Patent Applications – Structures, Trends and Recent Developments

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0. Summary

Transnational patent applications

During the economic crisis of the years 2008 and 2009 the number of international patent filings has decreased for most countries. This is due to the fact that many companies – which are responsible for the largest share of patent applications – decided not to follow the international patenting route, or not to publish their filings at all. Since applicants have one year time to decide if they should file a national patent also internationally, the decreasing number of patent filings can already be observed for the data starting of the priority year 2007, i.e. this has a retrospective effect on the data.

The impact of the crisis is especially visible in countries that are very active in the USA – including the USA themselves – where the crisis had its point of departure, which gives rise to also analyze patent applications at the USPTO in more detail in this year's report. Countries like Germany and Japan, on the other hand, do not show direct effects, although a slightly decreasing trend can be observed also for these two countries especially in 2008. However, for the year 2010, the decreasing trend seems to have an end for most of the countries and the numbers seem to stabilize, yet mostly at a lower level than in the years 2005 and 2006 before the financial crisis.

Taking a closer look at the technologies, the role of transnational patenting in high-tech is very stable, also in a long-term perspective. High-tech patents reach an almost constant rate of about 55% in total worldwide patenting, although some of the countries underwent a strict change of their profile in this respect. Italy, for example, has constantly lost ground in high-tech patenting since the beginning of the 1990s. In the years 2008 to 2010, Germany, Switzerland and to some extent also Sweden are the only countries that show a strict focus on high-level technologies, while most of the other countries – especially the new entrants – target leading-edge technologies.

When comparing the country specific technology profiles of Germany and the USA it can be found that they are largely opposite to each other. While Germany has a strong focus on transport, machinery and electrical engineering (power machines and power generation), the USA are mostly focused on life sciences and computers. Yet, when analysing the change of the two profiles in the recent decade, we can see that the distinction of the profiles might be becoming blurred and that the competition between these countries – as well as with many other competitors – may further increase in the future.

Patent Applications at the USPTO

The patent applications at the USPTO were also affected by the economic crisis. The absolute numbers for some countries stagnated or even decreased already in the priority year 2007. At latest in 2008, however, the effects are clearly visible for all countries. Yet, similar to the transnational trend, the decrease in USPTO applications seems to have an end for most of the countries and the numbers seem to stabilize. Also similar to the transnational patenting trends, Chinese applications are still growing, in 2010 again at a slightly faster pace than in the years 2007 and 2008. This means that China is able to outperform most of the other countries in terms of US patent filings and is the fourth largest foreign patent applicant within the analyzed country set behind Japan, Germany and South Korea in 2009 and 2010.

For Germany, which is the second largest foreign patent applicant at the USPTO, it can be stated that it has a more pronounced and focused technological profile at the USPTO than it has at the transnational level. While the strengths of electrical engineering, transport, and machinery are also visible in the USA, the German relative position in life sciences is more pronounced and more positive at the USPTO. Especially in the field of electrical medical instruments, a clear market orientation can be found. Germany is among the top applicants at the USPTO as well as in China, for example.

Valuable Patents – A Citation- and Family-Size Weighted Ranking

Next to the total numbers of patent applications, analyses using patent value adjustment indicators – namely patent citations and weighted patent family counts – were conducted. The citation weighted indicators do not have a strong impact on the relative positions of the countries and their relative distances. Only the level, but not the structure, is adjusted by the citation weighted patent counts when they are applied to national patent profiles. This is not to neglect that their impact might be high and relevant on the level of individual patents or company profiles. This story, however, is different for the value adjustments by the patent family indicator, that adjusts for market size or market attractiveness, where changes in the country rankings become more clearly visible. Although the USA and Japan still keep their positions, China scores third and thus outperforms Germany and South Korea. Changes are also visible in the medium ranks. Including this indicator into our analyses adds an interesting perspective to qualify our findings since it is able to provide new insights for country comparisons as well as technological profiles.

Structures of International Co-Patenting

In the final chapter of this year's report, international co-patenting trends are analyzed. The literature on research collaborations discusses several characteristics that can foster or hamper international cooperations. Besides the country size, a multitude of factors, e.g. geopolitical, historical, linguistic, social, intellectual, cognitive and economic, affects the propensity to collaborate internationally. However, the cooperation structures in international patenting are able to resemble the internationalization of R&D activities and indicate which countries can already be considered as attractive research partners for Germany and with which countries cooperations could be improved.

The number of international co-patents as well as the number of countries that are active in international co-patenting has increased massively over the last 20 years. Although the USA was, and still is, the major partner for international R&D cooperations, China enters the scene at latest from 2000 onwards and starts to play a role as a major partner for R&D cooperations. Germany has also played a key role in the international patenting scene so far and seems to continue to do so. The social network analysis also shows that Germany has an important function as a key node for co-patenting in Europe. Besides the USA, Switzerland, France, the Netherlands and Austria are the major research partners for Germany, which can be explained by geographic as well as cultural and linguistic proximity. The field specific trends reveal that Germany files most of its co-patents in fields where it is less specialized in international comparison, mostly in chemistry related fields but also in electrical engineering. This can be interpreted from a strategic point of view. German firms might willingly choose not to cooperate in fields in which they are comparably strong.

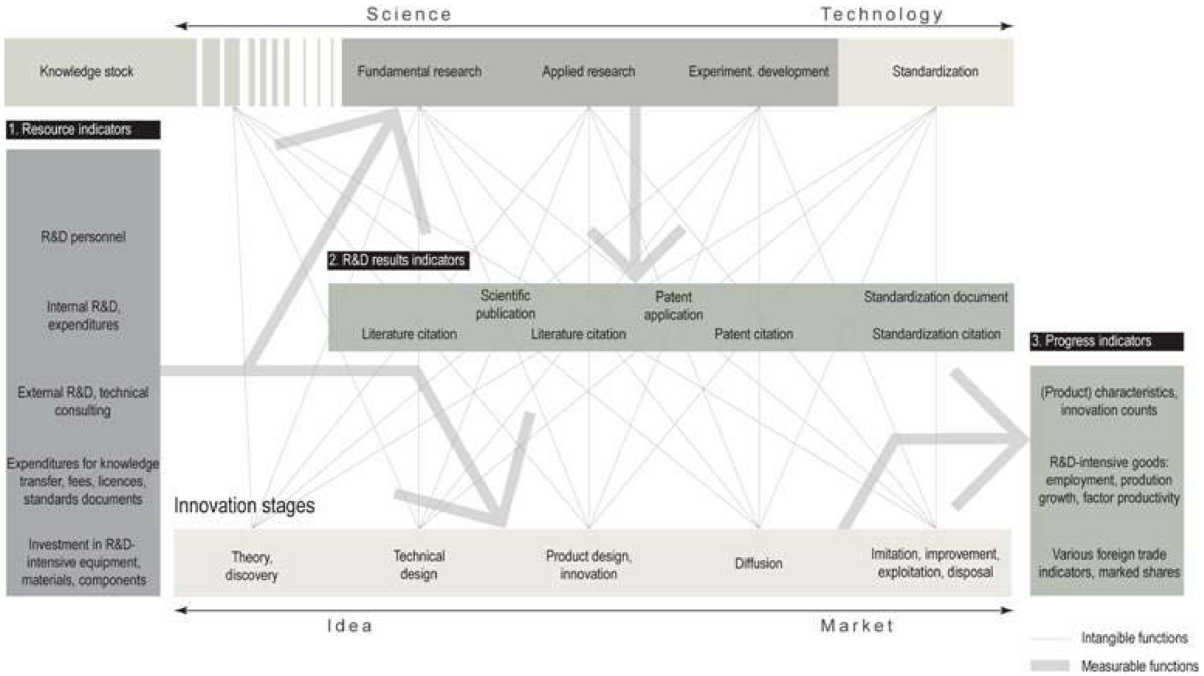
1. Introduction

The technological performance of countries or innovation systems in general 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). However, the methods and definitions applied for analyses using patent data do differ (Moed et al. 2004), which can be attributed to the increase of the body of literature in the field that steadily delivers new insights, knowledge and methods to researchers in the field.

Yet, patents can be seen and analysed from different angles and with different aims. 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 the 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 whole economies. 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 expenditures or human capital. In order to achieve a more precise approximation of the "black box" of R&D activities (Schmoch/Hinze 2004), both perspectives – i.e. input and output – are needed. The input side, however, has been widely analysed and discussed in other reports, also in this series (see for example Schasse et al. 2012). Here, we thus strictly focus on patents as an indication of output, following the very early approaches of patent statistics pioneers (Griliches 1981; 1990; Grupp 1998; Pavitt 1982).

Figure 1: Indicator System to analyse Innovation Systems Performance



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

Seen from a legal perspective, patents first of all give the patent applicant an exclusive right to use and sell the protected technology for a limited time period. 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 analyse 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, however, patents can be regarded as an input into further market activities, which are reflected, for example, by foreign trade, turnover or qualified labour. Thus, 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.

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, is 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.

This report gives a brief overview of the developments in transnational patent applications since the early 1990s with a special focus on the recent trends and structures. Chapter 2 presents the data and methods applied for the analyses in the following chapters. Chapter 0 discusses total trends, growth rates, intensities (patents per 1 million workforce) and specialisation[2] indices, which are designed to reflect patent structures beyond size effects of countries and technology fields. Chapter 4 focuses on the analysis of patent activities at the USPTO, which forms the largest and most important national market especially for high-tech goods. In Chapter 5, we discuss the internationalisation and value of countries' patent profiles by analyzing patent citations as well as patent families weighted by their coverage of differently sized and valued markets in terms of imports. Chapter 6 provides an overview of international co-patenting structures which are able to indicate knowledge flows between economies.

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1 Patents are especially dedicated to measure 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.

2 The specialisation index RPA (Revealed Patent Advantage) is defined as:

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

with P_{kj} indicating the number of patent applications of country k in the technology field j. Positive values point to the fact that the technology has a higher weight in the portfolio of the country than its weight in the world (all applications from all countries at EPO). Negative values indicate specialisations below the average, respectively.

2. Data and Methods

The patent data for the study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from 81 patent authorities worldwide. Besides patent applications, we extracted further patent indicators, i.e. the annual sum of cited patent applications, forward citations, weighted patent families and international co-patents, for more in-depth analyses. All of these indicators have been calculated in total, by selected countries and differentiated by 35 high-technology fields (Legler/Frietsch 2007).

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 do fractional counting by inventor countries and, on the other hand, we are also able to apply fractional counting to the IPC classes (International Patent Classification), so 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. Secondly, we are able to increase the power of our analyses by taking citations and family size information into account, which can be used for the valuation of patents (Frietsch et al. 2010a) and to try to get a more balanced perspective on the national technology profiles.

Patents are counted according to their year of worldwide first filing, the so-called 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 has already been used in earlier analyses of this series ((Frietsch et al. 2011; Frietsch, Jung 2009; Frietsch et al. 2010b; Frietsch et al. 2012) and 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 analysing the transnational patenting structures, patent applications at the United States Patent and Trademark Office (USPTO) are taken into account in this year's report. The USPTO covers the most important national market for high technologies in the world, namely the US market. However, it is still a national market. Some countries, especially the upcoming and emerging countries like South Korea or India, are specially focused on the US market and do not file every patent on a worldwide scale. In consequence, the bias of US applicants/inventors as well as of some other very US-oriented countries is considerable and the imbalance of European, North American and emerging countries cannot be neglected when looking at USPTO patent filings. This is why the US data is not the core of this analysis. However, we report them as an additional dimension in the discussion, keeping in mind that there are imbalances in the representation of certain countries. The USPTO data therefore do not appropriately reflect the general technological competitiveness of nations, but are appropriate to reflect the technological activities targeted to the US market – and this is therefore a helpful supplement to the overall analyses presented in this report.

Contrary to the EPO for example, the USPTO only published granted patents instead of applications until the publication year 2001. Since then, they publish both, applications after 18 months and granted patents immediately after the granting procedure is finished (which might take up to 7 years and more after priority filing). However, purely national filings are still exempted from the pre-grant publication demand so that some applications are still unpublished until the granting of the invention. In this transition phase from grant to pre-grant publication, it may not be meaningful to analyse longer time series at the USPTO, though it seems that the transition to the new system as such was successfully accomplished already in the middle of the first decade of the new century (Schmoch 2009).

In addition to the absolute numbers, patent intensities are calculated, which ensure 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, so called specialisations are calculated. For the analysis of specialisation, the relative patent share (RPA[3]) is estimated. It indicates in which fields a country is strongly or weakly represented compared to 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. 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 specialisation. 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.

2.1 Estimators of Value – Patent Citations and the Average Family Size

In chapter 5, the analyses of transnational co-patents will be complemented by analyses that are supposed to refine the country's patent profiles by differentiating them according to their patent quality. Patent quality here means that patents can be differentiated according to the technological or economic value they carry (for a detailed discussion on the dimensions of patent value see Frietsch et al. 2010a). Yet, the value of patents is extremely skewed. Only a few patents are highly (economically) valuable and a large number of patents being only of medium or low economic value (Bessen 2008; Gambardella et al. 2008; Grönqvist 2009; Harhoff/Hoisl 2007).

3 Revealed Patent Advantage

Besides the number of patent applications, several quality measures can be applied to assess and differentiate between the quality of patents (Frietsch et al. 2010a). The most frequently discussed range from citation measures, granted patents, opposition- or litigation history to the average number of inventors or IPC classes. Other indicators also include licensing history, licensing revenues, renewal history, the number of claims, expected sales values of patents measured by survey data; and different composite indicators (or indices) constructed from several of the above listed. Many of the those were tested and evaluated in a large project on behalf of the "The Experts Commission for Research and Innovation (Expertenkommission Forschung und Innovation – EFI)" (Frietsch et al. 2010a). It has been shown that while the value of individual patents is rather straightforward to understand, the value of national patent profiles cannot be assessed directly. Especially patent forward citations proved to be most promising for the evaluation of the quality of patents at the firm level, which is also true for the family size. However, at the country level, it has been shown that mainly a weighted count of patent families can be used as a robust indicator of patent quality (Frietsch et al. 2012; Neuhäusler/Frietsch 2012).

Patent forward citations are the most common and widely used indicator in the literature (Narin et al. 1987; Trajtenberg 1990). The number of forward citations (citations a patent receives) measures the degree to which a patent contributes to the development of further advanced technologies, thus this can be seen as an indicator of technological significance of a patent (Albert et al. 1991; Carpenter et al. 1981). Yet, several studies show that patent citations are a very noisy signal of patent quality (Alcacer et al. 2009; Alcacer/Gittelman 2006; Hall/Ziedonis 2001). We thus additionally take into account a second indicator of patent quality, namely the patent family size. The family size of a single patent document is determined by the number of countries or patent offices, at which a patent has been filed (Adams 2006; Putnam 1996). An application for a patent in a foreign country means that the applicant tries to secure that market to sell his invention and is willing to pay process and maintenance fees to the respective offices. Moreover, additional costs could emerge for the enforcement of patent rights in various countries. Therefore, the basic assumption is that a patentee only files a patent abroad, if he expects a corresponding profit with the sale of the protected technology or at least he tries to secure an option to be able to do so (Gambardella et al. 2008; Harhoff/Wagner 2009; Pakes 1986). In more simple words, a large patent family means greater market coverage which is associated with preliminary and running expenses (Frietsch et al. 2010a). Yet, it could be shown that weighting the family members by the size of the targeted market, especially in terms of imports, improves the use of this patent value indicator at the country level (Frietsch et al. 2012; Neuhäusler/Frietsch 2012). We thus only report the results of the analyses of the import weighted family size of a country's patent portfolio within this report.

2.2 Analyses of Social Networks – Methodology

In chapter 6, trends in international co-patents will be described by a social network analysis (SNA). Social network analyses are able to reveal complex patterns of relationships between actors of a network. It can show how important certain actors are, give insights on the strength of their relations to other actors and can also indicate groupings of actors within a system. Yet, before discuss the results of the SNA, we will first of all provide some information on the methodological issues and an introduction of some SNA specific terms, which will be necessary for the interpretation of the results.

An SNA consists of a set of actors, who may be arbitrary entities like persons or organizations, and one or more types of relations between them (Brandes 2001). In the parlance of SNA, the actors within the network are referred to as "nodes", while their relationships are called "edges".[4] Within this analysis, the actors within the social network - or the level of analysis - are countries, which have filed a transnational patent application with another country. More precisely, a transnational co-patent is defined as a patent on which at least two inventors named on the patent application are living in two different countries, i.e. a domestic and a foreign inventor.[5]

The countries included in the sample are all that are covered by the PATSTAT database in order to capture worldwide co-patenting within the SNA. As in the previous analyses, the patents are counted at the date of their worldwide first filing, the priority date. In addition, we focus on transnational patent applications. Yet, in contrast to the previous analyses, instead of a fractional count of the patent applications we use a "whole count", i.e. each patent is counted once for each country for which an inventor is named on the patent application. This is due to the nature of our SNA with co-patents. By fractional counting, we would assume that the knowledge flow by co-patents is directed, e.g. a share of co-patents would flow from Germany to the US and vice versa, which is not the case. Rather, we have to use an undirected network, indicating that there is a knowledge flow between the US and Germany, with its size determined by the number of co-patents between the two countries. The undirected network, however, requires that we count each co-patent once for each inventor country that is named on the patent application, implying that we need to use the "whole count" for this analysis.

The final methodological issues that should be discussed here are the SNA specific measures that will be used for the network analyses. The first one is called betweenness centrality, which belongs to the group of centrality measures. Centrality measures are essential tools for the analyses of social networks, which are designed to rank the actors of a network according to their position within the network or in other words, to find the actors that are most "central" to the network (Bavelas 1948; Freeman 1979; Sabidussi 1966). The basic idea behind the betweenness centrality is that a node within a network is important if it lies on a high share of "shortest paths" within the network. Maybe it is more illustrative to think of it as the amount of traffic that flows through a node due to its connection to several different actors. If the traf-

4 A comprehensive overview of methods and applications can be found in Wasserman and Faust (1994) or Scott (2000).

5 There are several ways to define an international co-patent, e.g. to use patent assignees instead of inventors or a mixture between the "inventor" and the "assignee concept" (Fraunhofer ISI et al. 2009). Yet, we decided to use the concept of inventors since this indicates that the R&D behind the patent application has been carried out in two different countries.

fic that passes this node is high, it has an increased importance for the whole system. Formally, the betweenness centrality is defined as (Brandes 2001; Freeman 1977):

$$C_B(v) = \sum_{s \neq v \neq t \epsilon V} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

where V is the total number of nodes or actors within the system, s and t are the starting and the end point of a path, and $\sigma_{st}(v)$is the number of shortest paths from s to t that some v ϵ V lies on.

The second measure that will be employed in the following analyses is the measure of modularity, which is used to detect communities - sets of highly interconnected nodes (Fortunato/Castellano 2009) -within a network. In other words, the network is divided into two or more clusters or partitions. Within these partitions, the individual nodes (or group members) have stronger relationships to each other than to the members of the other group as shown by the larger number of mutual connections (Fortunato/Castellano 2009).

