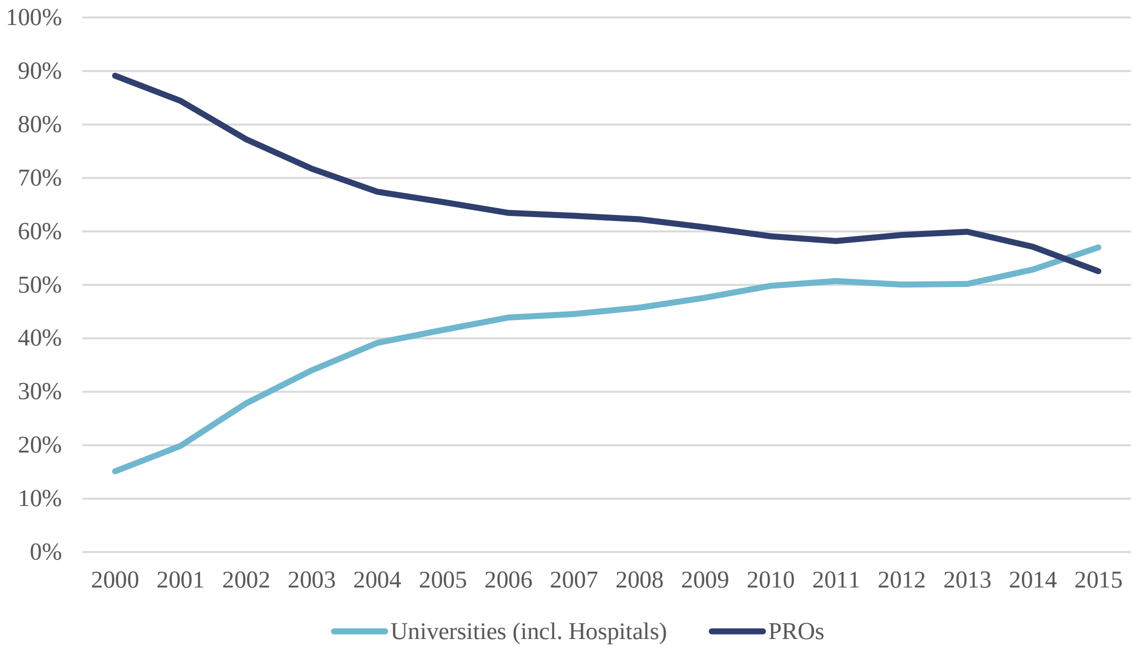


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

However, since 2010 a decline in the number of filings in Germany becomes visible. This is not only true for the industry, but also visible in filings by research organizations. Especially a decline between 2011 and 2013 becomes visible. After 2013, the number of filings by universities started to rise again, while the number of filings by PROs still went down. This has lad to the fact that at the first time in 2015 the number of patents filed by universities is larger than the number of patents filed by PROs.

Still, this has several explanations: first, and as already mentioned, the decline in filings follows the general trend of stagnating and even slightly decreasing transnational filing figures of Germany (though the decline seems to end in 2014/2015). Second, it is especially an effect of a decrease in international filings by universities and PROs. When looking at the German Patent and Trademark Office (DPMA) (not shown), it can be observed that the filings PROs only slightly decreased after 2010, while the filing figures for universities stagnated but started to rise again after 2013.

Figure 21: Shares of filings by universities and public research institutes in all filings by research organizations (3-years moving average)



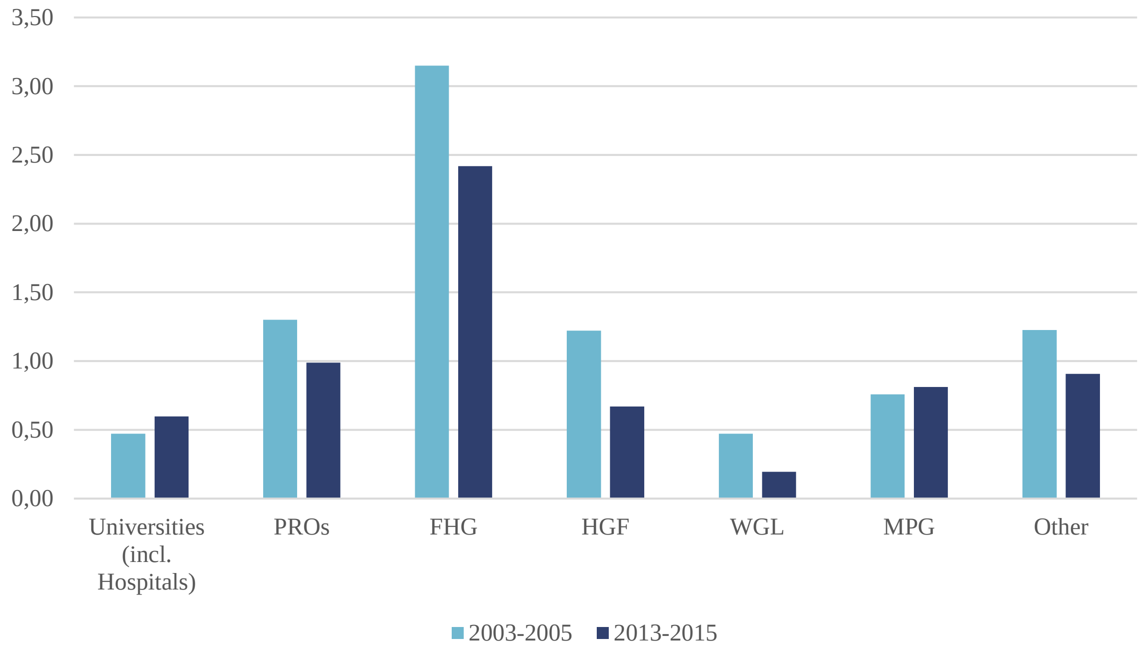
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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 trends in absolute filings figures are also resembled in the shares of filings by universities and public research institutes in total filings by German research organizations (Figure 21). Until the 2000s, the lion's share of filings from public research came from PROs. However, this has changed in the last ten years. In 2015, more than half (57%) of all filings from public research are filed by universities, with a major growth of these shares from the year 2000 onwards - though a slight stagnation between 2010 and 2013 can be found. Due to the fact that university filings have started to grow in the last two years, while the number of PRO filings was decreasing, we once again can observe an increasing share of PRO filings since 2013.

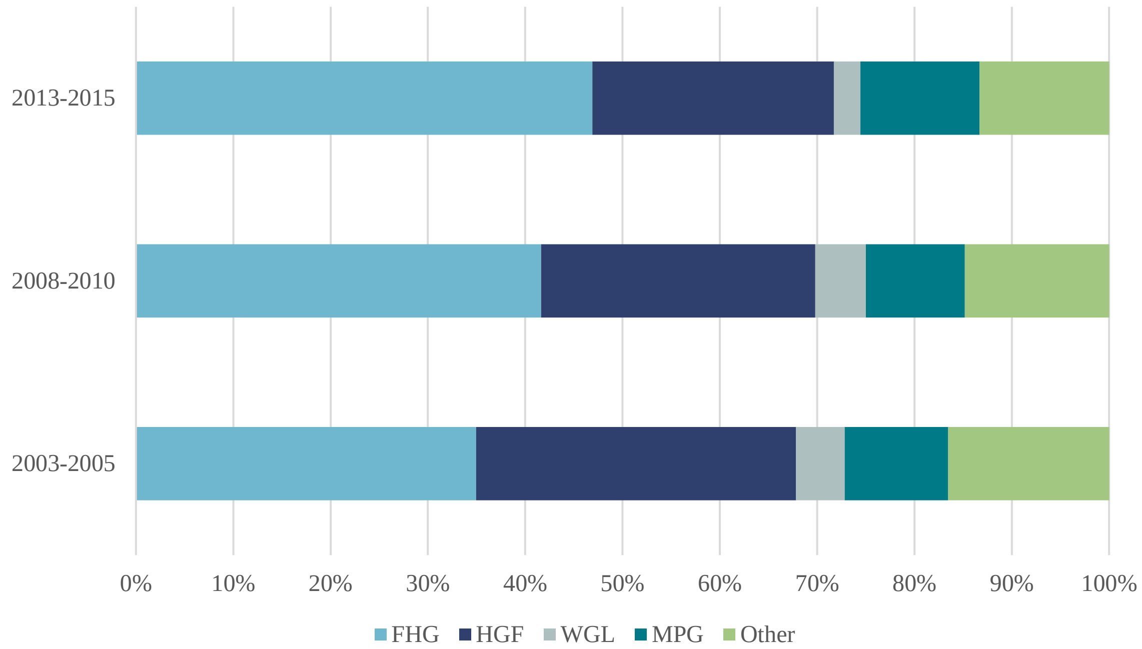
The patent intensities (Figure 22), i.e. the number of transnational patent filings per 1,000 R&D employees (full-time equivalents), of universities and PROs are also affected by these trends. In the recent years, the patent intensities for most PROs have been decreasing, which is due to the fact that patent filings have declined while the number of R&D employees has increased. The patent intensities of universities, on the other hand, have increased in 2013-2015 compared to 2003-2005. However, PROs are still far more patent intensive due to the lower number of R&D employees. In PROs on average 1 patent is filed per R&D employees, while this figure only lies at 0.6 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 and some of the Leibniz Institutes, are more focused on applied research, which explains the high patent intensity compared to universities.

