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Patent Applications – Structures, Trends and Recent Developments 2014

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0 Summary

Transnational Patent Filings

The USA is the largest technology-providing country at the international level, closely followed by Japan and, with a given distance, Germany. In terms of patent intensities, i.e. patent filings per one million employees, however, rather the smaller countries Switzerland, Finland and Sweden are at the top of the list of the technology-oriented countries analyzed. Japan scores fourth, followed by Germany. The USA is in the midfield, together with France and Great Britain.

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 2012. Germany scores fourth on this indicator but has slightly lost ground since 2002. Yet, Germany, Switzerland, Denmark and Japan 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 new list of research-intensive industries and goods (Gehrke et al. 2013), it can be shown to be specialized, i.e. has comparative advantages, in three main areas: transport (automobiles and engines as well as rail vehicles), machinery 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.

Structures in International Co-Patenting

The shares of international co-patents have constantly increased over the last twenty years for most of the countries in our analysis. Since 2007, however, a stagnation in world-wide co-patenting shares can be observed. While the shares of US and British co-patents are still increasing, the shares of German, French and Swiss filings are stagnating, and the Chinese shares are decreasing. In general, the European and North-American countries are more cooperation-intensive than the Asian countries.

The country-by-country trends reveal that the most important collaboration partner for Germany is the US. About 24% of all co-patents by German inventors are filed in cooperation with an inventor from the US. The next largest partners for Germany are Switzerland and France. The field specific trends show that Germany has especially high shares of co-patents within chemistry and related fields, while mechanical engineering is the least cooperation intensive among die fields under analysis here. However, this is a trend that can be observed for most countries in the sample, i.e. chemistry is on average more cooperation-intensive than mechanical engineering. Yet, we can still see that Germany is less cooperation-intensive than the average in mechanical engineering – a field where Germany has its particular technological strengths.

Patent Activities of the German Federal States

By disaggregating the German transnational patent filings by regions, i.e. the German "Bundesländer", we find that Baden-Württemberg and Bavaria file the largest number of patents at the transnational level, and, together with North-Rhine Westphalia, account for about two thirds of German transnational filings. The Northern and Eastern German states show lower filing numbers, although the federal states in these areas generally show higher growth rates than the southern and western states. With regard to the patent intensities, i.e. patents per one million employees, it can be found that Baden-Württemberg and Bavaria also score first on this indicator. North-Rhine Westphalia, on the other hand, loses ground and is located in the medium ranks within this comparison. However, the choice of perspective, i.e. applicant versus inventor centered, makes a difference for most of the German federal states. This is especially prominent for Hamburg, Bavaria, Baden-Württemberg, North-Rhine Westphalia, Lower-Saxony, Saxony and Berlin. When taking a look at the technology field composition of the "Bundesländer", it can be revealed that the German focus on mechanical engineering is clearly resembled in the profiles of its federal states, although each of the "Bundesländer" has its own peculiarities.

Trademarks

The number of Community Trademark filings has risen over the last decade, with slowdowns visible during the economic crises in 2000/2001 and 2008/2009. Although the largest share of trademark filings is related to products and product related services, also pure service marks have gained increased attention. About 13% of all filings are service marks. Germany is the largest trademark applicant at the OHIM, followed by the US, Great Britain and France, although new players such as China and Korea show extremely high growth rates in trademark filings. For the Asian countries in our sample, a clear trend towards filing product marks is visible, while the largest share of service marks can be found for Great Britain. In terms of trademark intensities, i.e. trademarks per million employees, the smaller countries like Austria, Sweden, Switzerland and Denmark, but also Germany, show the highest values. The differentiation by NICE classes reveals that Germany has positive specialization values in most technology fields. Yet, a clear specialization to the fields related to machines and metals can be observed.

1 Introduction

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

In this report, we focus on the macro-economic perspective by providing information on the technological capabilities and the technological competitiveness of economies as a whole. As already mentioned, patents are used as an output indicator of R&D processes. However, R&D processes can also be measured by the input – for example, in terms of expenditures or human capital. In order to achieve a more precise approximation of the "black box" of R&D activities (Schmoch and Hinze 2004), both perspectives – i.e. input and output – are needed. The input side, however, has been widely analyzed and discussed in other reports, also in this series (see for example Schasse et al. 2012). Here, we therefore strictly focus on patents as an indication of output (Griliches 1981; 1990; Grupp 1998; Pavitt 1982).

Seen from a legal perspective, patents give the patent applicant an exclusive right to use and sell the protected technology for a limited period of time. From a macro-economic point of view, however, patents can be interpreted as an indicator of the codified knowledge of enterprises[1], and, in an aggregated perspective, of countries. Yet, since patents are used as output indicators of innovation, they fit into a system of several further indicators to describe scientific and technological competitiveness and to analyze innovation systems. From this point of view, patents are to be seen as an intermediate measure, since they cover the output of R&D systems, for which expenditures or human capital are the input. At the same time, patents can be regarded as an input into further market activities, which are reflected, for example, by foreign trade (Frietsch et al. 2014),turnover or qualified labor. Consequently, we have to deal with a complex system of innovation indicators to be used at different stages of the innovation process. A representation of innovation indicators and their relations are depicted in Figure 1.

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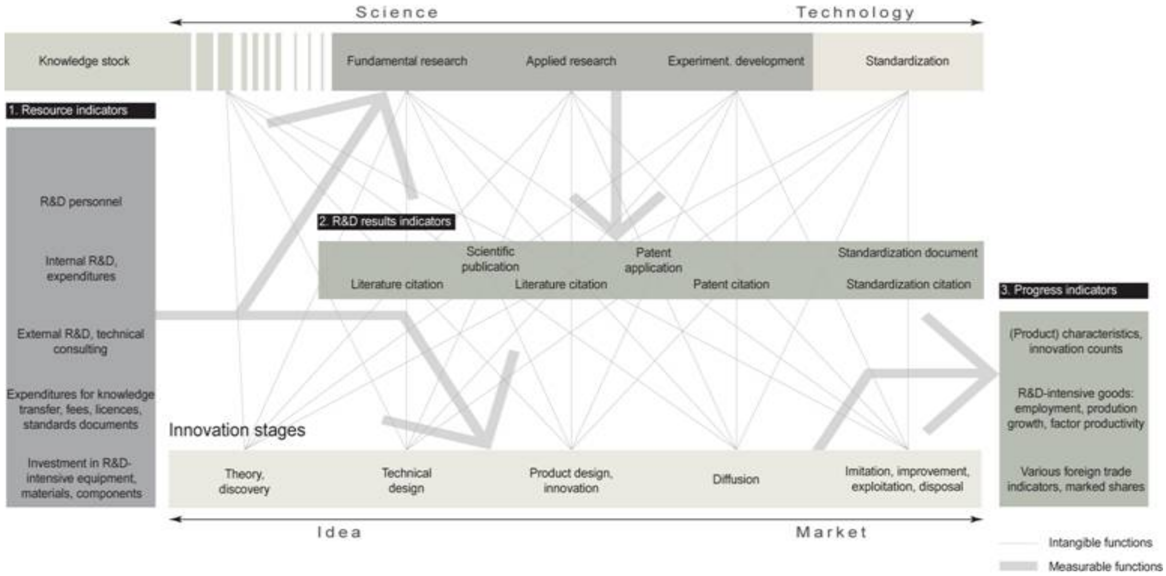
1 Patents are especially dedicated to measuring the output of industrial R&D activities, whereas scientific publications are still the most important output for the public research system, although this latter group of institutions also contributes to patent production.

Figure 1 Indicator System to Analyze Innovation Systems Performance



Source: Grupp (1998); further developed and designed by Fraunhofer ISI

Among the formal mechanisms of intellectual property protection, patents play a special and crucial role. This is because the formal requirements for patent applications are very strict and the assertion of patents is backed by a strong legal framework. Any patent filed at a patent office has to pass an extensive examination procedure performed by patent examiners that are skilled and trained experts in the field. This characteristic turns patents into a valuable source of information also for statistical purposes. Patents, i.e. the information they contain, are systematically structured and of high quality. In particular, international patent filings are meaningful for comparisons, as they reflect activities in international markets where national and multinational companies meet their competitors directly and on neutral ground (Frietsch and Schmoch 2010).

This report gives a brief overview of the developments of transnational patent applications since the early 1990s. However, we especially focus on the recent trends and structures. In this year's report, we will further focus on analyses of international cooperation structures in terms of co-patents. Moreover, we will provide a more differentiated look at the German technology landscape at the level of regions, i.e. the German "Bundesländer". Finally, as a complementary innovation indicator to patents, we analyze trademark filings in an international comparison.

Section 2 first of all 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 (patents per 1 million workforce) 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 structure and in section 5 we will show the differences in patenting behavior across the German federal states. Finally, section 6 presents the analyses on structures and trends in Community Trademark filings.

2 Data and Methods

The patent data for this study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from 83 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[2]) 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.

2 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

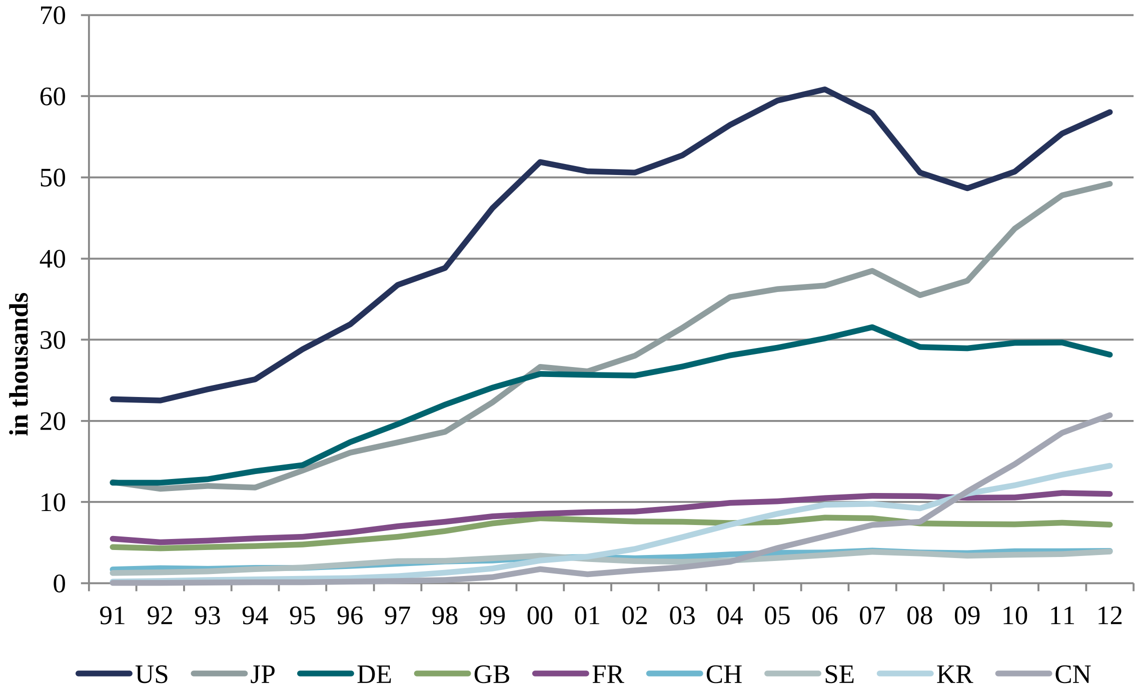
Within this section, the recent trends of transnational patent filings since the beginning of the 1990s will be described. The analyses will be carried out for a selected set of technology-oriented countries[3], although, for reasons of presentation, not every country is displayed in each figure. Besides 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

The absolute number of transnational patent applications by inventor countries is displayed in Figure 2. The USA is the largest technology-providing country at the international level, closely followed by Japan and, with a given distance, Germany. The number of US filings has been mostly affected by the economic crisis among the countries in comparison and US filings still have not returned to the level of 2006. This is different for Japan, where the number of filings has recovered more quickly from the crisis, which is indicated by the larger growth rates compared to the US. The number of German filings, which was less affected by the crisis, has remained rather constant over the last few years, however, with a slight decrease in 2012. China scores fourth in terms of the absolute number of filings since 2009 and has shown rather high growth rates since then. Following behind these four countries, there is a large group of countries led by Korea, followed by France and Great Britain. China and Korea have grown strongly in terms of patent filings since 2000 onwards and have thus managed to leave behind France and Great Britain in the total number of transnational applications. Sweden and Switzerland follow Great Britain with about 4,000 transnational filings in 2012.

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

Figure 2 Absolute number of transnational patent applications for selected countries, 1991-2012



Source: EPO – PATSTAT; Fraunhofer ISI calculations

The absolute data that has been presented so far, however, is affected by size effects. An adjustment to these size effects is shown in Table 1, where patent intensities per one million employees are displayed. This size adjustment sheds new light on the country ranks. Although the US is the largest country in absolute terms, it only scores thirteenth within our country set when looking at the patent intensities. Rather the smaller countries Switzerland, Finland and Sweden are at the top of the list of technology-oriented countries analyzed here. Japan, Germany and South Korea are first among the larger countries in terms of patent intensities. Japan even ranks fourth on this indicator this year, directly followed by Germany. This on the one hand resembles a strong technology orientation and the technological competitiveness. On the other hand, it is also a sign of a clear and strict international orientation and an outflow of the export activities of these countries. Patents are an important instrument to secure market shares in international technology markets (Frietsch et al. 2014). With the perspective of this indicator, France, Great Britain and the EU-28 are in the midfield together with the USA and Belgium. The BRICS countries score on the lower ranks.

In addition to the general patent intensities, Table 1 offers a differentiation of the patent intensities by technological areas and displays the respective shares on total patent filings. It is remarkable that especially Switzerland shows rather high activities in less R&D intensive fields. The same is true for Italy, the Netherlands, Poland, Spain and Austria. Also the BRICS countries Brazil and South Africa 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. China, however, especially shows large shares in leading-edge technologies, whereas in India the shares in leading-edge and high-level technologies are at a more comparable level.

Table 1 Patent intensities (patent applications per 1m employees) and shares of technological areas, 2012

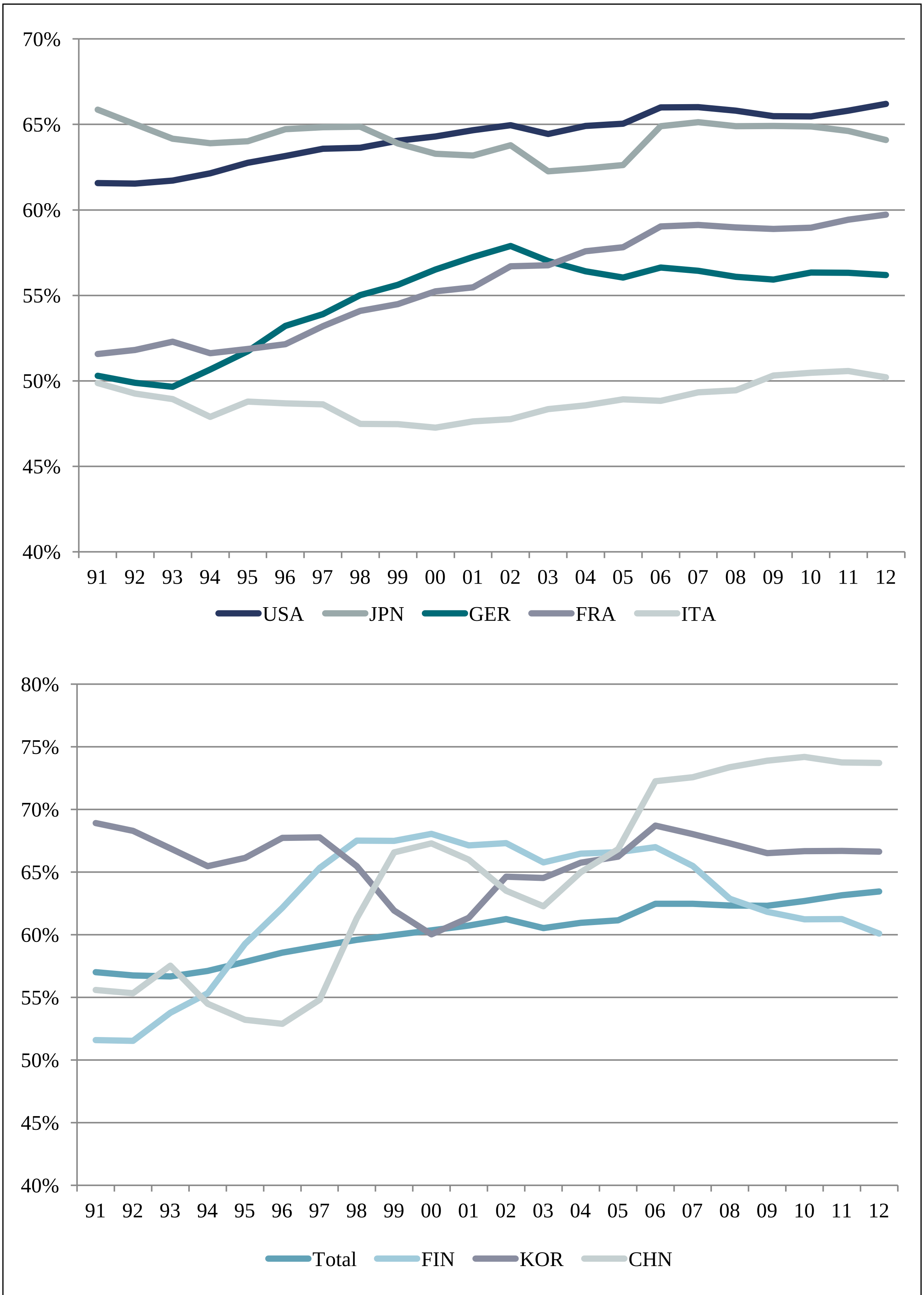
	Total	**Less R&D-intensive**		**High-Tech** of which are:		Leading-edge technologies		High-level technologies	
SUI	903	428	47%	499	55%	179	20%	320	35%
FIN	892	364	41%	527	59%	317	36%	210	24%
SWE	841	287	34%	568	67%	309	37%	259	31%
JPN	785	300	38%	500	64%	191	24%	309	39%
GER	703	315	45%	392	56%	125	18%	267	38%
ISR	668	208	31%	467	70%	258	39%	209	31%
DEK	606	246	41%	363	60%	113	19%	249	41%
KOR	587	206	35%	391	67%	184	31%	207	35%
AUT	549	276	50%	273	50%	87	16%	187	34%
NED	517	245	47%	275	53%	138	27%	137	26%
FRA	427	176	41%	256	60%	114	27%	142	33%
BEL	417	193	46%	228	55%	104	25%	124	30%
USA	408	141	35%	270	66%	136	33%	134	33%
EU-28	337	149	44%	191	57%	75	22%	116	34%
GBR	245	103	42%	145	59%	68	28%	77	31%
ITA	231	124	54%	116	50%	29	12%	87	38%
CAN	219	79	36%	141	64%	76	34%	65	30%
ESP	141	68	48%	76	54%	31	22%	45	32%
POL	43	21	50%	22	50%	8	19%	14	31%
RSA	28	15	54%	12	44%	4	14%	8	30%
CHN	28	7	27%	20	74%	13	48%	7	26%
RUS	18	8	44%	10	54%	5	27%	5	27%
BRA	8	4	54%	4	47%	1	15%	3	31%
IND	5	2	30%	4	70%	2	31%	2	38%

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%.

With regard to high-technology shares, the highest values can be observed for China, the USA and Canada, Sweden, Japan and Korea as well as Israel. For these countries, shares lie above 64%. In the case of India, Canada 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. The differentiation by leading-edge and high-level areas further qualifies these findings. The USA, Canada, Korea, Israel but also Finland, Sweden and especially China are filing many of their patents in leading-edge technologies. In consequence, these countries reach comparably low shares in high-level technologies compared to the other countries. Germany and Switzerland, as well as Japan and Denmark are focused on high-level technologies, but reach comparably low shares in leading-edge areas.

Figure 3 Shares of high-tech patent applications in total patent applications for selected countries, 1991-2012



Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 3 shows the trends in high-tech shares within the national profiles of selected large countries. While the average share of total transnational high-tech patent applications rose from about 57% at the beginning of the 1990s to about 63% in 2012, some countries underwent a considerable change of their patenting patterns in high-tech areas. The USA is at the top of the countries under analysis in this graph and shows rather constantly increasing shares in high-tech patents over the years. Japan is the second most high-technology active country in terms of transnational patenting in the year 2012, 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, has managed to catch up with the USA on this indicator, although a slight decrease is visible from 2011 onwards. France was able to increase its high-tech shares up to 2006, yet the share remains mostly stable from this year onwards, although a slight growth, beginning in 2010, can be observed. Italy encountered a slight decrease in the recent years, so the gap to the other large innovation-oriented countries has grown. Germany scores fourth on this indicator, however also with slightly decreasing shares over the last few years.

The lower panel of Figure 3 shows that the high-tech shares of Korea have been decreasing since 2006, although the absolute number of filings from Korea increased considerably. Yet, since 2009, stabilization in the high-tech shares of Korea can be observed. In the case of China, the number of filings has slowly started to grow after it joined the WTO and the TRIPS agreement in 2001. This growth is especially visible between 2003 and 2006. Since 2010, however, a slightly decreasing trend in high-technology shares can be observed.