In general, the modularity of a partition can take on values between −1 and 1, measuring the density of links inside communities as compared to links between communities (Blondel et al. 2008; Newman 2006; Newman/Girvan 2004). In the case of weighted networks (in our case the number of co-patents between two countries serve as weights), the modularity is defined as (Newman 2004):

$$Q = \frac{1}{2m} \sum_{i,j} \left[A_{i,j} - \frac{k_i k_j}{2m} \right] \delta(c_i, c_j)$$

where $A_{i,j}$ represents the weight of the edge between i and j, $k_i = \sum_j A_{ij}$ is the sum of the weights of the edges attached to vertex i, c_i is the community to which vertex i is assigned, the δ function $\delta(u, v)$ is 1 if $(u = v)$ and 0 otherwise and $m = \frac{1}{2} \sum_{ij} A_{ij}$.

However, since exact modularity optimization is a problem that is computationally very intense, we use an approximation of modularity proposed by Blondel et al. (2008).

3. Trends of Transnational Patent Applications

The recent trends of transnational patent filings – i.e. families with at least an EPO or a PCT filing – since the beginning of the 1990s will be described in this chapter. As already mentioned in the methodology section, patents are dated according to their worldwide first filing, i.e. the priority date. The analyses will be carried out for a selected set of technology-oriented countries[6]. In extension to the previous studies, also Brazil, India and South Africa are included in this year's report, meaning that now all of the BRICS countries are covered. Yet, for reasons of presentation, not every country is displayed in each figure.

We will also make a distinction between low-tech and high-tech areas. High-tech is defined as technologies for which usually an average investment in R&D of more than 2.5% of turnover is required. High-tech will further be differentiated by high-level and leading-edge technologies. While high-level covers technologies that require R&D expenditures between 2.5% and 7.5%, the leading-edge area covers technologies that are beyond 7.5% investment shares (Legler/Frietsch 2007). 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 the US and Germany – looking at 35 technology fields, according to the high-tech definition – will be presented in the section 3.2.

3.1 Trends and levels of patent applications by technology areas

In Figure 2, the absolute number of transnational patent applications of a selected set of countries is displayed. Already a first look reveals that the USA is the largest technology-providing country at the international level, followed by Japan and Germany. This trend can be observed for high-tech and also for low-tech areas (not shown). Following behind these three countries, there is a large group lead by France and the United Kingdom, for which the absolute number of transnational patent applications reaches a relatively similar level. Interestingly, South Korea as well as China, which both have grown strongly since the end of the 1990s, have managed to catch-up with France in 2009 and operate at a slightly higher level than France and the United Kingdom in 2010.

A striking general effect in international patenting can be observed in the period 2007 to 2009, namely a decrease in patenting applications for all of the analyzed countries, except China. This effect has already been observed in the last two years' reports and has been interpreted as an effect of the economic crisis. In 2010, however, the number of patent applications stabilizes – at a lower level – for most of the countries. Yet, only the future analyses will be able to really prove this stabilization.

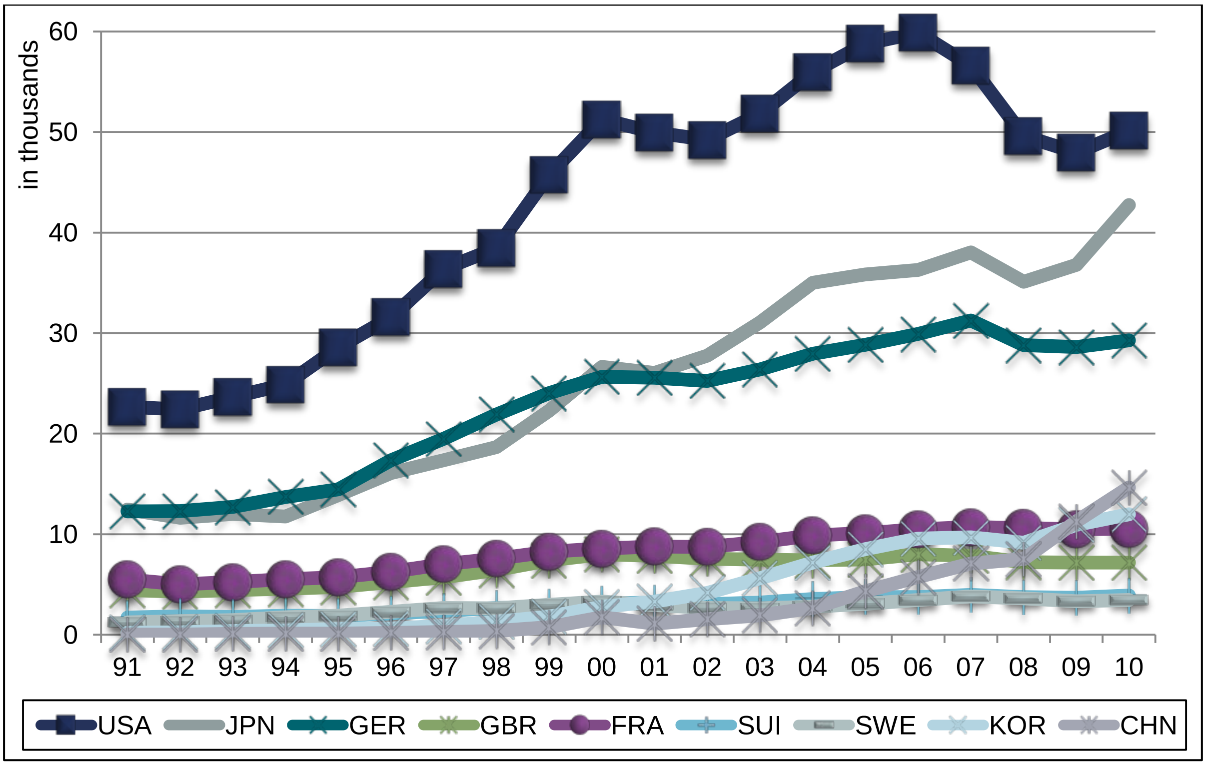
It seems that during the economic crisis, the companies first of all have applied a much more deliberate strategy for filing patents internationally. Put differently, the companies were still inventing technologies, but more often choose not to file a patent application also abroad. The

6 These are: Germany, USA, Japan, the United Kingdom, France, Switzerland, Sweden, South Korea, China, Canada, Italy, the Netherlands, Finland, Russia, Brazil, India and South Africa.

reason was that the filings of the priority year 2007 were to be transferred to the international offices in 2008 and 2009, when the economic crisis already took effect. This effect is also vivid for the priority year 2008. Second, the economic crisis also impacted the input side of the R&D process (in terms of R&D expenditures), implying that the output in terms of patents was also affected. Evidence for this statement stems from the national trends of patent applications, which were also decreasing in 2008. Companies that are active in patenting do this whenever they have an invention that is worth filing because they would otherwise risk losing their intellectual property (IP) to their competitors. Thus, their strategy is to secure their rights first by filing at their home base, i.e. the national patent office. Thus, as the national filings are decreasing, the conclusion is that they have less IP to protect.

Analyses of earlier recessions or crises have shown that companies tend to stretch innovation processes by reducing their investment, without cancelling the projects, or postpone the start of research projects (see for example Rammer et al. 2012). The theory, however, suggests to invest into R&D anti-cyclically, i.e. to invest in times of recession and crises, in order to prepare for the next economic boom with new technologies, which might lead to gain increasing market shares. Obviously, firms do not follow this theoretical reasoning in reality.

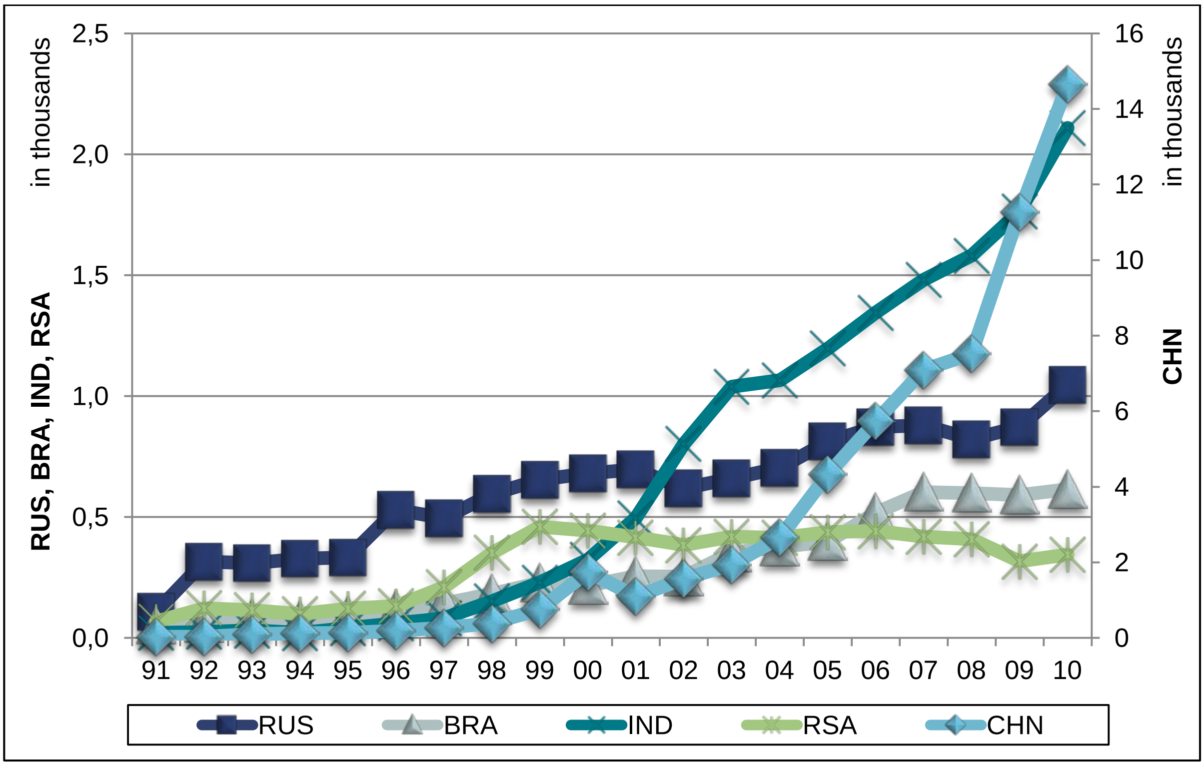
Figure 2: Absolute number of transnational patent applications for selected countries, 1991-2010



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

When looking at Figure 3, where the absolute number of transnational patent applications among the BRICS countries is presented, it directly becomes obvious that China by far applies for most transnational patents. A major rise in Chinese patent applications can be observed from 2008 onwards, a trend that has already been found in Figure 2. China is followed by India, where also a significant increase can be observed since the late 1990s. Interestingly, also the number of Indian patent applications seems not to be heavily affected by the economic crisis. Russia is the third largest BRICS country in terms of patent applications, followed by Brazil and South Africa. Brazil has managed to increase its international patent filings from 2005 onwards, yet here also the economic crisis seems to have had an impact because the number starts to slightly decline from 2008 onwards.

Figure 3: Absolute number of transnational patent applications for the BRICS countries, 1991-2010



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The absolute data that has been presented so far is – of course – affected by size effects. One adjustment to these size effects is shown in Table 1, where patent intensities per one million employees are displayed. This size adjustment sheds a new light on the country ranks. Although the US is the largest country in absolute terms, it only scores ninth when looking at the patent intensities. Rather the smaller countries Finland, Switzerland and Sweden are at the top of the list of the technology-oriented countries analysed here. Germany, Japan and South Korea are first among the larger countries. On the one hand, this is an expression of the strong technology orientation and the technological competitiveness of these countries. On the other hand, this is 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. With the perspective of this indicator, France, Great Britain and the EU-27 are in the midfield together with the USA.

Table 1: Patent intensities (patent applications per 1m employment) and shares of technological areas, 2010

	Total	less R&D-intensive		High-tech of which are:		Leading-edge technologies		High-level technologies	
SUI	861	453	53%	400	46%	144	17%	255	30%
FIN	773	374	48%	355	46%	195	25%	160	21%
SWE	771	380	49%	352	46%	149	19%	203	26%
GER	755	351	46%	382	51%	113	15%	269	36%
JPN	681	272	40%	401	59%	171	25%	231	34%
KOR	511	210	41%	280	55%	138	27%	142	28%
NED	393	198	50%	187	48%	89	23%	98	25%
FRA	393	179	46%	204	52%	92	23%	112	29%
USA	358	139	39%	213	59%	112	31%	101	28%
EU-27	329	158	48%	162	49%	59	18%	103	31%
GBR	249	115	46%	125	50%	54	22%	71	29%
ITA	235	128	55%	104	44%	28	12%	76	32%
CAN	224	95	42%	117	52%	68	30%	50	22%
RSA	23	14	60%	9	37%	3	13%	6	24%
CHN	19	9	47%	8	45%	5	25%	4	19%
RUS	15	8	50%	7	48%	3	21%	4	27%
BRA	7	4	56%	3	42%	1	14%	2	28%
IND	6	2	36%	3	60%	1	26%	2	34%

Source: EPO – PATSTAT; Fraunhofer ISI calculations.
Note: Due to missing data, the number of employees from the year 2009 had to be used for the calculations of the intensities in the case of FRA, CHN, BRA and RSA. For IND the numbers for the year 2000 had to be employed.

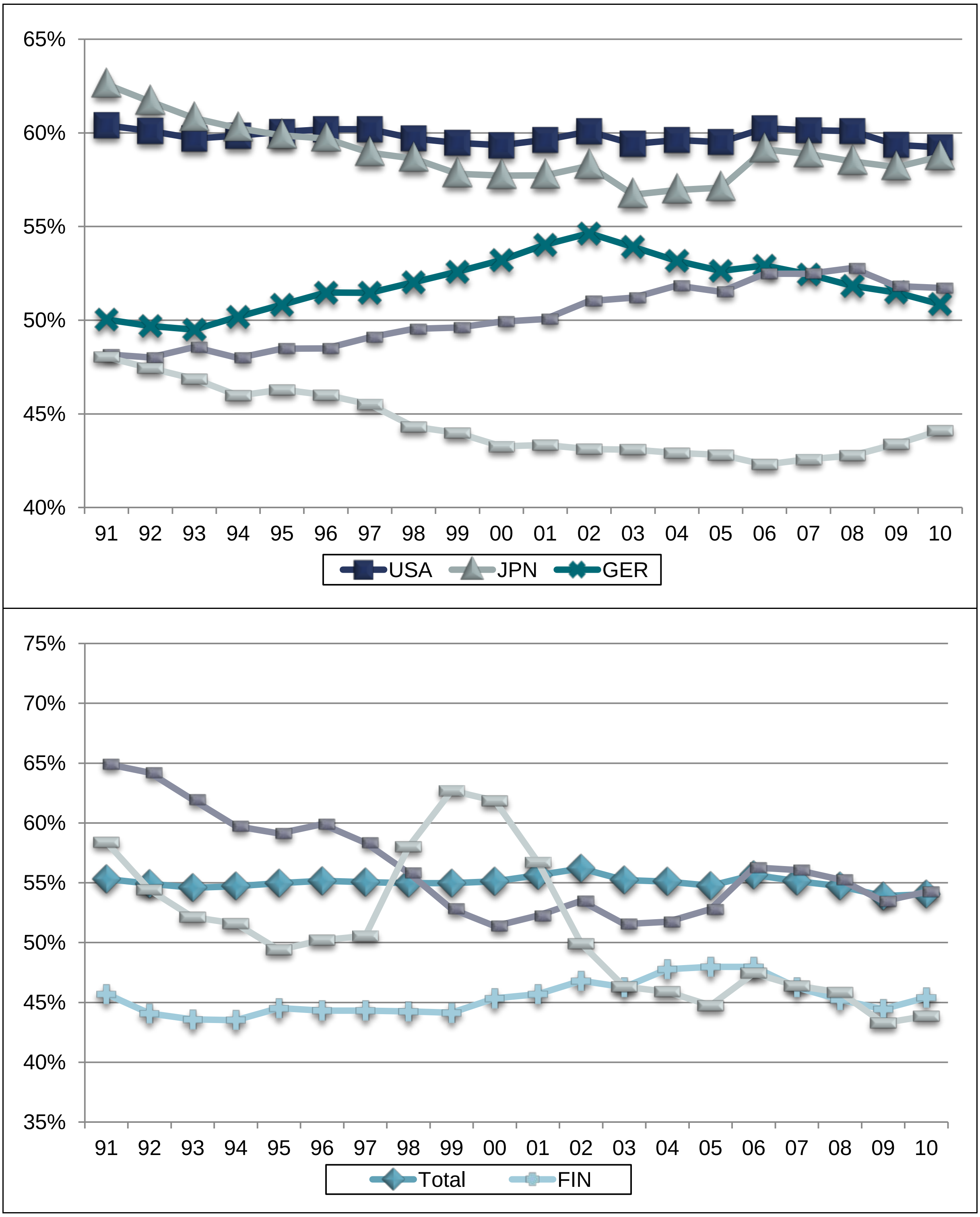
In addition, Table 1 offers a differentiation of the patent intensities by technological areas and displays the respective shares of total patent filings. It is remarkable that Switzerland, Finland and especially Italy show rather high activities in low-tech fields. The same is true for Sweden and the Netherlands, although both are especially well-known for their high-tech companies Sony-Ericsson and Philips, respectively. Also the BRICS countries, above all South Africa and Brazil are very active in low-tech fields. India seems to be the only country that does not fit into this pattern with a low-tech share of only about 36%.

In the case of high-tech patents, especially the USA, Japan and Korea reach rather high shares of between 55% and 59%, respectively. India, which has already been shown to have only a small share of low-tech patents, especially scores on this indicator and is able to outperform all other countries with a high-tech share of 60%. However, this can at least partly be explained by the fact that India is highly orientated towards the US market (compare section 4.1), which is the most important national market for high-tech products as well as a high share of Indian co-patents that are filed with US inventors.[7] The differentiation by leading-edge and high-level areas further qualifies these findings. The USA, Canada, Korea, but also

7 The share of transnational co-patents in all transnational patents of India is with 27% relatively high compared to other countries. Among these, most co-patents are filed in cooperation with US inventors (53%).

Finland, the Netherlands and Sweden are filing many of their patents in leading-edge technologies. This is also where the main technological activities of Sony-Ericsson and Philips are located. In consequence, Finland and the Netherlands reach rather low shares in high-level technologies compared to the other countries. Germany and also Switzerland are focused on high-level technologies, but reach rather low shares in leading-edge areas.

Figure 4: Shares of high-tech patent applications in total patent applications for selected countries, 1991-2010



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 4 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 is almost constant at a rate of 55% since the beginning of the 1990s, some countries underwent a considerable change of their patenting in high-tech areas. The USA is at the top of the countries and also reaches a rather stable share of high-tech patents at the transnational level, although the trend has been slightly decreasing in the last two years. Japan, which had been at the top at the beginning of the observation period, had clearly lost ground and had lower shares of patenting activities in high-tech areas. Yet, in the last two years, it has managed to increase its share slightly and now is at a similar level as the USA again. France was able to increase its high-tech shares and Italy decreased steadily since the early 1990s, so that the gap to the other large innovation-oriented countries grew constantly.

The lower panel of Figure 4 shows that the shares of Korea and China decreased and fell clearly below the average share, although their absolute numbers were increasing considerably. In the case of China, the filings began to grow from the year 2001 onwards when China joined the WTO and the TRIPS agreement. However, this is also the time when the shares of high-tech patents decreased. It is interesting to note that the Finnish trend is positive over the whole observation period, at least until 2006, and that this trend was accompanied by an increase in the absolute numbers of patent filings.