Figure 22: Patent intensities (patents per 1,000 employees, full-time equivalents) by German research organizations (3-years moving average)



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

Figure 23: Shares of filings by public research organizations in all PRO filings (3-years moving average)



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Table 5: Patent filings and patent intensities by university applicants

Universität	Transnational Filings		Intensities (per 1.000 R&D employees, FTE)	
	2003-2005	2013-2015	2003-2005	2013-2015
Universitaet Erlangen-Nuernberg	40	157	0.27	0.66
Technische Universitaet Muenchen	43	155	0.29	0.60
Karlsruher Institut fuer Technologie	122	146	1.39	1.21
Universitaet Heidelberg	30	124	0.21	0.44
Technische Universitaet Dresden	57	123	0.39	0.60
RWTH Aachen	28	104	0.19	0.48
Universitaet Mainz	59	94	0.49	0.53
Universitaet Freiburg (i.Br.)	110	93	0.76	0.39
LMU Muenchen	54	93	0.31	0.31
Medizinische Hochschule Hannover	36	75	0.86	1.06
Universitaet Stuttgart	37	72	0.34	0.52
Charite - Universitaetsmedizin Berlin	106	70	0.84	0.53
Technische Universitaet Berlin	23	65	0.20	0.46
Universitaet Tuebingen	54	58	0.85	0.68
Universitaet Hamburg	29	55	0.19	0.26
Universitaet Jena	8	53	0.09	0.36
Universitaet Muenster	16	46	0.11	0.23
Universitaet Frankfurt a.M.	8	44	0.08	0.29
Technische Universitaet Darmstadt	19	42	0.31	0.44
Universitaet Wuerzburg	19	41	0.16	0.23
Universitaet Bonn	14	39	0.12	0.21
Universitaet Rostock	23	33	0.38	0.37
Universitaet Koeln	8	29	0.07	0.14
Universitaet Hannover	11	28	0.13	0.26
Universitaet Goettingen	47	28	0.45	0.19
Universitaet Kiel	13	25	0.10	0.15
Universitaet Marburg	30	22	0.44	0.28
Universitaet Duisburg-Essen	24	22	0.22	0.13
Universitaet Giessen	17	21	0.14	0.15
Universitaet Leipzig	18	21	0.15	0.12
Universitaet des Saarlandes	13	20	0.13	0.21
Universitaet Konstanz	10	19	0.25	0.29
Universitaet Dortmund	10	19	0.16	0.22
Freie Universitaet Berlin	16	19	0.12	0.15
Technische Universitaet Bergakademie Freiberg	2	18	0.09	0.43
Universitaet Bremen	17	18	0.28	0.24
Universitaet Regensburg	21	18	0.24	0.13
Brandenburgische Technische Universitaet Cottbus	12	17	0.55	0.37
Universitaet Ulm	11	16	1.25	1.25
Universitaet der Bundeswehr Hamburg	3	15	0.43	0.94
Technische Universitaet Ilmenau	15	15	0.64	0.44
Universitaet Greifswald	11	15	0.25	0.23
Universitaet Luebeck	6	14	0.27	1.77
Technische Universitaet Kaiserslautern	4	14	0.12	0.24
Universitaet Magdeburg	10	14	0.17	0.18
Universitaet Kassel	21	14	0.40	0.16
Technische Universitaet Hamburg-Harburg	13	13	0.67	0.40
Universitaet Bayreuth	3	13	0.08	0.23
Technische Universitaet Braunschweig	28	13	0.41	0.17
Universitaet Duesseldorf	11	13	0.14	0.11
Universitaet Halle	5	12	0.06	0.11
Universitaet Paderborn	2	10	0.06	0.18
Universitaet Bielefeld	1	10	0.02	0.13

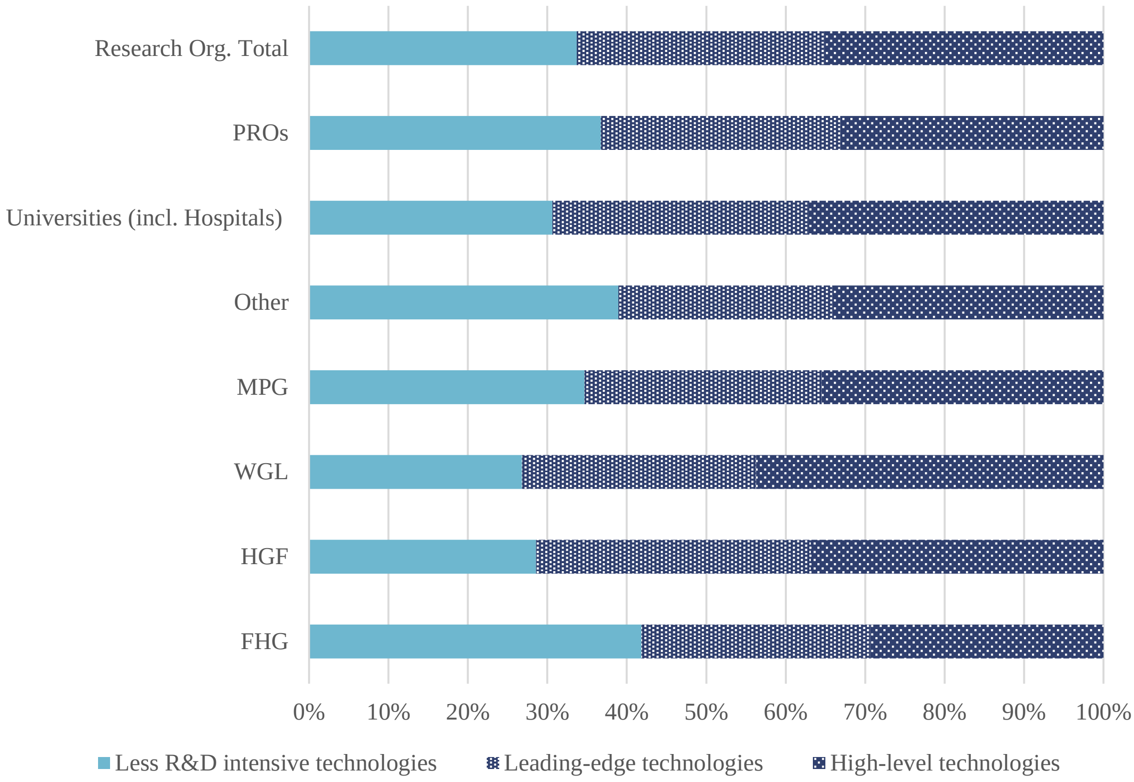
Universität	Transnational Filings		Intensities (per 1.000 R&D employees, FTE)	
	2003-2005	2013-2015	2003-2005	2013-2015
Ruhr-Universitaet Bochum	9	10	0.09	0.07
Humboldt Universitaet Berlin	22	9	0.19	0.08
Universitaet Potsdam	6	7	0.12	0.07
Universitaet Wuppertal	3	6	0.08	0.10
Universitaet der Bundeswehr Muenchen	0	5	0.00	0.19
Universitaet Mannheim	2	5	0.05	0.08
Universitaet Oldenburg	3	5	0.09	0.07
Technische Universitaet Chemnitz	3	5	0.08	0.07
Universitaet Hohenheim	4	4	0.13	0.11
Technische Universitaet Clausthal	9	3	0.56	0.14
Universitaet Koblenz-Landau	0	3	0.00	0.08
Universitaet Augsburg	6	2	0.17	0.03
Europa-Universitaet Viadrina Frankfurt (Oder) (Priv)	1	1	0.09	0.05
Universitaet Osnabrueck	6	1	0.16	0.02
Bauhaus Universitaet Weimar	5	0	0.79	0.00
Eichstätt-Ingolstadt, Kath. U	0	0	0.00	0.00
FernUniversitaet Hagen	0	0	0.00	0.00
Technische Universitaet Nuernberg	0	0	0.00	0.00
Universitaet Bamberg	0	0	0.00	0.00
Universitaet Hildesheim	0	0	0.00	0.00
Universitaet Lueneburg	0	0	0.00	0.00
Universitaet Passau	0	0	0.00	0.00
Universitaet Siegen	2	0	0.05	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

The shares of patents by the individual public research organizations in all PROs (Figure 23) draw a slightly different picture as the patent intensities. Here, it can be found that the Fraunhofer Society is responsible for the largest share of patent filings within the comparison of the public research institutes and that the share of filings by the Fraunhofer Society has increased over the years. The patent intensity, on the other side, has decreased for the Fraunhofer Society. This has to do with the fact, that the number of patent filings for all PROs has declined over the years, but this decline has been less severe for the Fraunhofer Society than for the other PROs. In sum, however, the picture is as expected. The Fraunhofer Society has the largest shares as its institutes are focused on applied research and their role within the German science system is to serve as a link between basic research and industrial application. In the recent years, the Fraunhofer Institutes were responsible for 47% of all PRO filings, while this share was only 35% between 2003 and 2005. The second largest PRO in terms of patent filings is the Helmholtz Association, whose role is to pursue more long-term oriented research, with a share of 25% and the "other research institutes" with a share of 13%. The shares of the Max-Planck Society, which is rather strongly focused on basic science within Germany, have slightly increased since the period 2008-2010. Finally, the Leibniz Association is smallest in terms of patent filings and is in the recent years only responsible for 3% of the patent filings by PROs.

Besides the single PROs, we also take a closer look at the patent intensities of the single universities. Their filing figures are provided in Table 5. The University of Erlangen-Nürnberg files the largest number of patents between 2013 and 2015, followed by the Technical University of Munich, the Karlsruhe Institute of Technology (KIT), the University of Heidelberg, the Technical University of Dresden and the RWTH Aachen. These universities also score high in terms of patent intensities, i.e. at least they are among the Top20 universities. However, also some smaller universities (in terms of patent filing figures) reach high patent intensities, e.g. the University of Lübeck, the University of Ulm, the Hannover Medical School or the University of Tübingen.

Figure 24: High-technology shares of patent filings by universities and PROs



Source: EPO – PATSTAT; calculations by Fraunhofer ISI.

