Patent Applications – Structures, Trends and Recent Developments

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Since 2002 the absolute number of patent filings has been growing in almost all countries, after the economic crisis at the beginning of the new century. Recently, however, the numbers for some countries decreased again, which can be explained by the recent economic crisis of the years 2008 and 2009. Applicants have one year time to decide if they should file a national patent also internationally. It seems that many companies decided not to follow the international route, under the impression of the recession in 2008 or not to publish their filings at all, which has a retrospective effect on the data starting of the priority year 2007. This 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. Countries like Germany and Japan do not show direct effects. From the priority year 2008 onwards, however, a decreasing trend can be observed also for these two countries.

The patent profiles of Germany and the EU-27 reveal considerable similarities. Europe is specialised in machinery and transport, which is also true for Germany, implying that both are specialised in medium-tech technologies. Clearly, Germany weighs heavily when calculating the EU figures, which explains this similarity to some extent.

Chinese patent applications

The Chinese patent applications have been growing considerably in the recent decade, both on the national and the transnational level. This is the result of enormous investments in R&D, but also of a political willingness to internationalise and to improve the role of technology and innovation in general. The Chinese patent system underwent several reforms in the past 20 years where the last two – one in 2000 and another one in 2009 – had the strongest impact and aimed to shift the Chinese system to international standards. In 2009 – this should have an impact on the filing as well as on the processing behaviour – absolute novelty has been introduced while before only novelty to the Chinese market was examined. The Chinese patent profile at the SIPO is distinct from the profile on the transnational level, which is driven by the fact that on the international stage a kind of "export filter" is at play so that differences in the national and the international market have an effect. On the other hand, in China companies need to get export approbation by the Ministry of Commerce (MOFCOM), which might have another considerable impact on the Chinese technology profile abroad. On the national level it is mainly chemistry and pharmaceuticals including biotechnology, where comparative advantages occur. On the transnational level it is by far communication engineering and related fields that play major role, while the contribution of chemistry in relation to this clearly diminished in the recent decade.

Both, in China and on the transnational level the share of high-tech patent applications is lower for China than for the large industrialised countries. And the share of high-tech patents has been decreasing over time – as it also did for the USA and Japan, for example. However, given the enormous increase of patent applications it is astonishing that the shares of Chinese high-tech patents did not decrease even more. So at least in terms of technological areas, China does high-tech. If this really comes along with high R&D investments and high quality cannot directly be derived from these figures. The shares of cited patents is lower for China than the average, but this might in part be grounded on delay of visibility and availability of Chinese applications due to translation issues. The average number of citations – once a document is cited at all – is only slightly lower for Chinese applications compared to the worldwide average. The technology cycle time – using backward citations – is in most areas shorter than for the worldwide average in the majority of technological fields, among them are broadcasting and communications engineering.

Patent families

To get a more refined picture of the worldwide patent applications by countries and technology fields in terms of market coverage, we weighted family members according to the size or strength of the market they were filed at. The main aim was to find an improved indicator of patent value at the country level. It could be shown, however, that country rankings are only affected when the average family size instead of the number of patent families is taken into account, because the number of patent families depends on the size of the filing country. Additional bivariate and multivariate analyses revealed that the unweighted average family size, as well as most of the weighted average family sizes, shows no effect in explaining absolute exports by countries. The GDP and import weighted family size, however, lead to robust positive results, which is why they seem to be able to act as an indicator of patent value at the level of countries and technology fields.

Growth of IPC subgroups

Taking last year's analyses of IPC-subclasses one step ahead, we were able to identify the major growth drivers within quickly growing technology fields at a much disaggregated level. It could be found, that the growth in most subclasses under analysis stems from high growth rates of only a few subgroups within these 4-digit IPC subclasses. This implies that forecasting the future relevance or development of technological fields has to be carried carefully at a much disaggregated level. Patent applications from Germany can be seen as even more concentrated to a single piece of technology. Apart from some outstanding technologies, however, the distribution of growth is more evenly spread over the different subgroups. Therefore, Germany operates at the technological frontier in major technologies, nevertheless not neglecting smaller technologies in its German patent profile. A comparison by the type of the applicant could also show that an increase in SME patents can be observed in the field of data processing methods. Batteries and fuel cells are more and more patented by large firms.