3.2 Technology profiles and patterns of specialisation

In this section, we will provide a discussion of the patent applications according to a classification of 35 technology fields of the high-tech sector (Legler/Frietsch 2007). We will focus on the comparison of the German and the US-American profile in order to be able to compare these figures also to the patent filings at the USPTO, which will be analyzed in the next chapter.

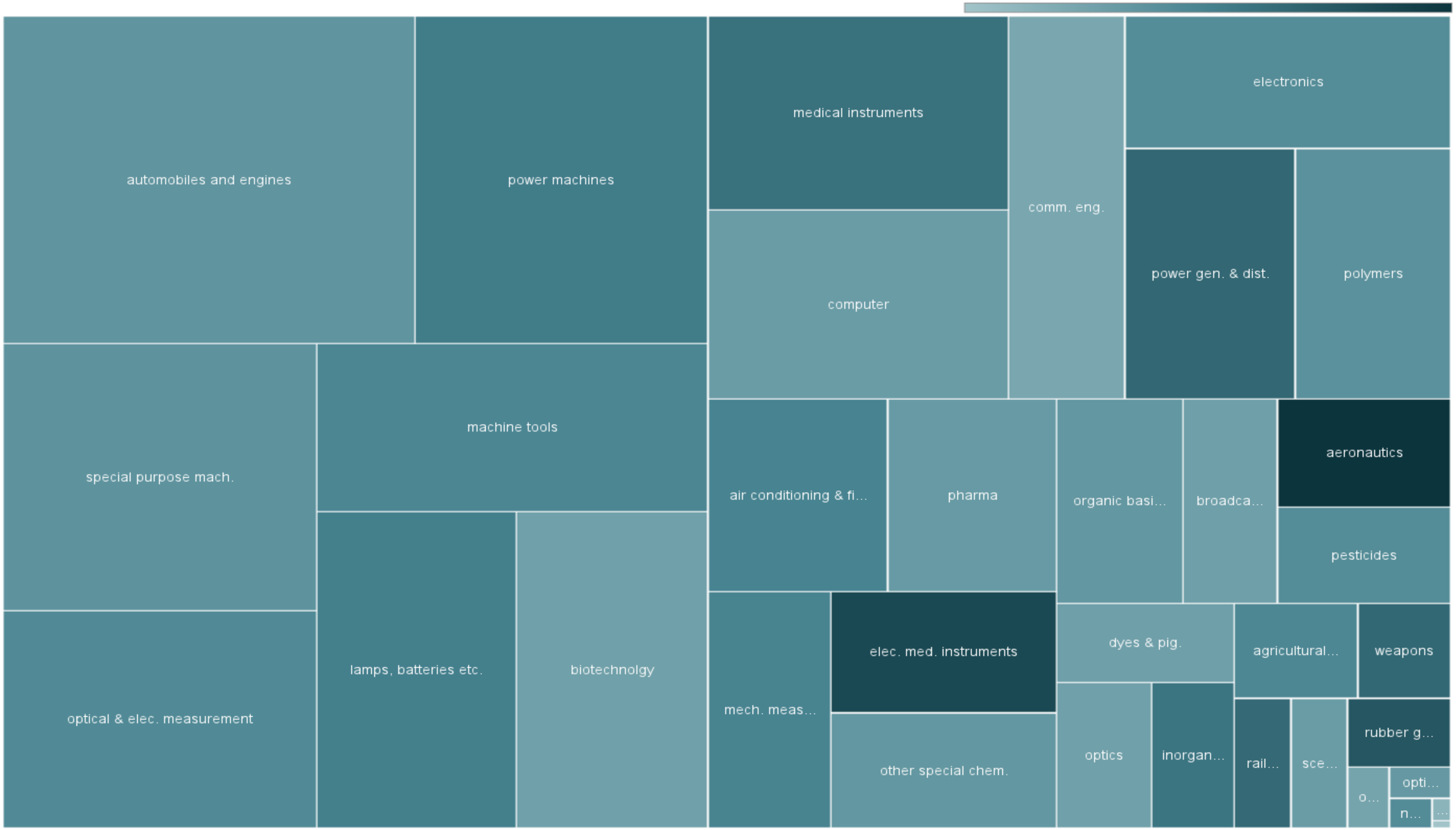
Table 2: Transnational Patent applications of Germany and the USA (absolute, specialisation, and growth), 2008-2010

	GER			USA		
	Abs.	**RPA**	**Growth (00-02=100)**	**Abs.**	**RPA**	**Growth (00-02=100)**
aeronautics	728	19	234	1317	25	148.5
electronic medical instruments	1,014	-22	196	3082	35	142.7
rubber goods	267	7	182	293	-36	102.4
power generation and distribution	1,650	27	164	1463	-36	174.7
rail vehicles	272	74	152	77	-69	154.2
medical instruments	2,196	-30	150	9062	52	126.7
weapons	310	52	147	321	7	154.1
inorganic basic materials	457	-12	142	732	-19	116.0
power machines and engines	3,707	57	136	2307	-35	118.8
nuclear reactors and radioactive elements	55	-46	131	240	42	281.1
lamps, batteries etc.	2,386	10	128	2273	-45	110.3
air conditioning and filter technology	1,282	22	122	1974	12	127.2
mechanical measurement technology	1,077	33	120	1268	-3	128.4
agricultural machinery	450	49	119	455	2	160.6
optical and electronic measurement technology	2,650	-12	116	4898	-4	94.8
machine tools	2,430	57	116	1515	-34	111.2
electronics	1,642	-49	110	5367	12	133.1
pesticides	624	-5	109	1983	52	213.8
polymers	1,470	17	102	1994	-6	84.3
special purpose machinery	3,144	43	99	2261	-38	79.3
automobiles and engines	5,145	63	98	1962	-64	79.4
organic basic materials	971	-17	93	2548	25	86.5
other special chemistry	969	-11	92	2368	25	91.7
pharmaceuticals	1,188	-43	87	4645	36	74.5
computer	2,131	-70	86	12654	36	121.3
scents and polish	271	20	85	417	10	79.0
optics	527	-49	83	1542	0	66.0
dyes and pigments	526	12	80	708	-11	89.8
optical and photo-optical devices	64	-74	80	182	-41	73.3
broadcasting engineering	722	-82	79	3015	-24	79.3
biotechnolgy and agents	2,265	-46	79	10217	45	75.0
communications engineering	1,664	-51	71	4391	-13	62.0
office machinery	84	-71	65	250	-31	61.9
pyrotechnics	16	20	55	24	9	43.4
photo chemicals	6	-53	29	33	53	10.0

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The German technology profile of the years 2000-2002 versus 2008-2010 is displayed in Figure 6. Germany is specialized, i.e. has comparative advantages, in three main areas: transport, machinery and some areas of electrical engineering like power machines and power generation. This is true for both time periods. An average activity rate in patenting can be found in chemical sectors (materials, polymers, pesticides etc.). Comparative disadvantages reflected in negative specialisation 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. An interesting trend that can be revealed is that Germany was able to improve its already existing strengths at least slightly. However, this comes at the expense of a relative loss of positions in many areas of relative weakness, above all ICT and electronics but also in the field of nuclear reactors and radioactive elements. In addition, German inventors were able to gain ground in some of the areas of average activity in 2000-2002, especially in aeronautics. This trend can be found to be even stronger for rubber goods, where the specialization has been negative in 2000-2002 but has become positive in 2008-2010. Rubber goods is thus among the fields with the largest growth rates, besides aeronautics, electronic medical instruments and power generation and distribution. The growth rates are smallest in communications engineering, office machinery, pyrotechnics and photo chemicals (compare Table 2).

Figure 5: Transnational Patent applications of Germany (shares and growth), 2008-2010



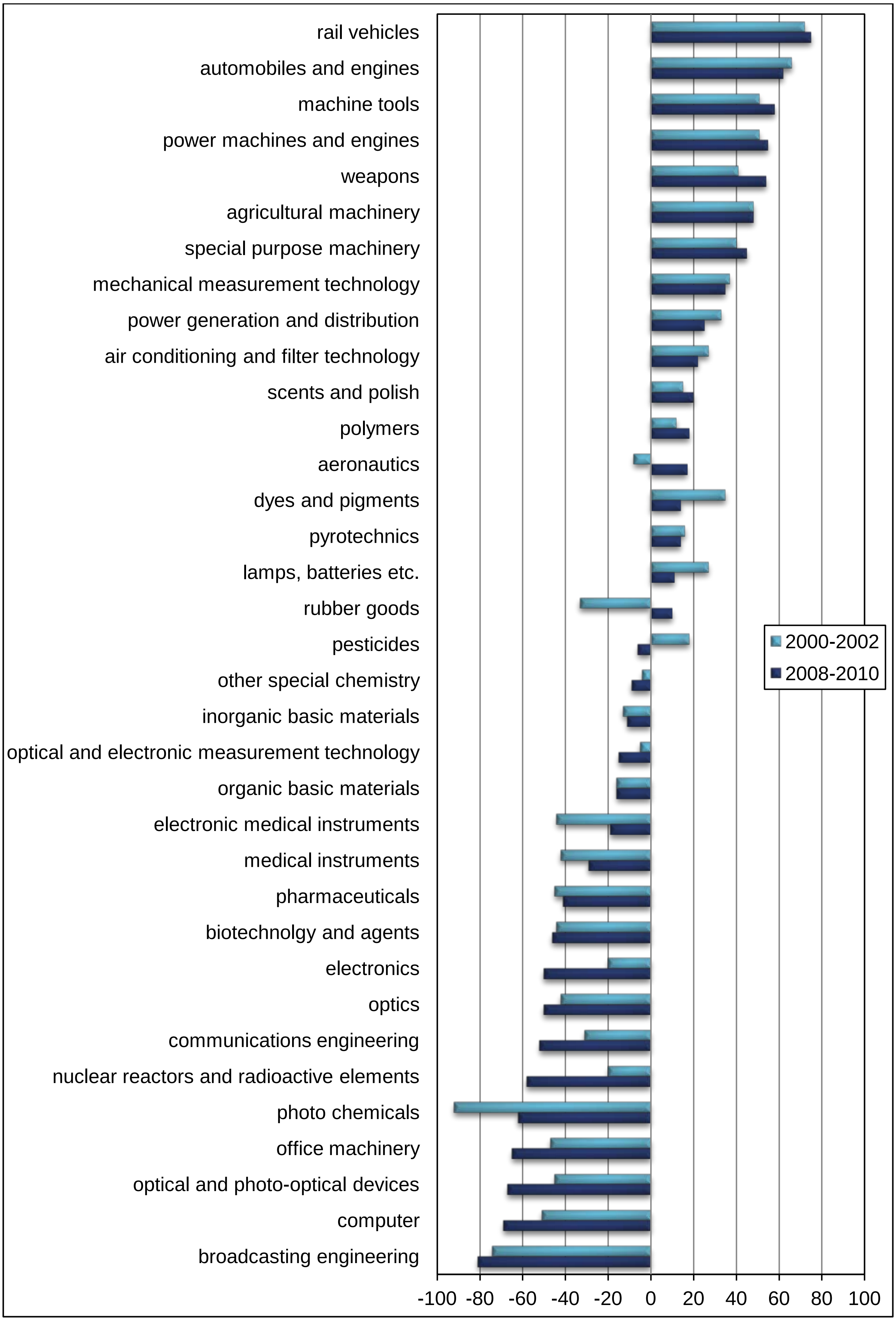
Source: EPO – PATSTAT; Fraunhofer ISI calculations.
Note: The colours resemble the growth of the respective fields compared to the period 2000-2002.

In order to gain a better impression of the size of the fields in relation to each other, Figure 5 shows a tree-map of the share of the field specific patent applications on all German transnational patent application based on the numbers in Table 2. The size of the boxes within this graph indicate the size of the respective technology fields within the German portfolio, the colours resemble the growth of the field within Germany. The darker the colour, the more a technology field grew compared to the period 2000-2002.

The US-American profile is displayed in Figure 7 and shows strengths in most of the life science fields (biotechnology and pharmaceuticals), medical instruments, as well as positive values in chemistry. A less significant but still highly positive specialization can be found in computers, electronic medical instruments and electronics. The areas of comparative disadvantage at the transnational level are transport, machinery and electrical engineering (power machines and power generation) as well as rubber goods and lamps and batteries. Also, the USA have been able to reinforce their positions in some of their outstanding fields like medical instruments, computers and some fields of chemistry. Here, it is also interesting to note that nuclear reactors and radioactive elements as well as pesticides reach the highest growth rates within the USA's technological portfolio (see also growth rates in Table 2).

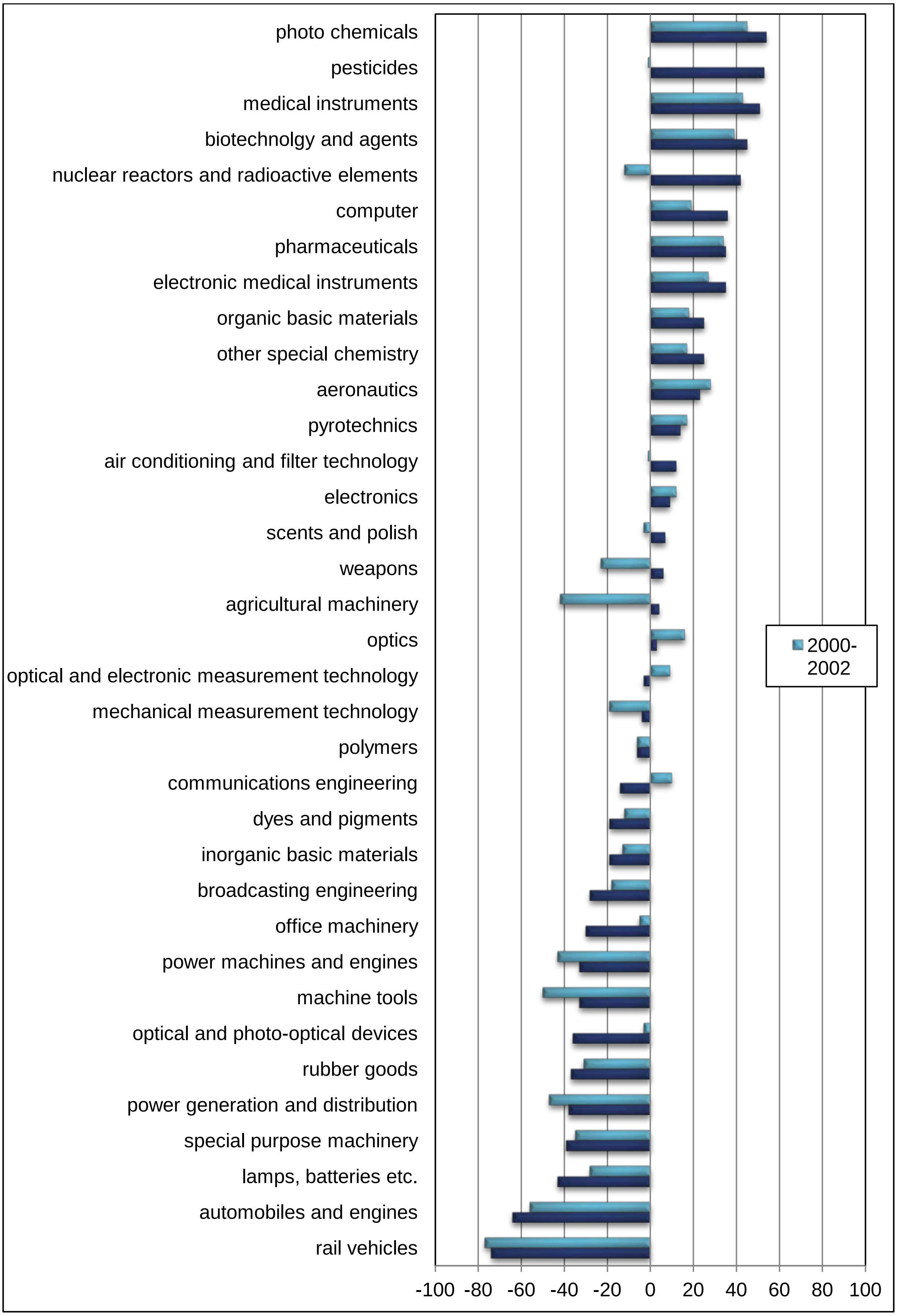
In sum, it can be stated that the German and the US-American profile are complementary to each other. The German strengths are the US-American weaknesses and vice versa. The profiles of the two countries have been rather distinct and differences are still clearly visible, like in transport, biotechnology or computers. The successes of the two countries in international markets in the past decades were also possible because they did not get in each other's ways. However, when looking at the changes of the profiles of the two countries and comparing the innovation policies in Germany (Frietsch/Kroll 2010) and the USA (Shapira/Youtie 2010), it seems that more and more intersections of the profiles and market activities will occur. Germany enters the circles of the USA in electronic medical instruments as well as biotechnology (or nanotechnology, which is not separately analysed here), while the USA enters the German circles in power generation, mechanical measurement technologies, and machine tools. This increasing intersection of the formerly more distinct profiles is symptomatic for an increase in international competition in high-technology in general.

Figure 6: Germany's technological profile, 2000-2002 vs. 2008-2010



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 7: The USA's technological profile, 2000-2002 vs. 2008-2010



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

4. Patent Applications at the USPTO

Transnational patents offer an assessment of the technological competitiveness of nations beyond home advantage effects, national idiosyncrasies and differing market orientations and are thus able to capture international patenting trends. Within this chapter, we take a completely different perspective by analysing the pre-grant published patent applications to the United States Patent and Trademark Office (USPTO).