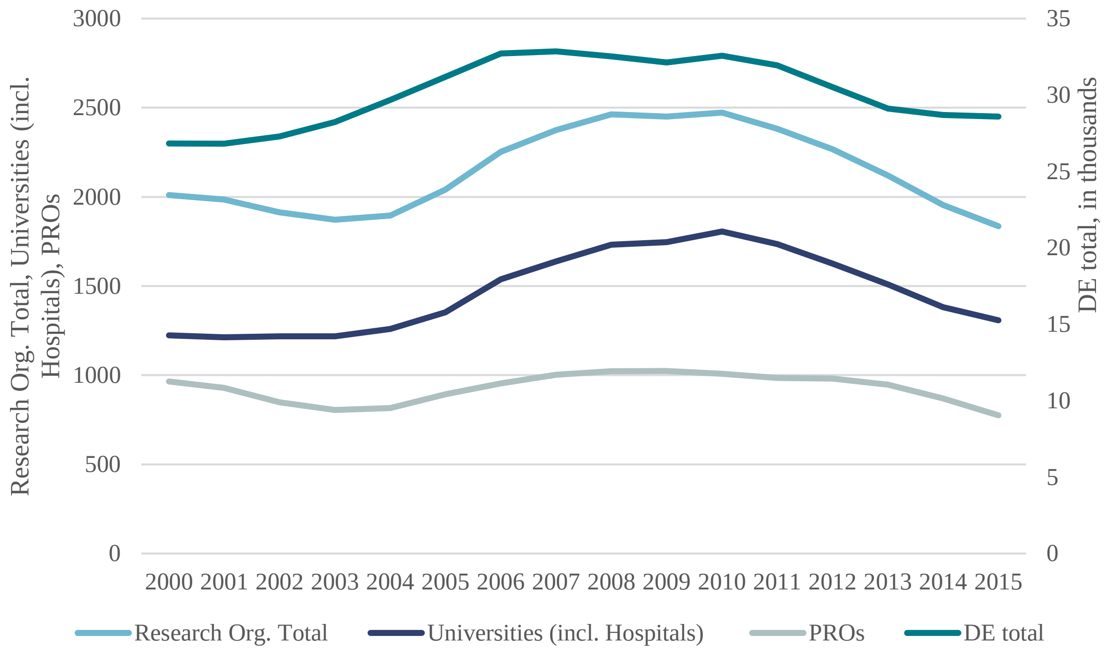
In a final step, the technological profiles of universities and the single PROs alongside the list of 38 high-technology fields are depicted in Figure 24. All in all, it can be found that there are no extreme differences in the high-tech shares between universities and the single PROs. However, the universities still show larger high-tech shares than the PROs in to total. The universities have a share of 69% of high-technology patents, while this share equals 63% in PROs. This sums up to a share of 66% for the research organisations in total. The difference in these shares, however, mostly comes from differences in the shares of high-level technologies, which is larger for universities than for PROs. In leading edge technologies, there are only minor differences in the shares.

Within the single PROs, the largest high-tech shares can be observed for the WGL Institutes, closely followed by the Helmholtz Society and the Max-Planck Society. The Fraunhofer Society as well as the "other" PROs have the smallest shares of high-tech patents within their portfolio. The shares of leading-edge technologies are largest for the Helmholtz Society, followed by the Max-Planck Society and the Leibnitz as well as the Fraunhofer-Institutes at the same level. In sum, it can the differences between the PROs can mostly be attributed to differences in high-level technology patenting.

7.2.2 Academic Patents

As already stated in the methodological section, academic patents provide a more complete picture of the trends in patenting by universities and PROs as a large share of patents from universities is registered by companies and the university staff only appears as an inventor. In this section, we will therefore focus on the extended perspective of "academic patents", which also takes university inventors into account.

Figure 25: Number of academic patents by German research organizations (3-years moving average), transnational

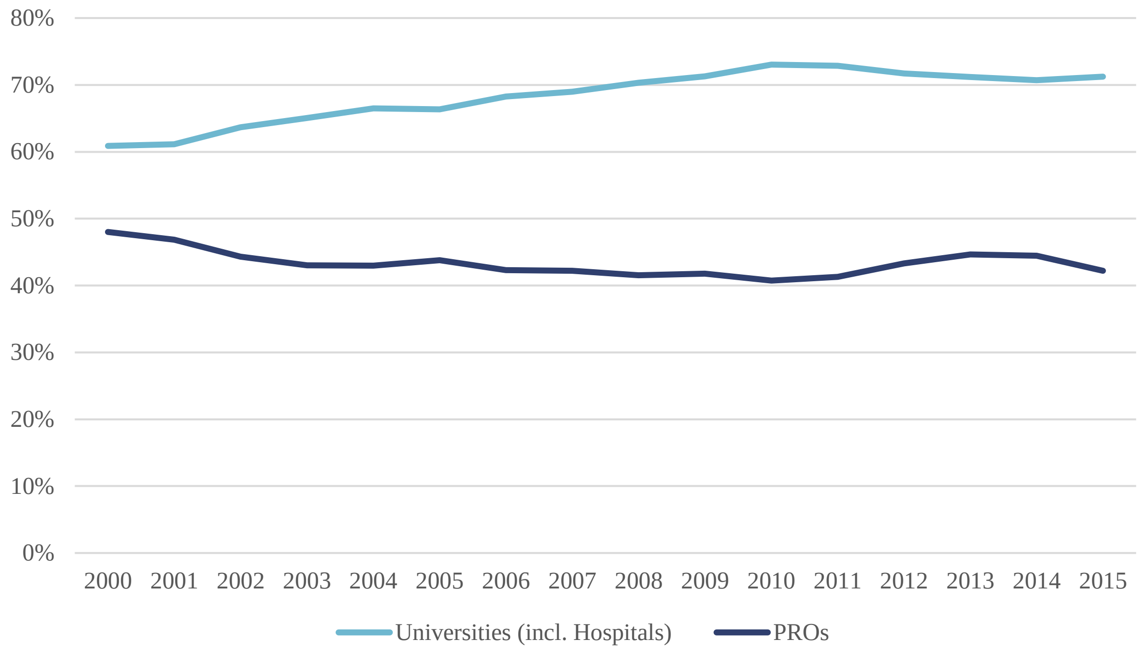


Source: EPO – PATSTAT; Scopus; calculations by Fraunhofer ISI

The absolute trends in academic patent filings are provided in Figure 25. Basically, these trends are similar to the trends in patent filings by university and PRO applicants. However, what we can observe is that the number of academic patents from universities is much higher than the number of academic patents from PROs. The number of academic patents is about two times higher than the number of patents filed by universities. In the beginning of the 2000's, i.e. before the legislation change this was even 3.5 times. For the PROs, this trend is similar, yet by far not so strongly pronounced. Still, in terms of trends find the increase in filings between 2003 and 2010 for universities as well as PROs. From there, we see a decrease also in academic patenting for universities and PROs from 2011 onwards. This implies that the abolishment of the "Hochschullehrerprivileg" in 2002 mostly led to a shift in filings from universities (as applicants) but not to an increase in the (patented) academic research output, at least in the long run.

These figures consequently are also resembled in the shares of academic patents by universities and PROs in all filings by German research organizations (Figure 26). The shares have grown slightly for universities until 2010. Afterwards a stagnation and a slight decrease can be observed. For the PROs the shares have slightly decreased until 2010, accordingly, but then increased slightly. In 2015, 65% of all academic patents are filed by universities, while 42% come from public research.[9]

Figure 26: 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

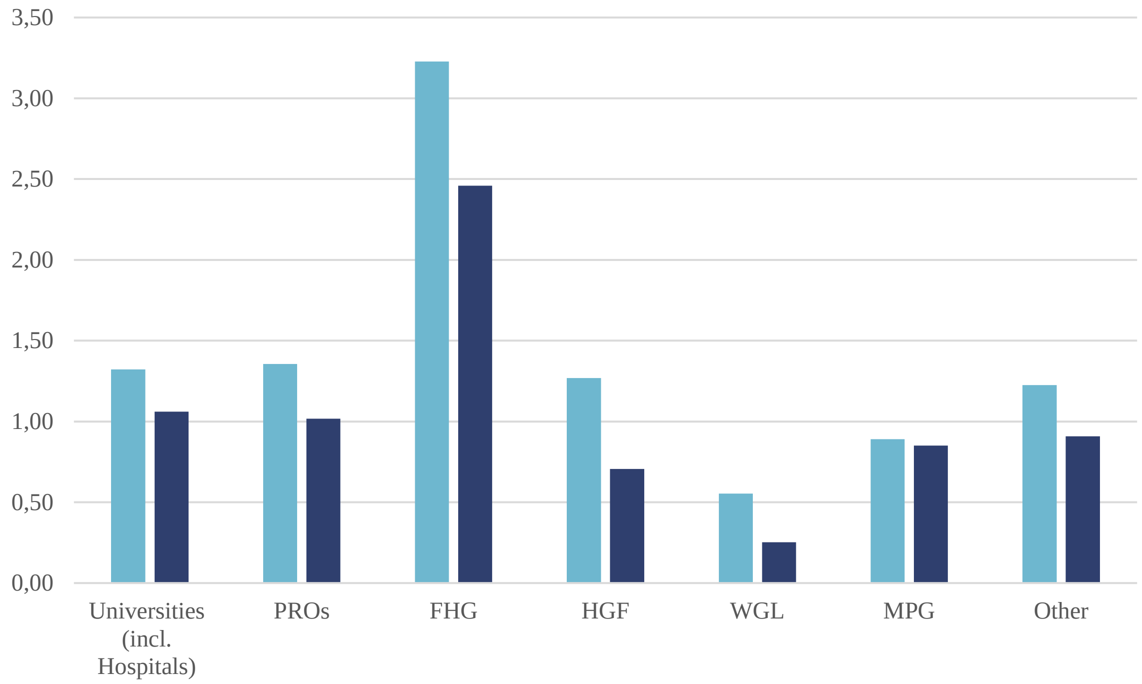
The patent intensities (Figure 27) for academic patents draw a similar picture. It can be observed that the patent intensities have decreased between the period 2003-2005 and 2013-2015. This is true for universities as well as PROs, implying that per capita, the output of patented inventions by academic researchers has decreased, although the intensity has increased for patents filed by the universities - at least at the international level. The patent intensity for universities, however, is slightly higher than for PROs in terms of academic patents. With regard to the single PROs, the picture resembles the one we have found for the patents where the PRO is named as an applicant. The Fraunhofer Society has

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

the largest patent intensity, followed by the Max-Planck Society, the Helmholtz Association and the Leibniz Association.