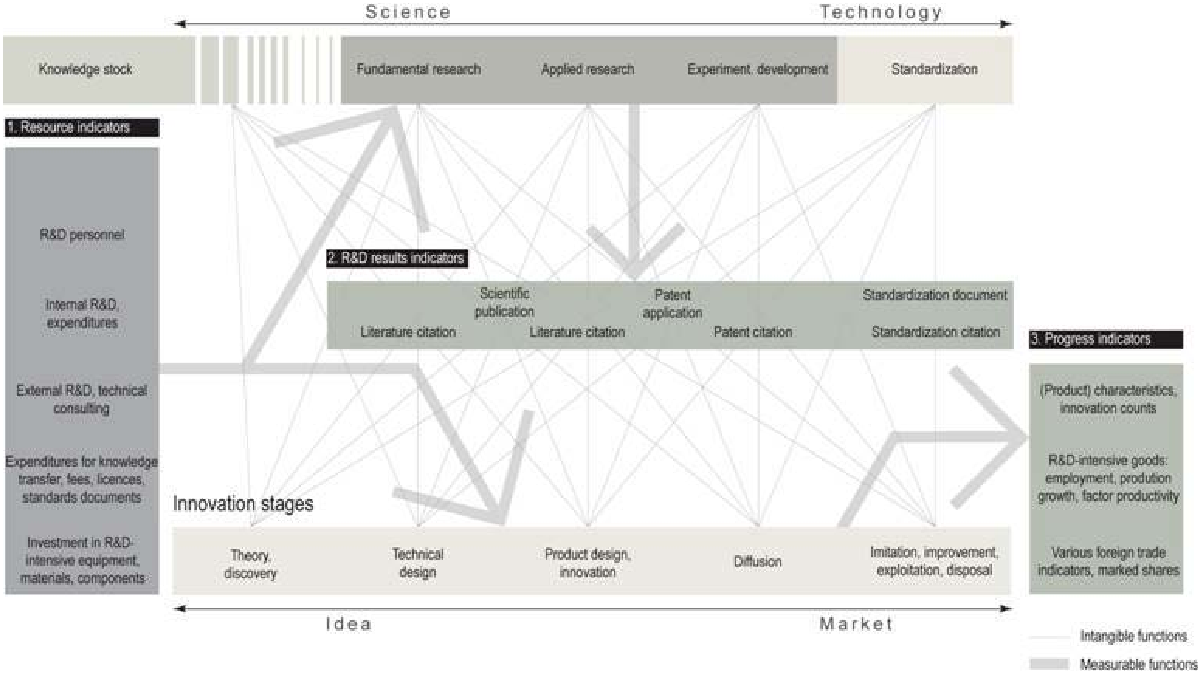
1. Introduction

Patent applications and grants – as output indicators for R&D processes – are the most common and widely used indicators for the measurement of the technological performance of countries or innovation systems in general (Freeman 1982; Grupp 1998). Patent data analysis is booming nowadays, increasing the body of literature in the field – and as the literature grows, so too do new insights and new knowledge. Though the methods and definitions applied for analyses using patents do differ (Moed et al. 2004).

First and foremost, patents can be seen and analysed from different angles and with different aims: the technological view allows prior art searches or the description of the status of a technology; micro-economic perspectives – for example – allow for the evaluation of individual patents or the role of patent portfolios in technology-based companies; a macro-economic angle offers an assessment of the technological output of national innovation systems, especially in high-tech areas.

In this report we trace the latter path, having in mind the very simple and sober intention of providing information on the technological capabilities and the technological competitiveness of nations. In this respect, patents are used as an output of R&D processes. R&D processes can either be measured by the input – for example, expenditures or human capital – or by the output. In order to achieve a more precise approximation of the "black box" (Schmoch/Hinze 2004) of R&D activities, both perspectives – i.e. input and output – are needed. The input side has been widely analysed and discussed in other reports, also in this series (see for example Legler/Krawczyk 2009). Here the strict focus of patents as an indication of output is pursued, following the very early approach of patent statistics pioneers (Griliches 1981; Griliches 1990; Grupp 1998; Pavitt 1982).

Figure 1: Indicator System to analyse Innovation Systems Performance



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

Starting from a simple legal perspective, patents give an exclusive right of usage to the applicant for a limited period. In addition, patents can be interpreted as an indicator of the codified knowledge of enterprises, and, in a wider perspective, of countries. As an innovation indicator, patents fit into a system of further indicators to describe scientific and technological competitiveness and to analyse innovation systems. The role of patents here is to be seen as an intermediate measure. Intermediate in so far as it covers the output of R&D systems, for which expenditures or human capital are the input. At the same time, patents form the input for market activities, which are reflected, for example, by foreign trade, turnover or qualified labour. 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. A representation of innovation indicators and their relation are depicted in Figure 1.

Beneath the mechanisms of protection, patents for technical innovations play a special and crucial role, as the formal requirements for patent applications are the strictest ones, and the assertion of patents is backed by a strong legal framework. Any patent has to pass an extensive examination procedure in the patent office(s), done by examiners skilled and trained in the field. This, in turn, makes them so valuable as a source of information also for statistical purposes. Patents and the information contained in patents is systematically structured and of high quality. The formal requirements as well as the technical content are checked by experts. From the perspective of innovation systems, patents indicate the output of technology generating processes and thereby enable the technological competitiveness of nations to be assessed. In particular, international patent filings are meaningful for comparisons, as they reflect activities in international markets where national and multinational companies meet with 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 the general methods applied. Chapters 3 discusses total trends, growth rates, intensities (patents per 1 million workforce) and specialisation[1] indices, which are designed to reflect patent structures beyond size effects of countries and technology fields. Additionally, patenting structures of large enterprises will be briefly discussed. Chapter 4 focuses on the analysis of China's patent activities at home and abroad, also discussing the citations of Chinese patents on the transnational level. In Chapter 5, we discuss the internationalisation and value of countries' patent profiles by analyzing patent families weighted by their coverage of differently sized and valued markets. Chapter 6 provides an analysis of IPC subgroups to identify the specific technological growth drivers within the fastest growing technological areas of the recent past.

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1 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. For further analyses we are able to add the annual sum of cited patent applications, forward citations and patent families which have been calculated in total, by selected countries and differentiated by 35 high-technology fields (Legler/Frietsch 2007).

As last year, PATSTAT was used for this reporting system. In earlier years, we used data from professional hosts, especially from Questel-Orbit. The advantage of these online databases was especially their topicality, as they are updated weekly, while PATSTAT is a snapshot of a current status twice a year. However, we have been able to speed up the implementation of PATSTAT in our system and to synchronize the data availability with the reporting process. By using PATSTAT as the basis of our analyses we are now 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 now able to increase the power of our analyses by taking citations and legal status information into account, which can be used for the valuation of patents (Frietsch et al. 2010b) 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 recently suggested by Frietsch and Schmoch (2010b), which has already been used in earlier analyses of this series (Frietsch et al. 2010a; Frietsch/Jung 2009) 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.

The State Intellectual Property Office of the Peoples Republic of China (SIPO) covers one of the fastest growing national markets for high technologies in the world, namely the Chinese market. However, it is still a national market and some countries, especially the upcoming and emerging countries like South Korea or India, are specially focused on national markets (like the US and China) and do not file every patent on a worldwide scale. Even more important, also a large proportion of Chinese patents is only filed at the home office. In consequence, the bias of Chinese applicants/inventors is considerable, and the imbalance of European, North American and emerging countries cannot be neglected when the technological performance is compared, based on patent filings at the SIPO. This is why the SIPO data is not the core of this analysis. However, we report them in a special focus chapter due to the growing importance of this particular market, keeping in mind that there are imbalances in the representation of certain countries. The SIPO data therefore do not appropriately reflect the general technological competitiveness of nations, but are appropriate to reflect the technological activities targeted to the Chinese market – and this is therefore a helpful supplement to the overall analysis presented in this report.