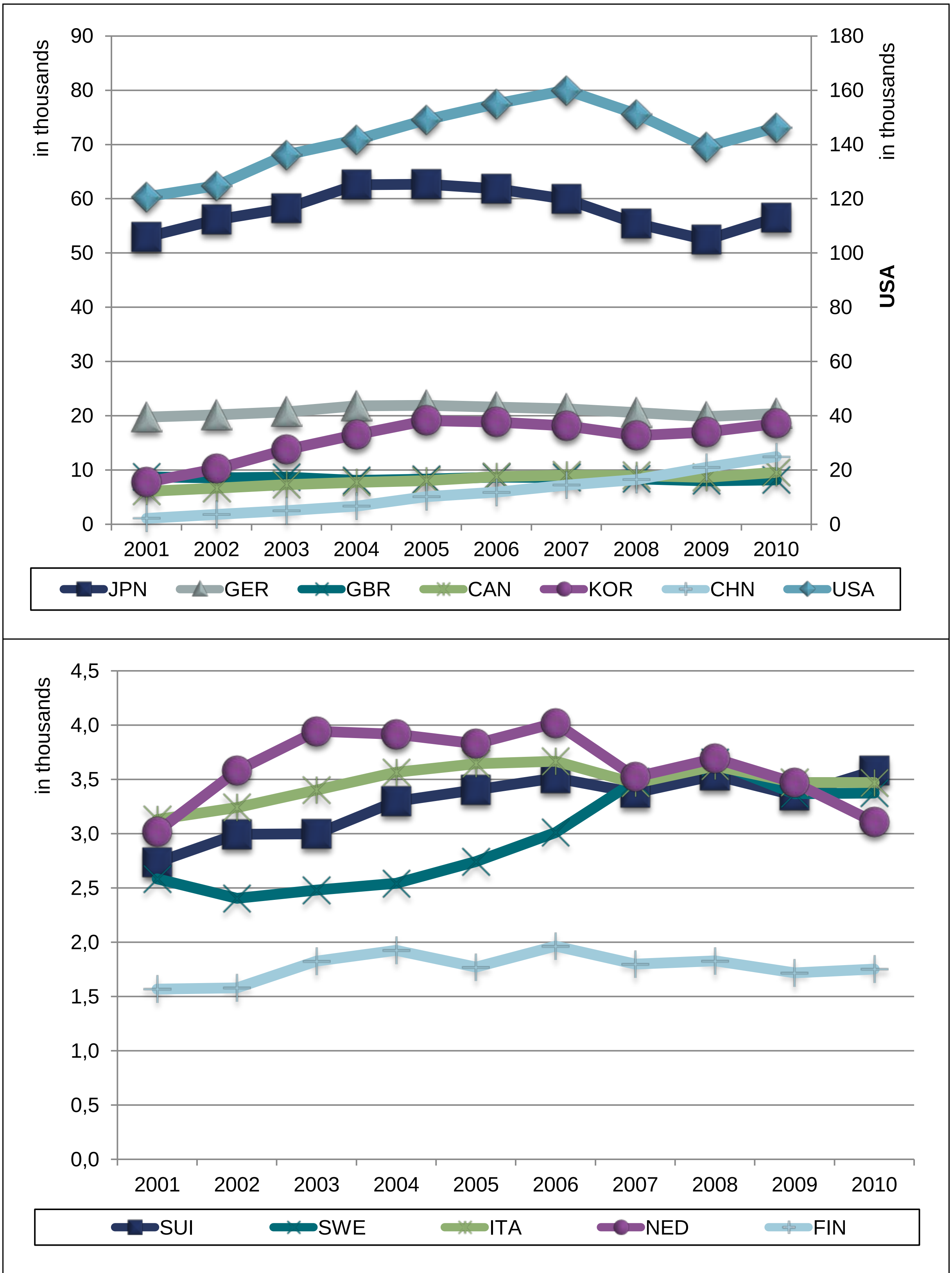
The USA still are the most important national market for high-tech products and many countries have a strong orientation towards this market. Countries like India, Taiwan or South Korea file most of their patents at the USPTO and thus almost only target the US-American market. Yet, it has to be kept in mind that inventors and applicants from the US have an advantage at their "home-office"[8], which makes the number of patent applications at the USPTO hardly comparable in terms of the general technological competitiveness of countries. However, the national competitiveness in the US-American market can best be compared with the help of USPTO patent filings.

4.1 General Trends at the USPTO

Figure 8 displays the absolute numbers of invention patent applications at the USPTO between 2001 and 2010 for a selected set of countries (larger countries in terms of patent applications in the upper panel, smaller countries in the lower panel, respectively). The graph for the USA is depicted at the right-hand scale of the figure. It shows that the absolute numbers of US patent applications at the USPTO are more than twice the number of the next largest country, namely Japan. It can thus be stated that the gap between Japan and the US is much larger at the USPTO than at the transnational level, where Japan nearly reaches the amount of US invented patent applications in 2010 (compare Figure 2). Yet still, Japan is far ahead of the other nations in absolute terms at the USPTO. It is followed by Germany, which is slightly in the lead of the group of countries that files less than 20,000 applications at the USPTO per year. Germany is closely followed by South Korea, implying that Germany is not so much USA-oriented as the other countries and files relatively less patents at the USPTO than it does at the transnational level. South Korea, however, is the third largest non-national inventor country at the USPTO. A similar trend can be observed for Taiwan (not further analysed in this report), which is also very US-oriented, filing about 21,000 USPTO patents in 2010 (USPTO 2012), thus being at a level comparable to Germany. These countries are followed by China, which outperforms the rest of the countries under analysis here and scores fourth behind the foreign countries Japan, Germany and South Korea.

8 The share of patents from US invented patent applications at the USPTO is about 46% in 2005. This number still is relatively low compared to other offices. At the Japanese Patent Office (JPO) or at the Korean Intellectual Property Office (KIPO) the share of patents by domestic inventors is 69% and 65% respectively. At the German Patent and Trademark Office (DPMA) and at the French Intellectual Property Office (INPI) these shares are even higher with 79% and 73%, respectively. At the State Intellectual Property Office (SIPO) of China, this value is with 46% in 2005 comparable to the USPTO.

Figure 8: Total number of pre-grant published patents at the USPTO for selected countries, 2001-2010



Source: Questel-Orbit – USAPPS, Fraunhofer ISI calculations.

As has already become visible at the transnational level, the economic crisis has also affected the filings at the USPTO. Especially for the US and Japan, a decrease in patent applications can be observed after 2007. This decrease is not so strongly pronounced for the other analysed countries. However, these countries also have far less filings at the USPTO in general. Most of the countries' patent filings already stagnated in 2007, which were the first impacts of the crisis.

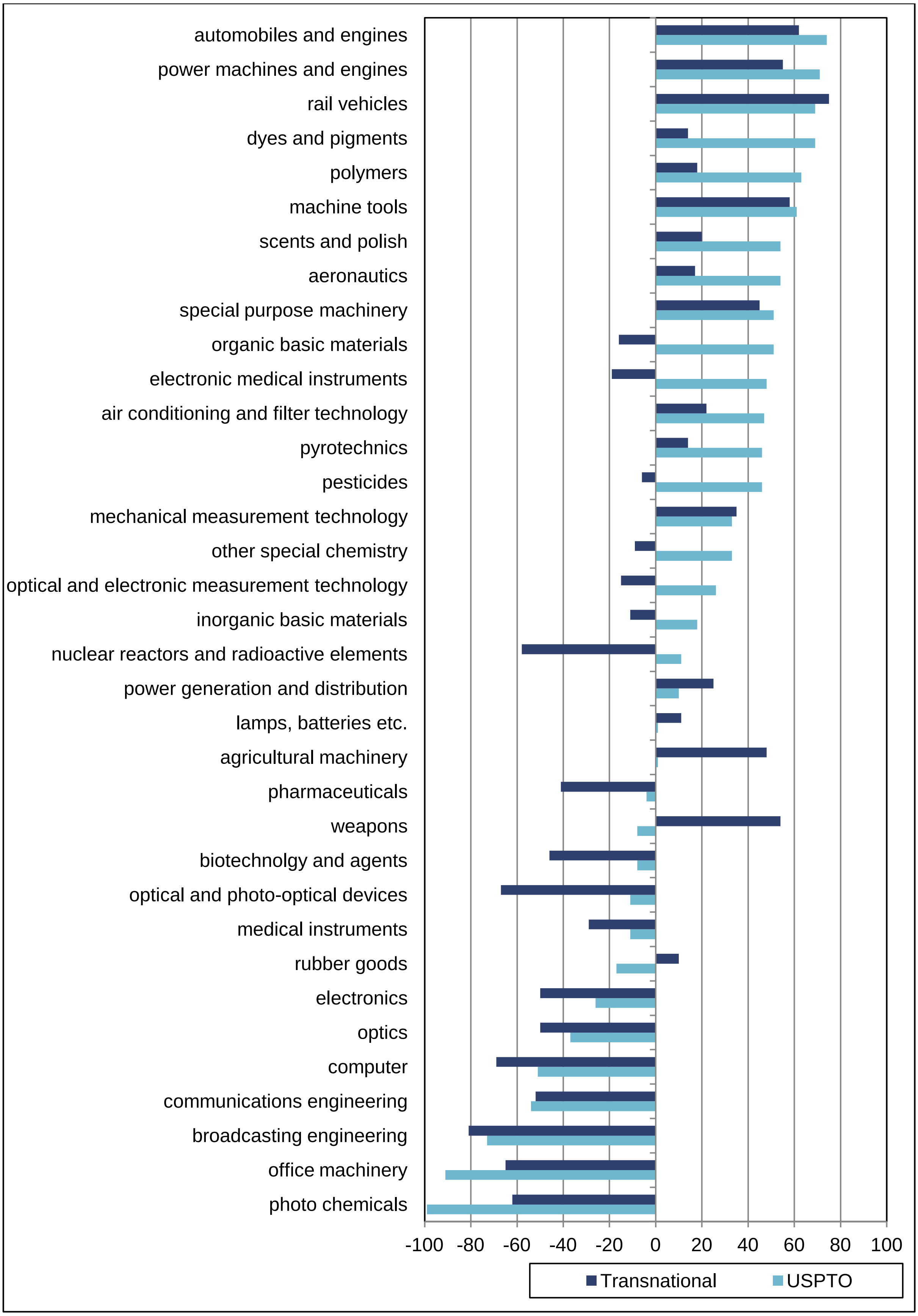
The argument here is the same as with the transnational patents. The companies from countries outside the USA target the USPTO via the PCT route or as a filing under the Paris Convention, so that the priority filing is done elsewhere and they have one year to decide where to go. As we analyse the data according to the priority date, 2007 priorities at the USPTO were already affected by the crisis, as they were to be transferred within the first year already under the first impressions of the crisis. Only for China a continuously growing trend can be observed, which has also been found at the transnational level. Among the smaller applicant countries, Sweden was only affected in 2008, but was still growing in 2007 (see lower panel of Figure 8).

It is interesting to note that the annual report of the USPTO shows only small statistical effects of the economic crisis on the published data, i.e. a small decline in overall utility patent filings for the year 2009 (USPTO 2012). Comparing our results with the official statistics, we find patent filings at the USPTO to be declining more strongly in 2008 and 2009. The explanation for this effect is threefold. First, the USPTO – like any other office – counts any patent by its filing date, which is the date when the process at the particular office starts. As the filing date is affected by the filing process (direct filing, Paris Convention, PCT application), up to 2.5 years difference are possible between these filing procedures; and 2.5 years in times of crisis means that it is over before it statistically impacts the data. Second, the statistics are a mixture of different patent types, while we only focus on invention patents. Third, the office is able to take all patents into account, also those meant to be pre-grant published, even if the process is abandoned before the publication, whereas we can only take the published data into account. Fourth, the USPTO allows applicants to file continuations (or continuations in part) of their patents. These continuations, however, are counted by the USPTO as if they were newly incoming patent applications, while we take them into account with the date of their (oldest) priority that they claim. Therefore, the numbers of official statistics are usually higher than those accessible to researchers. To sum up, the official USPTO statistics are not comparable to our analyses and they are not appropriate to reflect recent trends.

4.2 Technology profiles and patterns of specialisation at the USPTO

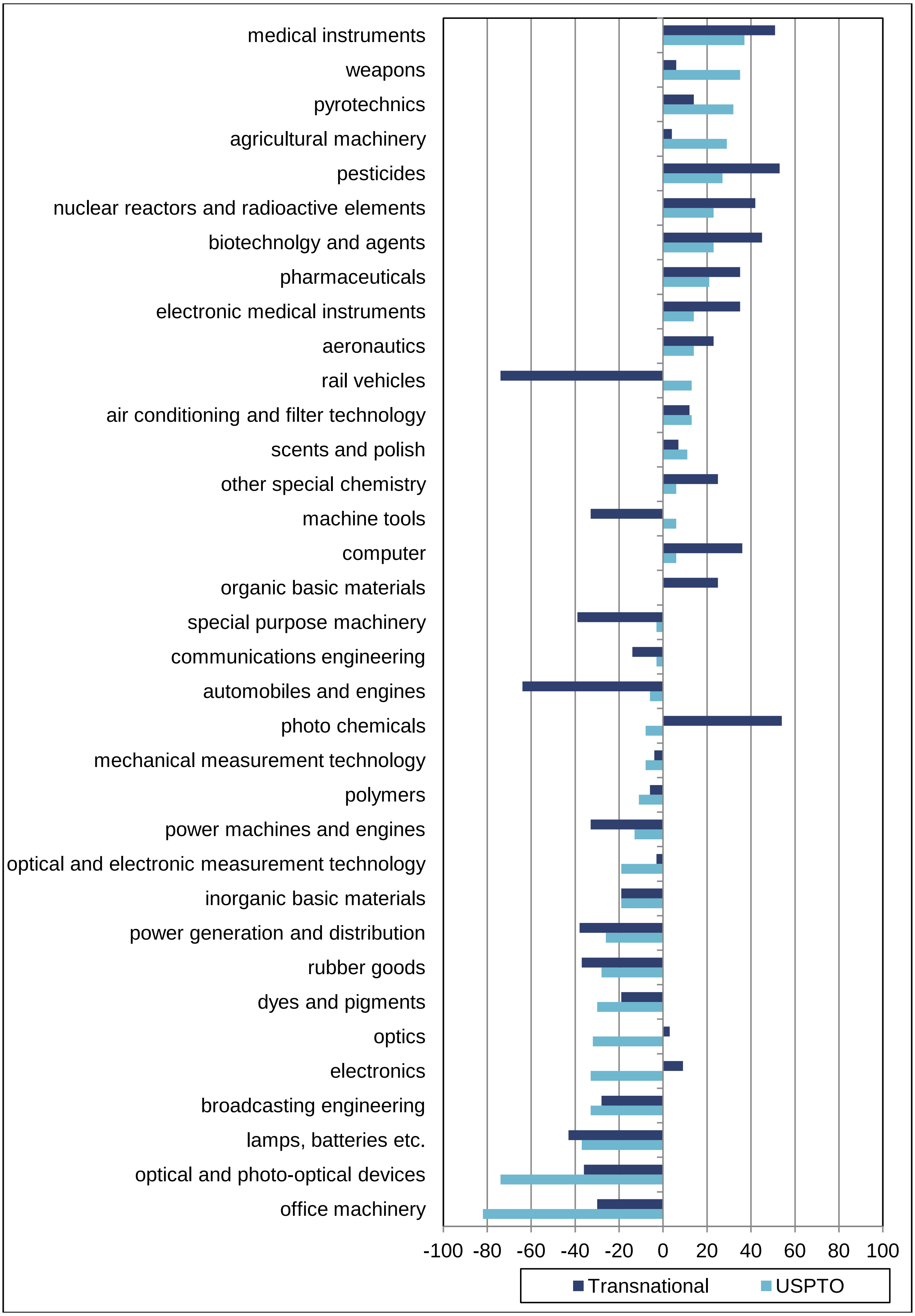
Like in the previous chapter on transnational patents, we will also focus on the comparison of the US-American and the German technology profile at the USPTO. The German profile shows similar but even more pronounced strengths and also some of the weaknesses compared to the transnational profile (Figure 9). It is in electrical engineering (power machines), transport and machinery where German engineers are targeting the US-American technology market. However, it can also be seen that the specialization towards transport and power machines and engines has slightly decreased compared to the observation period 2001-2003. Besides, the German profile is slightly more positive at the USPTO than at the transnational level in life sciences and chemistry. From this comparison, two more general trends can be derived. First, the German transnational profile is affected by the general competences of Germany. As described above, the intention of transnational patents is exactly to give a broad overview of the technological competitiveness of nations. Second, the US-American market especially for life science technologies seems much more attractive to Germans than the worldwide markets, implying that German firms have a selective view on markets depending on its attractiveness for certain technologies. This argument is also backed by the fact that Germany and the USA are the most active patenting countries in the medical instruments fields also in the Chinese market (Frietsch/Meng 2010). For the US-American profile, similar trends can be observed. However, the national profile is less pronounced compared to what the US-American inventors offer in worldwide technology markets (see Figure 10).

Figure 9: Technology profiles of Germany at the USPTO and in transnational patents, 2008-2010



Source: Questel-Orbit – USAPPS, Fraunhofer ISI calculations.

Figure 10: Technology profiles of the USA at the USPTO and in transnational patents, 2008-2010

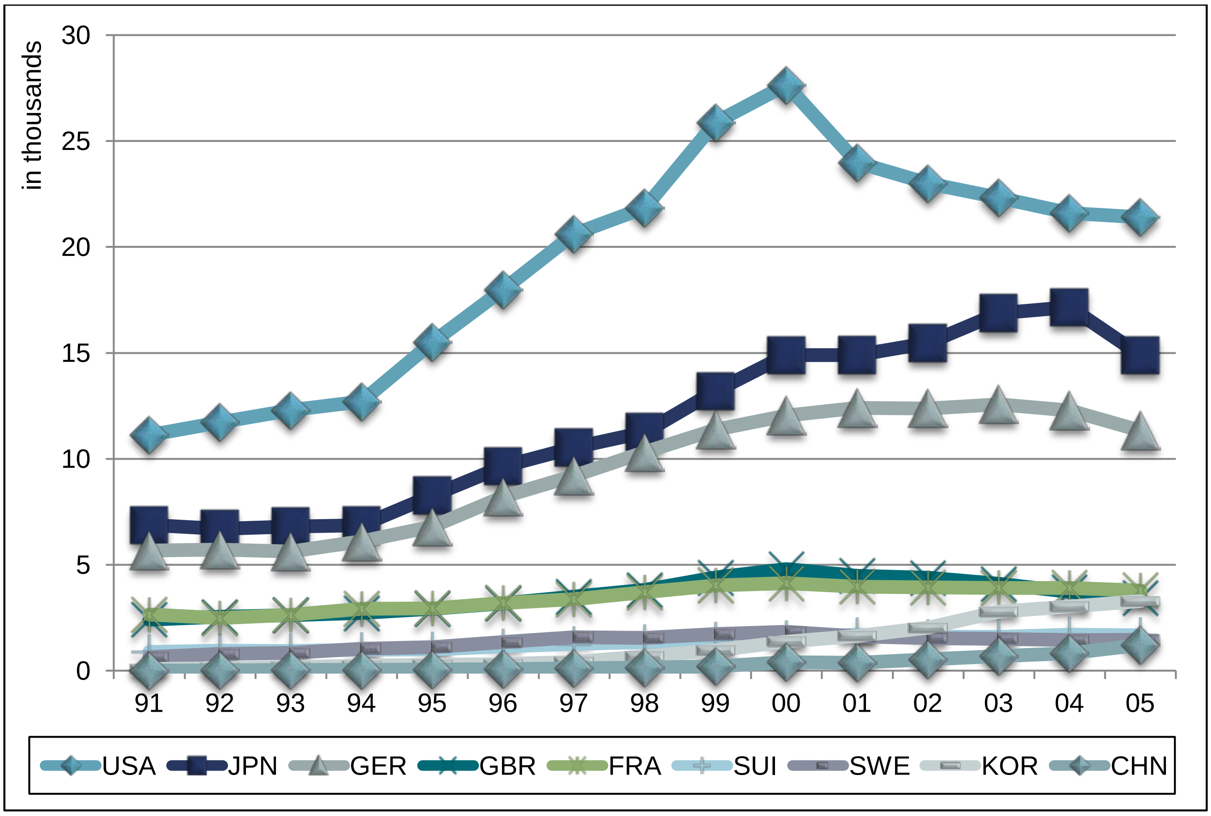


Source: Questel-Orbit – USAPPS, Fraunhofer ISI calculations.

5. Valuable Patents – A Citation- and Family-Size Weighted Ranking

The value of patents is extremely skewed – with only a few patents being highly (economically) valuable and a large number of patents being only of medium or low economic value (Bessen 2008; Gambardella et al. 2008; Grönqvist 2009; Harhoff/Hoisl 2007). While the value of individual patents is rather straightforward to understand, the value of national patent profiles cannot be assessed directly. In one of our recent studies (Frietsch et al. 2010a), several possible indications of the value of national patent portfolios were analyzed. This, as well as further analyses have shown, that especially a weighted patent family count and to some extent also patent forward citations can serve as an indication of patent value at the country level. Thus, these are the two measures we will apply in this chapter. For a broader discussion, please refer to the chapter on data and methods.