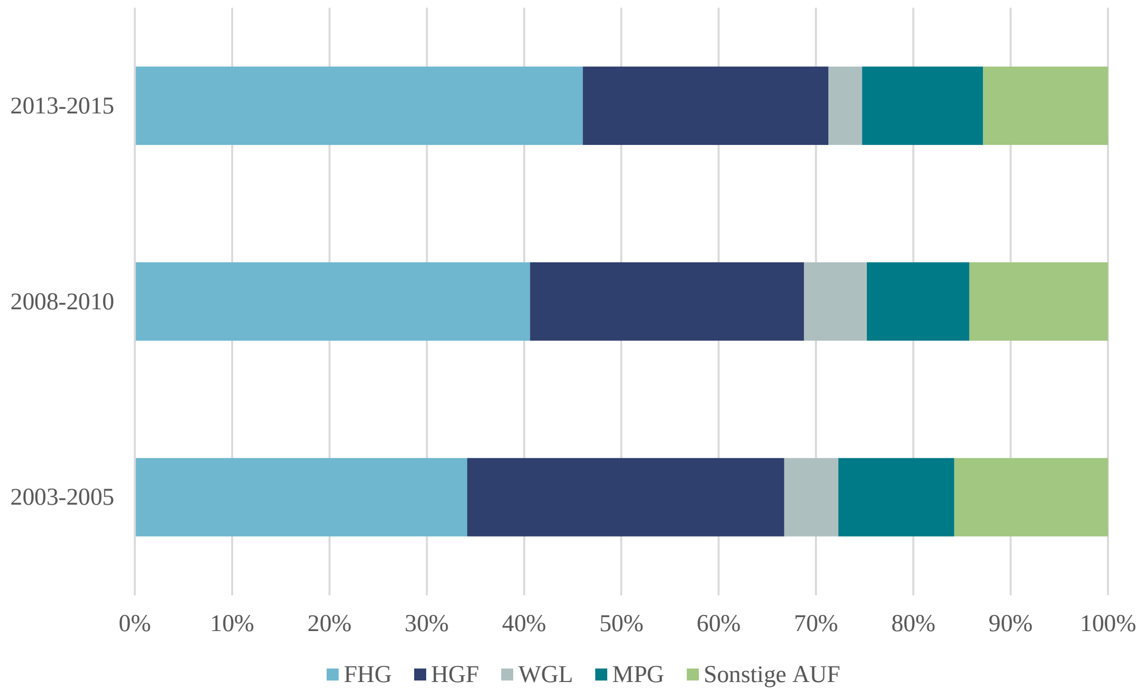
The shares by single PROs (Figure 28) provide a similar picture. The Fraunhofer-Society has the largest shares of academic patents, followed be the Helmholtz Association. However, the share of Fraunhofer has increased over the years while the share of the Helmholtz Association has decreased. The Max-Planck Society shows an increase after the period 2008-2010, while the Leibniz Association decreased its filings figures.

Figure 27: Patent intensities (patents per 1,000 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 28: 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.

Besides the single PROs, we again take a closer look at the academic patents of single universities. Their number of academic patents as well as patent intensities s are provided in Table 6. The University of Erlangen-Nürnberg shows the largest number of academic patents between 2013 and 2015, followed by the Technical University of Munich, the University of Jena, the Technical University of Dresden, the University of Heidelberg, the KIT and the LMU in Munich. In terms of patent intensities, once again the smaller univeristies, e.g. the University of Lübeck, the University of Ulm, the Helmut Schmidt University, the University of Jena and the Hannover Medical school are at the top of the list. However, also some larger universities like the KIT or the University of Erlangen-Nürnberg show up in the top 10 of patenting universities in terms of academic patents.

Table 6: Number of academic patents and patent intensities by universities

University	Transnational Filings		Intensities (per 1.000 R&D employees, FTE)	
	2003-2005	2013-2015	2003-2005	2013-2015
Universitaet Erlangen-Nuernberg	153	314	1.03	1.33
Technische Universitaet Muenchen	240	308	1.60	1.18
Universitaet Jena	173	281	1.87	1.93
Technische Universitaet Dresden	146	213	1.00	1.04
Universitaet Heidelberg	143	213	0.98	0.76
Karlsruher Institut fuer Technologie	194	207	2.21	1.72
LMU Muenchen	199	193	1.15	0.64
Universitaet Stuttgart	115	181	1.05	1.30
Universitaet Mainz	147	167	1.23	0.94
Charite - Universitaetsmedizin Berlin	230	158	1.83	1.20
Universitaet Freiburg (i.Br.)	182	143	1.26	0.61
Freie Universitaet Berlin	196	131	1.52	1.04
RWTH Aachen	33	121	0.23	0.56
Medizinische Hochschule Hannover	86	114	2.06	1.62
Humboldt Universitaet Berlin	199	113	1.72	1.06
Technische Universitaet Berlin	88	108	0.77	0.77
Universitaet Hannover	43	100	0.51	0.94
Universitaet des Saarlandes	58	94	0.58	0.97
Ruhr-Universitaet Bochum	39	90	0.41	0.67
Universitaet Tuebingen	131	83	2.06	0.98
Universitaet Hamburg	115	76	0.75	0.36
Technische Universitaet Darmstadt	70	74	1.14	0.78
Universitaet Dortmund	42	71	0.65	0.81
Universitaet Koeln	68	71	0.59	0.33
Universitaet Wuerzburg	71	70	0.61	0.40
Universitaet Frankfurt a.M.	91	63	0.89	0.42
Universitaet Duesseldorf	64	61	0.81	0.51
Universitaet Muenster	63	60	0.44	0.31
Universitaet Rostock	33	54	0.55	0.61
Universitaet Regensburg	48	50	0.55	0.36
Universitaet Giessen	42	45	0.36	0.33
Universitaet Bonn	28	42	0.23	0.23
Universitaet Bayreuth	29	41	0.73	0.72
Technische Universitaet Braunschweig	71	38	1.04	0.49
Universitaet Leipzig	32	38	0.27	0.22
Universitaet Luebeck	23	37	1.05	4.69
Universitaet Kiel	57	37	0.45	0.23
Universitaet Duisburg-Essen	55	37	0.51	0.22
Universitaet Ulm	81	36	9.19	2.82
Universitaet Goettingen	93	35	0.89	0.23
Universitaet Marburg	75	34	1.09	0.44
Universitaet der Bundeswehr Hamburg	22	33	3.16	2.07
Universitaet Bremen	34	32	0.56	0.42
Universitaet Paderborn	5	29	0.14	0.53
Technische Universitaet Kaiserslautern	33	26	0.99	0.44
Technische Universitaet Hamburg-Harburg	42	24	2.16	0.73
Universitaet Konstanz	39	23	0.97	0.35
Universitaet Magdeburg	34	23	0.58	0.29
Technische Universitaet Ilmenau	26	22	1.12	0.65
Technische Universitaet Bergakademie Freiberg	2	22	0.09	0.53
Universitaet Bielefeld	8	19	0.15	0.24
Universitaet der Bundeswehr Muenchen	10	17	0.62	0.63
Brandenburgische Technische Universitaet Cottbus	12	17	0.55	0.37

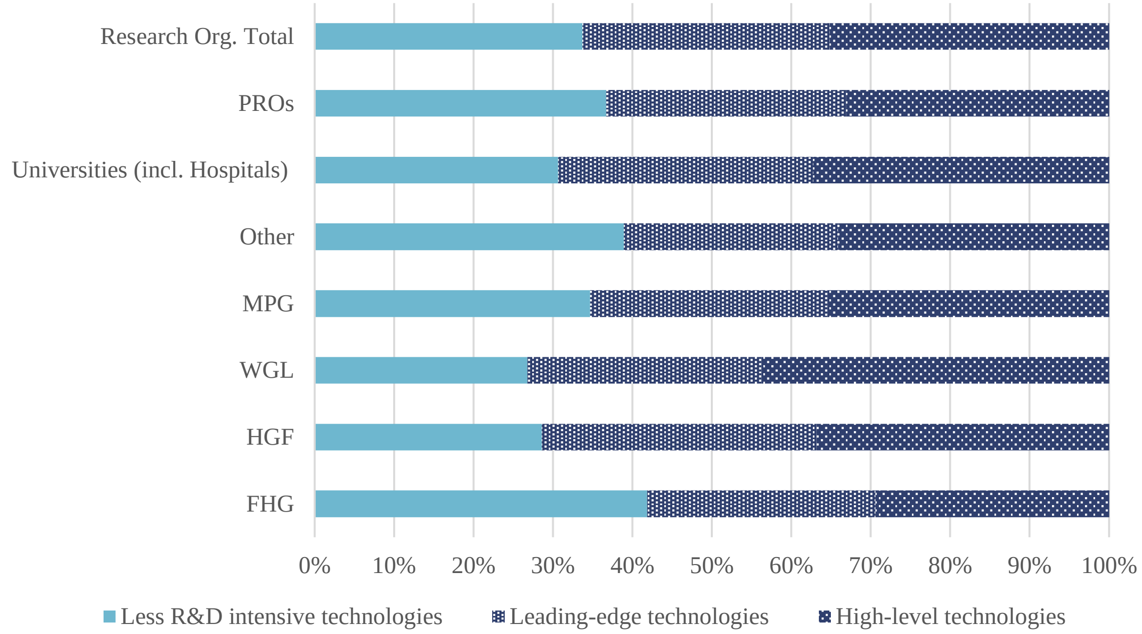
University	Transnational Filings		Intensities (per 1.000 R&D employees, FTE)	
	2003-2005	2013-2015	2003-2005	2013-2015
Universitaet Potsdam	30	16	0.62	0.17
Technische Universitaet Clausthal	25	15	1.55	0.71
Universitaet Greifswald	11	15	0.25	0.23
Universitaet Mannheim	28	14	0.77	0.24
Universitaet Kassel	23	14	0.43	0.16
Universitaet Wuppertal	31	12	0.86	0.19
Universitaet Halle	5	12	0.06	0.11
Universitaet Augsburg	8	6	0.23	0.09
Technische Universitaet Chemnitz	3	6	0.08	0.08
Universitaet Hohenheim	7	5	0.23	0.14
Universitaet Siegen	18	5	0.49	0.10
Universitaet Osnabrueck	16	5	0.42	0.10
Universitaet Oldenburg	3	5	0.09	0.07
Bauhaus Universitaet Weimar	5	4	0.79	0.38
Universitaet Koblenz-Landau	0	3	0.00	0.08
Europa-Universitaet Viadrina Frankfurt (Oder) (Priv)	1	1	0.09	0.05
Eichstätt-Ingolstadt, Kath. U	1	0	0.06	0.00
FernUniversitaet Hagen	0	0	0.00	0.00
Technische Universitaet Nuernberg	0	0	0.00	0.00
Universitaet Bamberg	0	0	0.00	0.00
Universitaet Hildesheim	0	0	0.00	0.00
Universitaet Lueneburg	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; Scopus; Statistisches Bundesamt, Fachserie 11, Reihe 4.4, calculations by Fraunhofer ISI

Analogous to the patents filed by universities, we will in a final step look at the technological profiles of universities and the single PROs alongside the list of 38 high-technology fields (Figure 29). As we can see, the research organizations in total show a high-technology share of 66%, with 31% being leading-edge technologies. For the universities the high-tech shares are with 68% higher than the shares for PROs with 64%. However, as in the case of patents filed by universities, this mostly has to do with larger shares of universities in high-level technologies. The leading-edge shares are highly similar.