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

For the analysis of patents in different technological fields, so called specialisations are calculated. For the analysis of specialisation, the relative patent share (RPA[2]) 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

Besides the mere number of patent applications, which can be seen as an outcome (or performance) of R&D activities, several quality measures can be applied to assess and differentiate between the value of patents (see Frietsch et al. 2010b). The most frequently discussed range from citation measures, patent grants, opposition or litigation history to the average number of inventors or IPC classes. Several other indicators 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 above mentioned were tested and evaluated in a large project on behalf of the "The Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation – EFI)" (Frietsch et al. 2010b). Especially patent forward citations proved to be the most promising for the evaluation of the quality of patents. The same holds for the average family size, which has shown to be a robust indicator of patent quality at the firm level. Yet, it seems to have only restricted explanatory power at the country level. This

2 Revealed Patent Advantage

could be due to the fact that the individual family members target markets of very different value, in terms of size or strength of the targeted market (Frietsch et al. 2010b). Therefore, we attempt to weight the individual family sizes by the size and value of the targeted markets, which will be described in more detail below. All in all, this present report makes use of these two indications of patent value as a supplementary perspective on the patenting activities of nations. Furthermore, the so-called technology cycle times (TCT) are calculated to shed some light on the speed of innovation in different countries.

Patent forward citations are the most common and widely used indicator in literature so far (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). Although several studies show that patent citations are a very noisy signal of patent quality (Alcacer et al. 2009; Alcacer/Gittelman 2006; Hall/Ziedonis 2001).

On the other hand, the number of citations listed in a patent document (backward citations) refers to previous patents and are usually taken as an indicator of technological breadth or the technological background of a patent application. Therefore, they provide information about the technological scope and the "newness" of a technology and are often used to measure spillover effects (Jaffe et al. 1993). Additionally, they are suitable to calculate so-called technology cycle times (TCT), which are also analyzed in more detail in this report for the Chinese applications on the transnational level. With the help of the technology cycle time, the speed of innovation can be measured. Shorter technology cycle times suggests that technology fields move faster from older to newer technology.

The basic assumption is that innovating faster contributes to greater success in product development (Narin et al. 2004) and a head start leads to better positions in the market However, one could also argue, that a prolonged TCT suggests that a technology field is more focused on advances in basic research and relies less on rapid changes in technology (Deng et al. 1999), or that the existing technology can not yet be replaced by a new one, since the older technology is still adequate to fulfil the requirements. To build this indicator, the median age of backward citations to patent documents from different countries in technology fields at the respective offices are calculated – in this case at the Chinese SIPO.

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. In more simple words, a large patent family means greater market coverage which is associated with preliminary and running expenses (Frietsch et al. 2010b).

3. Trends of Transnational Patent Applications

In this chapter, the status and the recent trends of transnational patent applications – i.e. families with at least an EPO or a PCT filing – since the beginning of the 1990s are described. Patents are dated according to their worldwide first filing, i.e. the priority date, and data for a selected set of technology-oriented countries[3] are analyzed. However, not all countries are displayed in all of the figures, for reasons of presentation.

In this chapter, we will also make a distinction between low-tech and high-tech areas. High-tech is defined as technologies which usually require an average investment in R&D of more than 2.5% of turnover. 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 the first section, we discuss the broad areas and broad trends, while the second section will differentiate the national technology profiles, looking at 35 technology fields, according to the high-tech definition.

3.1 Trends and level of patent applications by technology areas

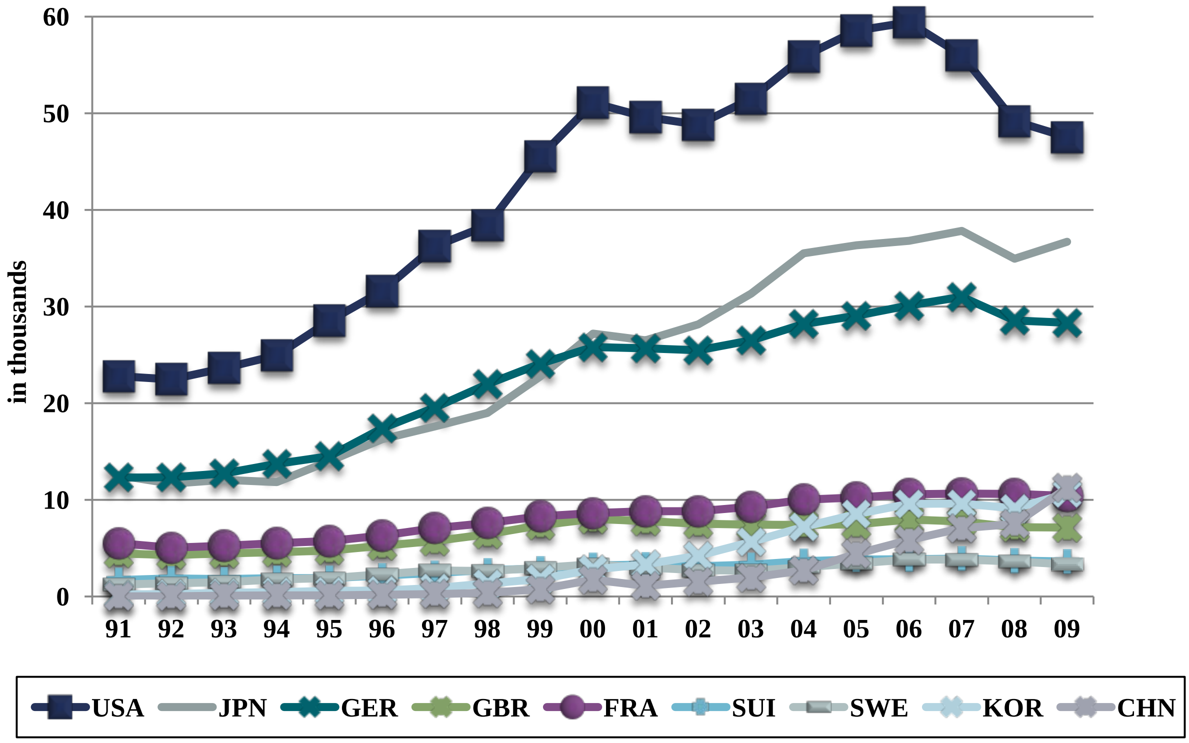
The absolute number of transnational patent applications of a selected set of countries is displayed in Figure 2. At the international level, the USA is the largest technology-providing country followed by Japan and Germany. This trend can be observed for high-tech as well as low-tech areas. A large group of countries like France, the United Kingdom and others follow behind this group of the three largest. It is interesting to note that South Korea is nowadays on a similar level to France, having strongly grown since the end of the 1990s. Also China has nearly reached the level of France and Korea in 2009, and now operates at a slightly higher than the United Kingdom in absolute terms. Therefore, it can be stated that China has been able to catch up considerably in the past 5 years since the middle of the first decade of the new century.