Figure 11: Number of cited transnational patent applications (4-year-citation window) of selected countries, 1991-2005

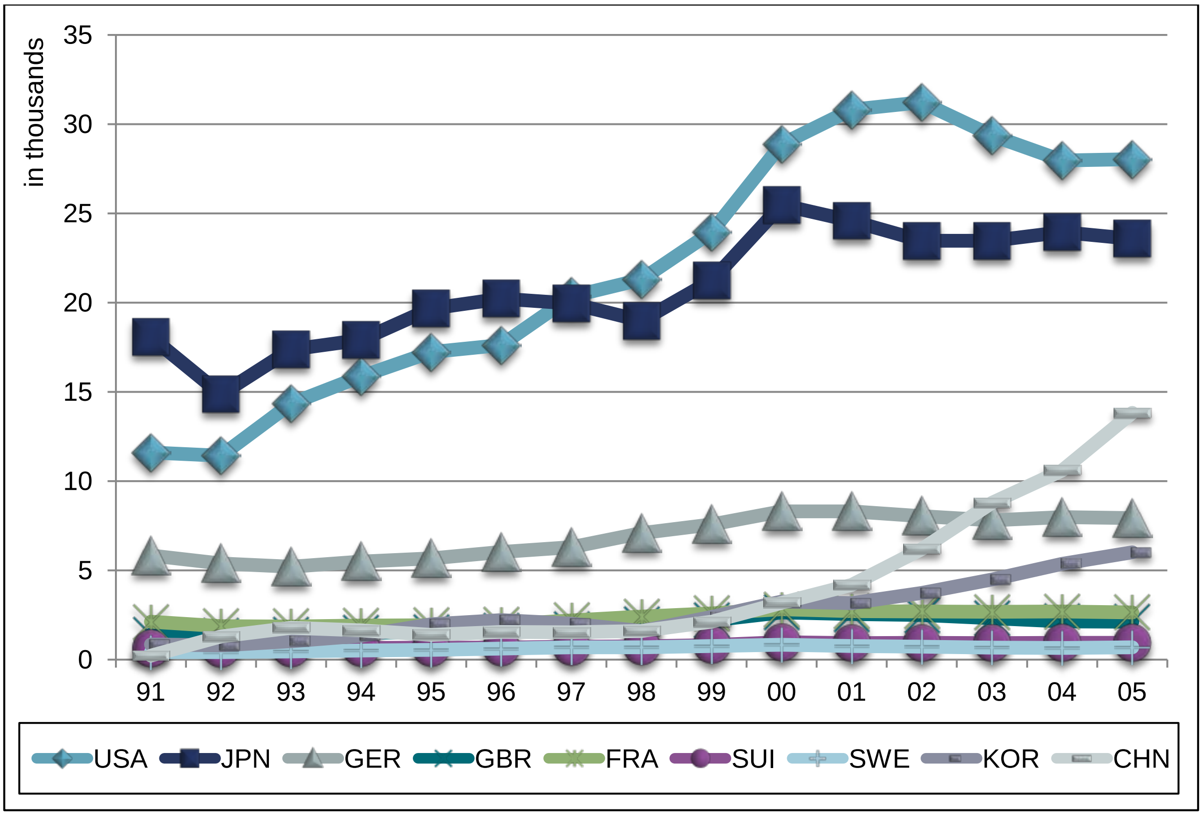


Source: EPO-PATSTAT; Fraunhofer ISI calculations.

For the analyses of cited patent applications, we apply a four-year citation window, which means that we analyse all citations that are made to a priority cohort of patents in the year of filing and the three subsequent years. However, this also means that our analysis only covers the priority years up to 2005 because afterwards the information on the number of forward citations is incomplete.

The absolute numbers of transnational patent applications that were cited within 4 years after priority date are depicted in Figure 11. It can be observed that the trends in patenting are almost the same as in the case of total transnational patent applications (see Figure 2), although at a lower level since only about 50% of all patent applications are at least cited once. However, the relations between the countries have slightly changed. The USA is downsized and thus the distance to Japan and Germany is reduced. The rest of the following countries, however, operate at a comparable level as in the case of total transnational patent applications.

Figure 12: Import weighted number of patent families, selected countries, 1991-2005



Source: EPO-PATSTAT; Fraunhofer ISI calculations.

Figure 12 displays the number of distinct patent families a country has filed in a given priority year (excluding "singletons" (Martinez 2009; Martínez 2010)) with the different family members weighted by the size of the markets (in terms of imports) in which the family member has been filed. This means that for this indicator we step away from the concept of transnational patents and analyze all patent families, no matter at which offices their members had been filed. A direct comparison to the data in Figure 2 is therefore not possible, but the trends and the relations between the countries can be interpreted. Here we also only analyze patenting trends up to the year 2005. This is due to the fact that it takes considerable time until a patent is granted at the EPO and then forwarded to the national offices where it can be counted as a "member" of a given patent family. Not including this time lag would introduce a bias towards patents that have been filed at offices other than the EPO, which would imply an advantage for (mostly) non-European countries.

Table 3: Absolute number, ranking and index of transnational patent applications of selected countries using value adjustment indicators, priority year 2005

	Absolute No. of filings			Rank			Index (Germany = 100)		
	Transnational	**Cited**	**Import weighted number of patent families**	**Transnational**	**Cited**	**Import weighted number of patent families**	**Transnational**	**Cited**	**Import weighted number of patent families**
USA	59,038	21,401	28,026	1	1	1	203	189	354
JPN	36,495	14,895	23,577	2	2	2	125	131	297
GER	29,134	11,340	7,926	3	3	4	100	100	100
FRA	10,272	3,793	2,644	4	4	6	35	33	33
KOR	8,568	3,285	6,007	5	6	5	29	29	76
GBR	7,539	3,431	2,125	6	5	7	26	30	27
ITA	6,245	2,484	1,238	7	7	9	21	22	16
CHN	4,427	1,217	13,823	8	12	3	15	11	174
NED	4,280	1,960	1,039	9	8	10	15	17	13
SUI	3,853	1,680	950	10	9	11	13	15	12
CAN	3,775	1,604	1,659	11	10	8	13	14	21
SWE	3,461	1,464	684	12	11	12	12	13	9
FIN	1,817	842	416	13	13	13	6	7	5
IND	1,242	540	413	14	14	14	4	5	5
RUS	869	206	332	15	15	15	3	2	4
RSA	439	159	67	16	16	17	2	1	1
BRA	420	148	129	17	17	16	1	1	2

Source: EPO-PATSTAT; Fraunhofer ISI calculations.

When looking at the weighted number of patent families, the trends compared to the ones in total transnational patent applications draw a slightly different picture. Although the USA still ranks first, the distance to Japan has declined even more than in the case of citation weighted patents. Until the end of the 1990s, Japan was even able to outperform the USA on this indicator. However, from 1998 onwards, the USA gained ground and was able to secure its first position. This means that the USA now files the largest number of patent families in the most important markets (measured in terms of imports) worldwide. However, this effect can at least also partly be attributed to the large home market of the US applicants. The USA and Japan are followed by Germany, which can also be seen as one of the major technology supplying countries in the world. As in the case of the total transnational patent applications, Germany is followed by a large group of countries that rank at a medium level on this indicator. Interestingly, from 2003 onwards, China is able to outperform Germany. This trend can also partially be attributed to the large Chinese domestic market. However, this is not the only explanation. China files more and more of its patents also internationally and tries to secure important markets to sell its technologies. A similar trend can be observed for South Korea, which ranks directly after Germany in the year 2005.

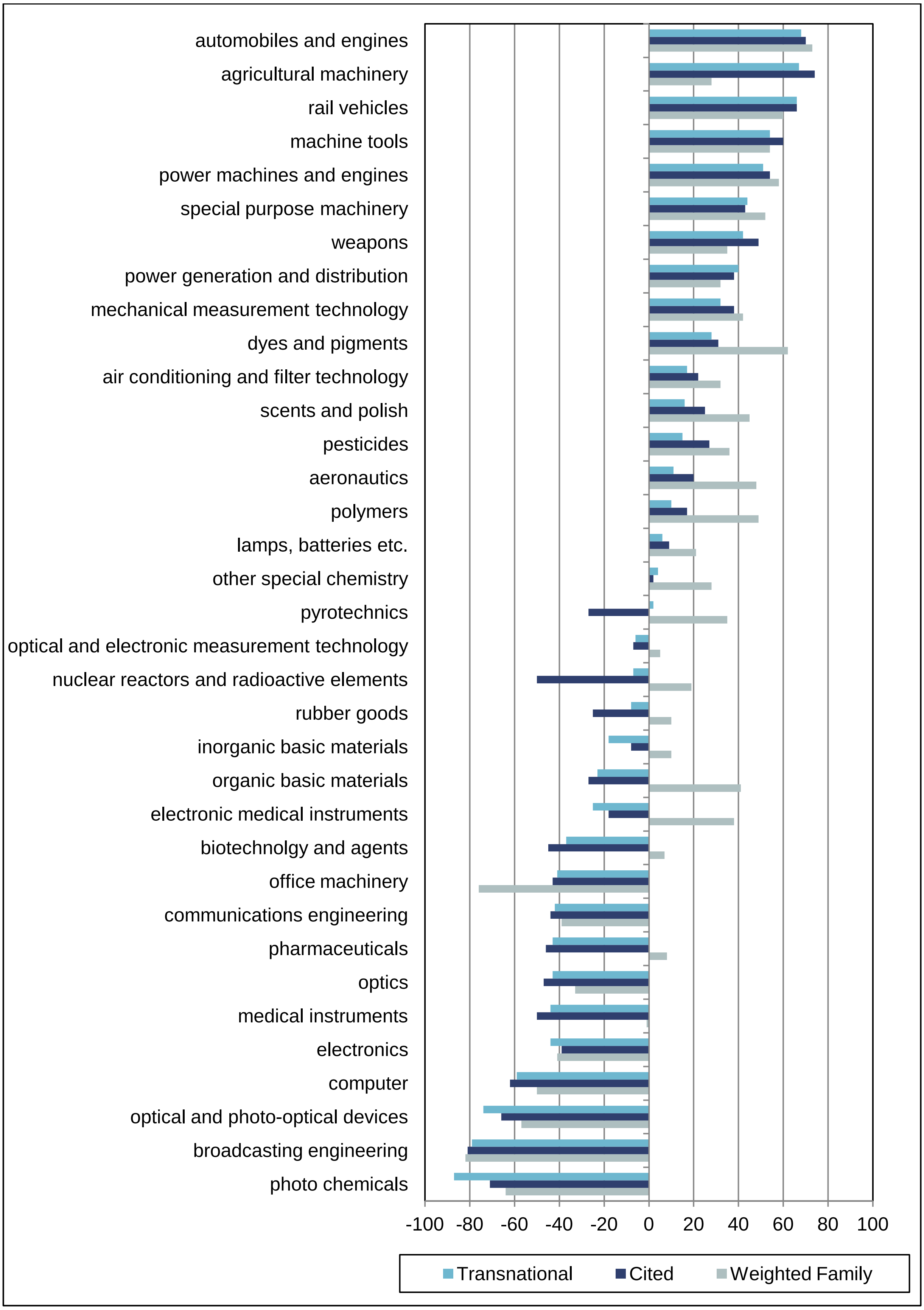
Table 3 further qualifies these findings. It contains the absolute numbers, the rankings of the countries and an index to measure the distance between the countries (Germany is set to a value of 100 as a benchmark) for the year 2005. Though the absolute numbers of the three indicators are clearly different, the ranking only changes slightly when the cited transnational patent applications are taken into account instead of the total number of transnational patent applications. Korea and the United Kingdom swop ranks and China loses ground due to a lower number of cited patent applications. Yet, in sum it can be stated that using the citation weights does not make a large difference, which replicates the results of our previous study (Frietsch et al. 2011). This, however, is different for the patent family indicator, which uses imports to weight the family members by the size or attractiveness of the market in which they were filed. In last year's study, we showed that especially the import weighted patent families are able to act as a robust indicator of patent value at the level of countries and technology fields (Frietsch et al. 2012; Neuhäusler/Frietsch 2012).

When looking at this indicator, it can be observed that the USA and Japan still keep their positions. China scores third and thus outperforms Germany and Korea. Changes are also visible in the medium ranks. France and Great Britain both loose ground due to the quick catching up of China and Korea, which is also true for Italy, the Netherlands and Switzerland. Canada, on the other hand, climbs up the ladder, yet mostly because many Canadian firms file their patents also at the USPTO, which has a large weight due to its market size. In sum, it makes a difference when the weighted family size indicator is taken into account.

It thus makes sense to have another look at the technological profiles of Germany in the years 2003-2005, taking the three different perspectives into account (Figure 13). In the case of citation weighted patents, the patterns are almost identical and the index values vary only little. Exceptions can only be found in the smaller fields in terms of absolute patenting, namely pyrotechnics and nuclear reactors. In the case of the family size indicator, however, the German profile looks a little bit different. Mostly the chemistry related fields (organic and inorganic basic materials) as well as biotechnology, electronic medical instruments and pharmaceuticals gain ground. Germany is thus more specialized in those fields when taking into account the number and size of markets a patent is filed at. This comes at the expense of a lower specialization in some smaller mechanical engineering related fields (agricultural machinery, office machinery), which seem to focus mostly on the German or European market.

All in all, the value adjustment by patent forward citations has hardly any impact on the rankings or on the relative positions of the countries analysed in this report. The only difference is the level of the absolute numbers. This is different for the family size indicator. It is able to provide new insights for country comparisons as well as technological profiles.

Figure 13: Germany's specialisation profile using value adjustment indicators, 2003-2005



Source: EPO-PATSTAT; Fraunhofer ISI calculations.

6. Structures of International Co-Patenting

In this chapter, the structures and trends of international cooperation and the internationalization of R&D activities will be analyzed via transnational co-patents.

The internationalization strategy of the German Federal Government of 2008 primarily aims at strengthening the cooperation with best scientific economies in the world and to make the world's innovative potential available for Germany. In the course of 2012 the German Ministry for Education and Research (BMBF) will publish a new framework for internationalization.

The cooperation structures in international patenting resemble the internationalization of R&D activities and indicate which countries can already be considered as attractive research partners for Germany and with which countries cooperations could be improved. It can be assumed that each collaboration which 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 enables statements on 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, we focus on the explicable and explicit knowledge (Grupp 1998).

Within the following chapter, the transnational co-patents of all OECD, EU-27 and BRICS countries plus some additional countries to capture worldwide co-patenting will be analyzed. First of all, some descriptive analyses on the "core-countries" will be performed and the co-patents of Germany and its importance as partner for international collaborations will be analyzed. In the second part of this chapter, we will give a refined picture of the German co-patenting structures by analyzing different trends in co-patenting between different technological fields. Finally, a social network analysis (SNA) of the transnational co-patents will be carried out on a worldwide scale. Social network analyses are able to reveal complex patterns of relationships between actors of a network. It can show how important certain actors are, give insights on the strength of their relations to other actors and can also indicate groupings of actors within a system. Thus, it allows a concise presentation of the countries' cooperation structures. In addition, it allows for more differentiated statements about the strength of cooperations ("strong" vs. "weak" ties) (Granovetter 2004; Granovetter 1973), which is especially interesting since – according to the network theory – the probability of cooperations with a third partner increases if one of the two cooperation partners is already engaged in cooperations with the third partner (Rapoport 1957). It is further able to show if cooperations between countries are concentrated to only one or several "core-partners" and if an economy has differentiated cooperational structures and, relatively seen, cooperates with many partners.

6.1 A brief review of the literature

The literature on research collaborations discusses several characteristics that can foster or hamper international cooperations (for an extended overview see Fraunhofer ISI et al. 2009). One of those characteristics is the size of a country. Already in 1979, Frame and Carpenter (1979) stated that the size of a country influences its propensity to collaborate internationally.

One of the main arguments is that smaller countries have more foreign collaborations than large countries because there are few partners with which they can collaborate inside their home country (Narin et al. 1991; Schubert/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 also points to the fact that, although country size seems to matter, there is considerable heterogeneity between countries in their propensity to collaborate, which can be attributed to a multitude of different factors (Hoekman et al. 2010). These mainly are geopolitical and historical factors as well as language, but also social, intellectual, cognitive and economic factors seem to be relevant (Frame/Carpenter 1979; Glänzel/Schubert 2004; Luukkonen et al. 1992). In addition, differences occur between fields (Liu et al. 2012): basic disciplines express a higher propensity to collaborate internationally than applied disciplines (Frame/Carpenter 1979). Frietsch (2004) as well as Schmoch (2005; 2006) also find that strategic aspects should be taken into account. Explicitly not collaborating with a national partner but to collaborate internationally for example in EU projects or to get access to certain data or research facilities might build an incentive. In addition, one might willingly choose not cooperate in a given field in order to protect proprietary knowledge, especially when the need to cooperate, e.g. to gain access to additional resources, 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/Dettmann 2012).

Katz (1994) further found that the intensity of collaboration 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 relevant too. Finally, Mattson et al. (2008) provide a good 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 programmes and others to facilitate collaboration).

In sum, it can be stated that analysing and interpreting international collaborations should be done with care, having in mind that there are several factors, which might be mutually dependent, 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).

Within this report we solely focus on international co-patents, which are only one way in which researchers can collaborate, but can be used to track international knowledge flows and transfers (Fraunhofer ISI et al. 2009). As with patents in general, international co-patenting is mainly driven by companies that are looking for collaboration partners for R&D projects all over the world. However, according to Fraunhofer ISI et al. (2009), there are some specialities about the co-patenting indicator which deserve to be mentioned. First, 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. Second, when interpreting co-patenting data it is also important to recognise that it is based on the concept of domestic inventors and not on the nationality of inventors, because patent data do not include information on the nationality. Third, co-patenting activity only picks up collaborations which actually result in a patent. Fourth, 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 transnational patent application are living in two different countries, i.e. a domestic and a foreign inventor (for a more detailed overview on the methodology please see chapter 2) also when they belong to the same firm that operates facilities or subsidiaries in two different countries (Fraunhofer ISI et al. 2009; Guellec/Pluvia Zuniga 2007).

6.2 International Co-Patenting Trends

In this section, we present the trends in international co-patenting. In section 6.2.1, first of all some country-level analyses will be performed, where German co-patents stand in the focus of the analyses. In the following section (section 6.2.2), we will give a refined picture of the German co-patenting structures by analyzing trends in co-patenting between different technological fields. Finally, a social network analysis (SNA) which shall provide further insights on the structures of international cooperation in terms of patenting will be carried out in section 6.2.3.