Within the single PROs, the largest high-tech shares can be observed for the WGL Institutes, closely followed by the Helmholtz Society and the Max-Planck Society. The Fraunhofer Society as well as the "other" PROs have the smallest shares of high-tech patents within their portfolio. Again, this resembles the shares found in the patents filed by PROs. Since the differences between academic patents and patents filed by PROs are much smaller than in the case of universities - PROs mostly commercialize their inventions themselves or at least are named as patent applicants - this is not surprising.

Figure 29: High-technology shares of academic patents by universities and PROs



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

7.3 Conclusions

Within this section, we have analyzed recent trends in patent filings by public research in Germany. By applying the applicant perspective, i.e. analyzing the patents where the universities and public research institutes are listed as applicants, we have found that patenting has become more and more important for universities and PROs over the last 10 years. Especially the growth in university filings has led to a convergence in the number of filings from PROs and universities. Yet, the analyses of academic patents show that this convergence is mostly due to the fact that universities more often show up as patent applicants. This implies that the abolishment of the "Hochschullehrerprivileg" in 2002 mostly led to a shift in filings from universities (as applicants) but not to an increase in the (patented) academic research output, at least in the long run. Since 2010, we even find declining patent numbers by universities and PROs. Though this to a certain extent reflects the trends in filings for Germany as a whole, it is also reflected in the patent intensities, i.e. the number of transnational patent filings per 1,000 R&D employees, of universities and PROs. Especially in the recent years the patent intensities have been decreasing. Though the patent intensities of universities have risen in the course of the 2000s, at least for filings where the universities are named as applicants, PROs are still far more patent intensive than universities. This is mostly driven by the fact that PROs, especially the Fraunhofer Society but also the Helmholtz Association and some of the Leibniz Institutes, are more focused on applied research leading to a larger amount of patentable inventions. The Fraunhofer Society thus is responsible for the largest share of patent filings within the comparison of the public research institutes, followed by the Helmholtz Association, the Max-Planck Society and the Leibniz Society.

The analyses if high-technology shares show it can that there are no extreme differences in the high-tech shares between universities and the single PROs. Though the universities still show larger high-tech shares than the PROs this mostly stems from differences in the shares of high-level technologies, which is larger for universities than for PROs. In leading edge technologies, there are only minor differences in the shares.

8 Trends in Community Trademark Filings

In this section, we will analyze basic structures of innovation in services and product-related services across major industrialized countries with the help of trademark. Although inventions in service sectors are also patent protected, patents are the mostly utilized by firms in the manufacturing sectors and there can serve as an output measure for innovation. To get a complete picture of innovative activities in services, however, other indicators are necessary. 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). Though 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).

Similar to patent protection, trademarks can be filed via several routes. To have a trademark protected in Germany, for example, a registration at the German Patent and Trademark Office (GPTO) is one option. Alternatively, a trademark can be 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, or the in the form of an international trademark at the WIPO, which is valid in all countries that have signed the Madrid Protocol. The Madrid system enables the applicant to protect a trademark in a large number of countries by obtaining an international registration that has effect in each of the designated contracting states, i.e. it can be considered a "one-stop-shop" for international trademark protection (WIPO, 2016a).

Trademarks are in widespread use as a formal instrument to protect intellectual property. Eligible for protection are all "tokens", e.g. words, pictures etc., which are suitable to distinguish a company's goods or services from those of other companies. These can be words, individual letters, numbers, pictures, colors and even acoustic signals. After the filing, a trademark is valid for ten years and can be renewed indefinitely (Deutsches Patent-und Markenamt, 2018; Graham and Harhoff, 2006).

After the receipt of an application of a trademark at the respective office the trademark will be processed. This includes classification of the trademark according to the NICE classification, a formality check, a check of the trademark "on absolute grounds" - i.e. the trademark is analyzed to see whether it is distinctive but not descriptive – a translation as well as a search for identical or similar marks including a "surveillance letter" that informs third parties about the filing of the given trademark (European Union Intellectual Property Office (EUIPO), 2017). As opposed to patents trademarks thus are not "certified", i.e. there is no granting process per se since only formal criteria are checked upon filing. The pursuit of potential violations or infringements of registered trademark rights remains in the hands of the trademark owner. Only if a trademark holder indicates a violation, a procedure of cancellation of the competing trademark can be initiated. After the examination period, a trademark is published. From the date of publication, third parties have three months to object to the registration of the trademark either based on "earlier rights" or on "absolute grounds". If nobody files an opposition, the trademark is registered and the registration is published. After registration, only official appeals can be used to challenge the official decision by the EUIPO (European Union Intellectual Property Office (EUIPO), 2017).

8.1 Methods & Classifications

For the analyses, data from the trademark register of the GPTO ("DPMAregister"), which covers all filings of EU trademarks directly filed at the EUIPO. Since the DPMAregister is an online database, it provides a significantly smaller analytical potential than offline databases like PATSTAT, for example. This means that the data had to be searched manually and certain indicators or methodological re-calculations, like fractional counting, are not available.

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 refer to services. The classes define the scope and the context of each trademark filing and are provided by the applicants themselves. At the EUIPO only one class is covered by the application fee, additional classes are subject to additional fees. This used to be different in the OHIM system, where three classes could be indicated by the applicant without additional fees.

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. This is even amplified by the fact that the contents of each class are defined by standard terms the applicant chooses upon filing. This means there is hardly any description of the actual content of the trademark via the keyword list within a class, which complicates interpretations. In particular, trademarks for example in the food industry or drugstore products can hardly be distinguished from marks with a technical background. Within the trademark system it is thus also not possible to identify any level of "inventive step", i.e. high-tech products can hardly be differentiated from less R&D-intensive goods. While for patents the formal criterion of inventive step is reviewed by the patent examiners, i.e. a patent must go beyond the current state of the art, such an assessment does not take place in the case of trademarks. A distinction between research-intensive and less research-intensive applications via the NICE classification is therefore not possible.

In sum, the differentiation of trademarks across NICE classes has to be made with caution. In our interpretation, we will therefore argue alongside the 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 the more fine-grained disaggregation, we further resort to the definition of "research-intensive services" with regard to service marks by Schmoch (2003), 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 7.

Table 7: Definition of technology related NICE-classes regarding goods

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

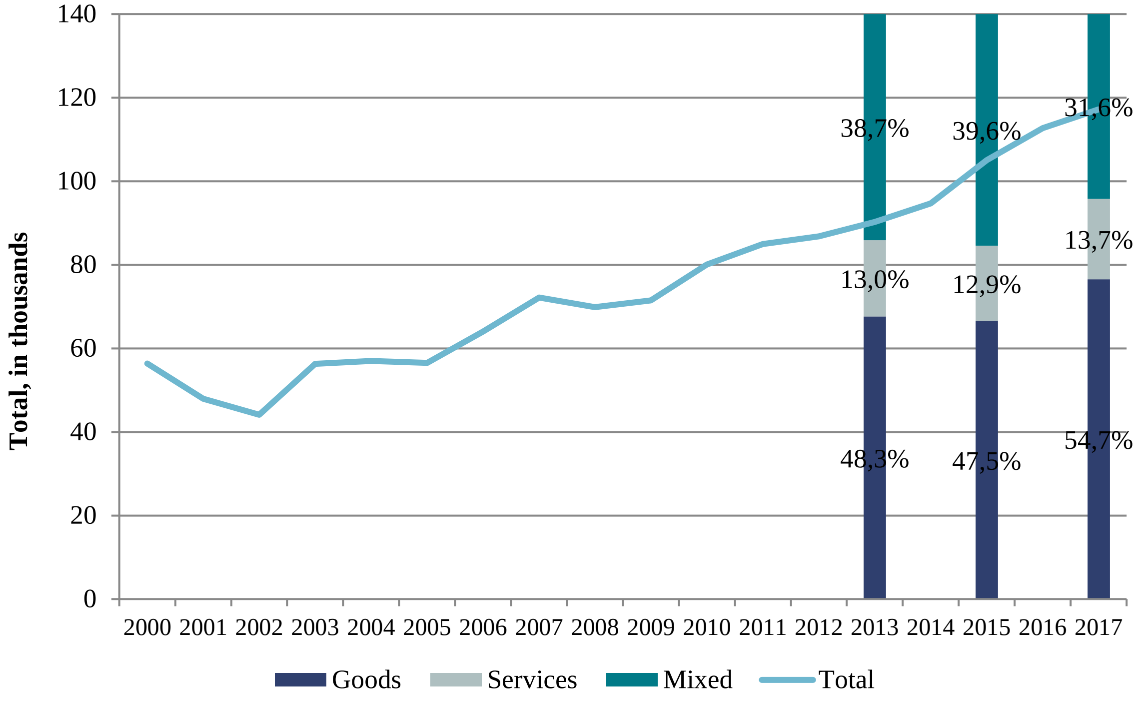
Source: Schmoch (2003)

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.