In the last two years of our observation period the most striking effect can be observed, as the absolute numbers for all countries are decreasing – except for China in the year 2009 –, a trend that we have already seen in the reports of the two last years. The explanation was – and this is still true to a large extent, but not the only explanation any more – that the companies applied a much more deliberate strategy for filing internationally. In other words, the companies were still inventing technologies, but the decision to file abroad much more often turned out to be negative. The 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 finding and this effect is also vivid for the priority year 2008, but in addition the economic crisis also had an impact on the input side of the R&D processes so that the outputs – namely the patents under analysis here – were also affected. The evidence for this statement

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

stems from the national trends of patent applications, which also decreased in 2008. Companies that are using the patent system do this whenever they have something worth filing, otherwise they would risk losing their intellectual property (IP) to their competitors. They secure their rights first by filing at their home base. Thus, as the national filings are decreasing, the conclusion is that they have less IP to protect. Analyses in 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. The theory suggests investing anti-cyclically in R&D, which means increasing the investment in times of recession and crises, because then the company is ready for the next economic boom with new technologies and might be able to gain increasing market shares. Obviously, reality is not a perfect reflection of the theory.

Figure 2: Absolute number of transnational patent applications for selected countries, 1991-2009



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. When using this indicator, the smaller countries Switzerland, Sweden and Finland are at the top of the list of the technology-oriented countries analysed here. Germany and – at some distance – Japan are first among the larger countries on this list. This expresses, on the one hand, 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, the USA is in the midfield together with France, Korea or the EU-27.

Table 1: Patent intensities (patent applications per 1 m employment) and shares of technological areas, 2007-2009

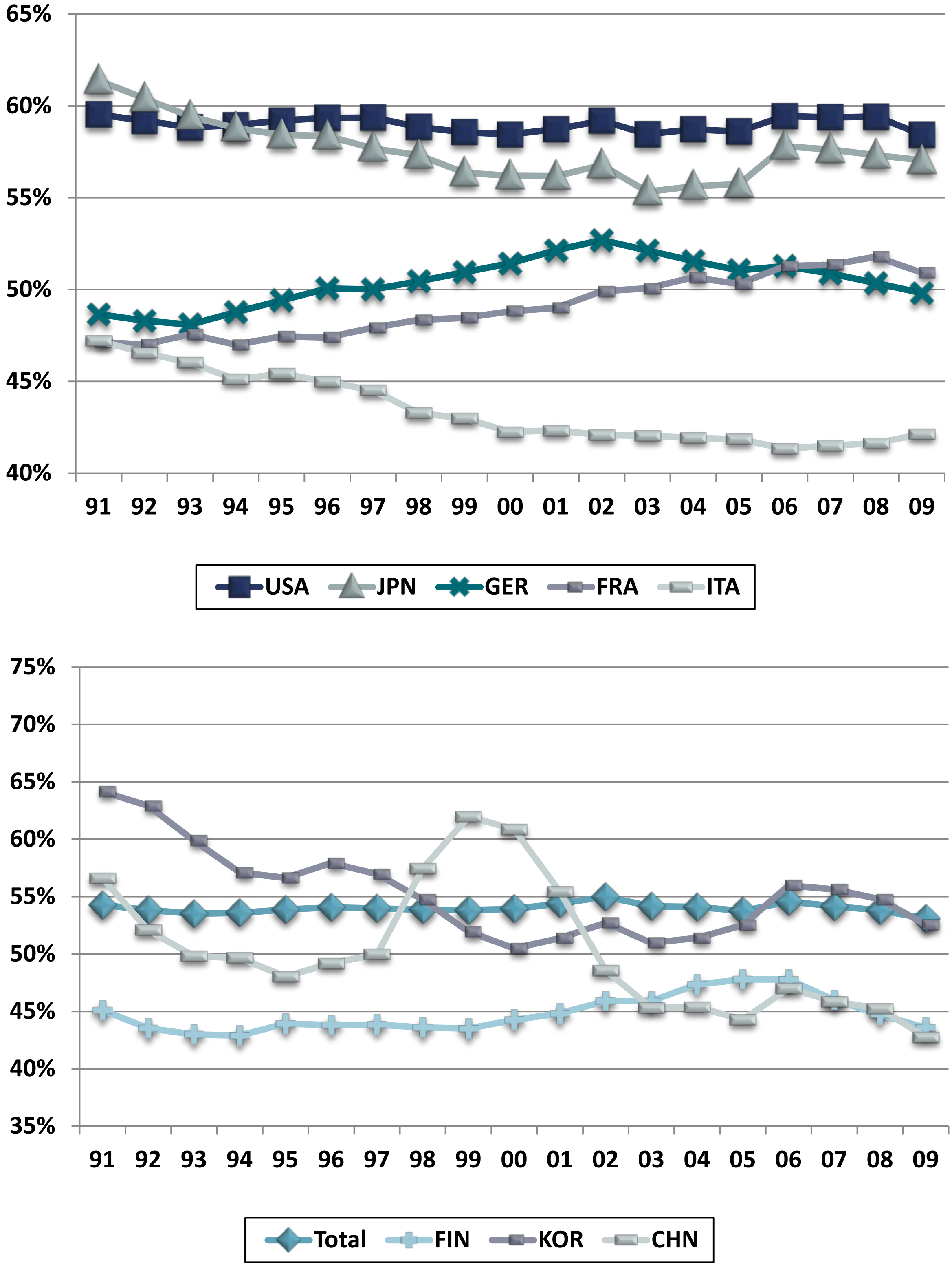
	Total	**Low-tech**		**High-tech** of which are:		Leading-edge technologies		High-level technologies	
SUI	804	400	49.8%	389	48.4%	141	17.5%	248	30.9%
SWE	740	342	46.2%	352	47.6%	153	20.6%	200	27.0%
FIN	736	370	50.3%	319	43.4%	163	22.2%	156	21.2%
GER	730	341	46.8%	362	49.7%	114	15.6%	249	34.1%
JPN	585	236	40.4%	334	57.1%	150	25.6%	184	31.5%
KOR	453	190	41.8%	236	52.0%	116	25.5%	120	26.5%
NED	443	222	50.1%	211	47.6%	100	22.6%	111	25.0%
FRA	395	180	45.6%	200	50.6%	91	23.0%	109	27.6%
USA	340	132	38.8%	197	57.9%	103	30.4%	94	27.5%
EU-27	322	155	48.0%	156	48.4%	59	18.4%	97	30.0%
GBR	247	115	46.8%	122	49.5%	56	22.8%	66	26.7%
ITA	234	130	55.4%	99	42.1%	29	12.6%	69	29.5%
CAN	202	92	45.4%	99	49.1%	54	26.8%	45	22.3%
CHN	14	7	47.3%	6	41.8%	4	24.3%	3	17.5%
RUS	13	7	57.1%	5	40.9%	3	20.3%	3	20.6%