3.2 Technology Profiles and Specialization Patterns

In this section, we provide a discussion of transnational patent applications by German inventors according to the new classification of 38 technology fields of the high-tech sector (Gehrke et al. 2013). The absolute number, specialization and the percentage growth of German transnational patent applications by technology fields are displayed in Table 2. The highest growth rates between 2002-2004 and 2010-2012 can be found in the fields of "electrical machinery, accessory and facilities", "rubber goods", "rail vehicles" and "power generation and distribution".

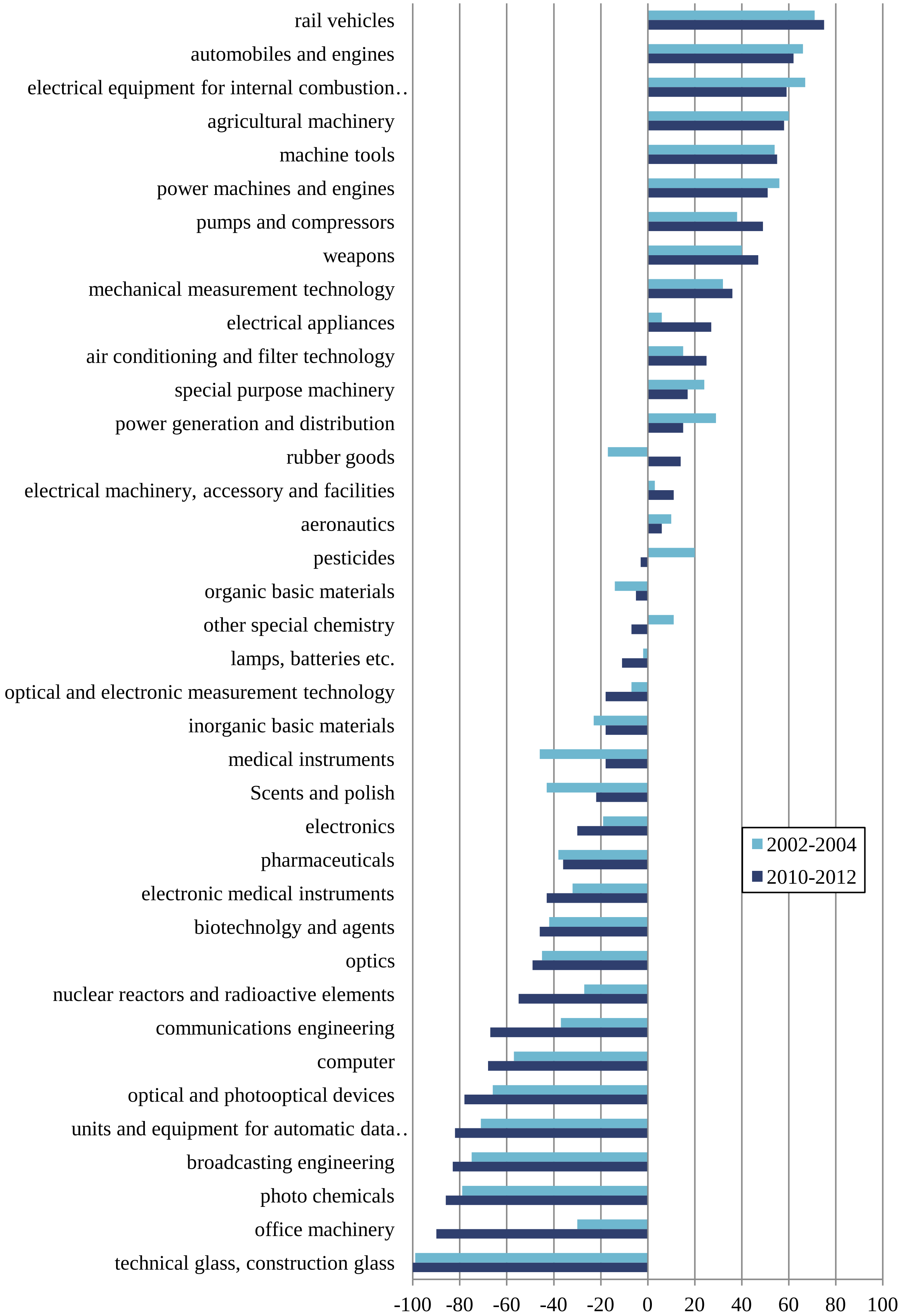
Among the fields that are growing most slowly in Germany are two smaller fields, namely "photo chemicals" and "office machinery". Yet, also the chemistry related fields "biotechnology and agents", "organic basic materials", "other special chemistry" and "pharmaceuticals" can be seen as comparably slowly growing fields within the German technology profile, followed by the ICT related fields of "computers" and "communications engineering". This confirms the results from last year's study. Most electronics related fields 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", "agricultural machinery", "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.

Table 2 Transnational Patent applications of Germany according by high-technology sectors (absolute, specialization, and growth), 2010-2012

Technology Field	Abs.	RPA	% Growth (02-04=100)
electrical machinery, accessory and facilities	638	11	215.8
rubber goods	320	14	182.8
rail vehicles	320	75	182.8
power generation and distribution	2055	15	182.6
electrical appliances	665	27	181.8
aeronautics	772	6	181.0
lamps, batteries etc.	1869	-11	175.4
medical instruments	2680	-18	149.5
air conditioning and filter technology	1933	25	146.7
power machines and engines	3834	51	139.8
electronics	1532	-30	139.2
Scents and polish	44	-22	136.2
inorganic basic materials	423	-18	136.0
pumps and compressors	765	49	134.7
units and equipment for automatic data processing machines	709	-82	122.7
mechanical measurement technology	1123	36	121.1
agricultural machinery	536	58	121.0
electrical equipment for internal combustion engines and vehicles	1183	59	119.2
weapons	277	47	118.2
optical and electronic measurement technology	2660	-18	114.8
electronic medical instruments	790	-43	114.4
nuclear reactors and radioactive elements	20	-55	114.1
machine tools	2334	55	108.9
optical and photooptical devices	69	-78	102.7
optics	567	-49	101.1
technical glass, construction glass	109	-100	99.9
automobiles and engines	5482	62	95.0
broadcasting engineering	675	-83	91.4
pesticides	520	-3	91.3
special purpose machinery	3324	17	91.2
communications engineering	3776	-67	82.6
pharmaceuticals	1214	-36	76.3
computer	1816	-68	76.0
other special chemistry	1009	-7	75.7
organic basic materials	1566	-5	74.4
biotechnolgy and agents	1607	-46	68.7
office machinery	42	-90	30.6
photo chemicals	2	-86	7.0

Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 4 Germany's technological profile, 2002-2004 vs. 2010-2012



Source: EPO – PATSTAT; Fraunhofer ISI calculations

The specialization (RPA) of the German technology profile of the years 2002-2004 and 2010-2012 is displayed in Figure 4. Germany is specialized, i.e. has comparative advantages, in three main areas: transport (automobiles and engines as well as rail vehicles), machinery and some areas of electrical engineering like power machines and power generation. Germany also has a very strong specialization within the new field of "electrical equipment for internal combustion engines and vehicles", which has already been found in last year's report.

An average activity rate in patenting can be found in the chemical sectors ("organic basic materials", "other special chemistry"). Comparative disadvantages, reflected in negative specialization indices, can be found in pharmaceuticals, biotechnology, information and communication technologies as well as optics and optical devices, meaning that Germany does not have 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.

4 Structures in International Co-Patenting

The cooperation structures in international patenting resemble the internationalization of R&D activities and are able to indicate the extent to which countries are cooperating with each other. This is based on the assumption that each collaboration that leads to a cooperative patent application is associated with the exchange of knowledge about the patented invention. The analysis of cooperation structures in patenting thus allows us to draw conclusions about international knowledge flows. It is assumed that usually implicit or experiential knowledge is exchanged (Polanyi 1985), which will later "explicitly" be stated in the form of a patent application. By analyzing patent applications, however, our focus remains on the explicable and explicit knowledge (Grupp 1998).

Basically, there are several ways to define an international co-patent, e.g. to use patent applicants or inventors or a mixture between the "inventor-" and the "applicant concept" (Fraunhofer ISI et al. 2009). Yet, we decided to reside to the concept of inventors since this indicates that the innovative endeavors resulting in an international co-patent have been carried out in two different countries, or at least there is a certain exchange of knowledge between inventors from two countries.

Yet, there are also downsides when using patent indicators to identify international knowledge exchange. First of all, patent filings are only one of many results that can be the outcome of international collaborations and patents can only give us information on the collaborations that have actually led to a patent filing. Second, tracing the direction and amount of the knowledge flow is challenging, i.e. it is hard to say which country benefits most from the exchanged knowledge. Third, it is also important to recognize that the analysis of patent filings only gives us information on the location of the inventor 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 subsidiaries (see also ADL 2005). The data thus reflects inter- as well as intra-firm international collaboration or in other words, an international co-patent is counted as such when two inventors named on the patent application are living in two different countries, i.e. a domestic and a foreign inventor, also when they belong to the same firm that operates facilities or subsidiaries in two different countries (Fraunhofer ISI et al. 2009; Guellec and Pluvia Zuniga 2007). These shortcomings have to be kept in mind for the analysis of international cooperation structures with the help of patent indicators. Still, since the data should not be systematically biased, they can still serve as an indicator of international knowledge exchange, especially in relative terms (Fraunhofer ISI et al. 2009).

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

4.1 A brief literature review

The literature on research collaborations discusses several characteristics that can foster or hamper international cooperation (for an extended overview see Fraunhofer ISI et al. 2009). Frame and Carpenter (1979) stated that the size of a country influences its propensity to collaborate internationally. The main argument hereby is that 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, evidence on the degree and direction of this relationship remains vague, since conflicting statements on this topic can be found in the literature (Luukkonen et al. 1992; Luukkonen et al. 1993; Narin et al. 1991).

The more recent literature points to the fact that, besides country size, there is considerable heterogeneity between countries in their propensity to collaborate. This can be attributed to a multitude of different factors (Hoekman et al. 2010), which mainly are geopolitical and historical as well as language related factors. However, social, intellectual, cognitive and economic factors also 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. Liu et al. (2012) for example state that basic disciplines express a higher propensity to collaborate internationally than applied disciplines. 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. Yet, if it is the aim to integrate complementary or additional knowledge, patenting is often done in cooperation with other inventors (von Proff and Dettmann 2013).

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

Figure 5 gives a first impression of the co-patenting trends by countries. It depicts the shares of transnational co-patents (with OECD countries) in all transnational patent filings of the respective country. This so-to-say offers an impression of the countries' "cooperation portfolios". Large shares imply that many inventors from a given country are cooperating internationally. The top-panel of the figure first of all provides the results for the larger countries in comparison as well as the total values. The lower-panel shows the results for the smaller countries.

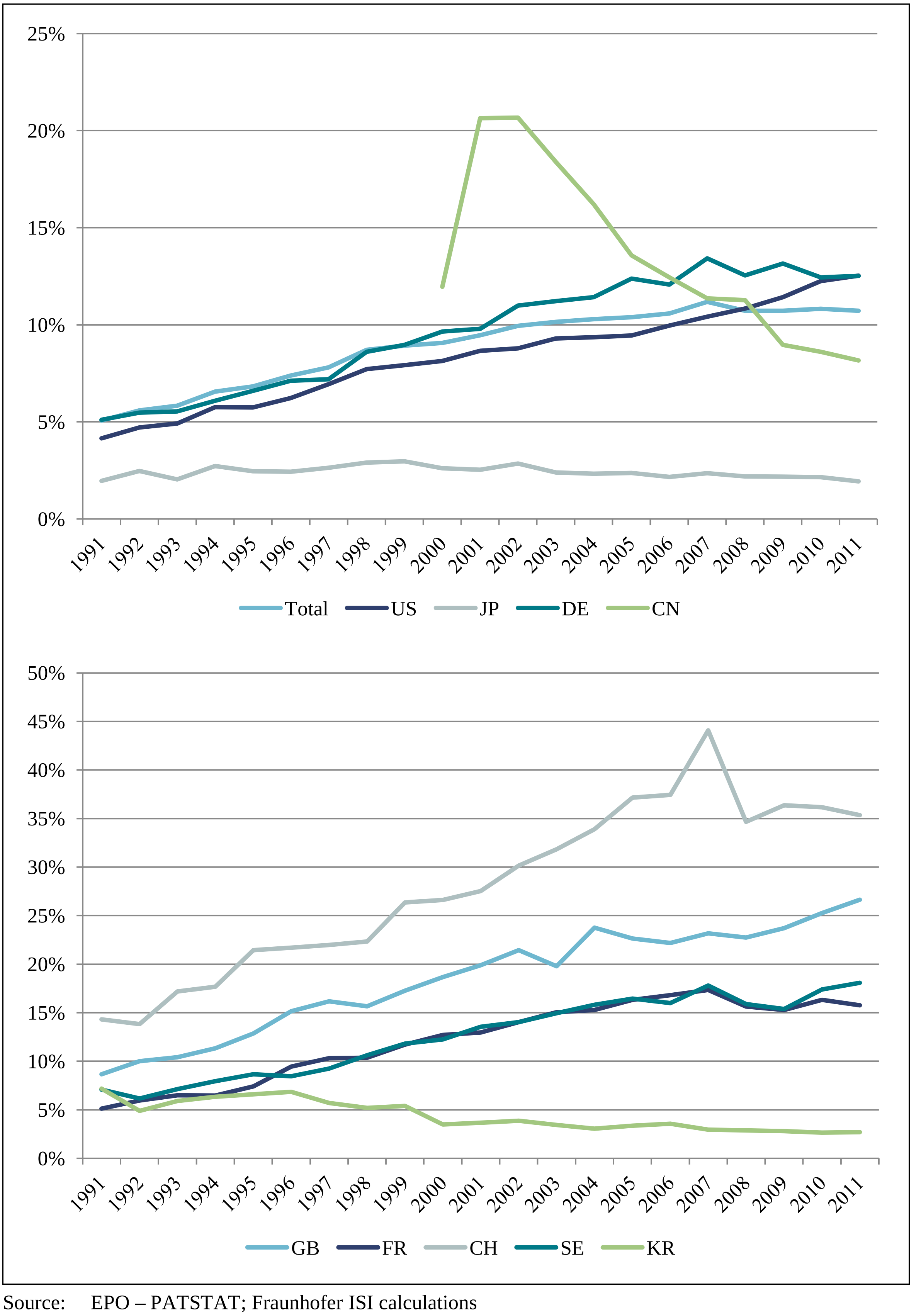
The total share of co-patents in all filings is constantly increasing over the years until 2007. While in 1991 only 5% of all transnational filings were international co-patents, this share went up to 11% in 2007. From 2007 onwards, however, the share remains stable, implying a constant rate of about 11% co-patent filings on average. Germany and the US mostly follow the general trend, although the US has increased its co-patent shares also after 2007 and therefore has an above average co-patent rate since 2008. Co-patent shares of Germany have been higher than the US shares over the entire time-period. Yet, due to a slight decline in the shares since 2009, the US and German shares are at a similar level of about 13% in 2011. A closer look at China reveals that, although starting from a very high level, the co-patenting rates have constantly decreased since 2003. Still, about 8% of all Chinese transnational filings are international co-patents. Compared to Japan and Korea, this share still is comparably high. Japan shows a more or less constant co-patenting rate of 2% to 3% over the years. Similar values can be observed for Korea, at least since the year 2000.

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). Over many years, they were not involved in the international research community (see also the report on bibliometrics in this year's reporting series). Furthermore, the Japanese and also the Korean large enterprises were hardly conducting R&D abroad. More recently, the governments in both countries set up programs to overcome these shortcomings, especially with respect to the public science system. They also realized that international collaboration is a crucial factor in nowadays innovation activities.

Apart from Korea, however, the smaller countries have higher co-patenting rates in comparison, which is in line with the theoretical arguments. Switzerland by far has the highest shares of co-patents in all transnational filings. Although a drop in the figures between 2007 and 2008 can be observed, the share lies at 35%. Switzerland is followed by Great Britain, where shares are constantly rising over the whole observation period, peaking in

2011 with about 27%. France and Sweden also show above average shares, with 18% and 16% in 2011, respectively.

Figure 5 Shares of transnational co-patents in all transnational patents of the respective country, selected countries, 1991-2011



Source: EPO – PATSTAT; Fraunhofer ISI calculations

In Table 3, the absolute number of transnational co-patents is depicted country-by-country. This table allows an assessment of the most important cooperation partners for each of the countries in this comparison. The values above the diagonal in the table show the share of co-patents between two 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. The US has the highest share of co-patents in all transnational co-patents with a value of 25%. However, the US is also the largest filing country in terms of total patents. The US is followed by Germany with a share of about 15%. Great Britain and France follow-up Germany with a share of about 7% each. Although a small country in absolute terms, Switzerland reaches rather high shares in all transnational co-patents (nearly 6%). The opposite is true for Japan, although it is the second largest country in terms of transnational patent filings. It reaches only a share of about 3.6%. 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.

A look at the absolute numbers reveals the importance of collaboration partners for each of the countries. This 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 most important collaboration partner for Germany is clearly the US. About 24% of all German co-patents are filed in cooperation with a US inventor. The next largest partners are Switzerland and France with 14% and 12%, respectively. This can mostly be explained by geographical proximity. Many of the countries in our comparison show a large tendency to cooperate with partners that are geographically close. This, however, might also partly be explained by the fact that some persons are commuting to work from one country to another. Looking at the figures for the US reveals a somewhat more "balanced" portfolio. US inventors are most often cooperating with inventors from Germany (15%), Canada (13%), Great Britain (13%) and China (11%), followed by inventors from India, France and Japan. China, on the other hand, is highly oriented towards cooperating with US inventors. About 52% of all Chinese co-patents are filed in cooperation with a US inventor, followed by Germany with 11% and Japan with 7%. Yet, this might at least partly have to do with research facilities and production sites of foreign companies in China (Ernst 2006). In sum, the US, and to a certain extent also Germany, are the most important cooperation partners for the countries in comparison.

Table 3 Absolute number of transnational co-patents and shares in total transnational co-patents, 2009-2011

	FR	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA	Share in total transnational co-patents
FR		0.04%	0.64%	0.04%	0.17%	1.07%	0.15%	1.79%	0.03%	0.21%	0.05%	0.43%	0.02%	0.06%	0.25%	0.15%	0.06%	0.21%	0.04%	0.04%	0.07%	1.60%	0.00%	7.14%
AT	28		0.07%	0.01%	0.02%	0.27%	0.01%	1.13%	0.02%	0.02%	0.07%	0.06%	0.00%	0.01%	0.05%	0.02%	0.00%	0.04%	0.01%	0.01%	0.05%	0.16%	0.00%	2.06%
BE	438	45		0.01%	0.05%	0.07%	0.09%	0.64%	0.01%	0.11%	0.01%	0.18%	0.00%	0.03%	0.08%	0.08%	0.01%	0.51%	0.03%	0.00%	0.03%	0.64%	0.00%	3.31%
BR	26	4	7		0.01%	0.03%	0.00%	0.08%	0.01%	0.02%	0.00%	0.01%	0.00%	0.01%	0.02%	0.01%	0.00%	0.01%	0.00%	0.00%	0.02%	0.19%	0.00%	0.47%
CA	118	14	35	6		0.06%	0.12%	0.22%	0.02%	0.02%	0.03%	0.38%	0.02%	0.04%	0.03%	0.07%	0.02%	0.06%	0.01%	0.01%	0.06%	3.27%	0.01%	4.70%
CH	732	186	50	18	40		0.12%	2.15%	0.02%	0.07%	0.04%	0.23%	0.02%	0.11%	0.23%	0.06%	0.02%	0.12%	0.02%	0.02%	0.12%	1.05%	0.00%	5.92%
CN	104	7	62	1	81	85		0.60%	0.07%	0.02%	0.14%	0.28%	0.02%	0.05%	0.06%	0.39%	0.07%	0.13%	0.01%	0.02%	0.18%	2.75%	0.00%	5.29%
DE	1,221	768	437	53	150	1,464	408		0.25%	0.34%	0.20%	0.87%	0.09%	0.19%	0.56%	0.57%	0.15%	1.01%	0.15%	0.12%	0.45%	3.74%	0.04%	15.35%
DK	18	14	6	4	10	14	46	168		0.01%	0.06%	0.19%	0.00%	0.03%	0.01%	0.04%	0.00%	0.03%	0.02%	0.00%	0.16%	0.27%	0.00%	1.23%
ES	141	13	76	13	13	45	12	229	6		0.01%	0.11%	0.03%	0.01%	0.09%	0.03%	0.00%	0.07%	0.01%	0.01%	0.04%	0.33%	0.00%	1.55%
FI	36	48	9	2	23	29	93	139	38	4		0.13%	0.00%	0.04%	0.03%	0.02%	0.00%	0.03%	0.03%	0.02%	0.13%	0.22%	0.00%	1.26%
GB	296	40	122	9	259	160	191	593	129	76	90		0.04%	0.15%	0.18%	0.29%	0.10%	0.26%	0.04%	0.04%	0.19%	3.28%	0.02%	7.47%
IL	16	1	3	2	16	13	13	63	2	18	1	30		0.02%	0.02%	0.01%	0.01%	0.02%	0.00%	0.02%	0.01%	0.90%	0.00%	1.28%
IN	40	10	18	4	25	77	35	132	17	10	25	105	15		0.02%	0.02%	0.06%	0.05%	0.01%	0.01%	0.04%	1.78%	0.00%	2.75%
IT	173	31	56	16	22	154	42	381	10	63	19	120	15	16		0.03%	0.01%	0.06%	0.01%	0.05%	0.09%	0.68%	0.00%	2.58%
JP	104	12	56	7	47	43	263	391	30	22	17	199	9	12	19		0.18%	0.03%	0.01%	0.03%	0.06%	1.52%	0.00%	3.64%
KR	38	1	8	1	16	14	49	104	2	1	2	65	7	43	4	124		0.03%	0.00%	0.05%	0.01%	0.63%	0.00%	1.42%
NL	140	25	345	5	44	84	89	690	19	47	17	180	12	33	43	23	17		0.02%	0.03%	0.04%	0.88%	0.01%	3.64%
PL	26	5	20	1	5	15	8	103	13	7	22	27		4	10	5	1	13		0.00%	0.03%	0.10%	0.00%	0.55%
RU	27	8	3	0	8	14	15	81	2	7	12	26	16	5	37	22	37	21	2		0.01%	0.37%	0.00%	0.88%
SE	50	31	21	11	39	81	121	308	107	31	87	128	7	30	59	38	6	27	21	5		0.55%	0.00%	2.33%
US	1,091	112	436	130	2,228	719	1,878	2,553	185	226	148	2,239	612	1217	465	1037	430	598	66	253	378		0.08%	25.02%
ZA	2	3	1	0	4	2	1	27	2	1		11	1	1	2	0	1	6	1		2	56		0.18%
Total	4,866	1,406	2,254	320	3,202	4,040	3,604	10,465	842	,1060	859	5,095	871	1,874	1,756	2,482	971	2,479	375	601	1,588	17,059	126	100.00%