8.2 Results

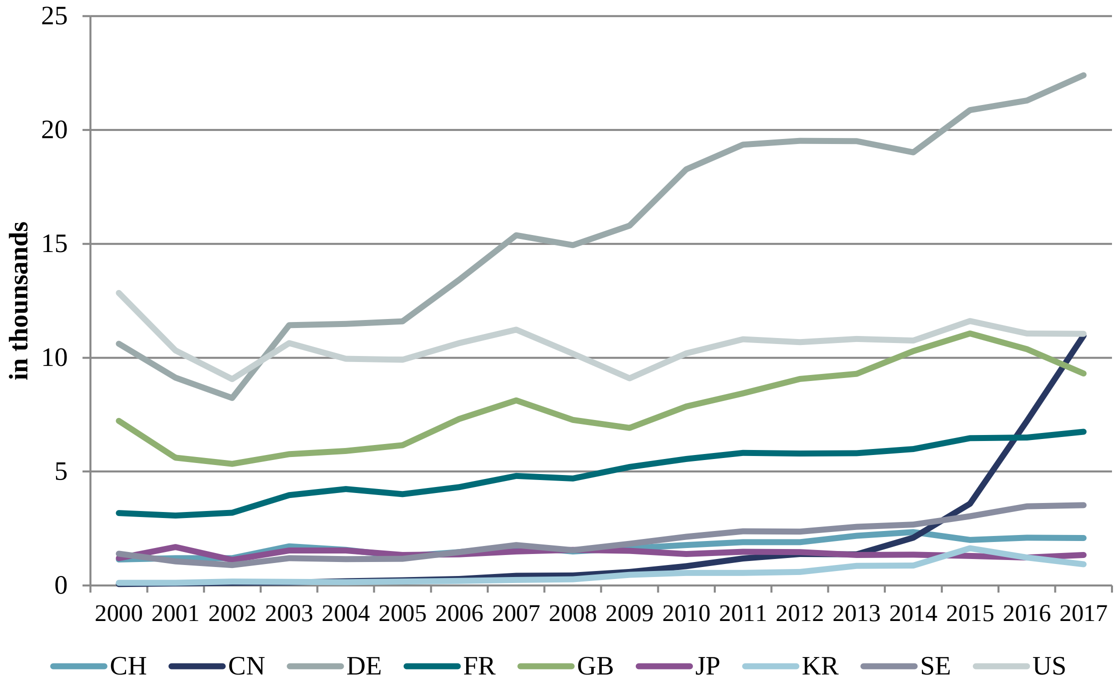
The general trends in trademark filings show a rather constant rise in filings since 2002, where about 44,000 CTMs were filed (Figure 30). In the year 2017, about 127,000 filings were made at the EUIPO, with a major growth between 2015 and 2017. There are basically two declines or at least stagnations in the trend across the years: one between 2000 and 2002 and one between 2008 and 2009. This shows that not only patent filings but also trademark applications were negatively affected by the financial crises in the respective years. Besides the overall trend in EU trademark filings, the figure also provides information on the shares of trademark filings by types for the most recent years, i.e. 2013, 2015 and 2017. From the chart it becomes obvious that the structure in total trademark filings has barely changed between 2013 and 2015, i.e. there is only a very slight shift from product marks to mixed marks (about 1%). In 2017, however, a shift into the other direction occurred. Especially the share of product marks has increased, which is, though to a lesser extent, also true for service marks. The share of mixed marks, however, has declined, which is most likely an effect of the change in fee structure by the EUIPO (only one class allowed without additional fees). 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. The 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).

Figure 30: Absolute number of EU trademark filings and shares by trademark types, 2000-2017



Source: DPMAregister; calculations by Fraunhofer ISI

Figure 31: Absolute number of EU trademark filings for selected countries, 2000-2017



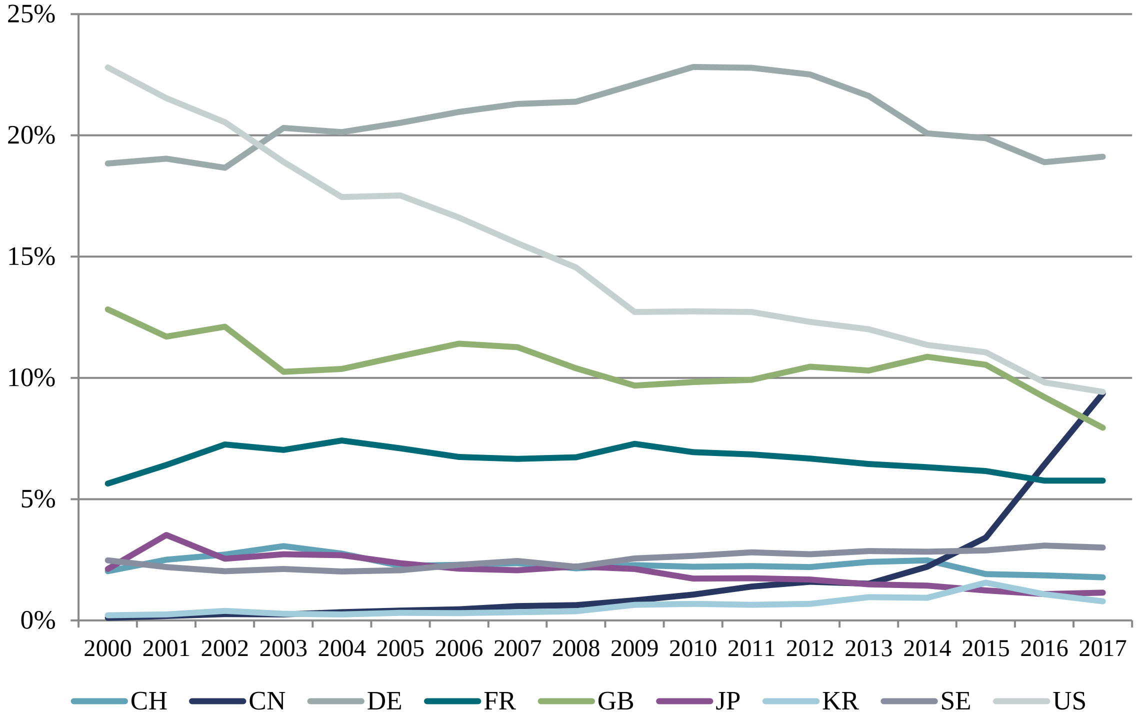
Source: DPMAregister; calculations by Fraunhofer ISI

Differentiating the absolute number of EU trademark filings by countries provides a clear picture of the largest trademark applicants at the EUIPO (Figure 31). Germany is by far the largest trademark applicant with more than 22,000 filings in 2017. Since the year 2000, the trademark filings by German applicants have grown quite constantly. The number of filings thus exceeded the filing figures of the second largest applicant, i.e. the USA, already in the year 2003.[10] Though there has been a stagnation phase after 2010, we can observe another increase in German trademark filings after 2014.

The number of U.S. trademark applications has remained quite constant at a between 10,000 and 11,000 filings across the whole time period. Still, the U.S. scores the second rank in EU trademark filings. However, the number of Chinese filings has massively increased after 2014, which is why China scores the third rank directly following the United States in terms of absolute filing figures (10,900 filings in 2017). Following China is Great Britain with 9,300 filings in 2017, where, after increasing trends between 2009 and 2015, a decrease can be observed. Therefore, it scores fourth after China in this comparison. France scores fourth with about 6,700 filings in 2017. These four countries are followed by a group of smaller countries in terms of trademark filings led by Sweden and Switzerland.

10 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.

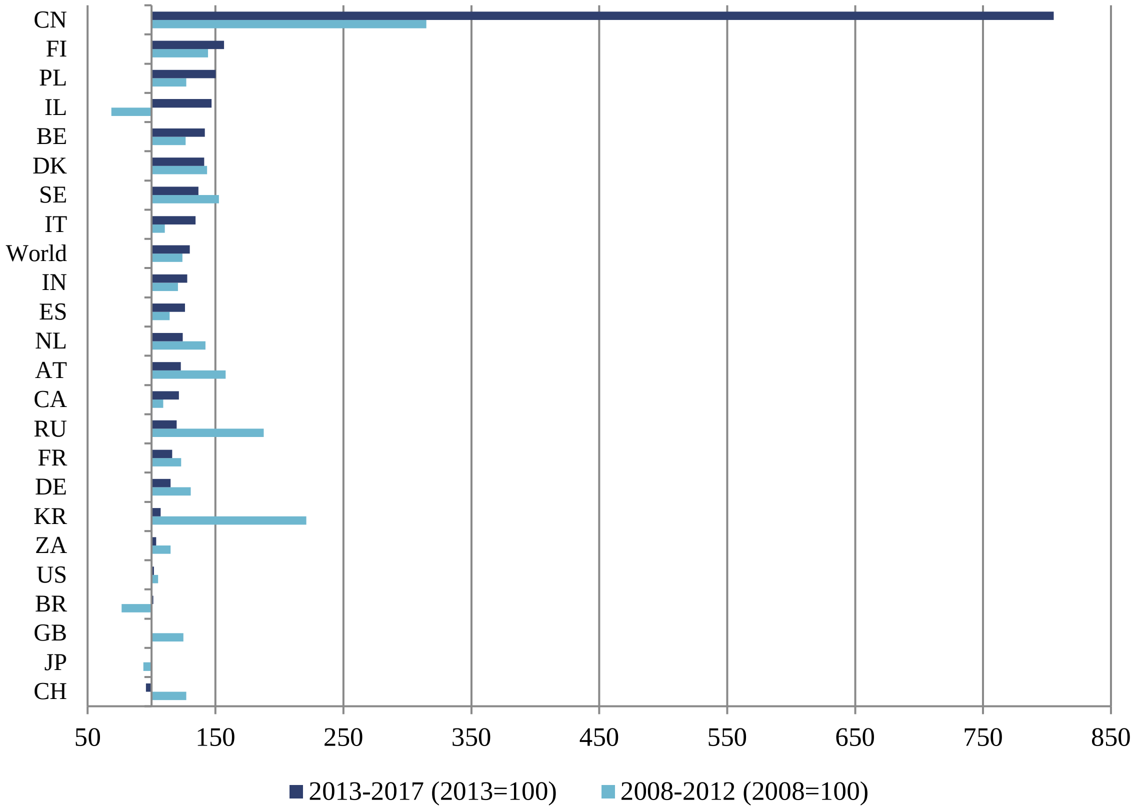
Figure 32: Shares in EU trademark filings for selected countries, 2000-2017