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

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 and even Sweden or the Netherlands, both especially well-known for their high-tech companies Sony-Ericsson and Philips, have comparably high shares in low-tech patenting. The USA, Japan and Korea, on the other hand, reach rather high shares of high-tech patents, between 52.0% and 57.9%, respectively. The differentiation by leading-edge and high-level areas further qualifies these findings. The USA, Canada, Korea, but also Finland, the Netherlands and Sweden are filing many of their patents in leading-edge technologies. The main technological activities of Sony-Ericsson and Philips are exactly to be found in these very R&D-intensive areas. 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 3 shows the trends in high-tech shares within the national profiles of selected large countries. While the average share of total transnational high-tech patent applications 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. Japan, which was at the top at the beginning of the observation period, clearly lost ground and has lower shares of patenting activities in high-tech areas. 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.

Figure 3: Shares of high-tech patent applications in total patent applications for selected countries, 1991-2009



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The lower panel of Figure 3 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 growing in the year 2001 when China joined the

WTO and the TRIPS agreement. 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 and that this trend was parallel to an increase also of 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). In this year's report we will focus on the comparison of the German and the profile of the EU-27. The German technology profile of the years 1999-2001 versus 2007-2009 are displayed in Figure 4. Germany has three main areas of activity where it has comparative advantages, i.e. where Germany is specialised in: transport, machinery and some areas of electrical engineering like power machines and power generation. An average activity rate in patenting can be found in chemical 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. So the latter do not belong to the relative German strengths in international technology markets. It is interesting to note that Germany was able to improve its relative position in most of the technology fields where it reaches a positive specialisation, but also at the expense of a relative loss of positions in many areas of relative weakness, namely ICT and electronics. In addition, German inventors were able to gain ground in some of the areas of average activity and considerably improved the values of the specialisation index. This is first of all true for aeronautics and electronic medical instruments.

Germany is the largest country within the EU, both in terms of inhabitants, but even more in terms of patent filings. The profile of the EU-27 is displayed in Figure 5. As the graph shows, the specialisation profiles of the EU and of Germany are rather similar. Of course Germany weighs heavily when calculating the EU figures, which explains this similarity to some extent. However, this can only be seen as a part of the complete picture.

The technological profiles of the EU and of Germany evolved over years and emerged from a long tradition (experience), certain specialisations (synergies), and of course also expertise (science base) in mechanical engineering and automobiles as well as related fields. Traditionally, leading-edge technologies play a subordinated role in the (national) profile of Germany and Europe – except for some sub-fields of chemistry, among them pharmaceuticals. Nowadays leading-edge technologies are mainly driven by information and communication technologies (ICT). However, it is by definition the group of leading-edge technologies that require large investments in R&D while certain areas of engineering and automobiles – though they are also defined as high-tech – demand lower shares of R&D investment in relation to turnover. Therefore, taking the 3%-goal of the EU seriously would have meant either spending more money on R&D in the engineering and automobiles sectors – which in some subfields is done automatically, due to structural changes within the sector – or considerably changing the structure and profile of the whole economy, moving towards ICT. The former strategy might have caused inefficiencies while the latter means entering a crowded market.