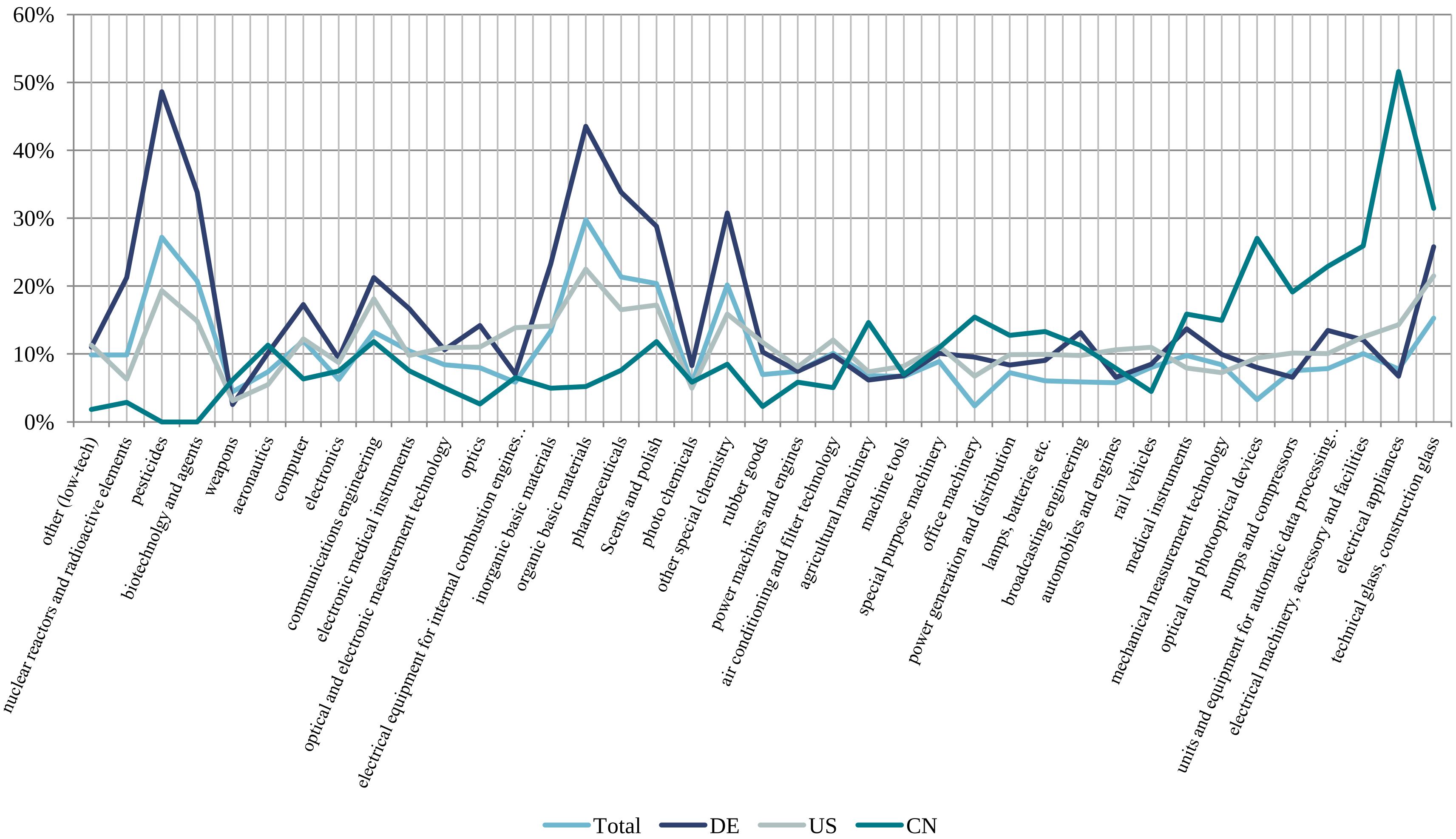
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Table 4 Share of co-patenting partners within the transnational co-patenting portfolio of a given country, 2009-2011

	FR	AT	BE	BR	CA	CH	CN	DE	DK	ES	FI	GB	IL	IN	IT	JP	KR	NL	PL	RU	SE	US	ZA
FR		2%	19%	8%	4%	18%	3%	12%	2%	13%	4%	6%	2%	2%	10%	4%	4%	6%	7%	5%	3%	6%	2%
AT	1%		2%	1%	0%	5%	0%	7%	2%	1%	6%	1%	0%	1%	2%	0%	0%	1%	1%	1%	2%	1%	2%
BE	9%	3%		2%	1%	1%	2%	4%	1%	7%	1%	2%	0%	1%	3%	2%	1%	14%	5%	0%	1%	3%	1%
BR	1%	0%	0%		0%	0%	0%	1%	0%	1%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	1%	1%	0%
CA	2%	1%	2%	2%		1%	2%	1%	1%	1%	3%	5%	2%	1%	1%	2%	2%	2%	1%	1%	2%	13%	3%
CH	15%	13%	2%	6%	1%		2%	14%	2%	4%	3%	3%	2%	4%	9%	2%	1%	3%	4%	2%	5%	4%	2%
CN	2%	1%	3%	0%	3%	2%		4%	5%	1%	11%	4%	1%	2%	2%	11%	5%	4%	2%	2%	8%	11%	1%
DE	25%	55%	19%	17%	5%	36%	11%		20%	22%	16%	12%	7%	7%	22%	16%	11%	28%	27%	14%	19%	15%	21%
DK	0%	1%	0%	1%	0%	0%	1%	2%		1%	4%	3%	0%	1%	1%	1%	0%	1%	4%	0%	7%	1%	1%
ES	3%	1%	3%	4%	0%	1%	0%	2%	1%		0%	1%	2%	1%	4%	1%	0%	2%	2%	1%	2%	1%	1%
FI	1%	3%	0%	1%	1%	1%	3%	1%	4%	0%		2%	0%	1%	1%	1%	0%	1%	6%	2%	5%	1%	0%
GB	6%	3%	5%	3%	8%	4%	5%	6%	15%	7%	10%		3%	6%	7%	8%	7%	7%	7%	4%	8%	13%	9%
IL	0%	0%	0%	0%	1%	0%	0%	1%	0%	2%	0%	1%		1%	1%	0%	1%	0%	0%	3%	0%	4%	1%
IN	1%	1%	1%	1%	1%	2%	1%	1%	2%	1%	3%	2%	2%		1%	0%	4%	1%	1%	1%	2%	7%	1%
IT	4%	2%	2%	5%	1%	4%	1%	4%	1%	6%	2%	2%	2%	1%		1%	0%	2%	3%	6%	4%	3%	1%
JP	2%	1%	2%	2%	1%	1%	7%	4%	4%	2%	2%	4%	1%	1%	1%		13%	1%	1%	4%	2%	6%	0%
KR	1%	0%	0%	0%	0%	0%	1%	1%	0%	0%	0%	1%	1%	2%	0%	5%		1%	0%	6%	0%	3%	1%
NL	3%	2%	15%	2%	1%	2%	2%	7%	2%	4%	2%	4%	1%	2%	2%	1%	2%		4%	3%	2%	4%	5%
PL	1%	0%	1%	0%	0%	0%	0%	1%	2%	1%	3%	1%	0%	0%	1%	0%	0%	1%		0%	1%	0%	1%
RU	1%	1%	0%	0%	0%	0%	0%	1%	0%	1%	1%	1%	2%	0%	2%	1%	4%	1%	1%		0%	1%	0%
SE	1%	2%	1%	3%	1%	2%	3%	3%	13%	3%	10%	3%	1%	2%	3%	2%	1%	1%	6%	1%		2%	2%
US	22%	8%	19%	41%	70%	18%	52%	24%	22%	21%	17%	44%	70%	65%	26%	42%	44%	24%	18%	42%	24%		45%
ZA	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Sum	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

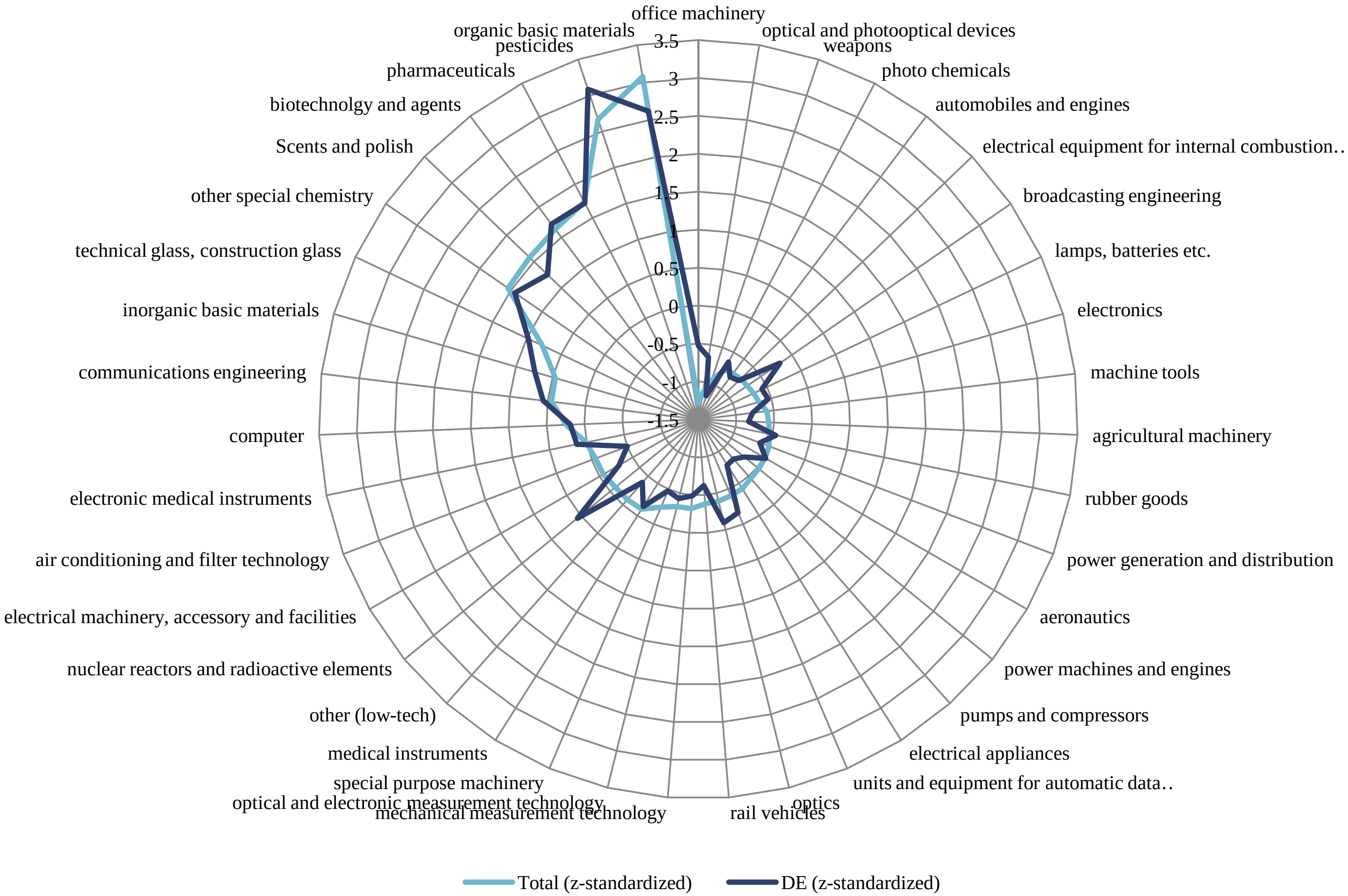
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 6 Share of co-patents by field in all transnational filings within the respective field, by country, 2009-2011



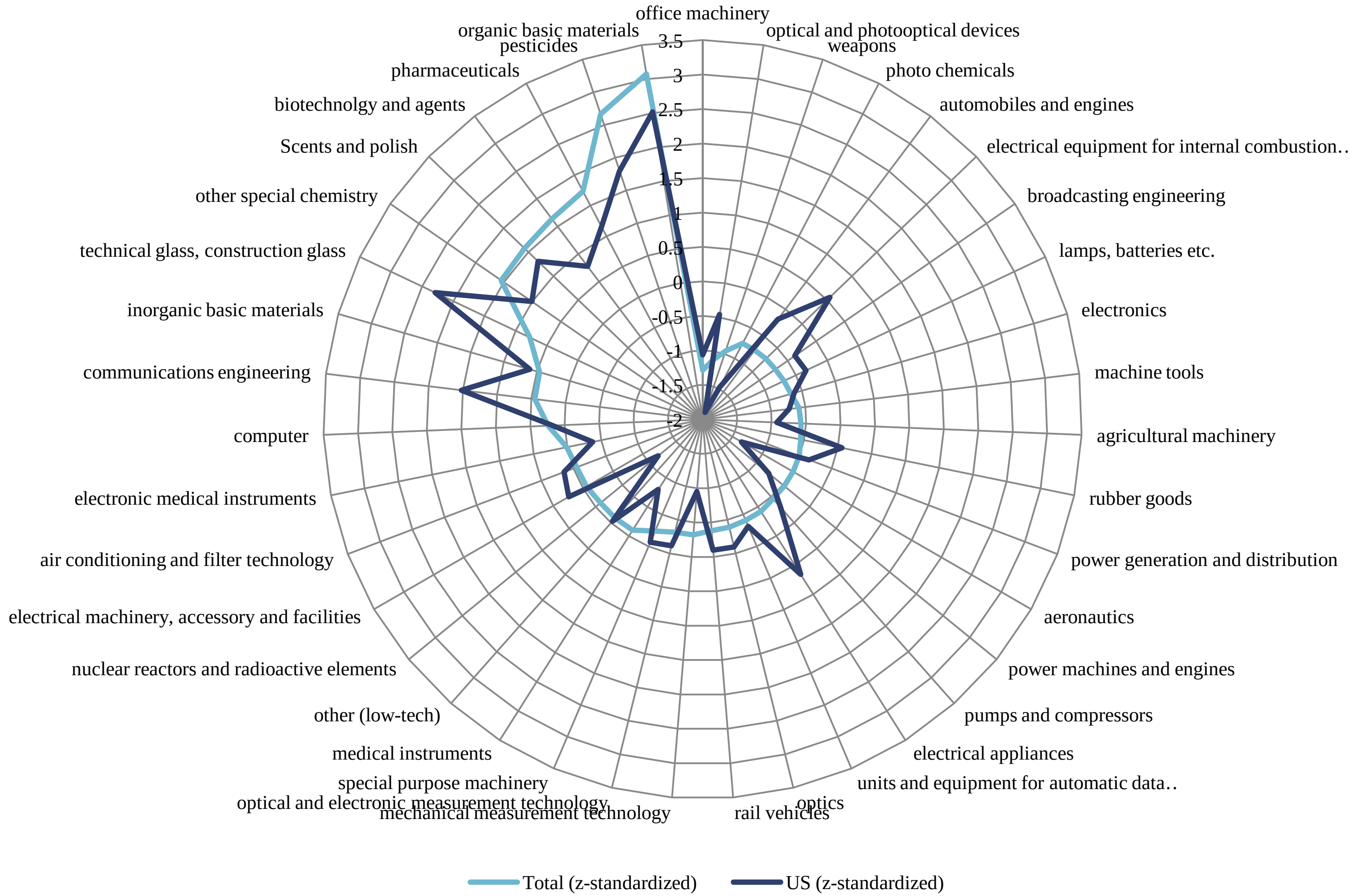
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 7 Differences in field-specific co-patenting trends, z-standardized values, total and DE, 2009-2011



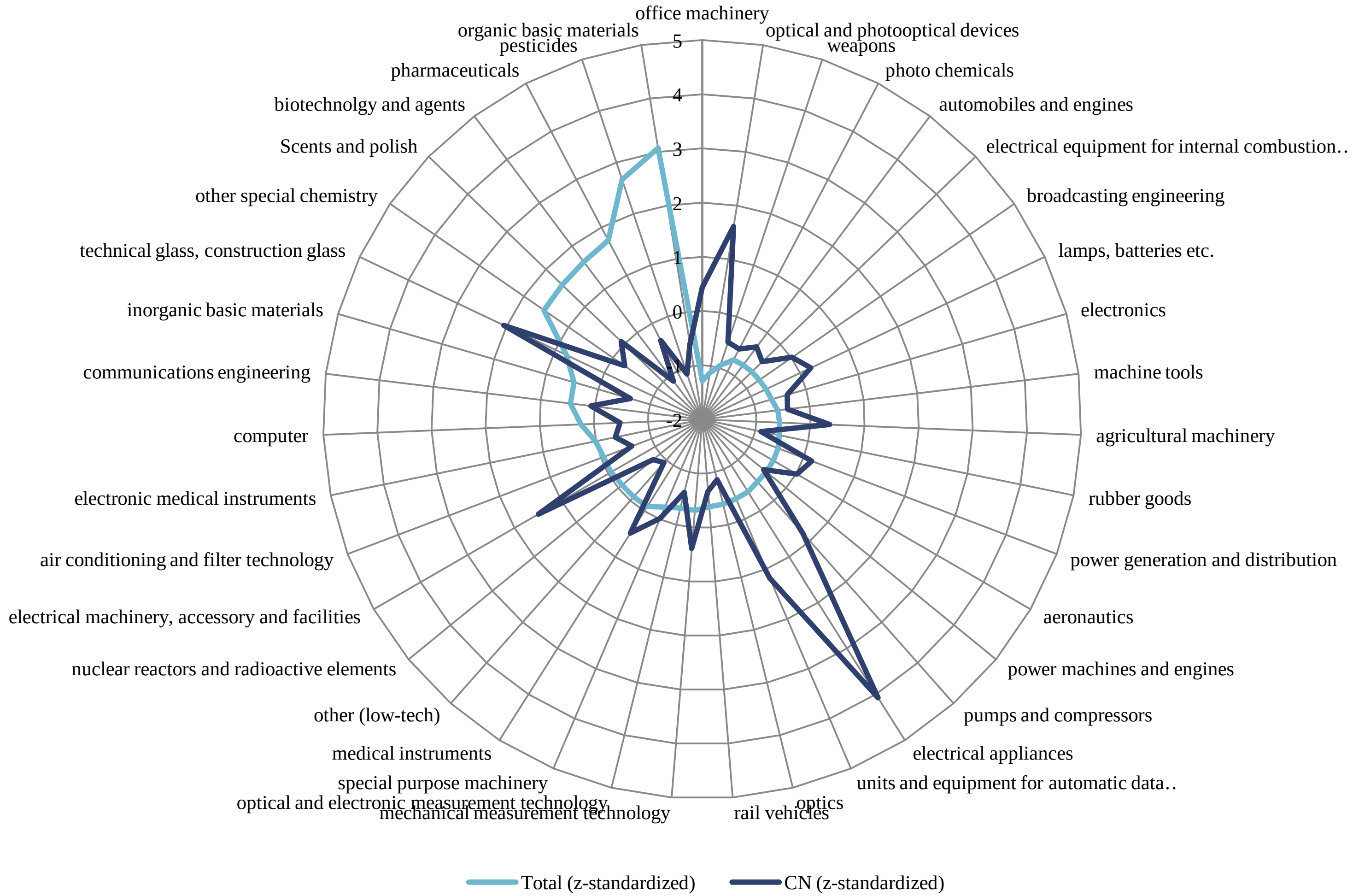
Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 8 Differences in field-specific co-patenting trends, z-standardized values, total and US, 2009-2011



Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 9 Differences in field-specific co-patenting trends, z-standardized values, total and CN, 2009-2011



Source: EPO – PATSTAT; Fraunhofer ISI calculations

Figure 6 offers a more detailed plotting of the field specific trends in total transnational filings for Germany, the US and China. In detail, the field specific shares of co-patents of a given country in all transnational filings of the given country and field are depicted. It therefore informs about cooperation trends within the given fields in the respective countries.