Source: DPMAregister; calculations by Fraunhofer ISI

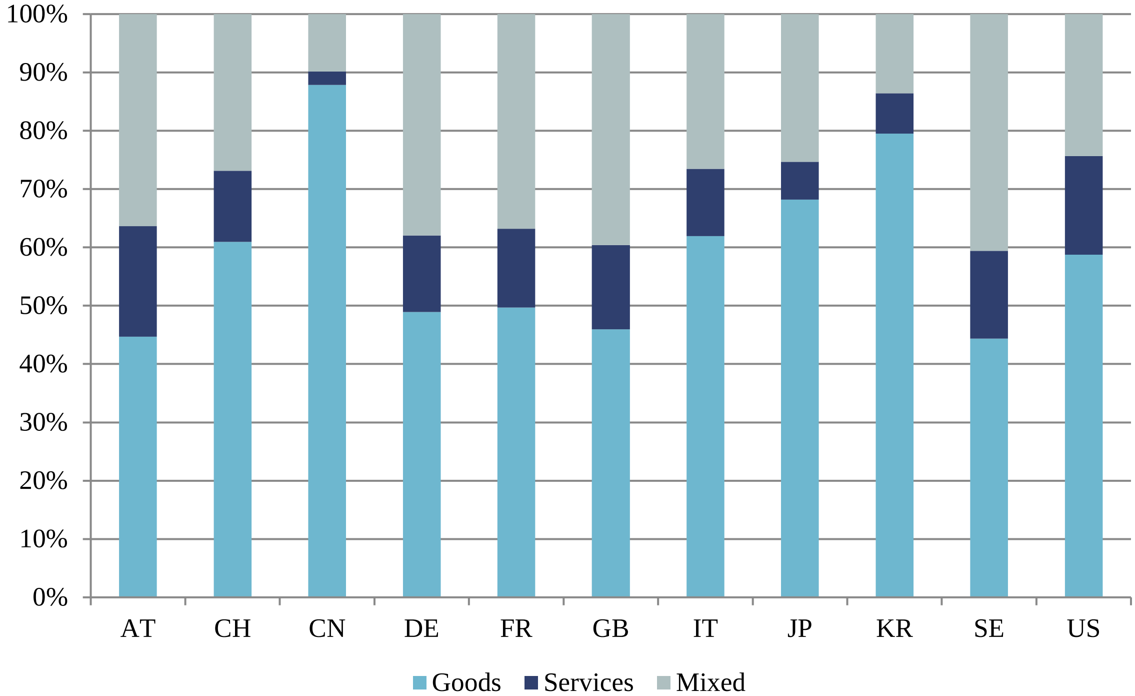
Apart from the absolute figures, the country-specific shares in global EU trademark filings reveal an interesting picture (Figure 32). Germany is responsible for 19% of all EU trademark filings. Between 2004 and 2010 Germany could constantly increase its shares. Especially since 2015, however, the massive growth of Chinese trademark filings has led to a decline in German shares as well as the ones of other countries. This is especially visible for the U.S., where the shares have decreased over the whole time period. The U.S. and China at the moment are tied for the second largest EU trademark applicant, each with a share of 9%. Both are closely followed by Great Britain with shares of 8%, though the shares of Britain have rather strongly declined after 2015. France, which is responsible for a share of 6% in 2015, shows a slight but constant decline over the years. With a share of 3%, Sweden scores sixth in terms of trademark shares. Due to a constant increase of Swedish trademark applications, the Swedish shares still have grown, also in the recent years.

Figure 33: Growth in EU trademark filings for selected countries between 2008-2012 and 2013-2017



Source: DPMAregister; calculations by Fraunhofer ISI

Figure 34: Shares of trademark types within the countries' portfolios, 2017



Source: DPMAregister; calculations by Fraunhofer ISI

The above described trends become even more evident when looking at the growth statistics (Figure 33). The largest growth in EU trademark filings between 2008 and 2012 can already be observed for applicants from China, followed by Korea, Russia and Austria. In 2013-2017, however, China once again shows a massive growth rate. Within this time period, all other countries show only moderate growth rates; the largest ones being from Finland, Poland and Israel.

A country-specific view on EU trademark filings by trademark type is plotted in Figure 34. Here, differences in the trademark portfolios of the analyzed countries can be observed. With regard to Germany, it can be found that the profile largely resembles the worldwide trends, although the share of mixed type trademarks is slightly larger compared to the share of product marks. Similar observations can be made for the other European countries in this sample, although the share of product marks is larger in Italy and Switzerland. Especially France, Great Britain, Austria and Sweden, however, resemble the German profile very well. The U.S. shows rather large shares of product marks than most of the European countries, though still 17% of the filed marks are service marks and 24% are mixed marks. This changes when looking at the Asian countries, where the share of product marks is even larger, while especially the share of service marks is comparably small.

In sum, it can be found that the share of product marks is much larger for the non-European countries than for the non-European countries. For the U.S. and Japan, the share of mixed and service marks still is larger than for China and Korea. Especially China is largely focused on product marks (88%). 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 the non-European countries.

Table 8: Trademark intensities (EU trademark filings per 1m employment) and shares of trademarks by types, 2017

Country	Total	Goods		Services		Mixed	
AT	703	314	45%	133	19%	255	36%
SE	702	311	44%	106	15%	285	41%
FI	657	279	42%	90	14%	288	44%
DK	597	310	52%	80	13%	207	35%
DE	538	263	49%	71	13%	204	38%
ES	499	237	47%	91	18%	171	34%
BE	474	217	46%	87	18%	169	36%
CH	449	274	61%	55	12%	121	27%
NL	449	199	44%	76	17%	174	39%
IT	435	269	62%	50	12%	115	27%
GB	291	134	46%	42	14%	115	40%
FR	251	125	50%	34	14%	92	37%
PL	201	104	52%	28	14%	69	34%
IL	90	66	73%	8	8%	16	18%

Country	Total	Goods		Services		Mixed	
CA	77	38	50%	10	14%	28	36%
US	72	42	59%	12	17%	18	24%
KR	35	28	80%	2	7%	5	14%
JP	21	14	68%	1	6%	5	25%
CN	14	13	88%	0	2%	1	10%
ZA	14	10	71%	2	12%	2	17%
BR	3	2	55%	1	18%	1	27%
RU	2	1	58%	0	14%	0	28%
IN	1	1	57%	0	11%	0	33%

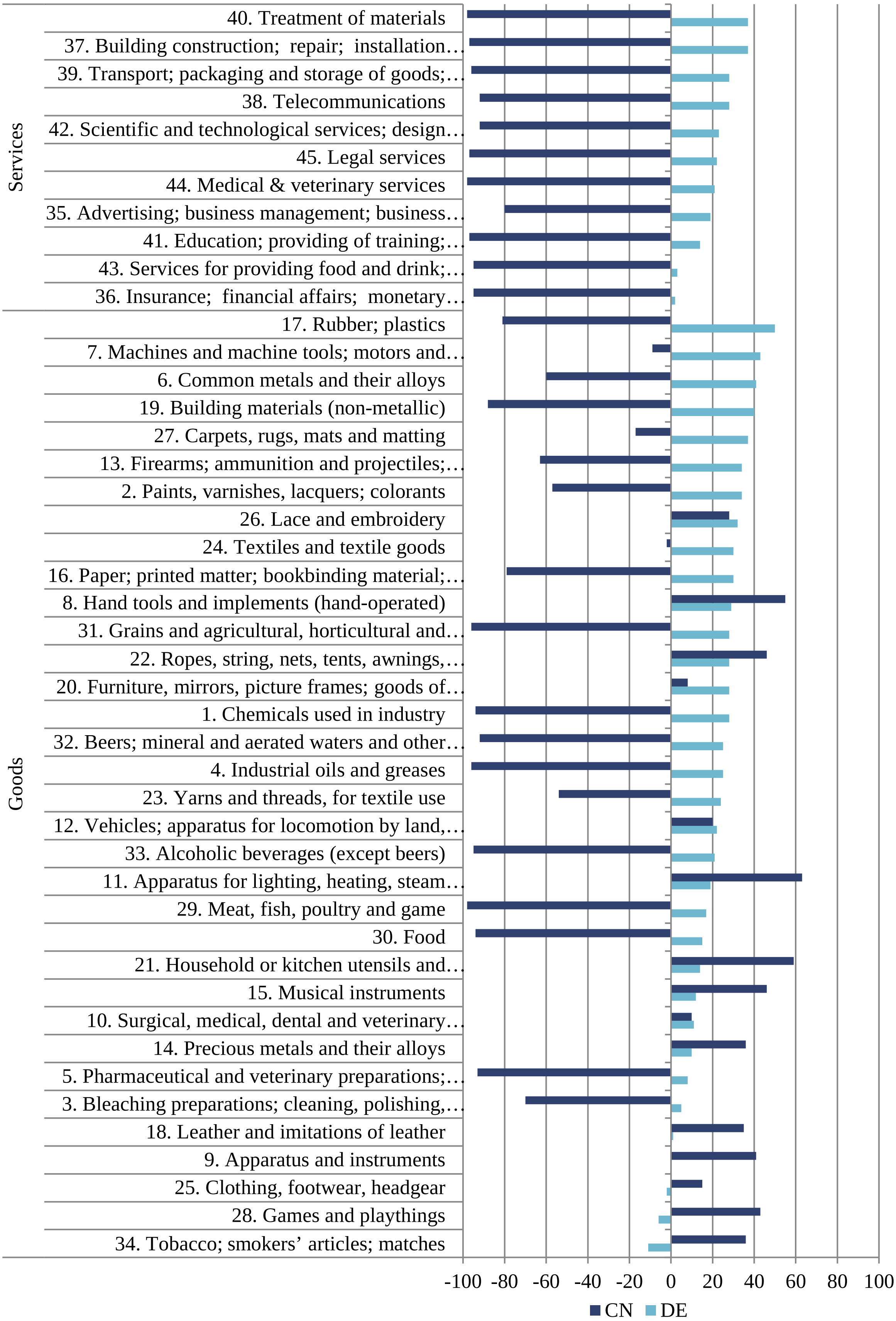
Source: DPMAregister; calculations by Fraunhofer ISI

Further interesting trends can be revealed when looking at the trademark intensities differentiated by trademark types for the year 2017 in Table 8. The trademark figures here are normalized alongside the workforce within the respective countries, i.e. the number of trademark applications per 1 million labor force, to account for size effects, is displayed. The table is sorted in descending order by overall trademark intensities. It becomes obvious that Austria has the highest trademark intensity, followed by Sweden, Finland, Denmark and Germany. The Asian countries and the BRICS countries have the smallest trademark intensities with regard to EU trademark filings. In terms of product marks, Austria, Sweden, Denmark and Finland show the highest trademark intensities, followed by Switzerland, Italy and Germany. With regard to service marks, Austria shows the highest intensities, followed by Sweden, Spain and Finland. The intensities for mixed service/product marks are highest for Finland, Sweden, Austria and Denmark.

In a final step, we have calculated the specialization indices for the trademark portfolios of Germany, China, Italy and Poland to find out in which field a country is strongly or weakly represented compared to the total EU trademark filings. The specialization indices were calculated in the same manner 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. The specialization indices of China, Italy and Poland compared to Germany are provided in Figure 35 to Figure 37.