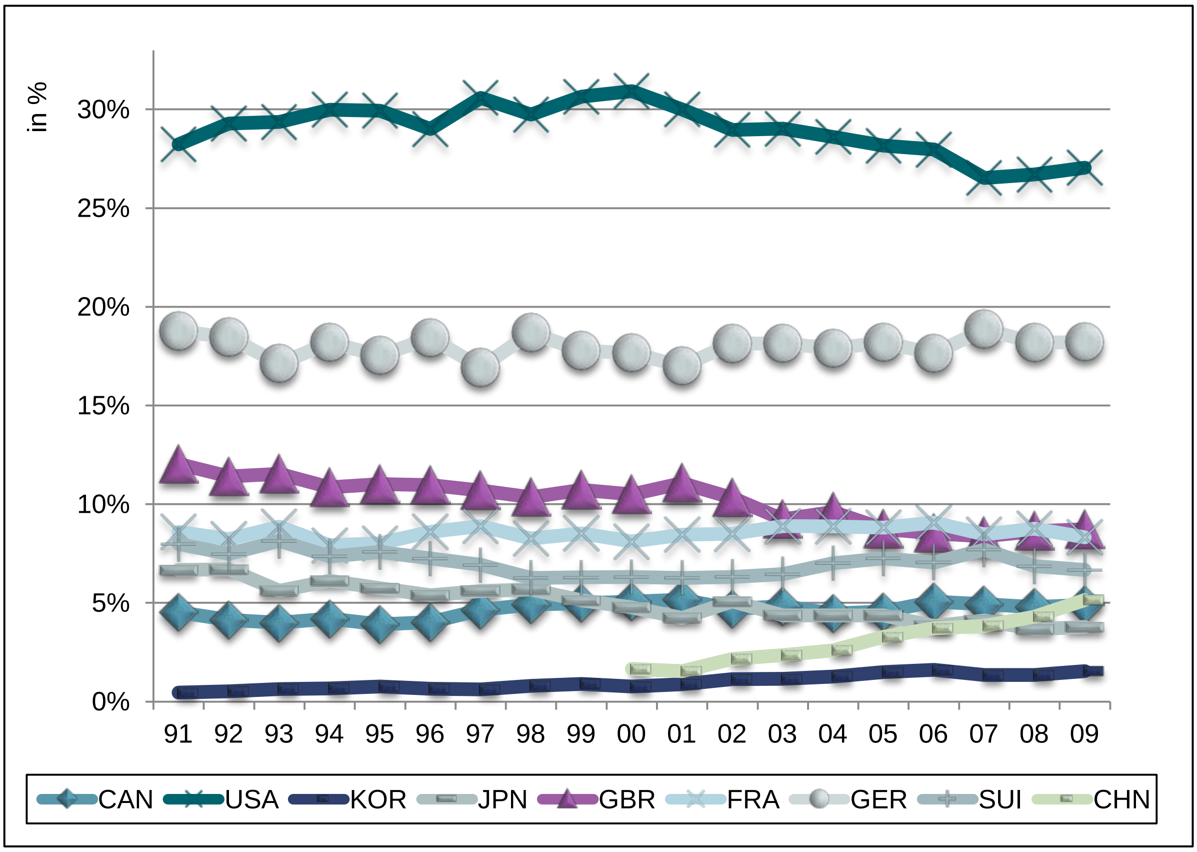
6.2.1 Cross-Country Comparisons

Figure 14 depicts the transnational co-patents by country as a share of all transnational co-patents world-wide. As can be seen from the figure, the US has the highest share of co-patents in all transnational co-patents with a value even exceeding 30% in some years. This is not overly surprising since the US is also the largest filing country in terms of the absolute number of patents. However, a slight decline in this share can be observed from the year 2000 onwards with the US reaching a value of 27% in 2009.

The US is followed by Germany, with a share of about 20% over the years. Besides some smaller variations, the German share remains relatively stable over time, implying that – already starting from a strongly internationalized position – Germany is able to maintain a significant amount of international R&D projects over the last 20 years. Germany is followed by Great Britain, with a share of about 12% in the early 1990s. Yet, the share declines to about 8% over the years and Great Britain is on a similar level like France in 2009. The remaining countries all have a share of 1% to 7% over the years.

Probably the most interesting finding relates to Japan. Although it is the second largest country in terms of transnational patent filings – after the US – it reaches only a share of about 7% in the early 1990s, which even declines to slightly below 4% in 2009. 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 seems to be similar for South Korea which ranks last on this indicator over the whole time period.

Figure 14: Shares of transnational co-patents in total transnational co-patents, selected countries, 1991-2009

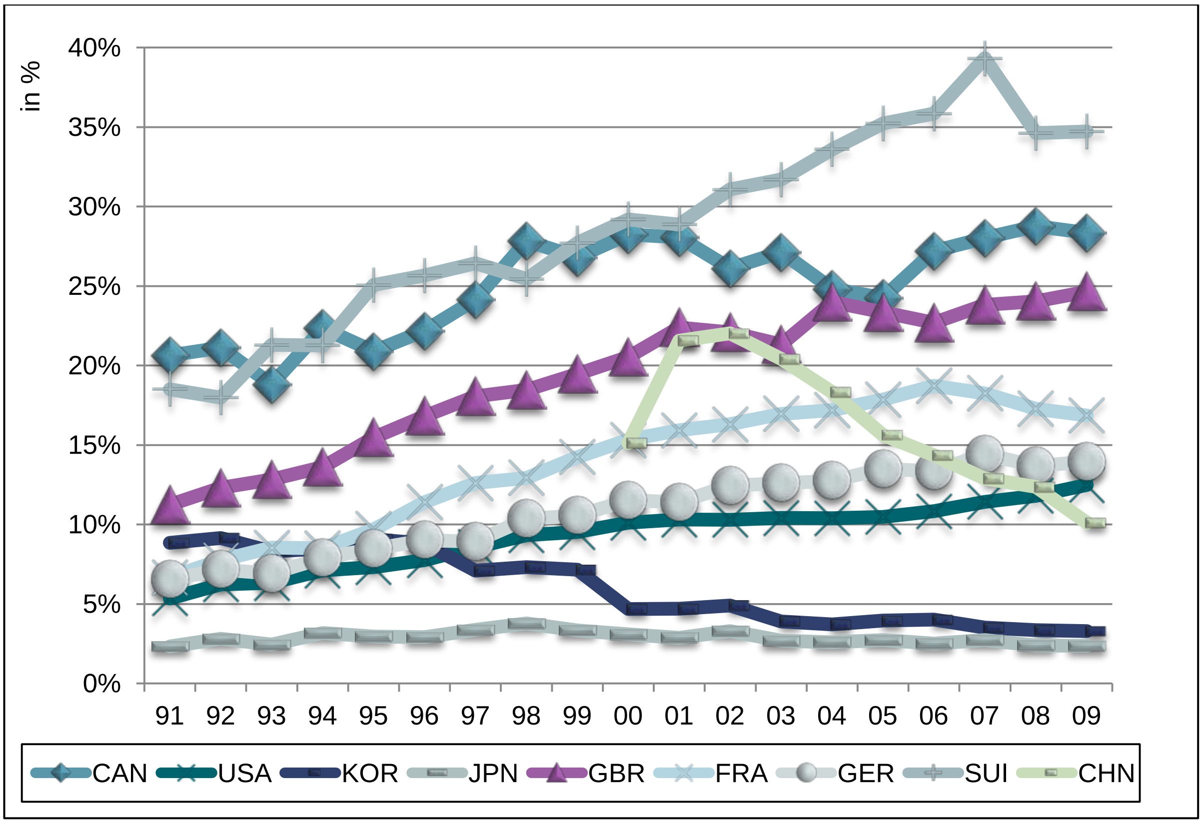


Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.
Note: The value of "all transnational co-patents" is calculated as the sum of all of the countries' co-patents within the figure.

Figure 15 shows the shares of transnational co-patents in all transnational patents of the respective inventor country, meaning that size effects do not play a role for the interpretation of these results. When looking at this indicator, Japan again ranks last with only a share of 2% to 4% of transnational co-patents within its transnational patent portfolio. A similar trend can be observed for South Korea. Although it achieved relatively high shares in the beginning to mid 1990s, the rate went down to the level of Japan in 2009. Switzerland reaches the highest shares of co-patents within its transnational patent portfolio, which is even increasing over the years. This means that Switzerland is the most internationalized country in terms of co-patenting and is heavily co-operating with other countries in R&D projects. It is followed by Canada, where the share is also at a very high level. Yet, this can at least partially be attributed to a very large number of co-patents with US inventors. Starting from a value of 7% in the year 1990, Germany only has a medium internationalization when regarding this indicator. The number rises up to about 14% in the year 2009, which shows the tendency of German R&D activities to become more and more internationalized. The USA, although ranking first when size effects are not cancelled out (Figure 14), shows comparably low shares of co-patents within its transnational patent portfolio.

A special trend can be observed for China. At the beginning of the 2000s, it had a relatively high share of about 20% of transnational co-patents within its portfolio. Yet, following the trend of Japan and South Korea, this share started to decline quickly down to only 10% in the year 2009. This trend deserves some special attention. We therefore added some China specific analyses in a brief special section of this report.

Figure 15: Shares of transnational co-patents in all transnational patents of the respective country, selected countries, 1991-2009

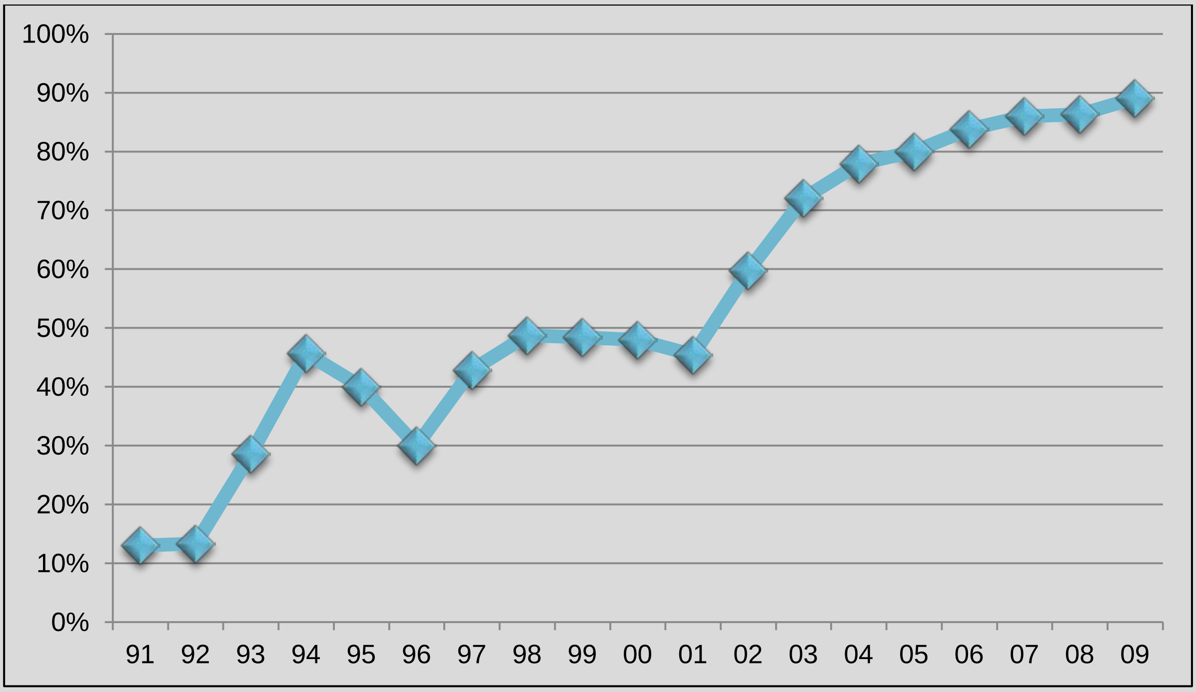


Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

Chinese Co-Patenting Trends – A closer look

The co-patenting trends of China deserve some special attention, especially against the background that the Chinese market has gained more and more importance over the last 20 years. In addition, at latest from 2000 onwards, China has become a major player in international technology competition, filing an ever increasing number of transnational patent applications. In order to shed some more light on the transnational co-patenting trends of Chinese inventors, two additional figures (Figure 16 and Figure 17) are provided. China has shown quite a special trend in transnational co-patents. The share of transnational co-patents within the Chinese transnational patent portfolio was rather high in the early 2000s, at a level of 21%. From then on, the number started to decline to a relatively low level of about 10% in 2009.

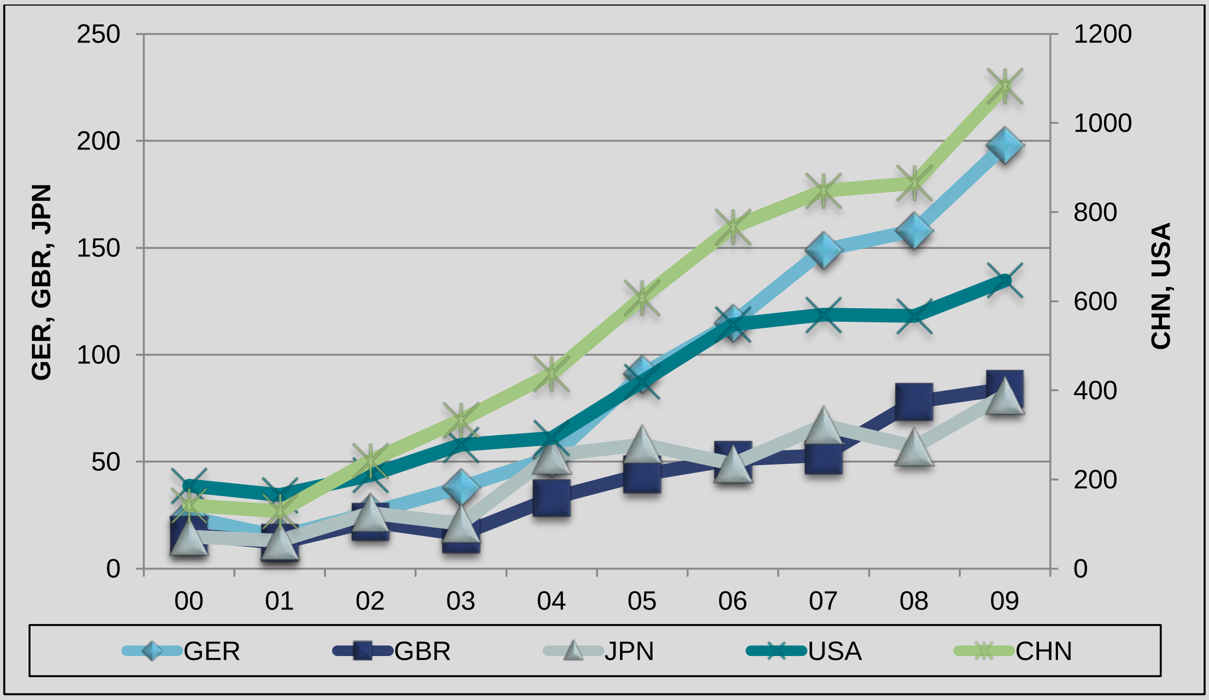
Figure 16: Share of transnational co-patents from Chinese inventors with a Chinese applicant named on the application, 1991-2009



Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

Since an international co-patent with an inventor located in China does not necessarily mean that the patent has been applied by a Chinese firm (it might also be that a large multinational enterprise from another country operates research facilities in China), this poses the question of the applicant structure behind the large amount of Chinese co-patents in the early 2000s. Thus, Figure 16 shows the share of transnational co-patents (with OECD countries only) from Chinese inventors with a Chinese applicant named on the application. It can be observed that in the early 1990s, only about 13% of Chinese co-invented patents were filed by a Chinese patent applicant. This means that foreign applicants, mostly large multinational firms (MNEs), make up the lion's share of Chinese co-invented patents in that period. To put it in other words, mainly the research facilities of foreign MNEs, co-inventing with inventors located in China, were responsible for this large share of transnational co-patents. However, one has to keep in mind that the absolute number of Chinese transnational patents was quite low during that time. Until the year 2001 more and more Chinese applicants enter the scene. In 2001, already 45% of Chinese co-invented patents are stemming from Chinese applicants. At the same time, however, the share of Chinese co-invented patents within the Chinese transnational patenting portfolio starts do decline, following the trend of Japan and South Korea, which also show a relatively low level of international co-patents within their patent portfolio.

Figure 17: Number of transnational co-patents from Chinese inventors by applicant country, 2000-2009

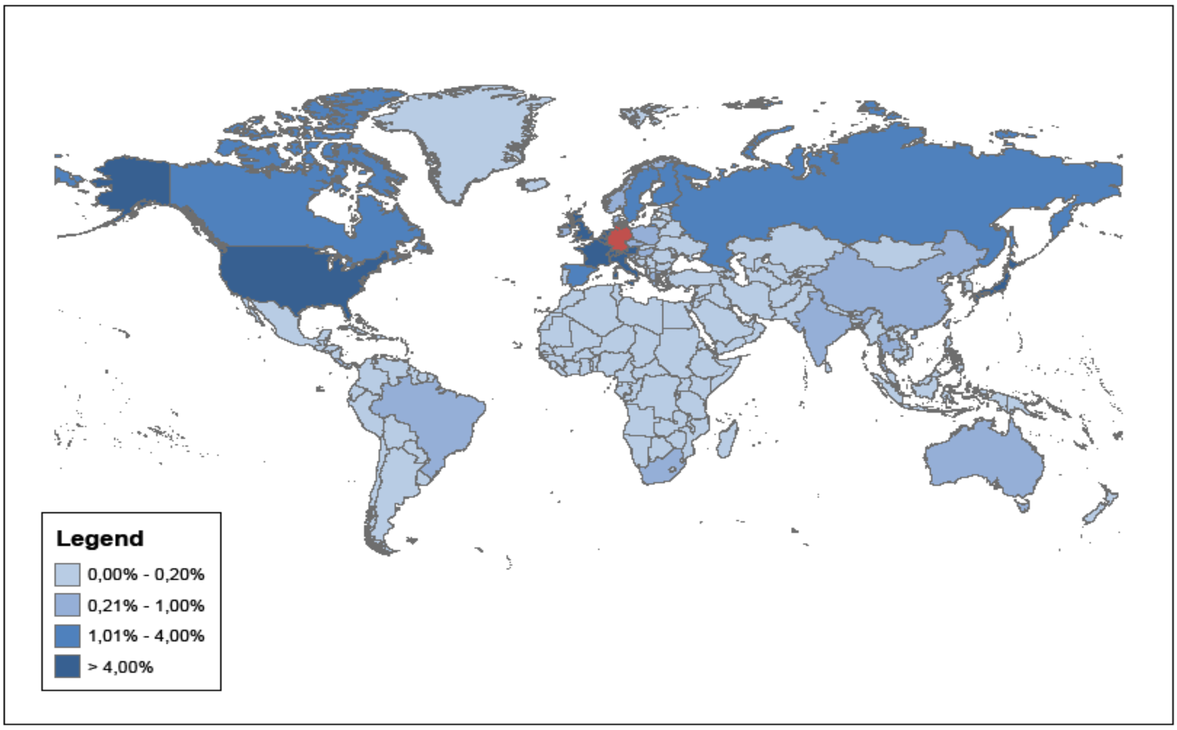


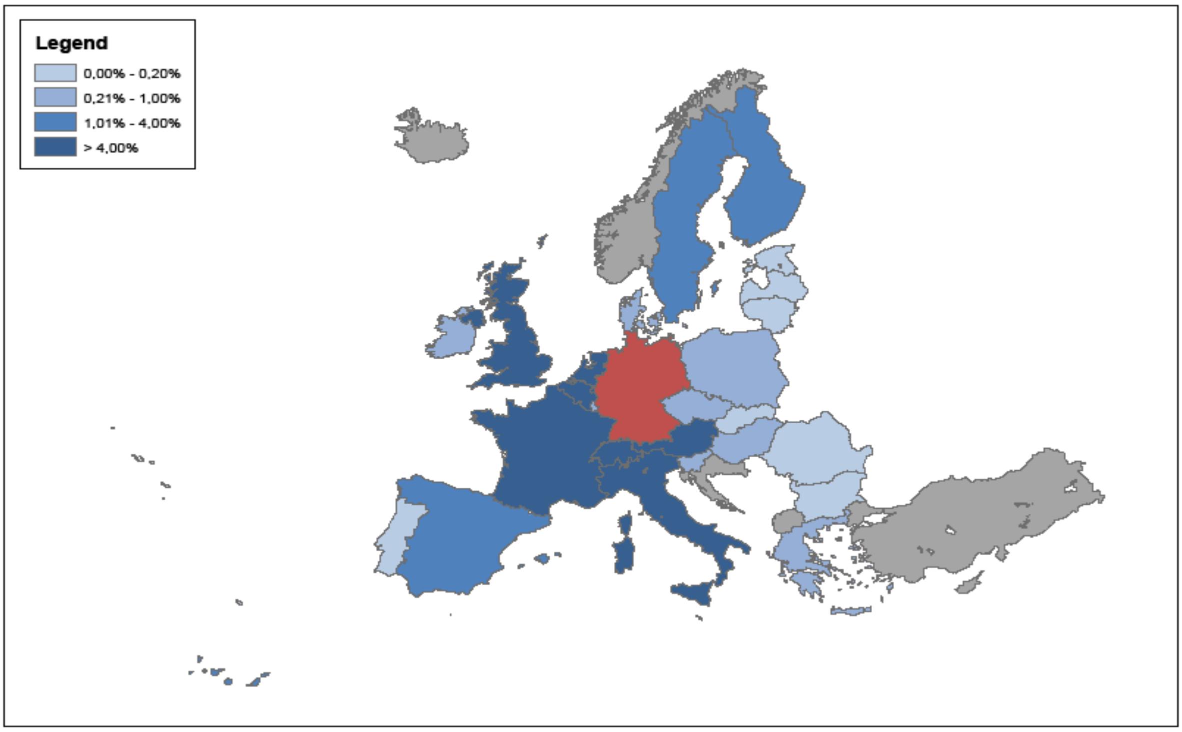
Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

To qualify these findings and to give a broader picture, Figure 17 shows the absolute number of transnational co-patents from Chinese inventors by the country where the applicant is located. It can be shown that this number is rising over the years for all of the analyzed countries. This is as expected, since the number of Chinese transnational patents increased massively since the year 2000. Also the number of co-patents applied by Chinese applicants is rising, but the share of co-patents within the national Chinese portfolio decreases, which can also be interpreted as a convergence to its neighbours.