Germany shows especially high shares of co-patents within the fields "pesticides", "organic-" as well as "inorganic basic materials", "pharmaceuticals" and "other special chemistry". The lowest shares can be found in the fields of "weapons", which, however, is true for all countries, "agricultural machinery", "pumps and compressors" and "automobiles and engines". Germany thus cooperates mostly in chemistry and related fields and less so in the fields of mechanical engineering. This is in line with the literature which says that companies tend to internationalize and cooperate particularly in the areas of their individual strengths to look for complementary technologies and knowledge (Belitz et al. 2006; Belitz 2012; Patel and Vega 1999). However, similar trends can be identified for the US and China. Yet, this has to do with the fact that the values within this graph are not size-independent, i.e. they cannot be compared across, but only within countries. Since, for example, Germany has above average co-patenting shares, it also has higher field-specific shares compared to the total number of filings (at least for the majority of fields). In order to correct for this effect, Figure 7, Figure 8 and Figure 9 show z-standardized values for these three countries in comparison to the total number of transnational filings. Here, we can observe which fields within a country are more or less cooperation-intensive compared to the worldwide average. In the case of Germany (Figure 7), we find that the co-patenting trends across fields resemble the average picture very well. The largest positive deviations from the worldwide average can be observed in the fields of "office machinery", "nuclear reactors and radioactive elements", "broadcasting engineering", "optical and photooptical devices" and "pesticides". Negative deviations, i.e. less co-patent filings than average, can be observed in "organic basic materials", "air conditioning and filter technology", "electrical appliances" and "pumps and compressors", followed by most of the mechanical engineering and related fields. Although Germany reaches high shares of co-patents in chemistry and related fields, these shares are not highly above average in an international comparison since co-patenting shares in chemistry are generally high. For the US this picture is different (Figure 8). Here, the positive deviations from average can be found in the fields of "technical glass, construction glass", "electrical equipment for internal combustion engines and vehicles", "electrical appliances", "communications engineering" and "optical and photooptical devices", implying that there are some fields related to electronics where the US is highly internationally cooperation-intensive compared to the worldwide average. Negative values can be found in "nuclear reactors and radioactive elements", "weapons", "pesticides", "aeronautics" and "biotechnology and agents". In the case of China (Figure 9), high deviations from the average can be observed in "pesticides", "organic basic materials", "biotechnology and agents", "pharmaceuticals" and "other special chemistry". Compared to the worldwide average, Chinese inventors thus are highly cooperation-intensive in chemistry and related fields. Negative values can be found in "electrical appliances", "optical and photooptical devices", "office machinery", "units and equipment for automatic data processing machines", "electrical machinery, accessory and facilities", i.e. most of the electronics related fields.

4.3 Conclusions

The shares of international co-patents have constantly increased over the last twenty years for most of the countries in our analysis, implying that the need to cooperate internationally has gained increased importance. Since 2007, however, which is the year where the number of patent filings was affected by the financial crisis, we observe a stagnation in the share of worldwide co-patents. This effect is mostly due to constant shares of co-patent filings from German, Swiss and French inventors as well as the decreasing shares of co-patents with Chinese inventors. The shares of US and British co-patents are still increasing. In sum, however, we can state that the European and North-American countries are more cooperation-intensive than the Asian countries, especially Japan and Korea. Japan and Korea have a comparably low level of internationalization of R&D activities, at least as measured in terms of co-patents. This implies that the innovation systems of these two countries are relatively isolated compared, for instance, to the German or the US innovation system (Schubert et al. 2013; Weissenberger-Eibl et al. 2011).

The country-by-country trends reveal that the most important collaboration partner for Germany still is the US. About 24% of all German co-patents are filed in cooperation with a US inventor. The next largest partners are Switzerland and France. US inventors are most often cooperating with inventors from Germany, Canada, Great Britain and China, while the Chinese are very much oriented towards cooperating with a US partner, followed by Germany and Japan.

The field specific trends show that Germany has especially high shares of co-patents within chemistry and related fields, while mechanical engineering is the least cooperation intensive. However, this is a trend that can be observed for most countries in the sample, i.e. chemistry is on average more cooperation-intensive than mechanical engineering. Nevertheless, we can still see that Germany is less cooperation-intensive than average in mechanical engineering, a field where Germany has its particular technological strengths. For the US, we find fields related to electronics with a high international cooperation-intensity. China, on the other hand, is highly cooperation-intensive in chemistry and related fields, compared to the worldwide average.

5 Patent Activities of the German Federal States

In the previous sections, we have discussed several patent related indicators at the international level. Now, we will take a more disaggregated look at the German patent filings, namely 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.

Economic, and thereby also innovative, activities are not equally distributed over geographical space. A regionalized patent statistic therefore allows to take a closer look at the structural composition of the German innovation landscape. A further differentiation by technologies additionally enables the identification of regional technology clusters 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.

The regionalisation of patent statistics comes along with two major challenges that are associated with the owner structure of patents. The first of these challenges is how to tackle the fact that some of the large, decentralized firms in Germany file their patents via their headquarter location, which might introduce a bias to our statistics. The second challenge is how to cope with employees who commute to their workplace and thereby cross federal state borders or even country borders, especially in the border areas. Especially for federal states with large firms operating at the state border, this might lead to a blurred picture of the patent activities of these federal states or at least this has to be kept in mind for the interpretation of the results. In the next subsection, we will discuss how we deal with these challenges in more detail.

5.1 Methodology – Taking into account the ownership structure

In the reporting system for the Expert Commission on Research and Innovation, we usually assign the patents to the country where the inventor is located. The reason is that it is usually more interesting to see where an invention has been made compared to the question where the proprietor of the patent is located. The challenge for regionalized patent statistics, however, is that the ownership structures of patent applications have to be taken into account more strongly than at the international level, where biases are less severe.

Patent statistics at the regional level are associated with two major challenges that have to be tackled in order to provide interpretable numbers. The first one is what can be called "commuter effect", meaning that employees often cross regional borders when commuting to their workplace. Within country statistics, the commuter effect is of less consequence, in part because commuting to another country for work is not so frequently the case and partly due to the larger number patent of filings as well as a balance in reverse direction commuting. The commuter effect can therefore largely be neglected in international comparisons. At the level of federal states, however, it actually makes a difference whether the address of the inventor or the address of the patent applicant is used for the regional statistics. By applying the *inventor principle*, where a patent application is assigned to the country of origin of the inventor, the statistic so to say penalizes the federal states in which companies are located near the border. By applying the *applicant principle*, however, one might overvalue the activities of the federal states where the company is actually located. This problem is even amplified when differentiating the statistics by technology fields. In the field of chemistry, for example, the profile of Baden-Württemberg would be positively affected by assigning patent filings on the basis of the inventor location, while the profile of Rhineland-Palatinate would be disadvantaged due to the border location of the BASF AG (Frietsch et al. 2010; Neuhäusler et al. 2013).

Another challenge, which is barely separable from the commuter effect, are the decentralized research activities of large firms. The Siemens AG, which files most of its patents via its headquarters in Munich but has research facilities scattered all over Germany, can serve as an example here.

In order to cope with these challenges, we will apply both, the inventor and the applicant principle within the following chapter. Only by taking both viewpoints, a correct assessment of the technological capabilities of the German federal states becomes possible. In addition, it allows an assessment of the magnitude of the commuter effect and its influence on regionalized patent statistics in Germany. For the identification of the German federal states in patent filings, we use the NUTS-code information from the OECD REGPAT database, complemented with address information obtained from the German Patent and Trademark Office (DPMA). For filings that could not be assigned a NUTS code with the help of these two data sources, we resorted to the patent family information within the PATSTAT database. In the case that address information could be obtained from any other than the transnational filing, this address information was assigned to the transnational filing.

To quantify the aforementioned commuter effect, we will – in a modified form – additionally resort to the internationalization indicators proposed by Guellec und van Pottelsberghe de la Potterie (2001; 2004). In detail, we will apply their concept of "cross-border ownership" of inventions, i.e. the inventor and the applicant reside in different countries. When the inventor and the applicant of a patent do not reside in the same country, this reflects in a) the fact that the patent protects an invention performed in a research facility of a large company abroad or b) at least in our case, inventors commuting to work from one federal state to another. To address this effect, two indicators have been proposed by Guellec und van Pottelsberghe de la Potterie, which we will apply to our regional statistics. The first of these indicators is the share of patents with an inventor in the target (or "domestic") federal state and an applicant from a "foreign" federal state in total filings of "domestic" inventors (SHIA). It reflects the extent to which firms from other federal states control "domestic" inventions. Applied to the "commuter effect", it also gives us an idea of the amount of inventors commuting to another federal state (or so to say the "outflow" of inventors). The second indicator (SHAI) is the share of patent filings with an inventor from a "foreign" federal state and a "domestic" applicant in a federal state's total "domestic" applications. The indicator consequently reflects the extent to which domestic firms control foreign inventions and in how far firms are operating across the borders of the focal federal state. With the commuter effect being more significant at the regional than at the international level, it also informs us about the amount of inventors commuting from another federal state (or so to say the "inflow" of inventors).

In correspondence to the structural indicators calculated at the international level (compare section 3) as well as to the work of Guellec und van Pottelsberghe de la Potterie, patents are counted fractionally, i.e. when a patent has several inventors/applicants residing in different federal states, each of the federal states is assigned a fraction corresponding to its share in the number of inventors/applicants.

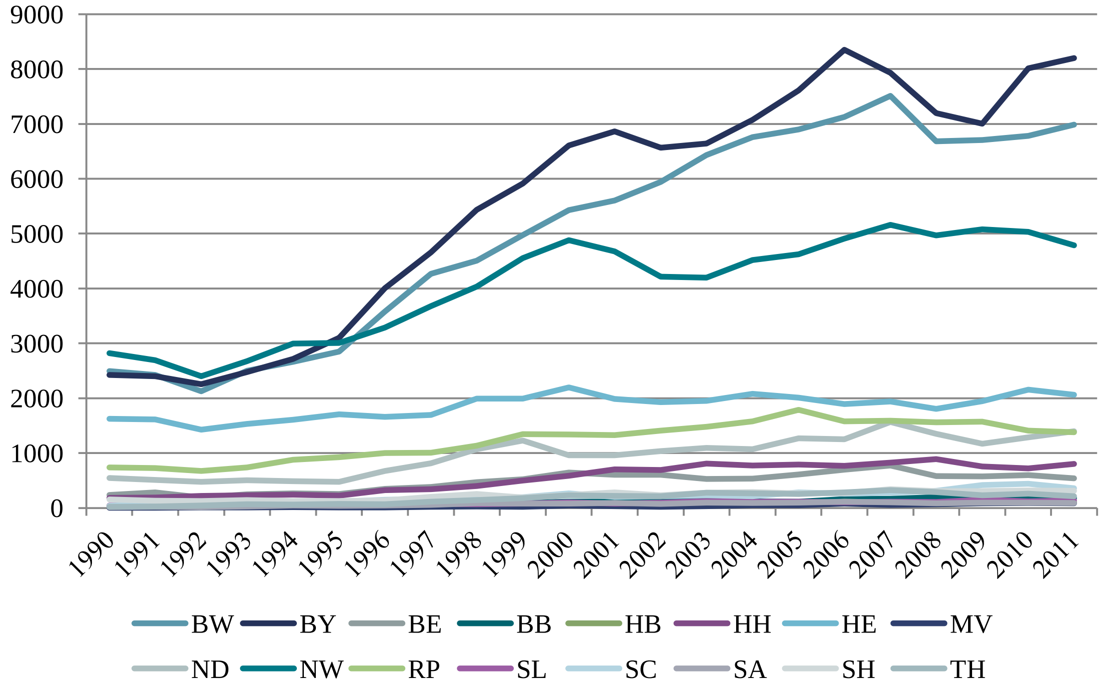
The application of this system of indicators does not only allow us to quantify the transnational patent output of the German "Bundesländer" but also gives us the opportunity to take into account the commuter effect.

5.2 Results

5.2.1 Structures and Trends

In Figure 10, the absolute numbers of transnational patent filings based on the address of the applicant are plotted. Over the years, the number of filings is increasing for all German federal states. The south of Germany has the largest number of transnational filings within the German comparison. Bavaria ranks first, with over 8,000 filings in 2011, followed by Baden-Württemberg (about 7,000 filings in 2011) and North Rhine-Westphalia, at a slightly lower level (about 5,000 filings in 2011). These three federal states together are responsible for 68% of all German transnational filings, which, however, is not surprising since large parts of the German industry is located there. At the fourth rank, with about 2,000 filings in 2011, is Hessia, followed by Rhineland-Palatinate and Lower-Saxony, who both reach similar levels in terms of patenting. The remainder of the federal states is at a similar level with less than 1,000 filings per year.

Figure 10 Number of transnational filings by federal states, applicant principle

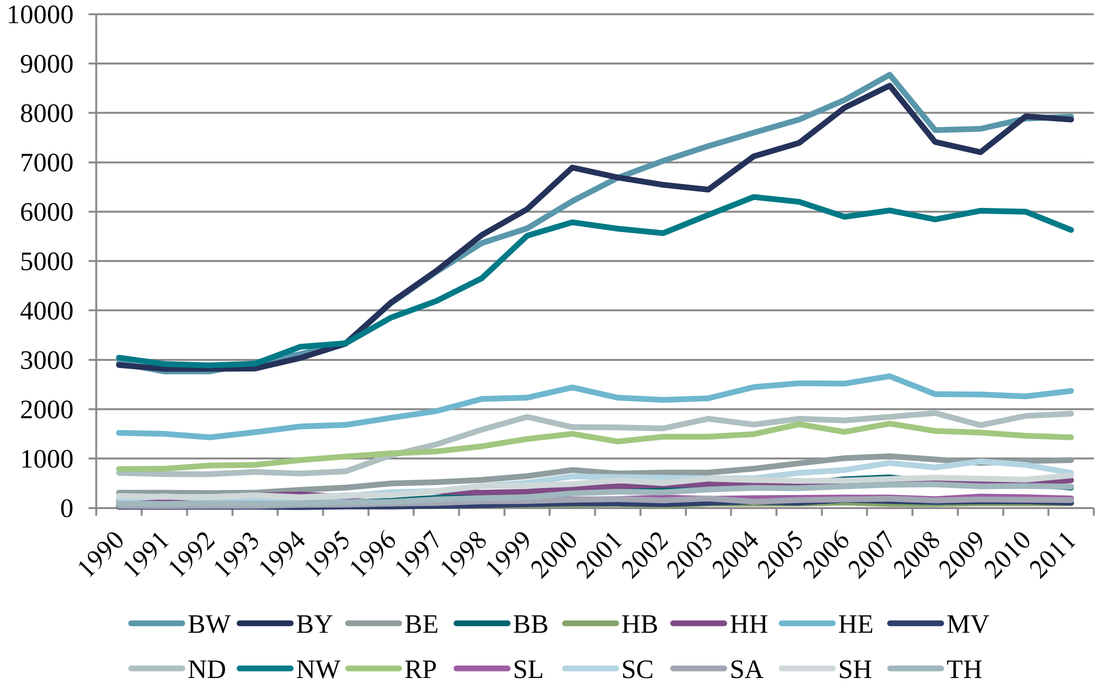


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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.

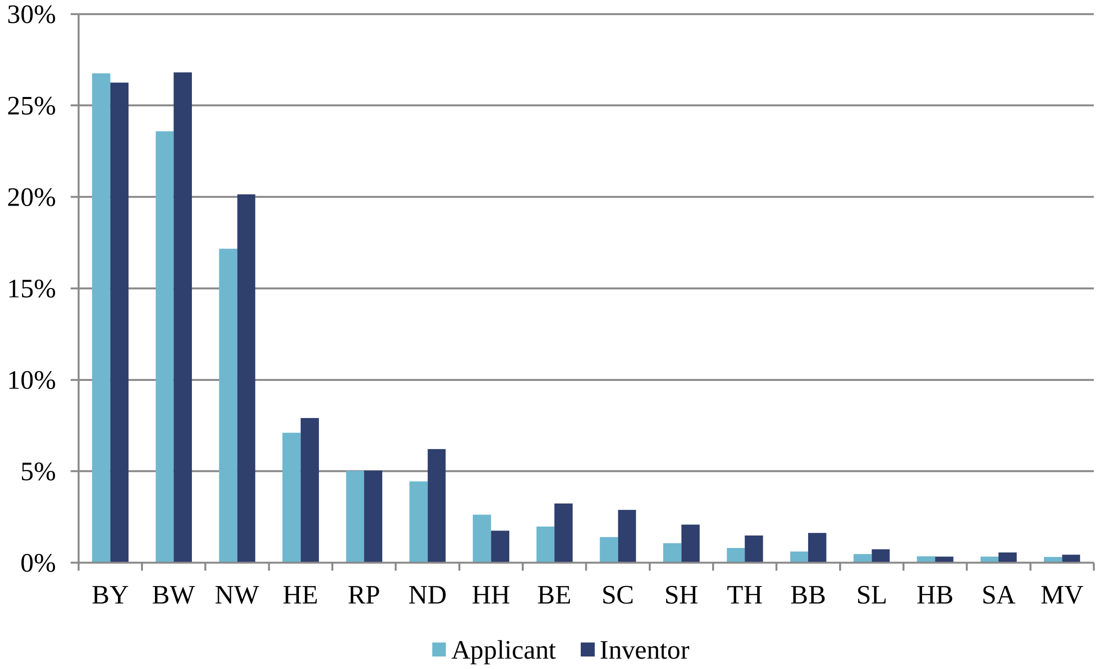
When comparing these numbers with Figure 11, where the absolute numbers of transnational patent filings based on the address of the inventor are plotted, the above mentioned commuter effect as well as the effect of decentralized research facilities becomes visible. Differentiated by inventor addresses, Baden-Württemberg scores above Bavaria in terms of the total number of filings. This can for example be attributed to the fact that the headquarters of the Siemens AG is located in Munich. The Siemens AG has decentralized R&D activities all over the country and is one of Germany's largest patent applicants. However, it files the majority of its patents via its Munich headquarters, implying that inventions made in different federal states are so to say "centralized" in Bavaria's capital. This, as well as to some extent the commuter effect, i.e. employees commuting from Baden-Württemberg to Bavaria, serves as an explanation for the difference in the figures. Depending on the perspective, either Baden-Württemberg or Bavaria score first within the German comparison in terms of absolute filings. A similar effect, yet less strongly pronounced, occurs for Lower-Saxony, which is also disadvantaged when looking at the applicant structure only.

Figure 11 Number of transnational filings by federal states, inventor principle



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Figure 12 Share of regional filings in total German transnational filings, 2009-2011



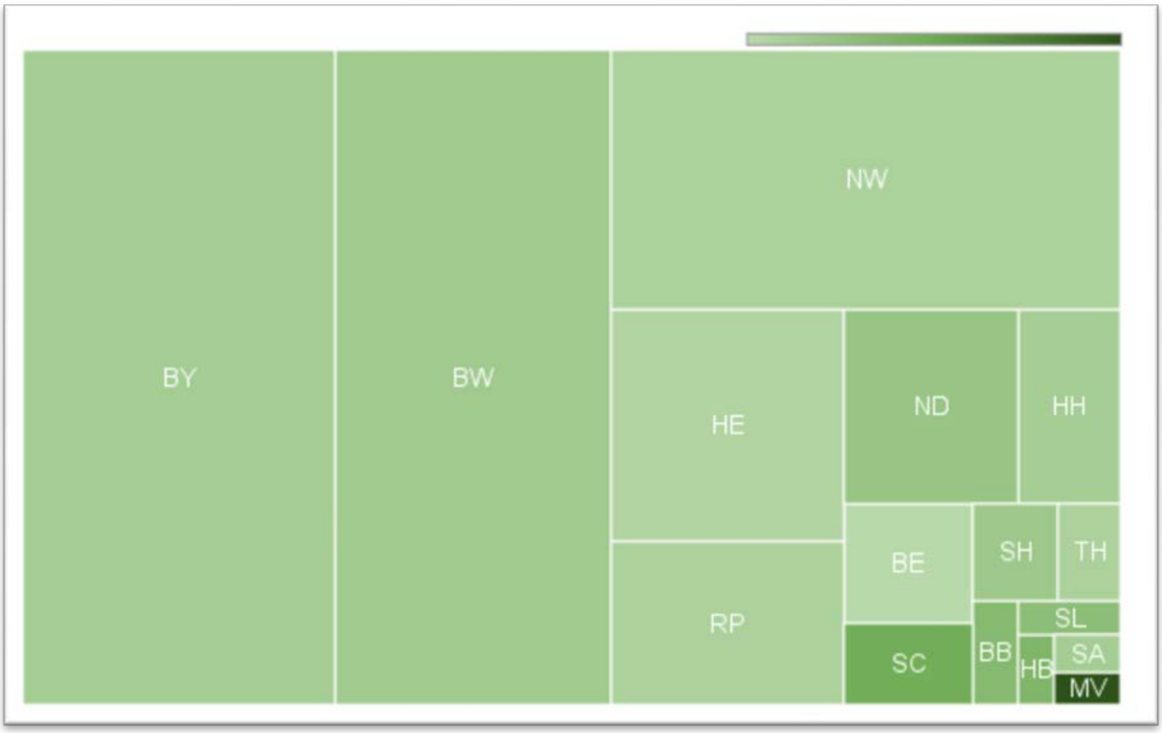
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Note: The differences between the inventor and the applicant principle do not exactly equal out since the basis of computation is slightly different, i.e. based on the applicant versus the inventor principle.