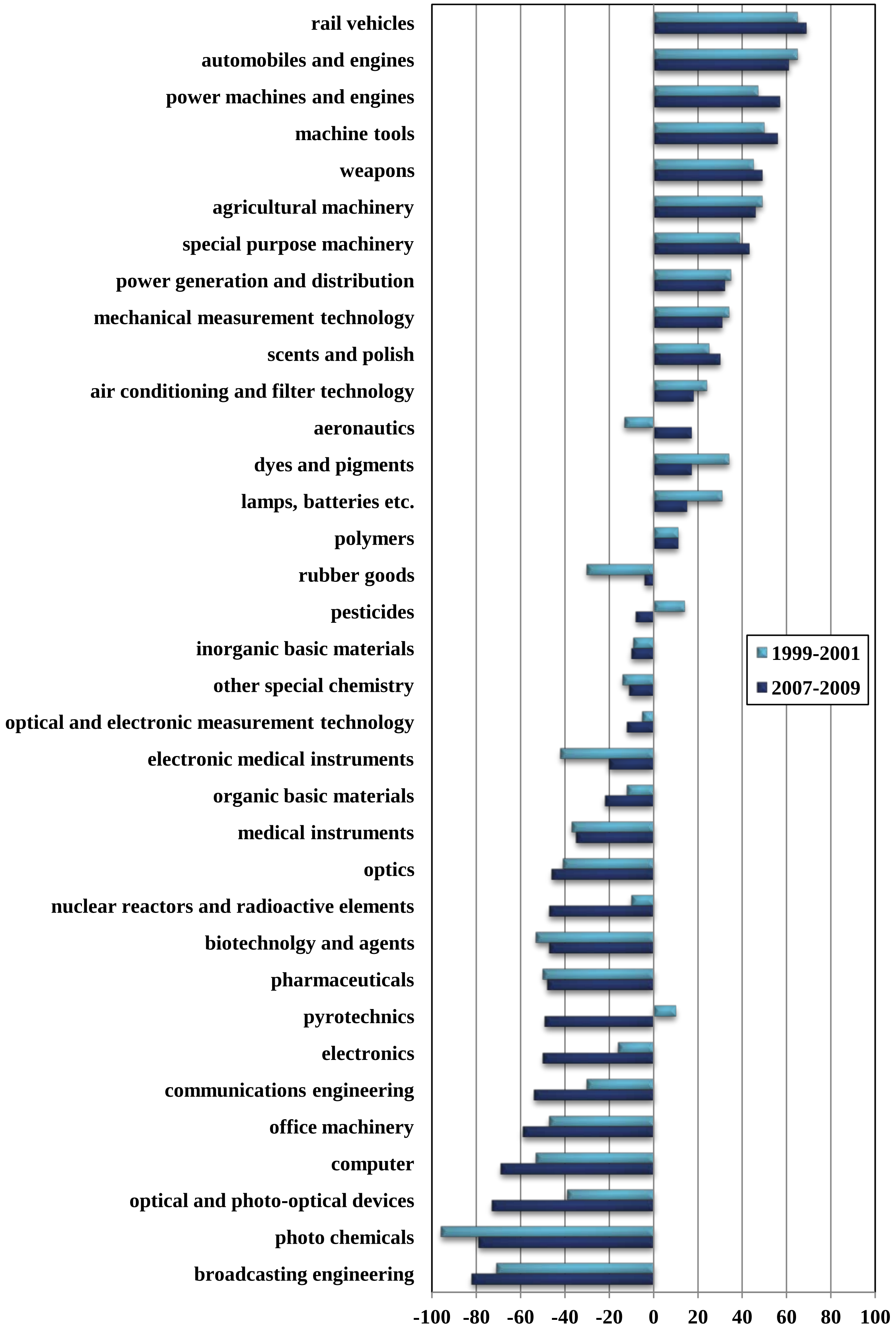
The fact that many other countries – among them the USA, Japan as well as the catching-up countries Korea and China – have high stakes in these areas, could serve as an explanation for the restricted move of European and German companies towards these fields. However, this does not mean that ICT does not play a role in Europe or in Germany. Rather the opposite is true. But these are used as enabling and supplementary technologies, often embedded in the traditional strengths, namely machines and automobiles.

Table 2: Transnational Patent applications of Germany and the EU-27 (absolute, specialisation, and growth), 2007-2009

	DE			EU-27		
	Abs.	**RPA**	**growth** (99-01=100)	**Abs.**	**RPA**	**growth** (99-01=100)
aeronautics	710	17	258	2,089	34	272
electronic medical instruments	1,073	-20	217	2,540	-23	174
rubber goods	249	-4	156	766	18	131
power generation and distribution	1,594	32	154	2,995	7	152
power machines and engines	3,865	57	151	6,668	29	148
weapons	310	49	147	634	35	147
inorganic basic materials	457	-10	147	991	-22	149
medical instruments	2,121	-35	143	5,938	-22	141
mechanical measurement technology	1,122	31	130	2,513	23	142
rail vehicles	232	69	126	439	53	122
lamps, batteries etc.	2,337	15	126	4,273	-14	136
optical and electronic measurement tech.	2,690	-12	123	6,573	-12	130
air conditioning and filter technology	1,259	18	121	2,838	10	130
machine tools	2,482	56	119	4,214	26	110
pesticides	652	-8	116	1,337	-25	112
other special chemistry	1,005	-11	111	2,740	0	123
agricultural machinery	419	46	105	946	39	105
special purpose machinery	3,314	43	105	7,160	33	105
automobiles and engines	5,394	61	105	9,669	38	113
organic basic materials	1,035	-22	104	2,898	-8	118
electronics	1,565	-50	103	3,478	-57	116
polymers	1,448	11	99	3,064	-3	104
biotechnology and agents	2,403	-47	99	8,618	-12	114
nuclear reactors and radioactive elements	49	-47	97	161	-21	116
pharmaceuticals	1,187	-48	96	4,216	-14	109
computer	2,245	-69	96	7,664	-48	106
optics	565	-46	90	1,451	-42	88
dyes and pigments	578	17	89	1,100	-8	95
office machinery	112	-59	82	258	-63	77
broadcasting engineering	735	-82	79	2,871	-59	79
communications engineering	1,834	-54	77	6,585	-21	91
scents and polish	309	30	74	771	32	76
optical and photo-optical devices	62	-73	71	179	-65	72
photo chemicals	5	-79	29	23	-37	17
pyrotechnics	8	-49	25	42	17	67