In Figure 18 and Figure 19 we again take the German perspective by plotting the most important German collaboration partners in terms of co-patenting (the share of Germany's co-patents in all German transnational patents) for the years 2000 and 2009 on a worldwide scale. Figure 18 first of all shows a world map (upper panel) of German co-patenting partners for the year 2000. For reasons of visibility, Europe is scaled up in the lower panel of the figure. As we can see, especially the central European countries (France, Switzerland, Great Britain, Italy, Austria) and the USA are the most important partners for Germany. They are followed by Finland, Sweden, Russia, Canada and Spain, with whom 1% to 4% of all German co-patents are filed. Yet, at least to some extent, Germany also co-operated with China, India, Brazil, South Africa and Australia already in the year 2000.

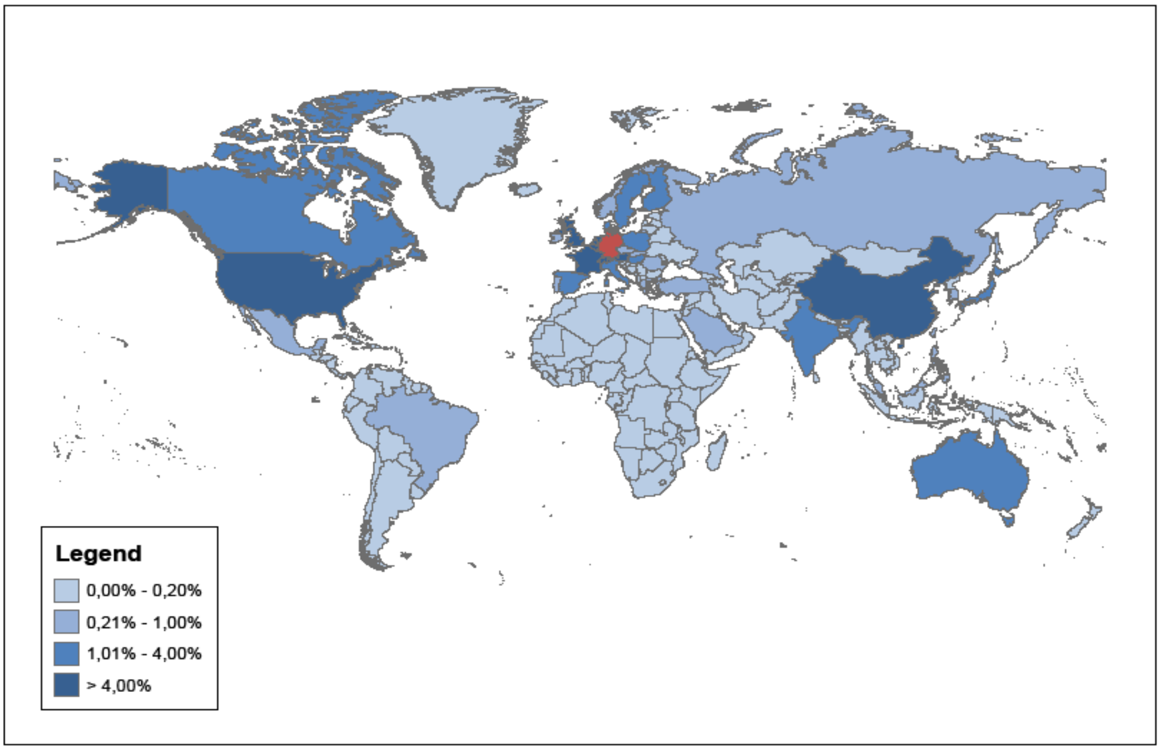
Figure 18: Map of German collaboration partners in terms of patenting, 2000

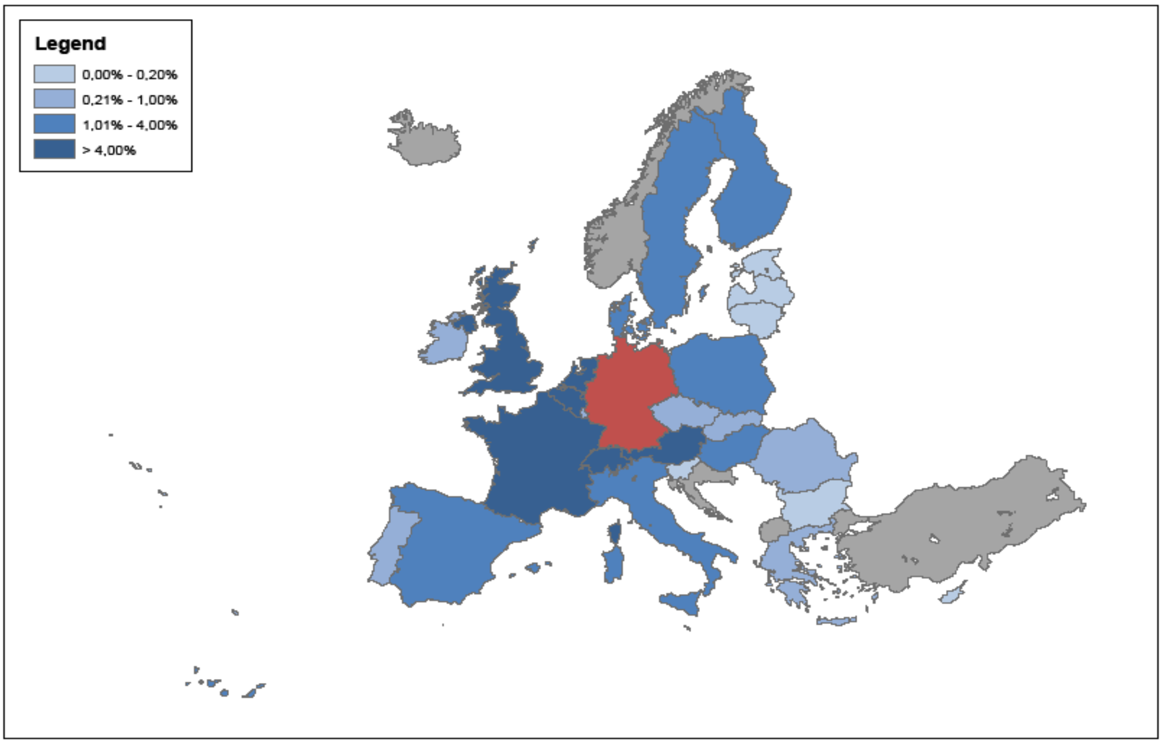




Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

Figure 19: Map of German collaboration partners in terms of patenting, 2009

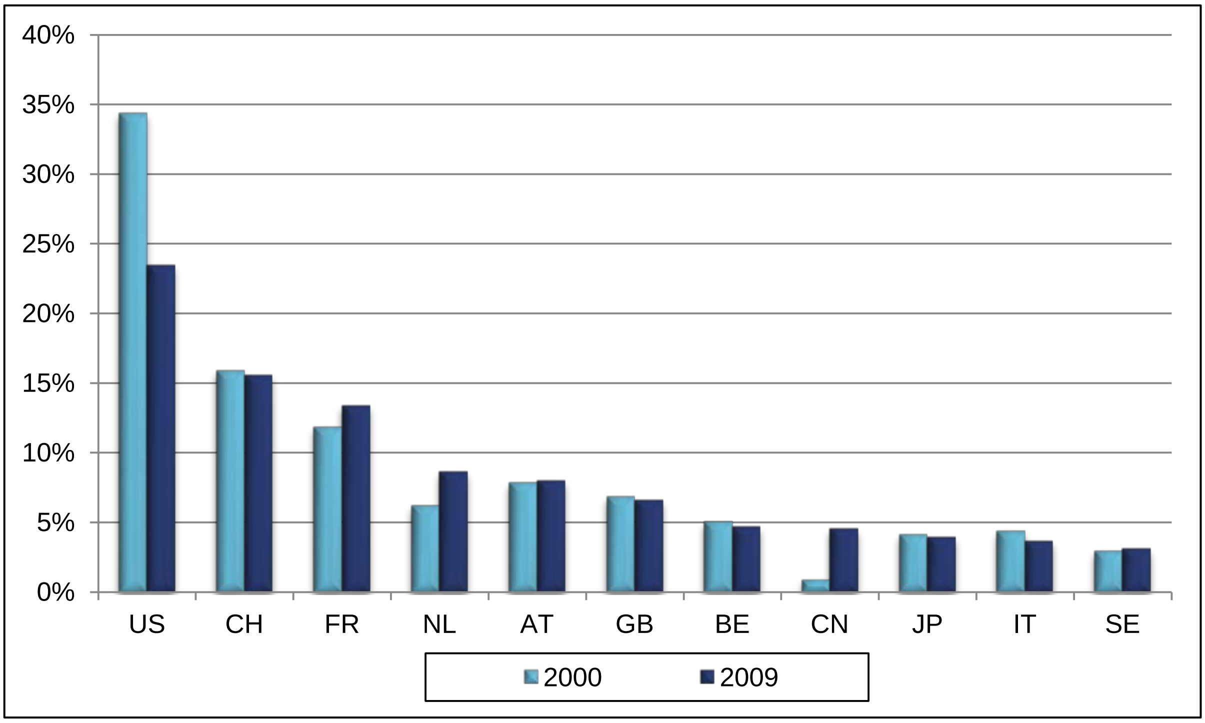




Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

As we can see in Figure 19, which repeats the analysis for 2009, besides slight increases in the cooperation intensity with Eastern European countries, there have not been major changes in the importance of German co-patenting partners within Europe. This picture, however, becomes different when looking at a world-wide scale. As we have seen from the analyses before, especially China as well as India and Australia have become more and more important as German research partners. The fading of distance as a hampering factor for international collaboration can also be found in the literature (Ahlgren et al. 2012; Hoekman et al. 2010). It thus seems that those markets have gained increased importance for Germany, since collaborating can also facilitate market entry and knowledge access. However, as we have seen in the literature review, this does not necessarily mean that these co-patents all are inter firm co-patents. It might well be that Germany has started to increasingly operate facilities or subsidiaries in those countries, which might at least partly drive those results. Also the Netherlands and France have gained importance (Figure 20). Russia as well as the USA, on the other hand, both have lost importance (Figure 20), which is mostly due to the increase in co-patenting activities with China but also due to more widespread German co-patenting activities.

Figure 20: The importance of collaboration partners for Germany, by country, 2000 and 2009



Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.
Note: In this figure, the Top 10 cooperation partners for Germany in terms of co-patenting are depicted. CHN has not been in this list in the year 2000 and SWE has not been in this list in 2009. However, both countries shares' are added to the figure for the sake of completeness.

In Table 4, we turn the argument the other way round and look how important Germany is as a collaboration partner for other countries, namely China, the USA and Japan. As can be seen from the table, the US is by far the most important collaboration partner for China and Japan. Germany scores second when looking at this ranking and even is the most important cooperation partner for the USA. Yet, what we also can see from the table is that Germany has gained importance for China and Japan over the years, whereas the US has lost importance for both countries. With the rise of China as an important research partner, however, Germany has also lost some of its importance as a partner for the US. All in all we can see that Germany, as well as other countries including the USA, are putting increased emphasis on the Asian countries as cooperation partners and the USA, although still being the major partner for most of the analyzed countries, seems to loose ground to Germany.

Table 4: The importance of collaboration partners of China, Japan and the USA, 2000 and 2009

CHN				JPN				USA			
2000		2009		2000		2009		2000		2009	
US	62%	US	52%	US	57%	US	44%	DE	20%	DE	16%
DE	11%	DE	16%	DE	15%	DE	19%	GB	18%	GB	13%
CA	6%	JP	7%	GB	8%	GB	9%	CA	12%	CA	13%
GB	6%	GB	6%	FR	5%	CN	9%	JP	9%	CN	10%
JP	6%	NL	4%	NL	4%	FR	5%	FR	9%	FR	8%
SG	5%	SE	4%	CA	3%	SG	5%	CH	5%	JP	6%
FR	4%	FI	3%	KR	2%	BE	5%	NL	4%	IN	6%
CH	3%	SG	3%	CH	2%	KR	4%	IL	4%	CH	5%
BE	3%	CA	3%	CN	2%	SE	3%	CN	3%	NL	4%
NL	2%	FR	3%	AU	2%	CA	3%	SE	3%	IL	3%

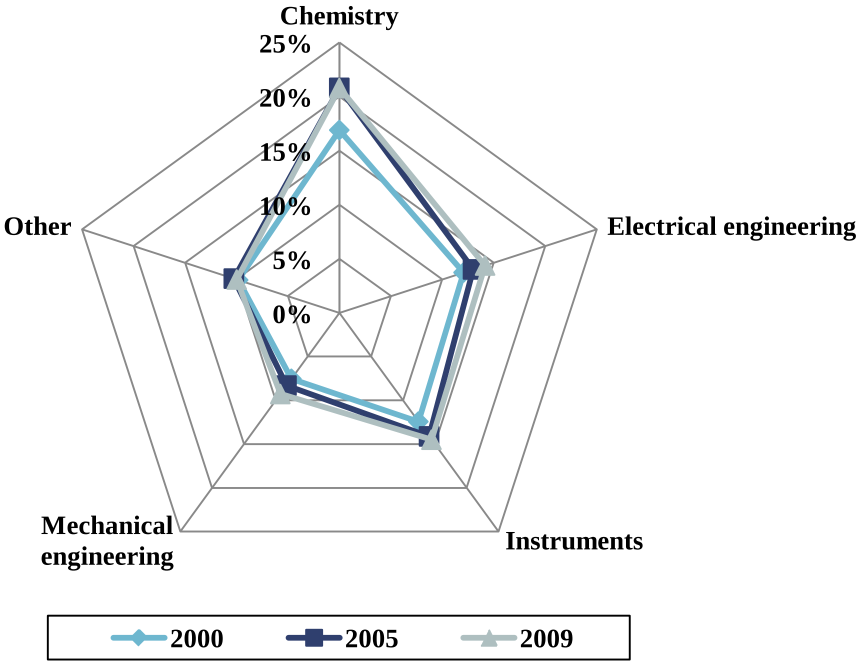
Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

6.2.2 Field Specific Trends – The German Case

As in the analyses above, we now go down to the level of technology fields in order to find out where the specific strengths and weaknesses of German technologies are in terms of international co-patenting.

When looking at Figure 21, which shows co-patenting trends of Germany by aggregated technology fields, it becomes clearly visible that the co-patenting activities are increasing over the years in all technology fields. This rise in co-patenting reflects a general trend, which has already been found at the country level. With a share of 20% of co-patents in all German transnational patents of the respective field, chemistry is the most internationalized technology field within the German innovation system. It is followed by electrical engineering and instruments, which both are in the medium range of co-patenting with a share of about 15%. The least internationalized fields are mechanical engineering and the "other fields", which both only reach a share of 10% of co-patents within all their transnational patent applications. These trends are especially interesting against the background that mechanical engineering is the technology field where Germany has its largest strengths and it is also very specialized, whereas it is less specialized in chemistry or electrical engineering. This is an indication for the argument that size effects matter, also within countries. German inventors are obviously more often able to find national collaborators in fields of relative strengths. Another argument would more focus on the quality and the knowledge loss, saying that countries collaborate less in areas of relative strengths, where the market and technological position is outstanding.