Digging deeper into the comparison between the applicant and the inventor principle, Figure 12 shows the share of regional filings in total German filings for the period 2009 to 2011 based on both, the applicant and the inventor address. Once again, it becomes obvious that Baden-Württemberg, Bavaria and North-Rhine Westphalia are responsible for the largest share of German filings. Here, we can also observe that most Northern and Eastern German states score at the lower ranks when looking at absolute and proportionate number of filings. The choice of perspective actually makes a difference for most of the German federal states. Hamburg and Bavaria are the two federal states that benefit most from the applicant centered view. In the case of Hamburg, this mostly can be attributed to commuter effects, i.e. people living in Schleswig-Holstein or Lower-Saxony and driving to work in Hamburg, whereas in Bavaria, as already discussed, the headquarters of the Siemens AG is located. The federal states that are most disadvantaged by the applicant centered view are Baden-Württemberg (as already discussed above), North-Rhine Westphalia, Lower-Saxony, Saxony and Berlin.

Figure 13 and Figure 14 provide a different view on the shares and growth rates of the filings of the German federal states by applicant (Figure 13) and inventor addresses (Figure 14). The size of the boxes within the figures indicate the share of the respective federal states, the color indicates the growth rate between the period 2000-2002 and the period 2009-2011.

Figure 13 Tree map for the shares (in total German filings) and growth of regional filings, applicant principle, 2009-2011

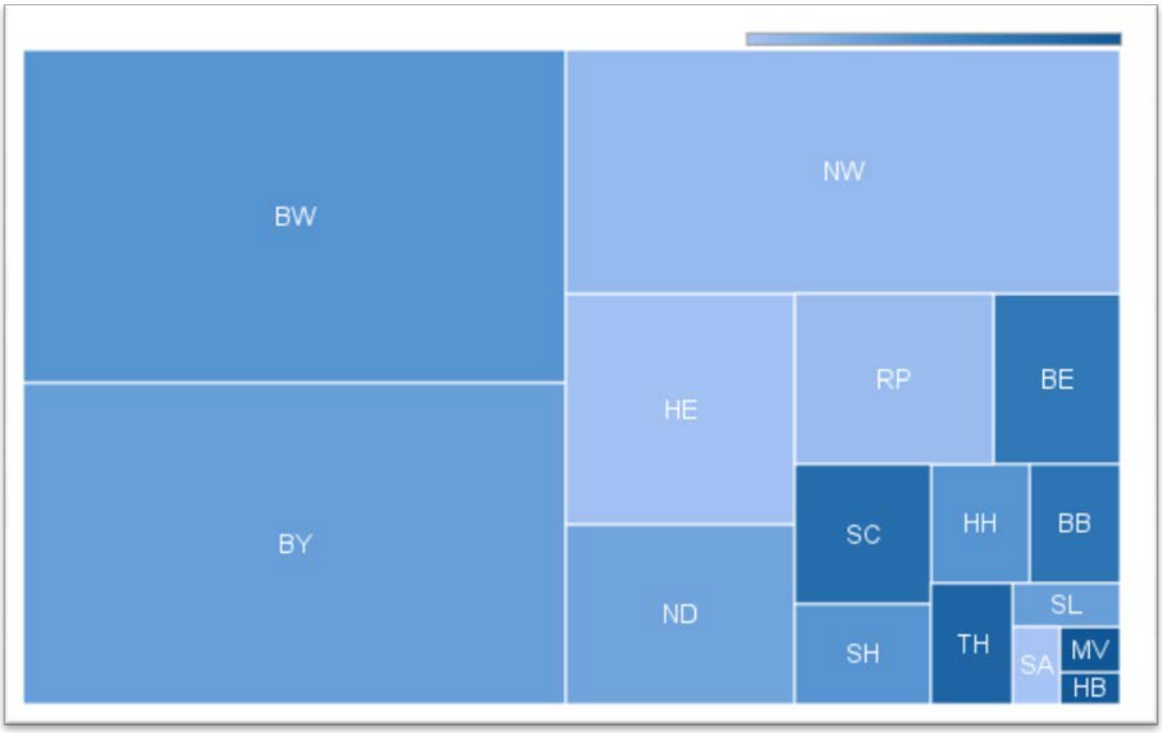


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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 from the period 2000-2002 to 2009-2011.

The respective shares have already been discussed in Figure 12. The growth rates, however, reveal several interesting results. From the applicant's perspective, Mecklenburg-West Pomerania has by far the largest growth in patent filings between the two time periods, followed by Saxony, Bremen and Brandenburg. It is thus mostly the Eastern German states who have the largest growth in patent filings. The three largest states in absolute terms, namely Bavaria, Baden-Württemberg and North-Rhine Westphalia only show moderate growth rates in comparison. The smallest growth rates can be observed for Berlin (here, the growth is even negative), Hessia, Thuringia and Rhineland-Palatinate. Once again, the inventor perspective shows a slightly different picture. The growth rates for the states located in Eastern Germany still are highest. Especially for Berlin, as well as Thuringia, however, by far higher growth rates can be observed when the inventor principle is applied. Taken together with the results from Figure 13, it thus seems that inventors from the Eastern German states are frequently commuting to their workplace in other federal states, for example from Thuringia to Bavaria. This might also help to explain the large difference between the applicant and the inventor centered perspective in the case of Bavaria and resembles to some extent the differences in the industry structure between south-western and north-eastern Germany.

Figure 14 Tree map for the shares (in total German filings) and growth of regional filings, inventor principle, 2009-2011



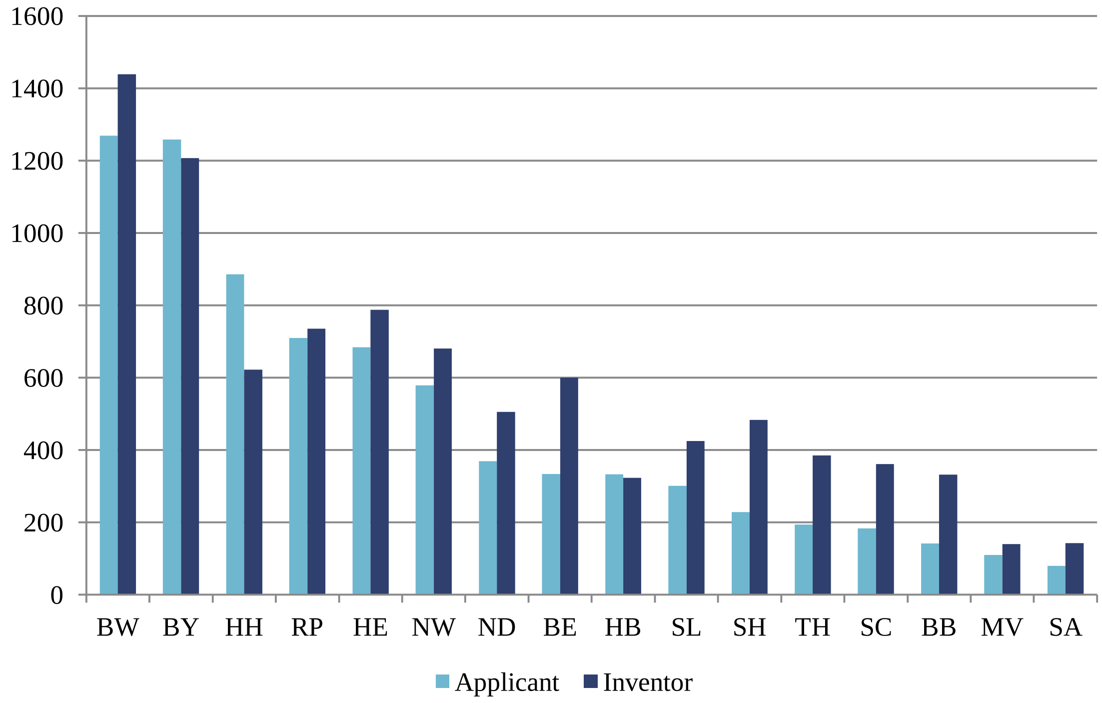
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

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 from the period 2000-2002 to 2009-2011.

In Figure 15, the patent intensities, calculated as the number of patent filings by a federal state divided by the number of employees in the respective state, are plotted. It can be found that Baden-Württemberg and Bavaria also score first on this indicator. North-Rhine Westphalia, on the other hand, which scored third in absolute terms, loses ground and is located in the medium ranks within this comparison. Hamburg scores third, followed by Rhineland-Palatinate and Hessia, which both are comparably patent intensive. The Eastern

German states have the lowest patent intensity in comparison, although, as already found above, seen from the inventor perspective, the eastern German states have managed to catch-up with the remainder of the federal states, which is especially true for Thuringia, Saxony and Brandenburg.

Figure 15 Patent intensities, per 1 million employees, 2011



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

5.2.2 Quantifying the commuter effect

In order to be better able to quantify the commuter effect, Table 5 provides the share of patent filings with an inventor from a "foreign" federal state and a "domestic" applicant in a federal state's total "domestic" applications. This indicator reflects the extent to which domestic firms control foreign inventions. It informs about the amount of inventors commuting from another federal state. In other words, it shows the "inflow" of inventors from other federal states. The table has to be read row-wise. The diagonal shows the share of patent filings for which the applicant and the inventor are located in the same federal state. The remainder of the respective row provides the percentage shares of patents with inventors from the respective federal states.

In Baden-Württemberg, for instance, 80% of all patent filings are owned by an applicant from Baden-Württemberg and have been filed by an inventor from Baden-Württemberg. The remaining 20%, which represents the SHAI, i.e. the extent to which domestic firms control foreign inventions, are divided among several federal states. The highest share of foreign inventors of patents owned by applicants from Baden-Württemberg comes from Bavaria (7%), followed by North-Rhine Westphalia (3%) and Rhineland-Palatinate (2%). This is not overly surprising since these are the federal states that share a border with Baden-Württemberg. This represents the commuter effect, with the largest number of inventors in Baden-Württemberg "flowing in" from Bavaria.

The SHAI values show that this effect is most strongly pronounced in Hamburg, Bremen, Mecklenburg-West Pomerania and Brandenburg. As for the city-states, this is also not a surprising result; also Berlin reaches rather high values on this indicator. This shows that many people are commuting to their workplace in the city from surrounding areas.

Table 5 Share of patent filings with an inventor from a "foreign" federal state and a "domestic" applicant (SHAI), 2009-2011

Applicant country		Inventor country																	
		BW	**BY**	**BE**	**BB**	**HB**	**HH**	**HE**	**MV**	**ND**	**NW**	**RP**	**SL**	**SC**	**SA**	**SH**	**TH**	**SHAI**	**Total**
	BW	**80%**	7%	1%	0%	0%	0%	2%	0%	2%	3%	2%	0%	1%	0%	0%	1%	20%	100%
	BY	9%	**70%**	3%	2%	0%	0%	2%	0%	2%	6%	1%	0%	3%	0%	0%	1%	30%	100%
	BE	4%	4%	**57%**	16%	0%	0%	2%	1%	2%	9%	1%	0%	3%	0%	0%	1%	43%	100%
	BB	1%	2%	27%	**49%**	0%	2%	3%	1%	3%	5%	1%	0%	3%	1%	2%	0%	51%	100%
	HB	2%	3%	0%	0%	**41%**	1%	1%	1%	41%	4%	0%	0%	2%	1%	2%	0%	59%	100%
	HH	2%	4%	1%	1%	3%	**40%**	1%	1%	12%	15%	0%	0%	1%	0%	20%	0%	60%	100%
	HE	5%	10%	1%	1%	0%	0%	**66%**	1%	2%	5%	5%	1%	2%	0%	0%	1%	34%	100%
	MV	1%	15%	7%	5%	0%	1%	1%	**46%**	6%	4%	1%	0%	3%	0%	10%	0%	54%	100%
	ND	4%	13%	2%	1%	0%	1%	5%	0%	**62%**	7%	1%	0%	1%	1%	1%	0%	38%	100%
	NW	3%	3%	2%	1%	0%	1%	3%	0%	3%	**79%**	2%	0%	1%	0%	1%	1%	21%	100%
	RP	19%	4%	1%	1%	0%	0%	7%	0%	3%	5%	**57%**	1%	1%	0%	0%	2%	43%	100%
	SL	7%	2%	0%	0%	0%	0%	2%	0%	0%	3%	11%	**74%**	0%	0%	0%	0%	26%	100%
	SC	3%	6%	2%	1%	0%	0%	3%	0%	1%	4%	0%	0%	**71%**	1%	0%	7%	29%	100%
	SA	5%	8%	5%	2%	0%	0%	1%	1%	5%	4%	0%	0%	11%	**57%**	0%	1%	43%	100%
	SH	1%	3%	1%	1%	0%	11%	2%	2%	3%	4%	1%	0%	1%	0%	**70%**	1%	30%	100%
	TH	9%	8%	1%	1%	0%	2%	1%	0%	5%	3%	1%	0%	3%	1%	0%	**65%**	35%	100%

Source: EPO – PATSTAT; calculations by Fraunhofer ISI

In Table 6, the share of patents with an inventor in the "domestic" federal state and an applicant from a "foreign" federal state in total filings of "domestic" inventors is presented. It mirrors the effects shown in Table 5 and reflects the extent to which firms from other federal states control "domestic" inventions and informs about the amount of inventors commuting to another federal state. In other words, it shows the "outflow" of inventors to other federal states. This table also has to be read row-wise. In the diagonal are the share of patent filings for which the inventor and the applicant are located in the same federal state. The values on the diagonal mostly are similar to the values reported in Table 5, yet they are not exactly the same. This is due to the fact the denominator is different in the two tables, i.e. patent filings based on the applicant or the inventor address, respectively.

Taking Baden-Württemberg once again as an example, 80% of all patent filings are filed by an inventor from Baden-Württemberg and owned by a local applicant. The highest share of foreign applicants is located in the adjacent Bavaria, followed by Rhineland-Palatinate and North-Rhine Westphalia. In the case of Bavaria, this might once again resemble the effect of the Siemens AG, in Rhineland-Palatinate, the location of the BASF AG at the border to Baden-Württemberg can explain this effect. We therefore now have a complete picture of the inflow of inventors to Baden-Württemberg as well as the outflow of inventors from Baden-Württemberg to other federal states.

Table 6 Share of patents with an inventor from the "domestic" federal state and an applicant from a "foreign" federal state (SHIA), 2009-2011

Inventor country	Applicant country																	
	BW	**BY**	**BE**	**BB**	**HB**	**HH**	**HE**	**MV**	**ND**	**NW**	**RP**	**SL**	**SC**	**SA**	**SH**	**TH**	**SHIA**	**Total**
BW	**80%**	10%	0%	0%	0%	0%	2%	0%	1%	2%	4%	0%	0%	0%	0%	0%	20%	100%
BY	8%	**82%**	0%	0%	0%	1%	3%	0%	3%	2%	1%	0%	0%	0%	0%	0%	18%	100%
BE	4%	29%	**37%**	8%	0%	1%	2%	1%	3%	12%	1%	0%	1%	1%	0%	0%	63%	100%
BB	5%	33%	21%	**22%**	0%	1%	4%	1%	2%	6%	1%	0%	1%	1%	1%	0%	78%	100%
HB	3%	13%	0%	0%	**50%**	20%	1%	0%	3%	8%	2%	0%	0%	0%	0%	0%	50%	100%
HH	4%	4%	0%	0%	0%	**67%**	1%	0%	3%	11%	0%	0%	0%	0%	8%	1%	33%	100%
HE	7%	7%	1%	0%	0%	0%	**67%**	0%	3%	9%	4%	0%	1%	0%	0%	0%	33%	100%
MV	3%	11%	3%	3%	1%	11%	6%	**39%**	4%	6%	3%	0%	2%	1%	7%	0%	61%	100%
ND	8%	9%	1%	0%	3%	6%	3%	0%	**54%**	12%	3%	0%	0%	0%	1%	1%	46%	100%
NW	4%	9%	1%	0%	0%	2%	2%	0%	2%	**77%**	2%	0%	0%	0%	0%	0%	23%	100%
RP	11%	6%	0%	0%	0%	0%	8%	0%	1%	10%	**61%**	1%	0%	0%	0%	0%	39%	100%
SL	12%	12%	0%	0%	0%	0%	10%	0%	1%	3%	4%	**58%**	0%	0%	0%	0%	42%	100%
SC	7%	26%	2%	1%	0%	1%	3%	0%	2%	6%	2%	0%	**47%**	1%	0%	1%	53%	100%
SA	10%	12%	1%	1%	0%	0%	5%	0%	9%	8%	5%	0%	2%	**44%**	0%	1%	56%	100%
SH	4%	3%	0%	1%	1%	31%	0%	2%	2%	9%	0%	0%	0%	0%	**46%**	0%	54%	100%
TH	11%	18%	1%	0%	0%	1%	5%	0%	1%	7%	4%	0%	9%	0%	1%	**41%**	59%	100%

Source: EPO – PATSTAT; calculations by Fraunhofer ISI

The SHIA values are highest in northern and eastern Germany, i.e. Brandenburg, Berlin, Mecklenburg-West Pomerania, Thuringia, Saxony-Anhalt and Schleswig Holstein. Especially the cases of Brandenburg and Mecklenburg-West Pomerania are interesting, as we can observe a high inflow of inventors (compare Table 5) as well as a high outflow. In Brandenburg, the location of Berlin might serve as an explanation for the effect, i.e. employees commuting to their workplace to and from Berlin.

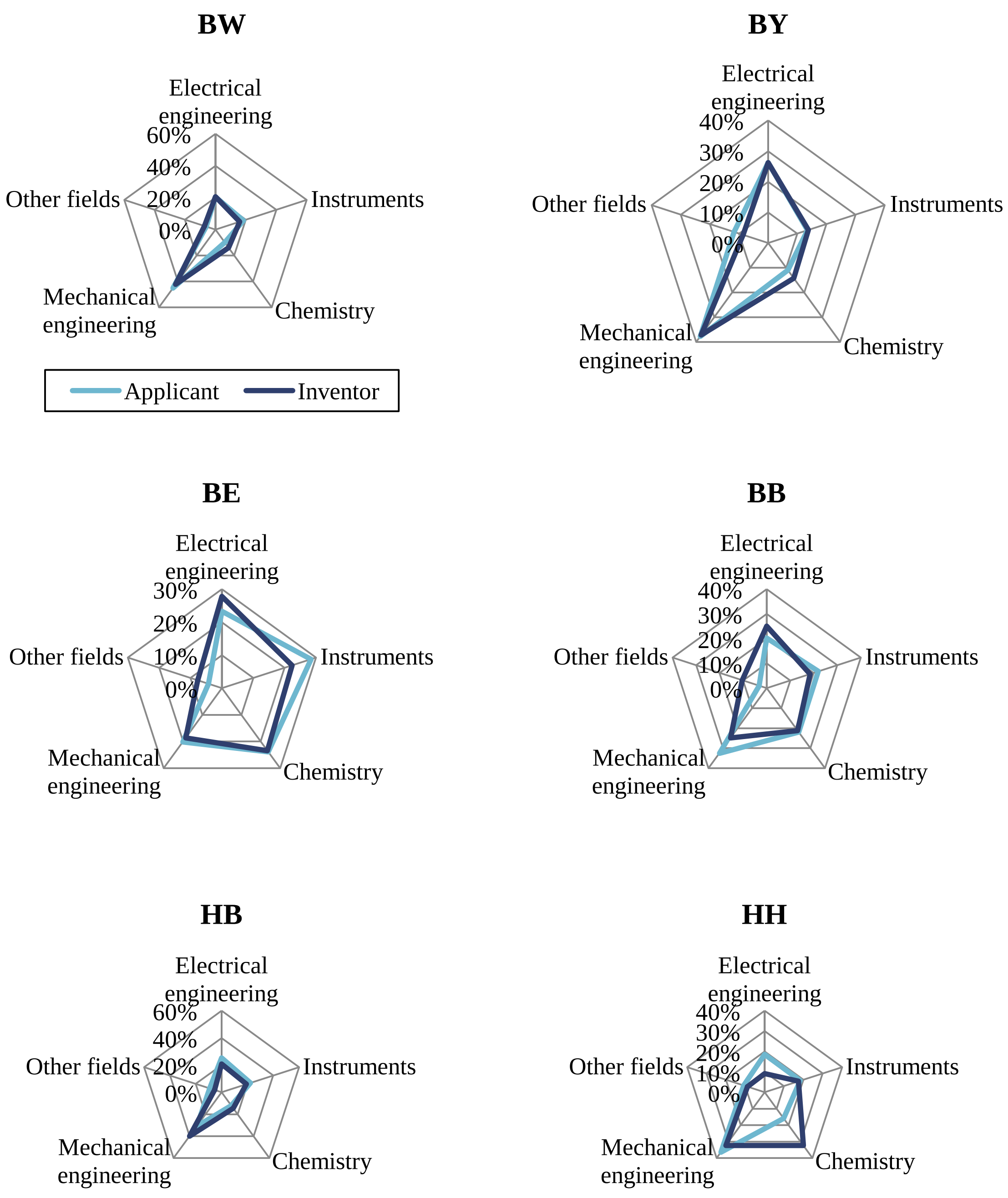
5.2.3 The technological profiles of the "Bundesländer"

Within this subsection, the technological profiles of the German federal states are presented. They are calculated as the share of filings in a given technology field in total transnational filings from the respective federal state. The technology field classification is an aggregate of the WIPO list of 35 technology fields based on Schmoch (2008). The technological profiles are provided in Figure 16 and always show the profile based on the addresses of the patent applicant and inventors, respectively.