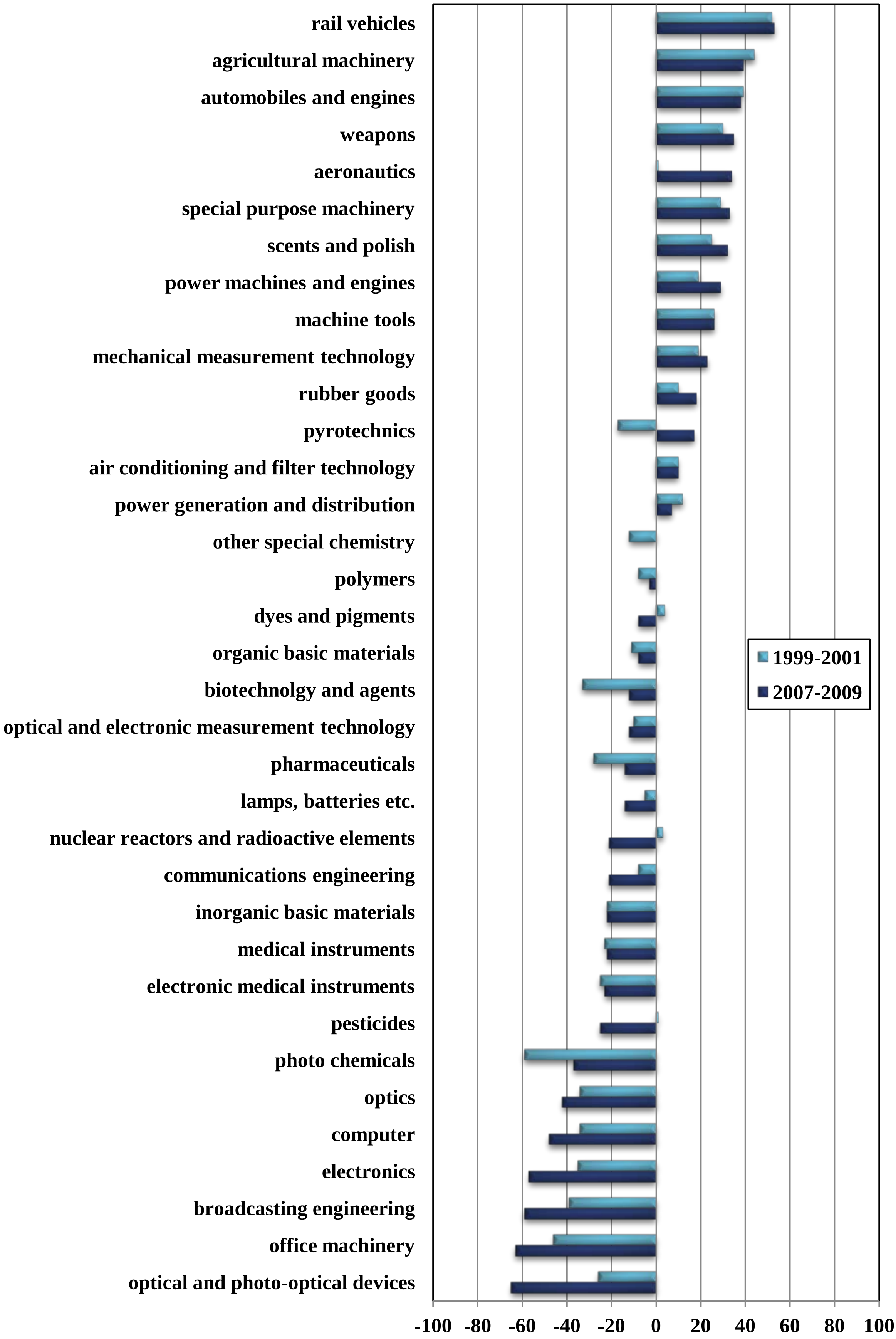
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 4: Germany's technological profile, 1999-2001 vs. 2007-2009



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 5: EU-27's technological profile, 1999-2001 vs. 2007-2009



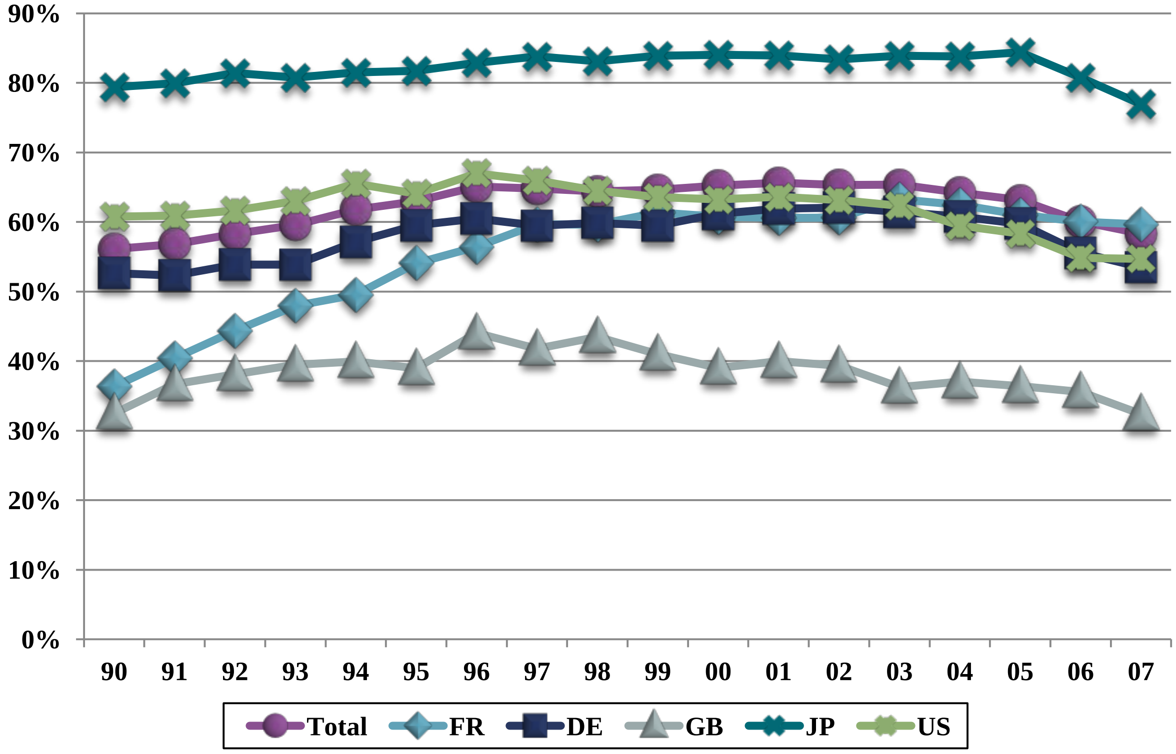
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

3.3 Patent applications by large enterprises

In addition to the structural analyses, this paragraph focuses on international patent applications from large multinational enterprises (MNEs). It is often argued, that especially international patent filings are more and more dominated by MNEs, which aggravates an international comparison by countries, especially against the background that very large enterprises cannot easily be assigned to one single country because they act very globally, spanning their R&D and manufacturing facilities as well as subsidiaries all over the world.