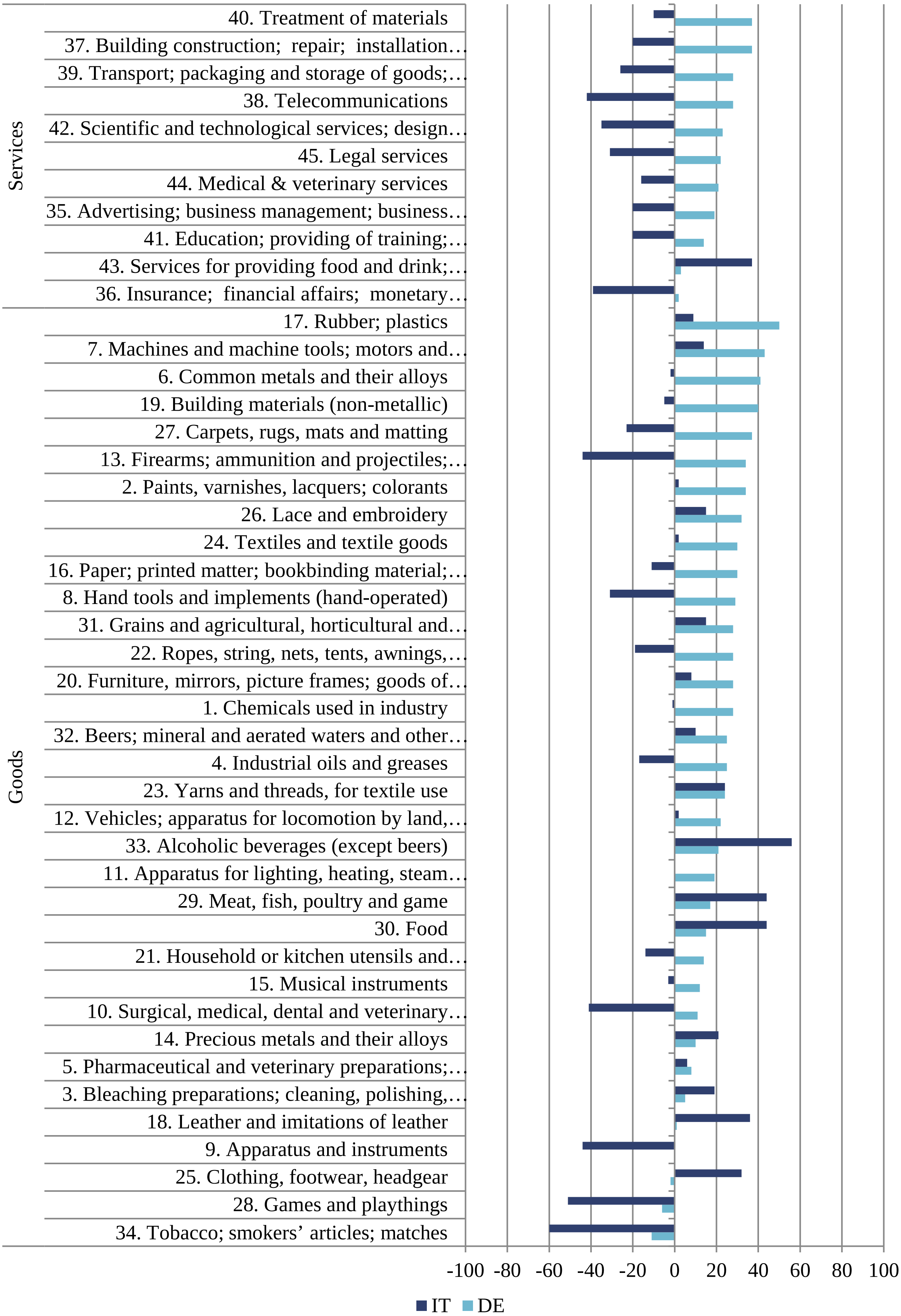
Germany shows positive specialization rates in terms of trademarks across most of the NICE classes in goods as well as services. China, on the other hand, mostly shows negative specialization values. With regard to fields with a high technology relatedness, positive values for China can be found in machines, vehicles, electronic devices and electronics (instruments). For Germany, specialization values are highest in fields related to machines and metals, while Italy is more specialized in less-technology related fields (except for parts of machines and electronic components). In Poland, the largest values can be found in bleaching preparations as well as chemicals used industry and oils and greases but also building materials, common metals and their alloys.

Figure 35: EU trademark related profiles Germany and China, 2017



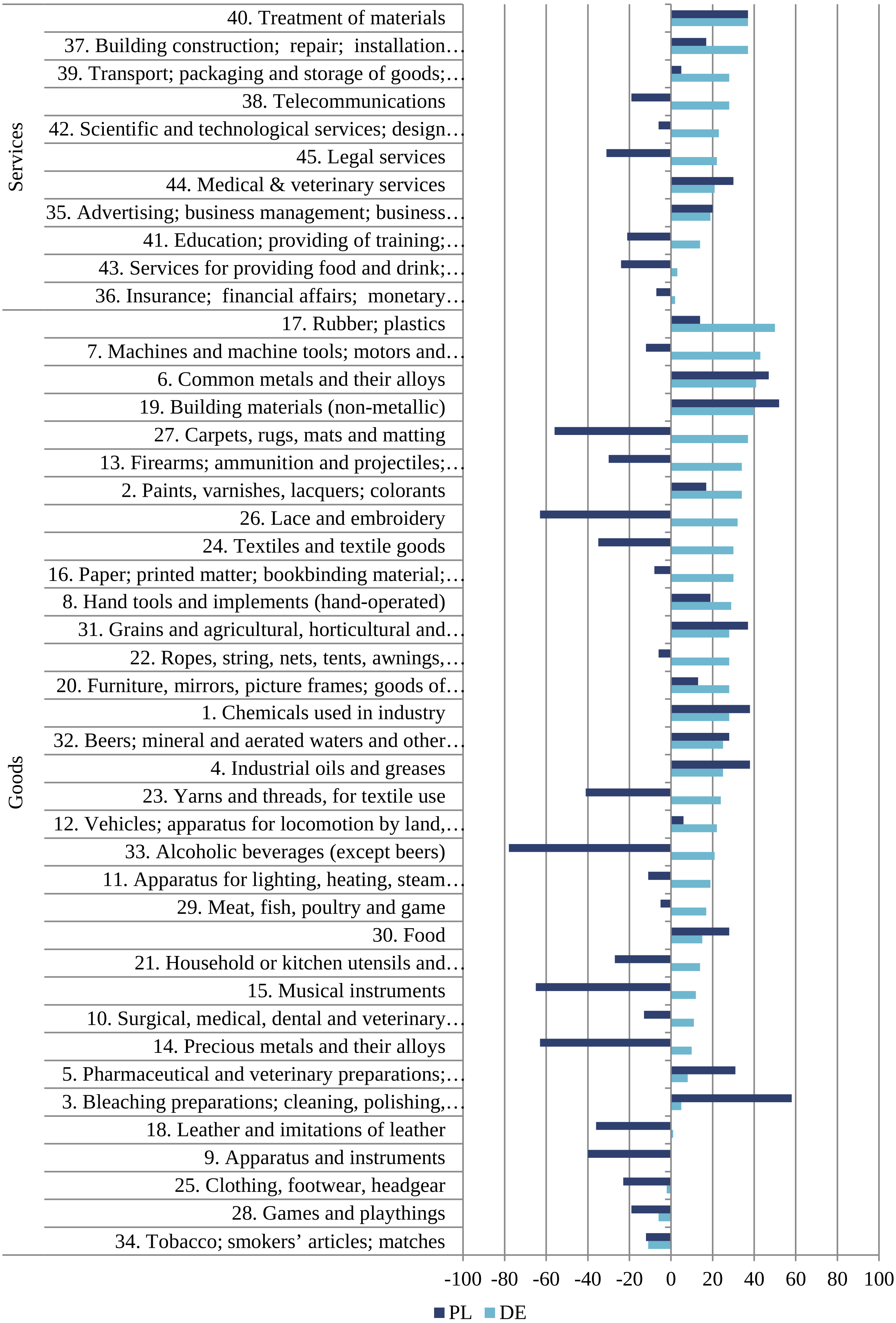
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Figure 36: EU trademark related profiles Germany and Italy, 2017



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Figure 37: EU trademark related profiles Germany and Poland, 2017



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

8.3 Conclusions

In this section, we have taken a closer look at structures and trends in Community Trademark filings at the EUIPO across major industrialized countries and alongside NICE classes. Especially with regard to the service sectors, trademarks can be seen as a complementary innovation indicator to patents that is closer to the commercialization of a certain product (Gauch, 2007). However, it has to be kept in mind that statistical trademark analyses are associated with pitfalls regarding data availability, the classification system and the content certification of trademark filings as there is no granting process per se but only a formal validity check.

The general trends in trademark filings show an increase EU trademark filings between over the years until 2017 where nearly 127,000 filings have reached the EUIPO. The only slowdowns in EU trademark were visible during the economic crises in 2000/2001 and 2008/2009, which mostly resembles the trends also found in the patent analysis. Overall, the largest share of trademark filings are related to products (54.7%), followed by product related services (31.6%) and pure service marks (13.7%).

Germany is the largest trademark applicant at the EUIPO with more than 22,000 filings in 2017. The U.S. scores second after Germany together with China, where a massive increase in EU trademark filings could be observed during the last few years. This has led to a decline in German shares as well as the ones of other countries.

The patterns in trademark types, however, also differ across countries. Here, it becomes obvious that the non-European countries show a larger share of product marks than their European counterparts. This is most obvious for China and Korea, while the profile is still more balanced for the U.S. and Japan. Since we look at the EUIPO, i.e. we have a very strong focus on the European market, however, this can also be attributed to the fact that cross-border "trade" with services is much less common than with products.

In terms of trademark intensities, i.e. trademark filings normalized alongside the workforce within the respective countries, the smaller economies like Austria, Sweden, Finland, Denmark and Germany show the largest values. Per employee, trademark filings are rather low for the North American, Asian as well as the BRICS countries. This, however, is influenced by the fact that we are analyzing EU trademarks, which, by nature, are Europe centered.

In sum, it can be stated that Germany has a strong position when it comes to EU trademark filings. Although we need to stress that we analyze a Europe-centered system Germany can be shown to have by far the largest number of trademark filings, which is spread across all technology fields. However, the Germany strengths in mechanical engineering also become visible in terms of EU Trademarks.

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