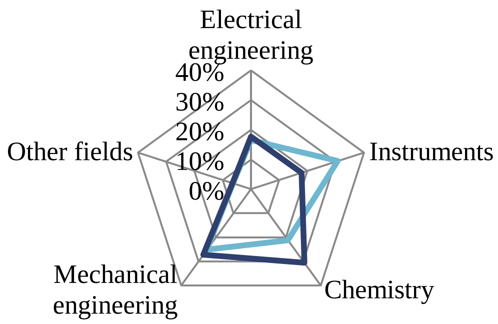
In the technological profile of Baden-Württemberg, the differentiation of applicant and inventor addresses mostly shows an influence in chemistry patents. Clearly, the profile of

Baden-Württemberg is dominated by the field of mechanical engineering, followed by electrical engineering and instruments. A similar profile can be found for Bavaria, although the field of electrical engineering is more prominent. In Berlin, on the other hand, the profile is rather balanced. Mechanical engineering, chemistry and instruments reach similar shares, with electrical engineering being a little more in the focus. When applying the applicant instead of the inventor principle, we can observe a slight shift from electrical engineering to the instruments field.

Figure 16 Technological profiles of the federal states, 2009-2011



HE



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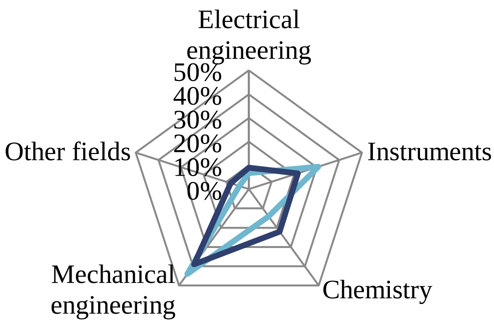
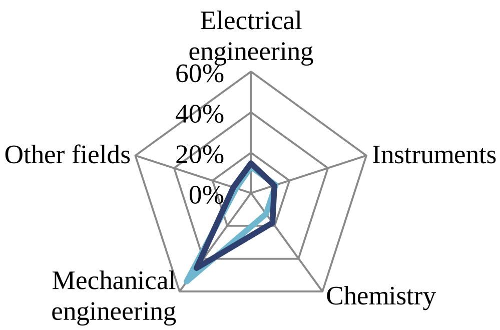


ND



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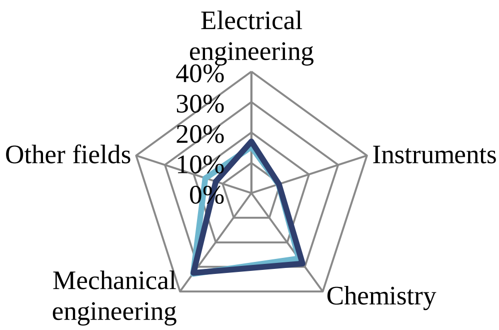
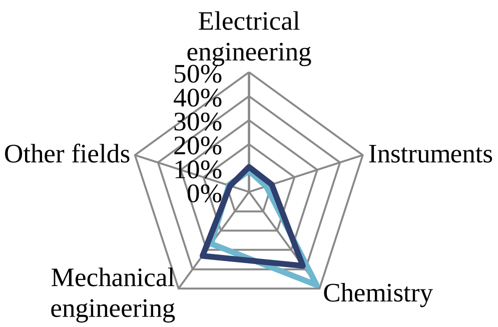
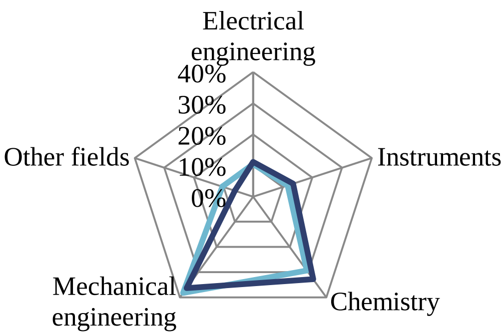


RP



SL



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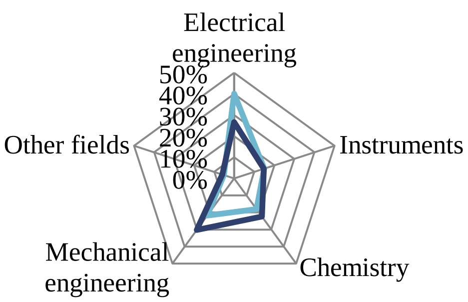
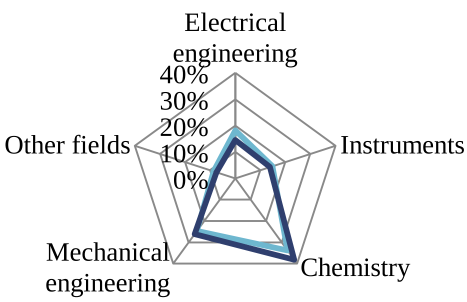
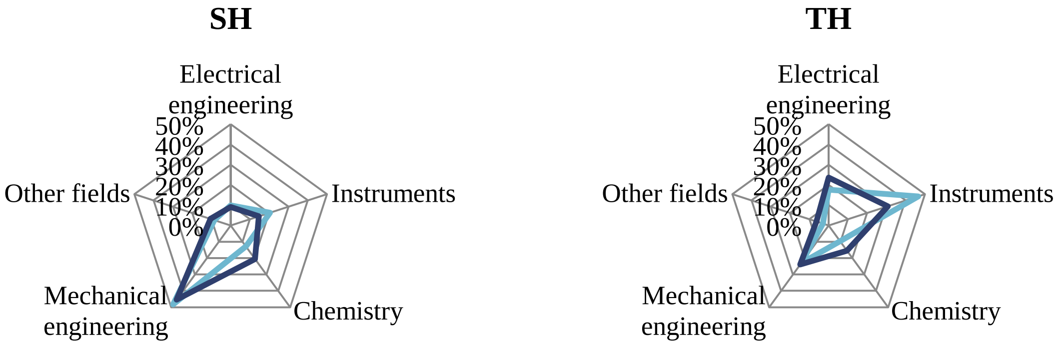


SA





Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Brandenburg also shows a rather balanced portfolio in the inventor centered view. Seen from the applicant perspective, however, a focus on mechanical engineering can be found. In *Bremen*, the application of the applicant or the inventor perspective does not make a difference for the technological profile. It is focused on mechanical engineering and followed by electrical engineering and closely resembles the profile of Baden-Württemberg. In *Hamburg*, on the other hand, the field composition is rather heavily affected by the chosen perspective. This makes sense, since Hamburg has a high inflow of inventors from other federal states. Seen from the inventor's perspective, the highest shares in Hamburg can be observed in mechanical engineering and chemistry. From the applicant perspective, however, we see a shift from chemistry to electrical engineering. The industry structure in Hamburg and the surrounding areas can explain this effect. In Hamburg, many mechanical and electrical engineering firms, like for example the Airbus Operations GmbH, the Deutsche Lufthansa AG or the Deutsche Bahn AG are located, which drive the profile from an applicant perspective. North of Hamburg, in Schleswig-Holstein, however, chemistry parks, like the "Chemiepark Brunsbüttel" are located, where firms like the Drägerwerk AG Co. KGaA, Johnson & Johnson Medical GmbH or AstraZeneca GmbH, are active. In *Hessia*, a similar effect can be observed, although the shift from chemistry is directed towards the instruments field. The profile of *Mecklenburg-West Pomerania* is mostly centered on the fields of mechanical engineering as well as instruments, which is even more prominent from the applicant's perspective. In *Lower-Saxony*, the field of mechanical engineering is very dominant. The profile once again resembles the profile of Baden-Württemberg and Bremen. The profile of *North Rhine-Westphalia* is focused on mechanical engineering and chemistry, followed by electrical engineering and instruments. Hereby, the differentiation by applicant or inventor principle carries no weight. *Rhineland-Palatinate* is somehow a special case within Germany. It shows a large focus on chemistry, especially when seen from the applicant's perspective. This can mostly be attributed to the BASF AG, one of the largest German patent applicants, who has its headquarters in Ludwigshafen, close to the border of Baden-Württemberg. The technological profile of the *Saarland* is very similar to the profile of North-Rhine Westphalia. The focus here lies on mechanical engineering and chemistry. In *Saxony*, on the other hand, the profile is centered on the electrical engineering field, which becomes even more pronounced when the applicant perspective is taken into account. Here, a shift from mechanical engineering to electrical engineering can be observed. The adjacent *Saxony-Anhalt* has a completely different structure with a focus set clearly on chemistry. *Schleswig-Holstein* is mostly centered on mechanical engineering, followed by chemistry or instruments, depending on the perspective. Finally, *Thuringia* is the only federal state with a very clear focus on instruments, especially from the applicant's perspective. This can mostly be attributed to the Carl Zeiss Group, which operates many facilities and subsidiaries in Jena.

In sum, the German focus on mechanical engineering is clearly resembled in the profiles of its federal states. Although the field composition differs across the "Bundesländer", each having its own peculiarities, the field of mechanical engineering is highly prominent in nearly all of the federal states' technological profiles.

5.3 Conclusions

In this section, we have provided regional patent statistics for the German "Bundesländer". The main issues that had to be tackled were the commuter effect, i.e. employees commuting to their workplace in other federal states, which might induce a bias in the statistics depending on the perspective (applicant vs. inventor centered) and the fact that some large, decentralized companies file their patents via their headquarter location. In order to cope with these challenges, we have calculated our statistics based on the applicant as well as the inventor perspective and applied the SHIA and SHAI indicators, developed by Guellec und van Pottelsberghe de la Potterie (2001; 2004), to address these problems. This allowed us to quantify the commuter effect and get a detailed overview of the regional composition of the German innovation landscape.

The south of Germany, especially Baden-Württemberg and Bavaria, file the largest number of patents at the transnational level, and, together with North-Rhine Westphalia, account for about two thirds of the German transnational filings, while accounting for only about the half of the employees in Germany. Baden-Württemberg and Bavaria also show the highest patent intensities within the German comparison. The Northern and Eastern German states score at the lower ranks when looking at absolute and proportionate numbers of filings, although the federal states in these areas generally show higher growth rates than the southern and western states.

We also found that the choice of perspective actually makes a difference for most of the German federal states. Hamburg and Bavaria benefit most from the applicant centered view, whereas Baden-Württemberg, North-Rhine Westphalia, Lower-Saxony, Saxony and Berlin score higher ranks when the inventor centered perspective is applied. The SHIA values are able to additionally provide information about the amount of inventor flows between federal states. The values are highest in northern and eastern Germany, i.e. Brandenburg, Berlin, Mecklenburg-West Pomerania, Thuringia, Saxony-Anhalt and Schleswig

Holstein. The SHAI values, on the other hand, provide information about the inflow of inventors, which is most strongly pronounced in Hamburg, Bremen, Mecklenburg-West Pomerania and Brandenburg.

Finally, disaggregating the statistics by technology fields offered technology profiles of the German "Bundesländer". The German focus on mechanical engineering is clearly resembled in the profiles of its federal states. The field composition is different across the "Bundesländer". Considerable activities in mechanical engineering can be found in nearly all of the federal states' technological profiles.

6 Trends in European Trademark Filings

In quantitative innovation research, trademarks are more and more extensively used to measure innovation activities, especially in service sectors (Gauch 2007). Particularly at the micro level, the relationship between trademarks and innovation activity has been well established (Greenhalgh and Rogers 2006; Sandner and Block 2011). Trademarks not only protect products, like for example technical equipment or technical procedures. Services are also eligible for protection within the system of trademark rights. Accordingly, trademarks can be used as a complementary, close to the market indicator for new products as well as an indicator of innovation activities in the service sector (Gauch 2007; Mendonca et al. 2004; Schmoch 2014). Trademarks as innovation indicators gain additional relevance through the fact that services are not protectable via patents and a registration of copyrights is not possible in many jurisdictions (Schmoch 2003). Especially in the case of knowledge-intensive business services trademarks have shown to be well applicable (Schmoch and Gauch 2009) and can also be seen as a valuable complement within a firm's IPR portfolio (Sandner and Block 2011).

There are various ways to obtain trademark protection. In order to achieve protection in Germany, for instance, a registration at the German Patent and Trademark Office (GPTO) is possible. Alternatively, the registration of a Community Trademark (CTM), which is valid across the EU, or the registration of an international trademark at the WIPO, which is valid in all countries who have signed the Madrid Protocol, are possible ways to achieve trademark protection in Germany. Among formal instruments of intellectual property protection, trademarks are in widespread use. All "tokens", e.g. words, pictures, that are suitable to distinguish a company's goods or services from those of other companies are eligible for protection. These can for example be words, individual letters, numbers, pictures, colors and even acoustic signals. Trademarks are valid for ten years after filing and can be renewed indefinitely (Deutsches Patent- und Markenamt (DPMA) 2008; Graham and Harhoff 2006).

Upon receipt of an application of a trademark at the OHIM, for example, the trademark will be processed. This step includes classification of the trademark according to the NICE classification, check of formalities, a check of the trademark "on absolute grounds", i.e. the trademark is analyzed to see whether it is distinctive but not descriptive, 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 (Office for the Harmonization of the Internal Market (OHIM) 2014). This means that, different to patents, trademarks are not content certified. Only formal criteria are checked upon filing. The pursuit of potential violations or infringements of registered trademark rights lies 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 OHIM (Office for the Harmonization of the Internal Market (OHIM) 2014).

In the following, we will compare trademark filings across major industrialized countries to analyze basic structures of services and product-related services based on trademark indicators. For this purpose, CTMs filed at the OHIM are investigated.

6.1 Methods & Classifications

The database used for our analyses is the trademark register of the GPTO ("DPMAregister"), which covers all filings of CTMs filed directly at the OHIM. Since the DPMAregister is an online database, access is far less comfortable and provides significantly smaller analytical potential than for example, the PATSTAT database. The data must be searched manually certain indicators or methodological re-calculations, like fractional counting to avoid double counts, are not possible. This has to be kept in mind for the interpretation of trademarks differentiated by NICE classes.

The NICE classification is an international classification of goods and services applied for the registration of trademarks consisting of 45 classes. It has been established by the Nice Agreement in 1957. Classes 1 to 34 refer to goods, classes 35 to 45 to services. The classes define the scope and the context of each application and are provided by the applicants themselves. Three classes are covered by the application fee, additional classes are subject to additional fees (Office for the Harmonization of the Internal Market (OHIM) 2014), which is why the classification to NICE classes offers only limited insight. A description of the content of the trademark, like an abstract or even a description, 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" or "technological height". While for patents the formal criterion of inventive step is reviewed by the patent examiners, i.e. a patent must go beyond the 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. The multiple assignments of NICE classes to trademarks furthermore implies that double counts occur when differentiating trademarks based on NICE classes, i.e. the sum over classes exceeds 100%.

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 can be regarded as research-intensive services. In the case of products, we will concentrate on eight fields that have been defined as having high technology relatedness (Schmoch 2003). 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

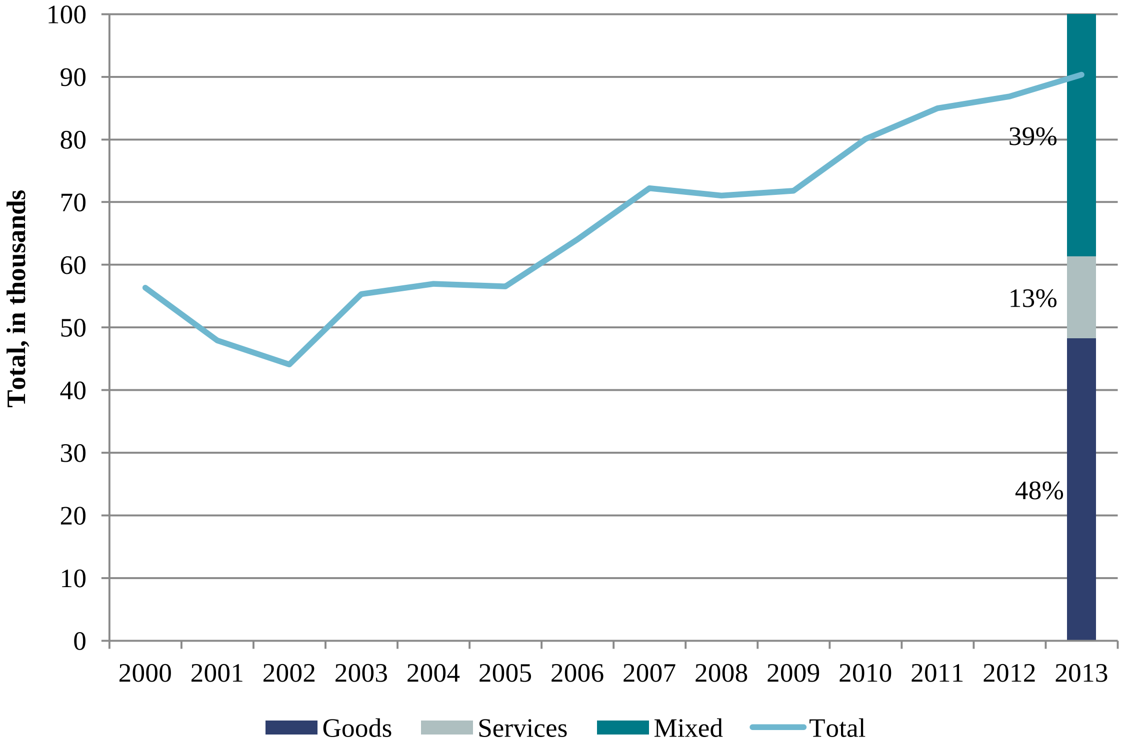
Source: Schmoch (2003)

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 for CTM applications are offered.

6.2 Results

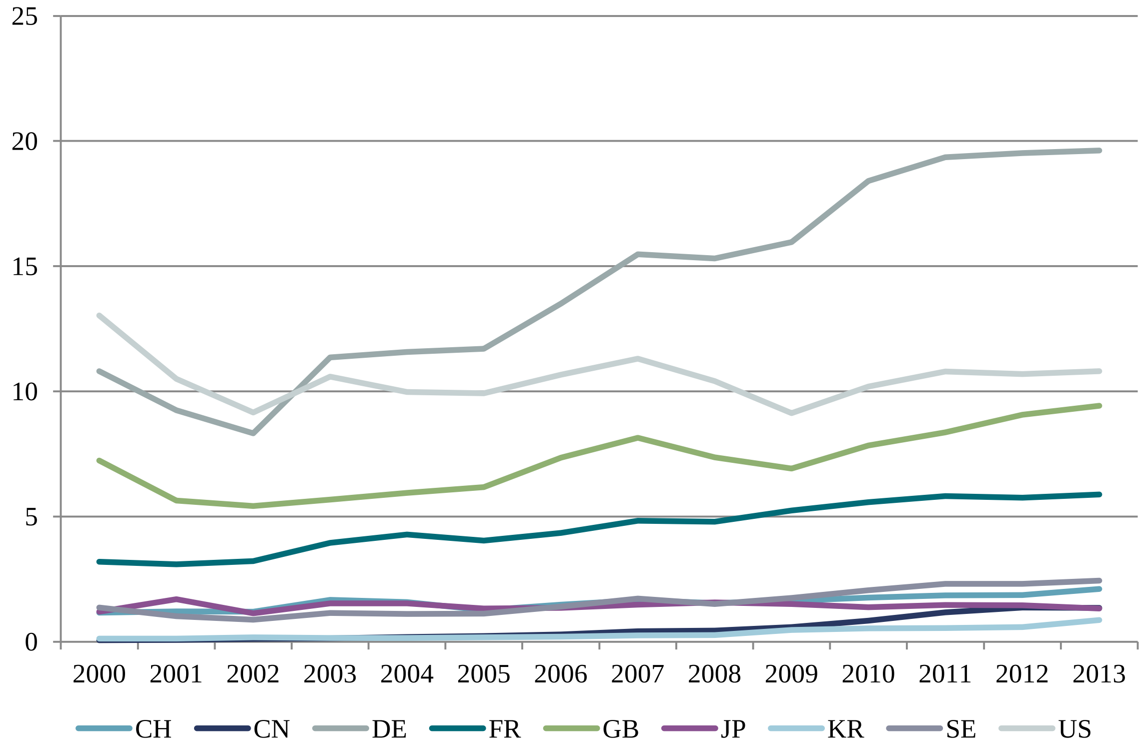
The absolute number of CTM filings from the year 2000 onwards is plotted in Figure 17. In the year 2013, about 90,000 filings in total have reached the OHIM. Since 2000, a mostly increasing trend in filings can be observed. However, we find a decline in the numbers between the years 2001 and 2002 as well as the 2008 and 2009. It therefore seems that not only patent filings but also trademark applications were negatively affected by the financial crises in the respective years. Besides the overall trend, the figure also provides information on the shares of trademark filings by types for the year 2013. In total, 48% of the trademarks filed in 2013 are product marks, whereas 39% are mixed product/service marks and the remaining 13% are pure service marks. The mixed marks, however, can mostly be seen as "product-related", i.e. the product is in the foreground, as mostly manufacturing firms are filing marks on goods. The additional filing of a service mark thereby represents product related services, which have gained increased importance within the manufacturing sectors over the last decade (Schmoch 2003).