Figure 21: Co-patenting trends by technology field, aggregated fields, 2000, 2005, 2009

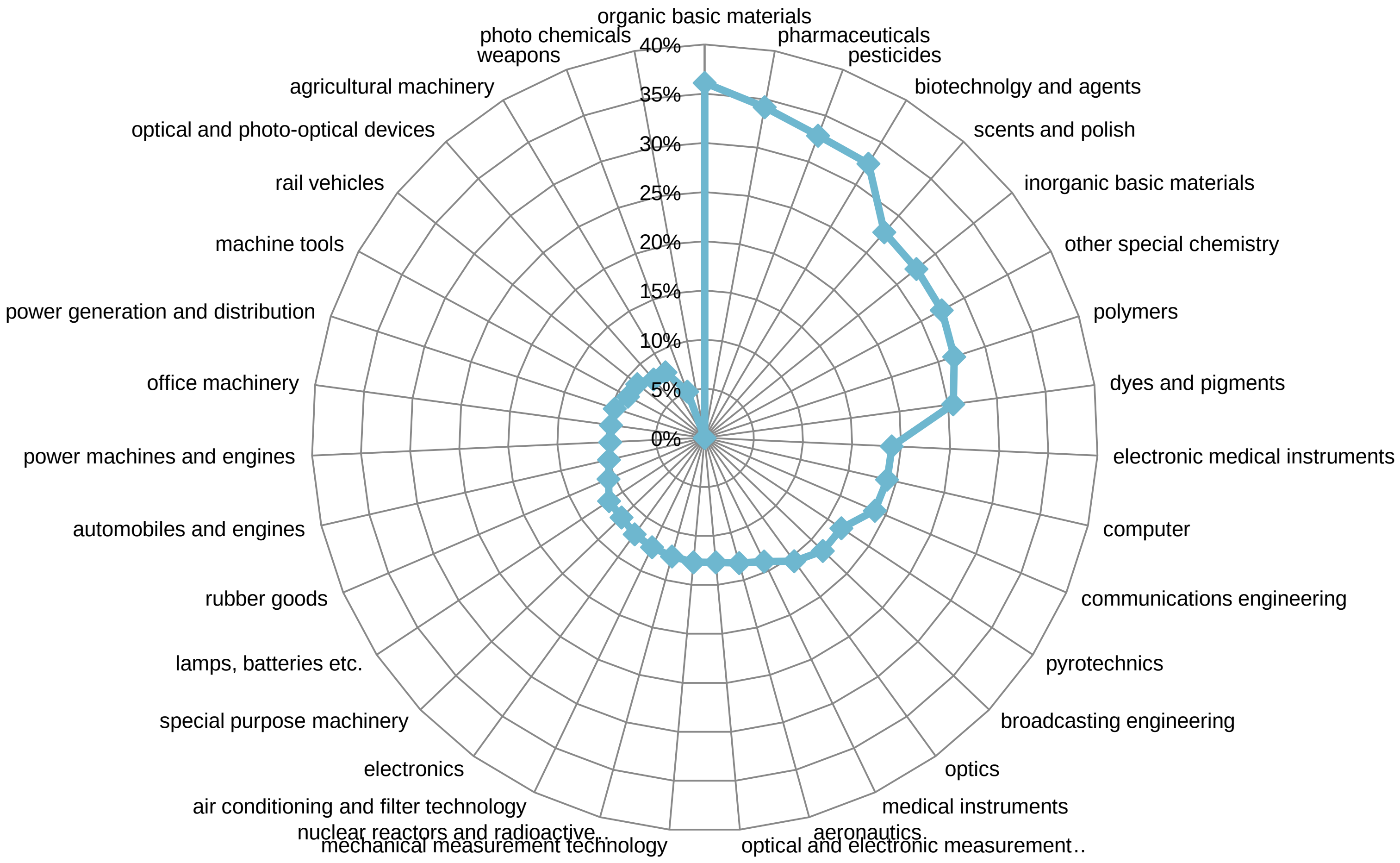


Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

However, co-patenting with another country might not only imply that a country (or companies in certain technology fields within a given country) is an important partner for R&D activities. It can also imply that a country is dependent on the resources, i.e. technological knowledge, access to research facilities etc., of another country and thus is coerced to cooperate if it wants to stay at (or catch-up to) the technological frontier. The low degree of international co-patents in the field of mechanical engineering could thus also mean that Germany has a lesser need to cooperate with another country in a given field because it is not dependent on other resources. To put it less technically, Germany uses the innovation potential of international partners where it has its technological weaknesses, yet is not forced to cooperate with others where it is relatively strong.

In order to give a complete picture, Figure 22 depicts the same indicator at a more disaggregated level, namely at the level of 35 technology fields. Here it can be shown that Germany especially cooperates in organic basic materials, pharmaceutical, pesticides as well as biotechnology. The fields that are the least internationalized in terms of co-patenting are weapons, rail vehicles, agricultural machinery and machine tools. Besides machine tools, these fields are also relatively small when measured in terms of the absolute number of patents.

Figure 22: Co-patenting trends by technology field, 2009



Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.

6.2.3 Results of the Social Network Analyses

In this section, the results of the social network analyses on transnational co-patenting will be presented. As already mentioned in the introduction, the cooperation structures in international patenting resemble the internationalization of R&D activities and indicate international knowledge flows between countries.

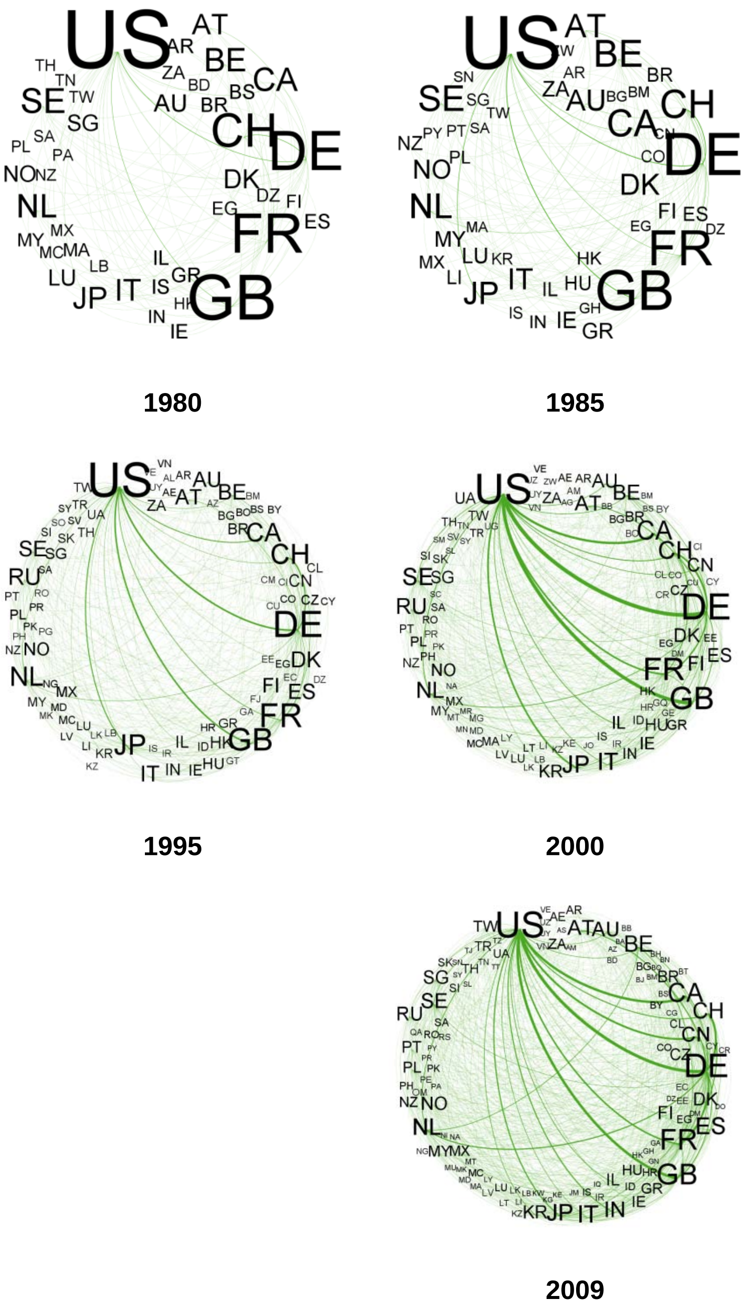
The evolution of transnational co-patenting from 1980 to 2009 is depicted in Figure 23. We decided to use a circular layout for this SNA since it allows a comparison of the co-patenting networks on a yearly basis and thus to track the development over time. Within this SNA, the font size indicates the total number of cooperations with different countries, i.e. the font size is large when a country has co-patents with several different countries and vice versa. The thickness of the lines indicates the cooperation intensity between two countries, or in other words, how many transnational co-patents the two countries have filed together. Countries with a connection to only one country are not shown in the graphs in order to reduce the complexity of the network.

Two general trends can be revealed when looking at the figure. First of all, the number of co-patents largely increases over the years. This increase is rather small in the 1980s and the beginning of the 1990s. However, from 1995 to 2000 a major increase in transnational co-patenting can be observed. From 2000 onwards the number of international co-patents stabilizes at this higher level up to 2009. This trend resembles the major increase in patenting in the 1990s which is known as the patent surge (Blind et al. 2006; Blind et al. 2009). The second general trend that becomes visible is that the number of countries that participate in international co-patenting is rising over the years. Once again, the major increase can be observed from the beginning of the 1990s until the early 2000s. From 2000 onwards, international co-patents are filed by countries all over the world, although the intensity is very low for most of the smaller economies.

Taking a more in depth look at the yearly trends, it can be revealed that only few countries actually participate in international co-patenting in 1980. The country with the most connections to other economies is the USA, followed by the United Kingdom, France, Germany and Switzerland. The cooperation intensity is highest between Germany and the USA as well as the United Kingdom and the USA. In addition, Switzerland can be seen as one of the major research partners for Germany already at the beginning of the 1980s, which is a trend that can be observed for all the years that are covered by this analysis.

In 1985 and 1990 these trends remain similar. China enters the scene in 1985, yet with only few co-patents. From 1985 onwards, however, it becomes more and more important within the network, yet it is mostly co-operating with the US. In the case of Japan, on the other hand, which has already been shown to file relatively few co-patents, the number of co-operations with different countries has decreased over the years, implying that Japan is less and less co-operating with different economies and mostly concentrates on the USA as a research partner. From 1990 onwards, the USA looses the position of being the sole top priority research partner with most connections to other countries. This, however, is also due to the fact that many new countries enter the scene as possible co-operation partners. In terms of the cooperation intensity, however, the USA remains the country with most collaborative research all over the world.

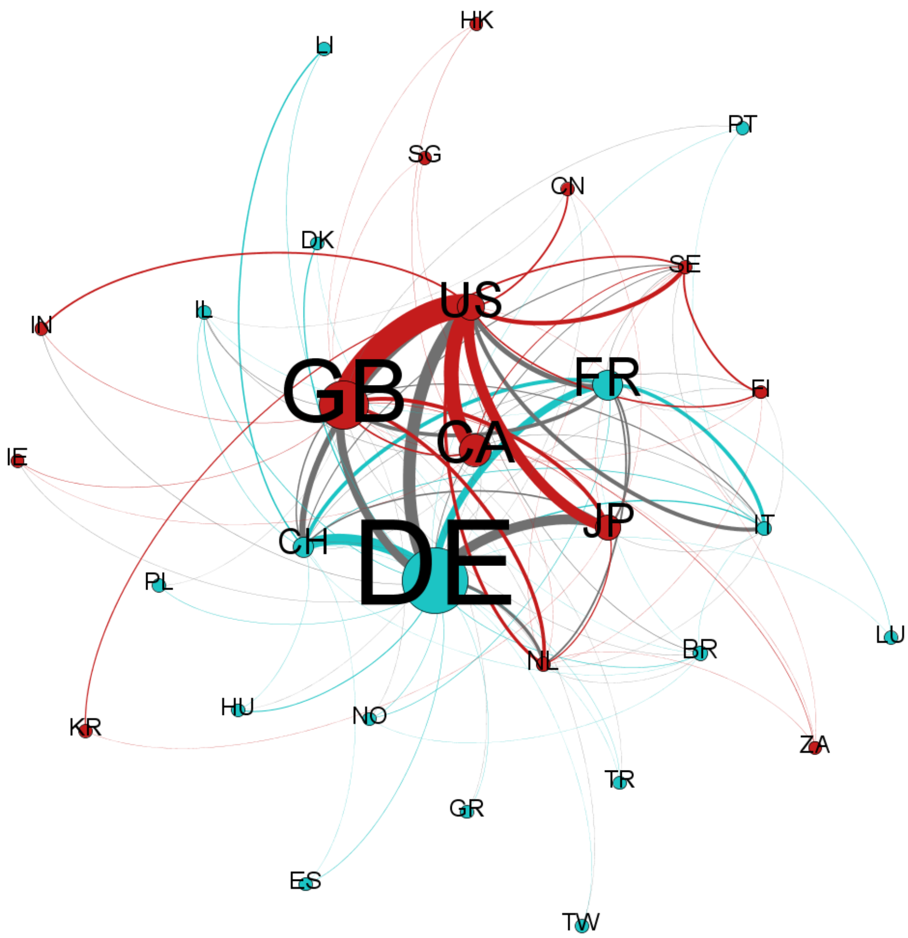
Figure 23: The evolution of transnational co-patenting from 1980 to 2009, all countries



Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.
Note: Font Size: Total number of cooperations with different countries, Lines: Cooperation intensity with country X.

In sum, it can be stated that besides the US, Switzerland, France and the United Kingdom gain importance as research partners for Germany over the years. To some extent this is also true for China, yet only for the year 2009. This, however, implies that China has managed to catch-up with other economies in terms of its attractiveness for Germany.

Figure 24: The central actors and groups within the network, "core-countries" and their connections only, 1990



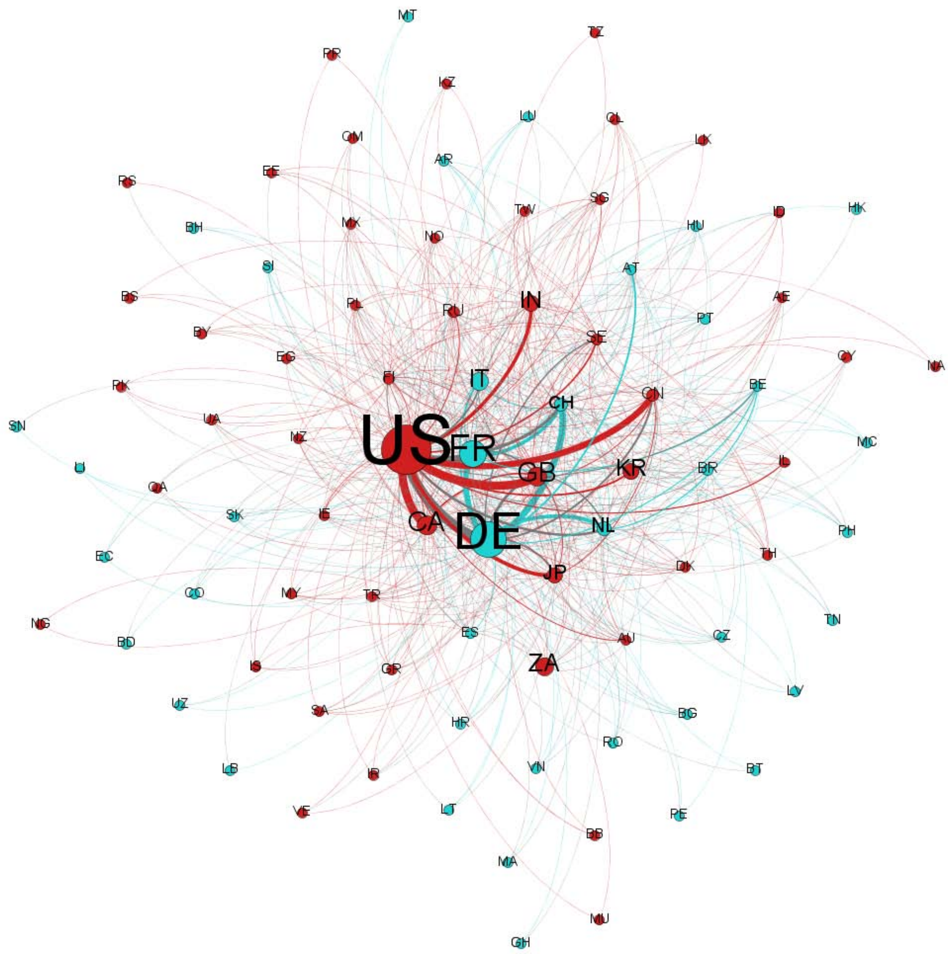
Source: EPO – PATSTAT, calculations of the Fraunhofer ISI
Note: Font Size/Size of Nodes: Betweenness Centrality, Lines: Cooperation intensity with country X, Colour: Countries within the same cluster.

A second set of network analyses is presented in Figure 24 and Figure 25. Here we shift the focus to emphasize central actors within the network as well as identifying groups or clusters within the country set. In order to keep both figures readable, all countries that have no connection with the countries analyzed in the previous chapters in terms of international co-patents were left out of the analysis.

In both figures, the font size (as well as the size of the nodes) resembles the betweenness centrality of the respective actor. The betweenness centrality shows the importance of an actor within a network. A large font size thus indicates that much "traffic" passes that node and it so to say has a "gatekeeper" function within the network. The colours of the nodes, on the other hand, indicate the modularity within the network. Modularity is a measure of communality and is thus able to identify groups within networks. In both of the following networks (1990 and 2009) two groups (red and blue) have been identified.

Figure 24 shows the central actors and groups within the network for the year 1990. Compared to Figure 25, where the same network is plotted for the year 2009, it can be observed that the number of different cooperation partners has largely increased over the years. This has already been found in the above mentioned network analysis and implies that more and more countries have started to cooperate in general.

Figure 25: The central actors and groups within the network, "core-countries" and their connections only, 2009



Source: EPO – PATSTAT, calculations of the Fraunhofer ISI.
Note: Font Size/Size of Nodes: Betweenness Centrality, Lines: Cooperation intensity with country X, Colour: Countries within the same cluster.

In both years, two groups can be identified, which largely resemble each other, meaning that the main cooperation partners have mostly stayed the same over the years. The first of this two groups consists of the USA, the United Kingdom, Canada and Japan as the key players within this group. This group could be labelled the Anglo-American cluster. The second group, which could be called European cluster, is formed by Germany, France, Switzerland and Italy. Although the US is a major partner for all of these countries, the density of links inside the cluster is higher than the density of links outside the cluster.

When looking at the centrality measure, interestingly Germany and the United Kingdom stand out as the most central actors. In the case of Germany, this can be explained by its central function within Europe. Great Britain seems to be a kind of central hub, for the North American countries to enter Europe and for the European countries to cooperate with the US and Canada.

When looking at Figure 25, however, one can see that although Germany keeps its role as a key node in Europe, the United Kingdom looses this role to some extent, whereas the US becomes more and more prominent as a gatekeeper. This can be explained by the growing importance of the Asian countries, especially China and Korea, as well as India. The United Kingdom still might be the gate to Europe for the North American countries. The US, however, seems to play an important role for opening the network of co-patenting towards the East.

6.3 Conclusions

The analyses of international co-patenting trends reveal several interesting findings. First, it can be stated that the number of international co-patents as well as the number of countries that are active in international co-patenting have increased massively over the last 20 years. Especially form 1995 onwards this rise in international co-patenting becomes visible, implying that the need to cooperate internationally - as well as the benefits from such cooperations - has gained increased importance.

The country level trends reveal further insights into this interesting phenomenon. The USA was, and still is, the major partner for international R&D cooperations, at least in absolute terms. When looking at the relative values, smaller technology oriented countries, above all Switzerland, seem to be most active in co-patenting. However, Germany has also played a key role in the international scene and seems to continue to do so. At latest from 2000 onwards, China comes into play and also starts to play a role as a major partner for R&D cooperations, especially for Germany as well as the USA.

The field specific trends within Germany also provide us with some interesting insights. Germany files most of its co-patents in fields where it is less specialized in international comparison, mostly in chemistry related fields but also in electrical engineering. It seems that there is a need for Germany to cooperate in order exchange knowledge in those fields. In mechanical engineering, however, where Germany has a strong international position, the number of co-patents is rather small, implying that Germany is able to access relevant knowledge nationally within this sector, has a lesser need to enter international R&D cooperations, and is not willing to give away specific knowledge created within this sector.

Finally, the network analysis provides us with the result that Germany serves as a kind of key node for international cooperations, being strongly cross-linked to most European countries and thus able serve as a cooperation hub within Europe.

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