Figure 17 Absolute number of CTM filings and shares by trademark types, 2000-2013



Source: DPMAregister; calculations by Fraunhofer ISI

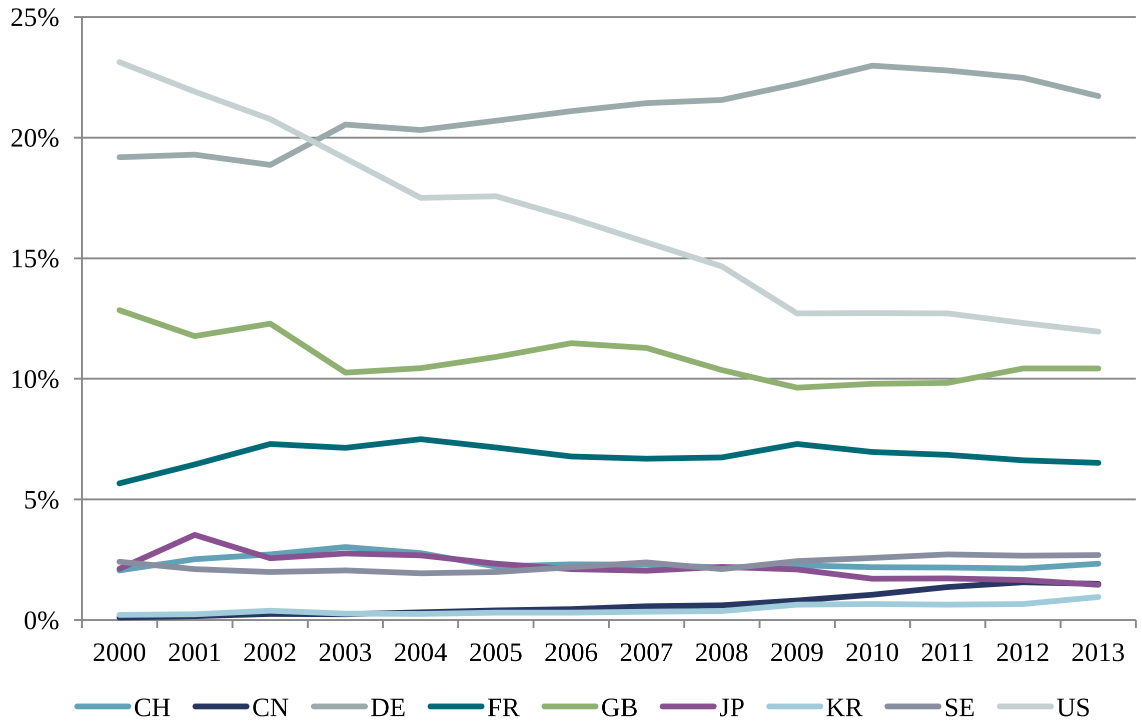
Figure 18 Absolute number of CTM filings for selected countries, 2000-2013



Source: DPMAregister; calculations by Fraunhofer ISI

The differentiation of the absolute number of CTM filings by countries is provided in Figure 18. Since the year 2000, the trademark filings by German applicants have constantly grown, with the number of filings exceeding the numbers of US applicants from 2003 onwards. In 2013, German applicants have filed nearly 20,000 trademarks, which is twice as much as the US, which scores second with about 10,000 filings per year.[4] Following the US are Great Britain and France with about 9,500 and 6,000 filings in 2013, respectively. These four countries are followed by a group of smaller countries in terms of trademark filings. Since 2005, the Swedish and especially the Chinese filings have grown rather rapidly, although stagnation in Chinese filings can be observed between 2012 and 2013.

Figure 19 Shares in CTM filings for selected countries, 2000-2013



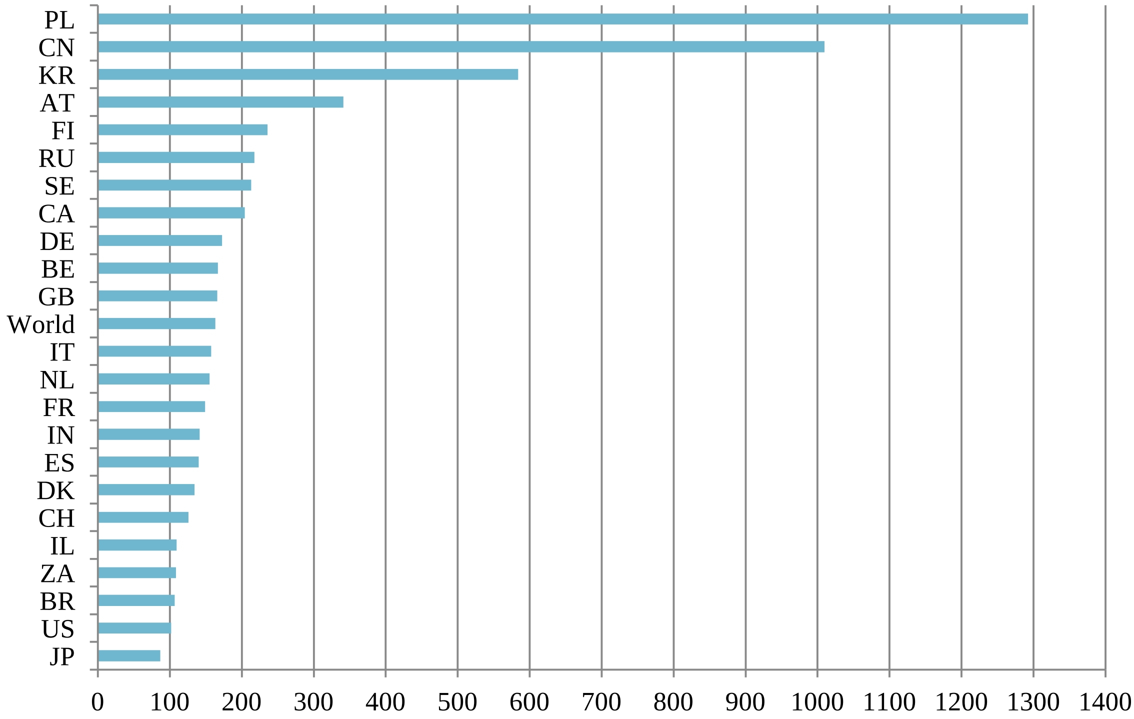
Source: DPMAregister; calculations by Fraunhofer ISI

The country specific shares in filings reveal a similar picture (Figure 19). Germany is responsible for 22% of all trademark filings at the OHIM. Between 2004 and 2010 Germany could constantly increase its shares. Since 2010, however, especially the growth of Chinese filings leads to a slight decline in German shares as well as the ones of other countries. Although following a constantly declining trend regarding the shares in trademark filings, the US is the second largest trademark applicant, being responsible for about 12% of all filings at the OHIM. In the year 2000, however, this share was about 23%. As we have seen in Figure 18, this is not due to a decline in the absolute numbers of filings from the

4 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.

US, since these have remained constant over the years, but can be explained by the fact that most of the countries under analysis have increased their absolute filing numbers, leading to declining shares for US applicants. Great Britain makes up for about 10% of all OHIM filings, with a slight growth in filing numbers after a decline during 2007 and 2010. France, which is responsible for a share of 7%, shows a very constant trend over the years. The remainder of the countries is responsible for less than 3% of trademark filings at the OHIM per year.

Figure 20 Growth index in CTM filings for selected countries between 2003 and 2013 (2003=100)

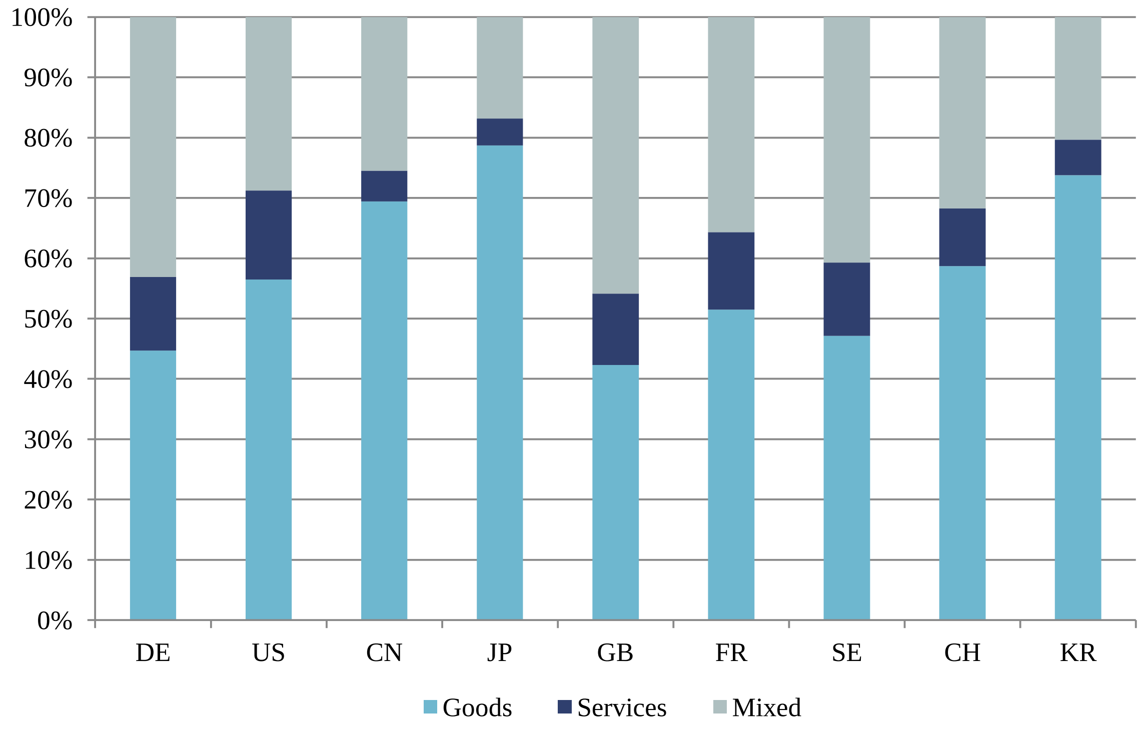


Source: DPMAregister; calculations by Fraunhofer ISI

The largest growth in CTM filings between 2003 and 2013 can be observed for applicants from Poland and China. Both countries file more than ten times as many trademarks at the OHIM than in the year 2000, where, however, both countries started from a rather low level of 30 and 60 filings, respectively. Also filings from Korea and Austria have grown massively above average. German applicants are in the midfield in terms of growth of CTM filings in the last decade, reaching values slightly above average. Interestingly, the growth figures for the US and Japan are rather low. This might have to do with the fact that non-European applicants might more frequently use the Madrid system for their trademark filings, directly designating the national level with their trademark filings. It might, however, also resemble a tendency to not file so many trademarks in Europe. Yet, the final explanation here remains speculative to a certain degree with the numbers at hand. More in-depth analyses, including additional data from the WIPO, would be necessary to get more detailed information.

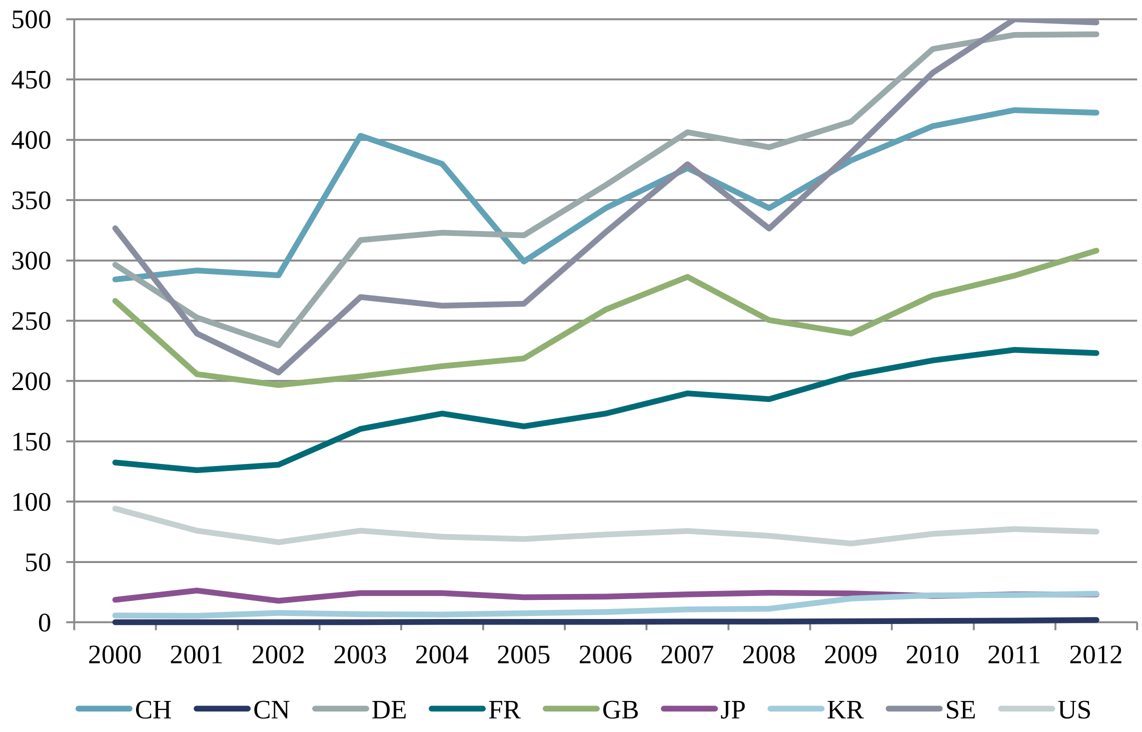
The differentiation of country-specific CTM filings by trademark type is plotted in Figure 21. Here, we can observe differences in the trademark portfolios of the given countries. Especially the Asian states, Japan, Korea and China, have very high shares of product marks in CTM filings, reaching nearly 80% in the case of Japan. Only 4% to 6% of CTMs from these countries are pure service marks. A high share of product marks can also be found for the US, where, however, the share of service marks still lies around 15%. The lower shares of service marks from non-European countries at the OHIM can however also 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 OHIM, this helps to explain the low shares of the non-European countries. The portfolios of Germany, Sweden, France and Switzerland are rather balanced and mostly resemble the average portfolio, i.e. around 50% product marks, 15% service marks and 30% to 40% mixed marks. Great Britain is the only country in this comparison with shares of service marks exceeding 45%. This clearly resembles the industry structure of Great Britain, which is very much oriented towards services.

Figure 21 Shares of trademark types within the countries' portfolios, 2013



Source: DPMAregister; calculations by Fraunhofer ISI

Figure 22 Trademark intensities (CTM filings per 1m employment), 2000-2012



Source: DPMAregister; calculations by Fraunhofer ISI

Further interesting trends can be revealed when looking at the development of trademark intensities for selected countries between 2000 and 2012. 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. As can be observed in Figure 22, Sweden is very trademark intensive, closely followed by Germany, which had the highest intensities in CTM filings until the year 2010. This is due to the above-average growth of the trademark intensity for Swedish applicant between 2008 and 2011.

Ranking third on the trademark intensity measure within this comparison is Switzerland, where also a large growth in the recent years could be observed. Great Britain and France, scoring fourth and fifth within this comparison, also show high growth rates in trademark intensities in the last few years. The large countries in terms of employees, i.e. the US and China, rank lower on this indicator. Per employee, especially China files comparably few CTMs. What we can also see in the figure is the downturn of the trademark intensity during the crisis of 2008 and 2009. For most countries, the trademark intensity in these years has declined, probably due to cost-saving strategies of the firms. After this decline, however, the numbers have again increased and now mostly score higher than in the years before the crisis.

The trademark intensities are further differentiated by trademark types in Table 8. Since this table covers more countries than Figure 22, we can first of all observe that Austria has an even slightly higher trademark intensity than Sweden. The Asian countries and the BRICS countries have the smallest trademark intensities with regard to CTM filings. In terms of product marks, Switzerland, Sweden, Austria, Germany and Denmark show the highest trademark intensities. With regard to service marks, Austria also shows the highest intensities, followed by Spain, Sweden and Germany. The intensities for mixed service/product marks also are highest for Austria, Spain, Sweden and Germany. All in all, these four countries can be seen as the most trademark-intensive at the OHIM within the countries under comparison.

Table 8 Trademark intensities (CTM filings per 1m employment) and shares of trademarks by types, 2013

Country	Total	Goods		Services		Mixed	
AT	585	224	38%	109	19%	252	43%
SE	523	246	47%	64	12%	213	41%
DE	490	219	45%	60	12%	211	43%
CH	478	281	59%	46	10%	152	32%
DK	434	220	51%	45	10%	168	39%
ES	430	130	30%	68	16%	231	54%
FI	427	178	42%	52	12%	197	46%
NL	368	159	43%	51	14%	158	43%
BE	339	132	39%	57	17%	150	44%
IT	326	194	59%	31	9%	102	31%
GB	320	135	42%	38	12%	147	46%
FR	228	117	51%	29	13%	81	36%
PL	141	58	41%	19	13%	64	46%
US	76	43	56%	11	15%	22	29%
IL	72	43	59%	10	14%	19	27%
CA	67	30	45%	11	16%	27	40%
KR	35	26	74%	2	6%	7	20%
JP	21	17	79%	1	4%	4	17%
ZA	15	11	72%	1	7%	3	20%
BR	3	2	51%	1	17%	1	32%
CN	2	1	69%	0	5%	0	25%
RU	1	1	44%	0	7%	1	49%
IN	1	1	53%	0	11%	0	35%

Source: DPMAregister; calculations by Fraunhofer ISI

Table 9 presents the shares of CTM filings in total filings at the OHIM for Germany, the US and China disaggregated by single NICE classes. Across nearly all NICE classes, the German shares exceed 20%, while the US shares are mostly located in the range of 10% to 15%. Chinese shares are comparably low across classes, ranging mostly between 1% and 3%. With regard to the classes with high technology relatedness, i.e. NICE classes 1 to 14, the highest shares for German applicants can be found for "Common metals and their alloys", "Machines and machine tools; motors and engines (except land vehicles)" and "Hand tools and implements (hand-operated)".

Table 9 Shares of filings in total filings by country and NICE class, 2013

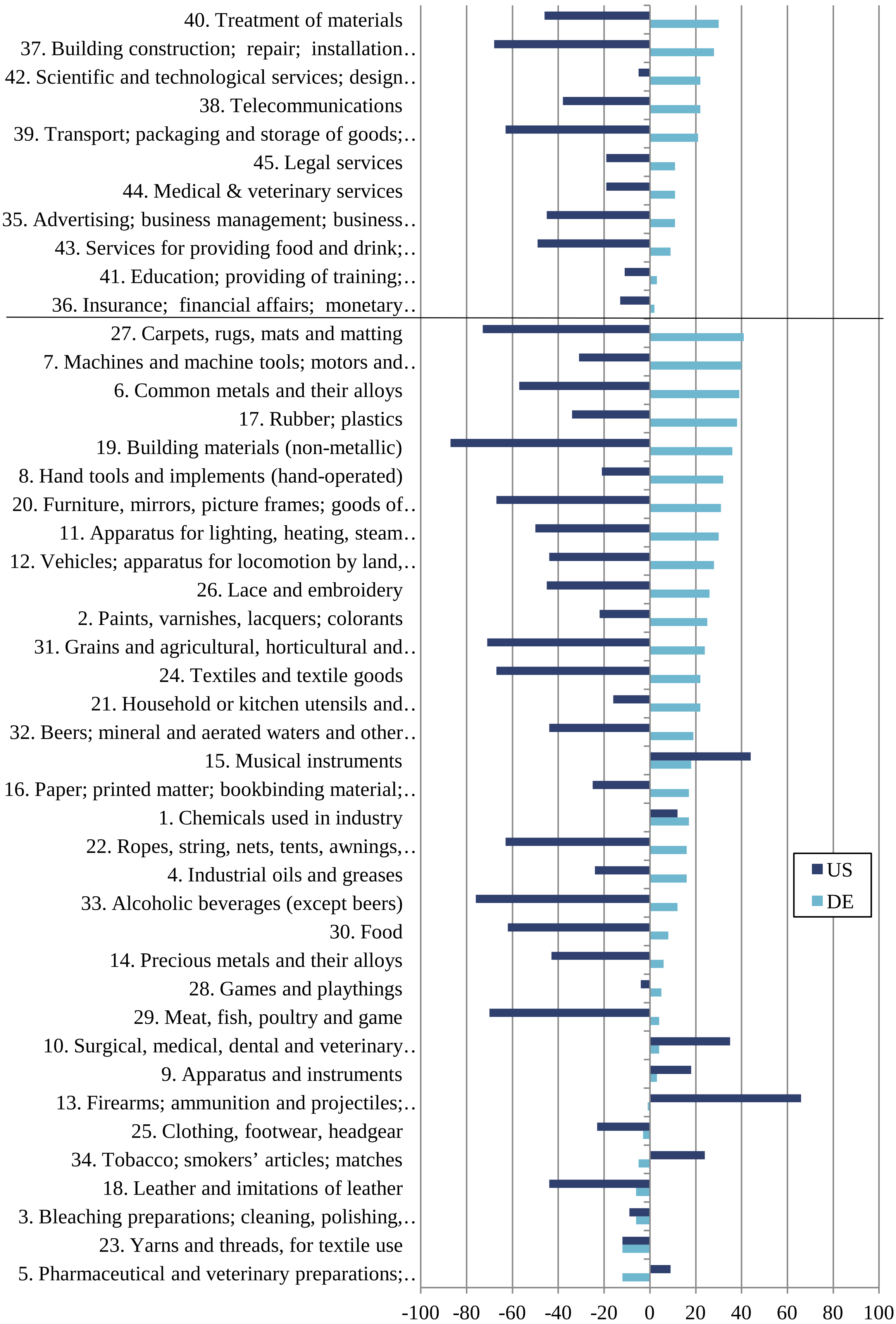
NICE class	DE	US	CN
1. Chemicals used in industry	26%	14%	1%
2. Paints, varnishes, lacquers; colorants	28%	10%	1%
3. Bleaching preparations; cleaning, polishing, scouring; cosmetics	20%	11%	1%
4. Industrial oils and greases	25%	9%	1%
5. Pharmaceutical and veterinary preparations; fungicides, herbicides	19%	13%	1%
6. Common metals and their alloys	33%	6%	2%
7. Apparatus for lighting, heating, steam generating, cooking, refrigerating	33%	9%	3%
8. Hand tools and implements (hand-operated)	30%	10%	2%
9. Apparatus and instruments	22%	14%	2%
10. Surgical, medical, dental and veterinary apparatus and instruments	23%	17%	2%
11. Apparatus for lighting, heating, steam generating, cooking, refrigerating	30%	7%	3%
12. Vehicles; apparatus for locomotion by land, air or water	29%	7%	3%
13. Firearms; ammunition and projectiles; explosives; fireworks	22%	26%	1%
14. Precious metals and their alloys	23%	8%	2%
15. Musical instruments	26%	19%	2%
16. Paper; printed matter; bookbinding material; photographs	26%	9%	1%
17. Rubber; plastics	32%	8%	1%
18. Leather and imitations of leather	20%	7%	2%
19. Building materials (non-metallic)	32%	3%	2%
20. Furniture, mirrors, picture frames; goods of wood, cork,	30%	5%	2%
21. Household or kitchen utensils and containers; glassware	27%	10%	2%
22. Ropes, string, nets, tents, awnings, tarpaulins, sails, sacks and bags	26%	6%	3%
23. Yarns and threads, for textile use	19%	11%	4%
24. Textiles and textile goods	27%	5%	2%
25. Clothing, footwear, headgear	21%	9%	2%
26. Lace and embroidery	28%	7%	3%
27. Carpets, rugs, mats and matting	34%	5%	1%
28. Games and playthings	23%	11%	2%
29. Meat, fish, poultry and game	23%	5%	1%
30. Food	24%	6%	1%
31. Grains and agricultural, horticultural and forestry	28%	5%	1%
32. Beers; mineral and aerated waters and other non-alcoholic beverages	26%	7%	1%
33. Alcoholic beverages (except beers)	25%	4%	1%
34. Tobacco; smokers' articles; matches	21%	15%	3%
35. Advertising; business management; business administration	24%	7%	1%
36. Insurance; financial affairs; monetary affairs; real estate affairs	22%	11%	0%
37. Building construction; repair; installation services	29%	5%	1%
38. Telecommunications	27%	8%	1%
39. Transport; packaging and storage of goods; travel arrangement	27%	6%	1%
40. Treatment of materials	30%	7%	1%
41. Education; providing of training; entertainment; sporting	22%	11%	0%
42. Scient. and technol. services; design and dev. of computer hard- and software	27%	11%	1%
43. Services for providing food and drink; temporary accommodation	24%	7%	1%
44. Medical & veterinary services	24%	10%	0%
45. Legal services	24%	10%	0%

Source: DPMAregister; calculations by Fraunhofer ISI

In the case of the US, the classes, "Firearms; ammunition and projectiles; explosives; fireworks", "Surgical, medical, dental and veterinary apparatus and instruments" and "Apparatus and instruments" reach the highest shares. Chinese shares are highest in "Vehicles; apparatus for locomotion by land, air or water", "Apparatus for lighting, heating, steam generating, cooking, refrigerating" and "Apparatus for lighting, heating, steam generating, cooking, refrigerating". This pretty much resembles the picture we can also observe for these countries in terms of patent filings. Germany reaches highest shares in the fields of machines and metals, while the US is more focused on chemistry, pharmaceuticals, medical technologies as well as electronics. Chinese shares are highest in the fields of electronic devices, vehicles and machines. With regard to the knowledge-intensive business services, Germany shows the largest shares in "Treatment of materials", "Scientific and technological services; design and development of computer hard- and software" and "Telecommunications", while the US, besides having highest shares also in "Scientific and technological services;..." seems more focused on " Insurance; financial affairs; monetary affairs; real estate affairs" and "Education; providing of training; entertainment; sporting".

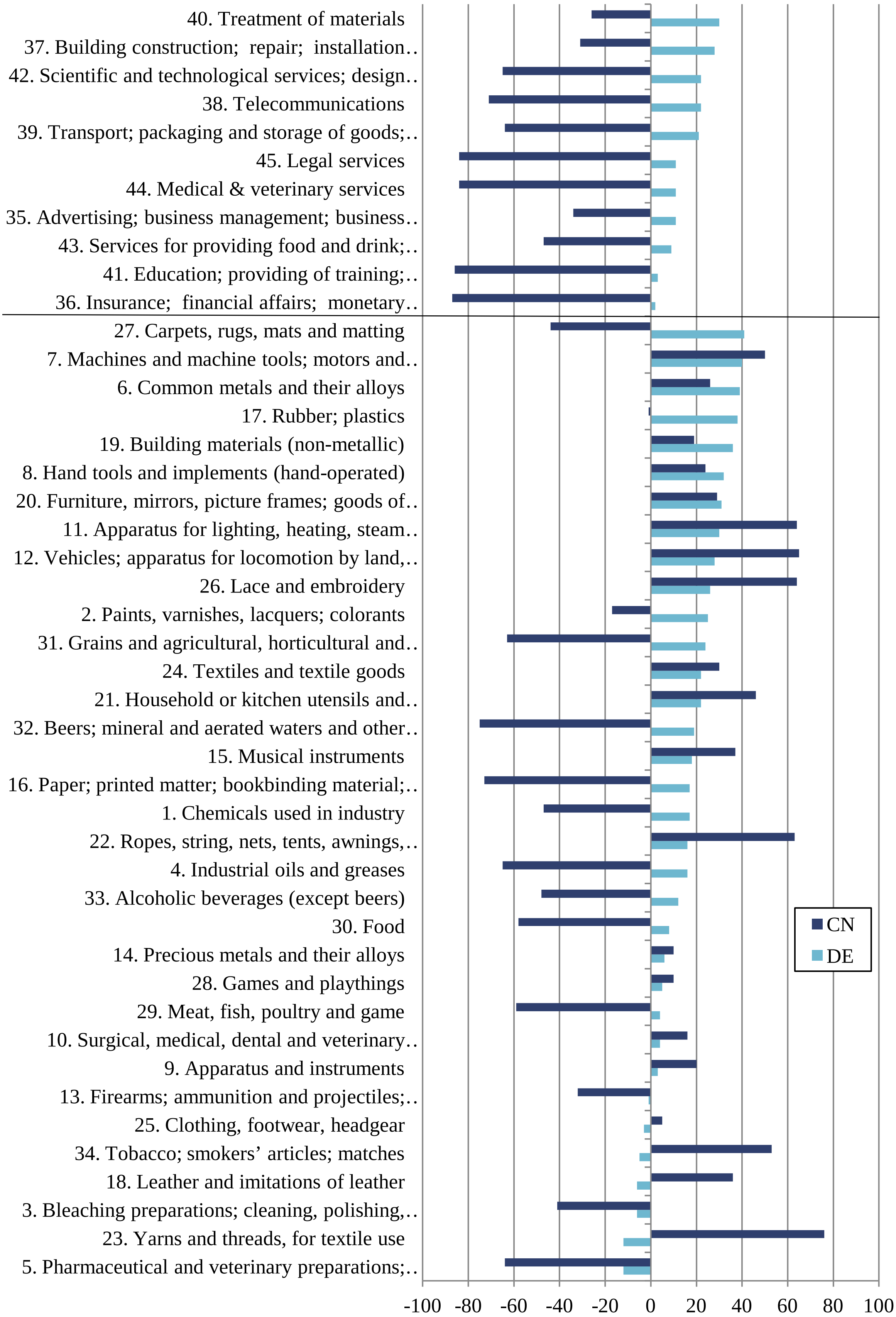
A closer look at the specialization index of the three countries (Figure 23 and Figure 24) further supports these findings. Germany shows high specialization rates in terms of trademarks across most of the NICE classes. The US, on the other hand, mostly shows negative specialization values. Highest specializations for the US in fields with high technology relatedness can be observed in chemistry and related fields. For Germany, specialization values are highest in fields related to machines and metals. As already stated above, the specialization profile of China more closely resembles the German profile than the US profile, i.e. rather high specialization in machines and vehicles but also in fields related to electronic devices, especially in product marks. In terms of service marks, the Chinese specialization profile is mostly negative. With regard to products, this can on the one hand be seen as a challenge for German firms in terms of increased competition, although the absolute levels of Chinese trademark filings targeting the European market are still comparably low, but on the other hand also as a chance through increased collaboration and trade potential.

Figure 23 CTM related profiles Germany and the US, 2013



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Figure 24 CTM related profiles Germany and China, 2013



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

6.3 Conclusions

In this section, we have explored structures and trends in Community Trademark filings across countries and fields. Although statistical trademark analyses are associated with pitfalls regarding data availability, the classification system and the content certification of trademark filings, trademarks are able to act as a complementary innovation indicator to patents, which can be seen as more close to commercialization also covering innovative activities in the service sectors (Gauch 2007).

The results of our analyses show an increase in trademark filings over the last decade, with slowdowns visible during the economic crises in 2000/2001 and 2008/2009 and growth afterwards. This is in line with earlier arguments that firms apply cost-saving IPR strategies during economic crises (Neuhäusler et al. 2014) and resembles the trends we also find when looking at the number of patent filings. Overall, the largest share of trademark filings is related to products and product related services. However, also pure service marks have gained increased attention. About 13% of all filings are filings of service marks. The country-specific trends show that Germany is the largest trademark applicant at the OHIM, followed by the US, Great Britain and France. The absolute number of filings from the US is rather constant over time. However, due to an increase in the number of filings from other countries, including new players such as China and Korea, which show extremely high growth rates, the US shares have steeply decreased over the years. Also the patterns in trademark types are differing across countries. For the Asian countries in our sample, a clear trend towards filing product marks is visible. The share of service marks and marks for product related services are rather low for these countries. Yet, we have already discussed that this might at least partly be explained by the fact that trade with services across national borders is much more uncommon for services than for products, which might explain the low-shares of non-European countries when analyzing filings that target the European market. The largest share of service marks can be found for Great Britain, where the industry is rather oriented towards services.

In terms of trademark intensities, i.e. trademarks per million employees, the smaller countries like Austria, Sweden, Switzerland and Denmark, but also Germany show the highest 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 CTMs, which, by nature, are Europe centered.

The differentiation by NICE classes reveals that Germany has a positive specialization in most of the fields. Yet, a clear specialization to the fields related to machines and metals can be observed. The US is more focused on chemistry, pharmaceuticals, medical technologies as well as electronics. Although the absolute levels of Chinese trademark filings targeting the European market are still comparably low, the specialization profile of China with regard to product marks more closely resembles the German profile than the US profile, i.e. rather high specialization in machines and vehicles but also in fields related to electronic devices, especially in product marks.

7 References

ADL (Ed.) (2005): *The internationalisation of R&D in the UK*, Report for the DTI/OST, November 2005, Ref. 20547, 117 pages.

Belitz, H. (2012): *Internationalisierung von Forschung und Entwicklung in multinationalen Unternehmen*. Berlin: EFI.

Belitz, H., Edler, J. and Grenzmann, C. (2006): Internationalisation of Industrial R&D. In: Schmoch, U., Rammer, C. and Legler, H. (Eds.): *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*. Dordrecht: Springer.

Deutsches Patent- und Markenamt (DPMA) (2008): Marke. Online: http://www.dpma.de/marke/index.html (accessed 12-06-2008).

Ernst, D. (2006): *Innovation Offshoring - Asia's Emerging Role in Global Innovation Networks*, East-West Center Special Reports. Honolulu, Hawaii: East-West Center.

Frame, J.D. and Carpenter, M.P. (1979): International research collaboration. *Social Studiesof Science*, 9, 481-497.

Fraunhofer ISI, Idea Consult and SPRU (2009): *The Impact of Collaboration on Europe's Scientific and Technological Performance*. Karlsruhe, Brussels, Brighton.

Freeman, C. (1982): *The Economics of Industrial Innovation*. London: Pinter Publishers.

Frietsch, R., Neuhäusler, P., Jung, T. and van Looy, B. (2014): Patent indicators for macroeconomic growth - The value of patents estimated by export volume. *Technovation*, 34, 546-558.

Frietsch, R. and Schmoch, U. (2010): Transnational Patents and International Markets. *Scientometrics*, 82, 185-200.

Frietsch, R. (2004): *Entwicklung der internationalen Wissenschaftskooperationen*, Studien zum deutschen Innovationssystem Nr. 11-2004. Berlin.

Frietsch, R., Koschatzky, K. and Weertman, N. (2010): *Strategische Forschung 2010: Studie zur Struktur und Dynamik der Wissenschaftsregion Baden-Württemberg*: Fraunhofer Verlag, Stuttgart.

Gauch, S. (2007): Marken als Innovationsindikator: Fraunhofer-Institut für System- und Innovationsforschung ISI.

Gehrke, B., Frietsch, R., Neuhäusler, P., Rammer, C. and Leidmann, M. (2013): *Re-definition of research-intensive industries and goods - NIW/ISI/ZEW-Lists 2012* (= Studien zum deutschen Innovationssystem No. 8-2013). Berlin: Expertenkommission Forschung und Innovation (EFI).

Glänzel, W. and Schubert, A. (2004): Analysing Scientific Networks Through Co-Authorship. In: Moed, H., Glänzel, W. and Schmoch, U. (Eds.): *Handbook of quantitative science and technology research. The use of publication and patent statistics in studies of S&T systems*. Dordrecht: Kluwer Academic Publishers, 257-276.

Graham, S.J.H. and Harhoff, D. (2006): *Can Post-Grant Reviews Improve Patent System Design? A Twin Study of US and European Patents*: Governance and the Efficiancy of Economic Systems (GESY).

Greenhalgh, C. and Rogers, M. (2006): The value of innovation: The interaction of competition, R&D and IP. *Research Policy*, 35, 562-580.

Griliches, Z. (1981): Market Value, R&D and Patents. *Economics Letters*, 7, 187.

Griliches, Z. (1990): Patent statistics as economic indicators: a survey. *Journal of Economic Literature*, 18, 1661-1707.

Grupp, H. (1998): *Foundations of the Economics of Innovation - Theory, Measurement and Practice*. Cheltenham: Edward Elgar.

Guellec, D. and Pluvia Zuniga, M. (2007): Globalisation of technology captured with patent data. A preliminary investigation at the country level. In: Statistics Sweden (Ed.): *Productivity Yearbook 2006*.

Guellec, D. and van Pottelsberghe de la Potterie (2001): The internationalisation of technology analysed with patent data. *Research Policy*, 30, 1253-1266.

Guellec, D. and van Pottelsberghe de la Potterie, B. (2004): Measuring the Internationalization of the Generation of Knowledge: An approach based on patent data. In: Moed, H.F., Glänzel, W. and Schmoch, U. (Eds.): *Handbook of Quantitative Science and Technology Research. The Use of Publications and Patent Statistics in Studies of S&T Systems*. Dordrecht: Kluwer Academic Publisher, 1-15.

Hoekman, J., Frenken, K. and Tijssen, R.J.W. (2010): Research collaboration at a distance: Changing spatial patterns of scientific collaboration within Europe. *Research Policy*, 39, 662-673.

Hong, W.A. and Su, Y.-S.B. (2012): The effect of institutional proximity in non-local university-industry collaborations: An analysis based on Chinese patent data. *Research Policy*, (in press).

Katz, J.S. (1994): Geographical proximity and scientific collaboration. *Scientometrics*, 31, 31-43.

Liu, H.I., Chang, B.C. and Chen, K.C. (2012): Collaboration patterns of Taiwanese scientific publications in various research areas. *Scientometrics*, 92, 145-155.

Luukkonen, T., Persson, O. and Sivertsen, G. (1992): Understanding patterns of international scientific collaboration. *Science, Technology and Human Values*, 17, 101-126.

Luukkonen, T., Tijssen, R.J.W., Persson, O. and Sivertsen, G. (1993): The Measurement of International Scientific Collaboration. *Scientometrics*, 28, 15-36.

Mattsson, P., Laget, P., Nilsson, A. and Sundberg, C.J. (2008): Intra-EU vs. extra-EU scientific co-publication patterns in EU. *Scientometrics*, 75, 555-574.

Mendonca, S., Pereira, T.S. and Godinho, M.M. (2004): *Trademarks as an Indicator of Innovation and Industrial Change*, LEM Working Paper Series No. 2004/15. Pisa: Laboratory of Economics and Management Sant'Anna School of Advanced Studies.

Moed, H.F., Glänzel, W. and Schmoch, U. (Eds.) (2004): *Handbook of Quantitative Science and Technology Research. The Use of Publications and Patent Statistics in Studies of S&T Systems*. Dordrecht: Kluwer Academic Publisher.

Narin, F., Stevens, K. and Whitlow, E.S. (1991): Scientific co-operation in Europe and the citation of multinationally authored papers. *Scientometrics*, 21, 313-323.

Neuhäusler, P., Frietsch, R. and Rothengatter, O. (2014): *Patent Applications - Structures, Trends and Recent Developments 2013* (= Studien zum deutschen Innovationssystem No. 4-2014). Berlin: Expertenkommission Forschung und Innovation (EFI).

Neuhäusler, P., Rothengatter, O. and Frietsch, R. (2013): *Patent Applications - Structures, Trends and Recent Developments* (= Studien zum deutschen Innovationssystem No. 5-2012), Expertenkommission Forschung und Innovation (EFI) (Hrsg.). Berlin.

Office for the Harmonization of the Internal Market (OHIM) (2014): Registration Process. Online: https://oami.europa.eu/ohimportal/en/registration-process, last accessed: 29.09.2014.

Patel, P. and Vega, M. (1999): Patterns of internationalisation of corporate technology: location vs. home country advantages. *Research Policy*, 28, 145-155.

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

Polanyi, M. (1985): *Implizites Wissen*. Frankfurt am Main: Suhrkamp.

Sandner, P.G. and Block, J. (2011): The market value of R&D, patents, and trademarks. *Research Policy*, 40, 969-985.

Schasse, U., Kladroba, A. and Stenke, G. (2012): *Forschungs- und Entwicklungsaktivitäten der deutschen Wirtschaft*. Berlin: EFI.

Schmoch, U. (2014): Knowledge transfer from German universities into the service sector as reflected by service marks. *Research Evaluation*, 23 (2014), 341-351.

Schmoch, U. and Gauch, S. (2009): Service marks as indicators for innovation in knowledge-based services, 18, 323-335.

Schmoch, U. (2003): Service marks as novel innovation indicator. *Research Evaluation*, 12, 149-156.

Schmoch, U. (2005): *Leistungsfähigkeit und Strukturen der Wissenschaft im internationalen Vergleich*, Studien zum deutschen Innovationssystem Nr. 6-2005. Berlin.

Schmoch, U. (2006): Scientific Performance in an International Comparison. In: Schmoch, U., Rammer, C. and Legler, H. (Eds.): *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*. Dordrecht: Springer, 69-88.

Schmoch, U. (2008): *Concept of a Technology Classification for Country Comparisons. Final Report to the World Intellectual Property Office (WIPO)*. Karlsruhe: Fraunhofer ISI.

Schmoch, U. and Hinze, S. (2004): Opening the Black Box. In: Moed, H.F., Glänzel, W. and Schmoch, U. (Eds.): *Handbook of Qualitative Science and Technology Research. The Use of Publication and Patent Statistics in Studies of S&T Systems*. Dordrecht: Kluwer Academic Publishers, 215-235.

Schubert, A. and Braun, T. (1990): World flash on basic research: international collaboration in the Sciences, 1981-1985. *Scientometrics*, 19, 3-10.

Schubert, T., Rammer, C., Frietsch, R. and Neuhäusler, P. (2013): *Innovationsindikator 2013*. Bonn: Deutsche Telekom Stiftung.

von Proff, S. and Dettmann (2013): Inventor collaboration over distance: a comparison of academic and corporate patents. *Scientometrics*, 94, 1217-1238.

Weissenberger-Eibl, M., Frietsch, R., Hollanders, H., Neuhäusler, P., Rammer, C. and Schubert, T. (2011): *Innovationsindikator*. Bonn: Deutsche Telekom Stiftung.