To analyze this pattern of MNEs applications in more detail, Figure 6 shows the share of applications from MNEs on total patent applications at the EPO by country. MNEs are defined as having more than 500 employees and more than three patents at the EPO.

Figure 6 Share of patent applications from MNEs on total applications at the EPO by country, 1990-2007



Note: The total numbers are a sum of all patent applications from US, DE, JP, FI, FR, IT, GB, NL, SE and CH, since only these ten countries are classified into large and small enterprises in our database.
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

As can be seen from the Figure, MNEs account for 56 to 65% of all patent applications at the EPO over the years, with an increasing share especially from 1990 to 1997. This can be explained by the so-called patent surge during the 1990s, where the number of patent applications almost doubled in all OECD countries. At least partly this massive rise in patent applications was driven by MNEs, using patents strategically in technology competition (Blind et al. 2006). From 1997 onwards, the share of patents from large enterprises remains quite stable at about 65%. This means that on average still about 35% of all patent applications at the EPO stem from small enterprises (SMEs).

A look at the countries, however, reveals a quite differentiated picture. While Germany, the US and France, at least from 1997 onwards, largely follow the general trend, Japan has a very high share of patent applications by MNEs. More than 80% of all patent applications from Japan are applied for by large multinationals. However, it has to be taken into account that the Japanese industry structure is very concentrated on MNEs. On the other side, exactly the opposite is true for patent applications from Great Britain. Only about 40% of patents at the EPO stem from MNEs, showing that the British industry structure to a large extent is dominated by smaller firms.

In sum, the argument that international comparisons are aggravated by large applicants can be confirmed at least for Japan. The general trend, however, shows that still about 35% of all EPO patents are applied by SMEs. Patent analyses at the EPO should take into account the typical peculiarities of those structures, especially when country comparisons are in the focus. To account for this particular problem, we count patents by the origin country of the inventor, not the origin of the applicant. This makes sure that each patent is assigned to the country where the invention has been made and therefore implicitly accounts for the fact that larger firms might apply all their patents for example from the country their headquarter or main research facility is located.

4. China’s patent activities – at home and abroad

The first patent law in China came into being in 1889. Several new laws and revisions have been introduced since then, before 1949 – after the foundation of the Peoples Republic of China – also new intellectual property institutions were founded (Liang/Xue 2010; Mertha 2005). Not before the end of the Cultural Revolution and the death of Mao Zedong it was possible to refocus on the importance of science and technology, and in this context also a legal framework of intellectual property regulations. When the “opening up” under Deng Xiaoping started in 1978 also a discussion started on the introduction of a patent system and a patent law, which was finally approved in 1984 after long debates and a period of studying and examining international patent systems. At that time, opponents to the introduction of a patent system were arguing that patents are against socialist principles and it will hamper the development of the domestic industry also by making China more dependent on foreign technologies and foreign companies. These arguments can still be heard today from time to time. The concept and the pushing of “indigenous innovation” as well as an index that is published by state authorities on the dependence of foreign technologies need to be interpreted in this context.

In that first patent law that took effect in 1985 chemicals and pharmaceuticals were not patentable and it was very applicant centred – applicants which were essentially state owned. Inventors were only conceded a bonus payment, but no ownership of patents (Alford 1995; Mertha 2005). A revision in 1992 introduced chemical and pharmaceutical patents and it extended the maximum duration of patent protection to 20 years. Another revision in 2000, already anticipating the WTO membership and the acceptance of the TRIPS regulations (Agreement on Trade-Related Aspects of Intellectual Property Rights)[4], strengthened the position of private companies and individual inventors in the patent system (Frietsch/Wang 2007; Yang/Clarke 2005). The latest revision in 2009 and its implementation rules released in early 2010 made some considerable changes to the patent law. First and foremost, absolute novelty was introduced where only Chinese prior art was taken into account before. This might have an enormous effect on the patent applications but especially on the examination and granting process. Besides, the fines and punishment of counterfeiters were considerably raised. While before, the fines to be paid were often simply adjusted to the economic loss of the IPR owner – and the owner often had to prove the amount of economic loss –, considerable amounts of fines that might really have discouraging effects were introduced with the new regulations.

Since China joined the WTO in 2001 and also adopted the TRIPS agreement, the Chinese patent system is – from a formal perspective – in line with international standards and conventions. The Paris Convention was already adopted earlier (in 1985) and the Patent Cooperation

4 The TRIPS Agreement defines international "minimum rules", which should facilitate dealing with international "flows" of intellectual property. It says that "… the agreement addresses the applicability of basic GATT principles and those of relevant international intellectual property agreements; the provision of adequate intellectual property rights; the provision of effective enforcement measures for those rights; multilateral dispute settlement; and transitional arrangements." (http://www.wto.org/english/docs_e/legal_e/ursum_e.htm#nAgreement; 31.10.2011).

Treaty (PCT)[5] was signed in 1994. However, what were falling short of this formal regulation were the effective use and the enforcement of the patent law in particular, but also of other IPR regulations like trademarks or copyrights. In consequence, counterfeiting and abuse of intellectual property was not to be embarked sufficiently and satisfyingly. And even where law suits resulted in decisions, the enforcement on the one hand and especially the punishment on the other hand – the fines were rather low for counterfeiters – were not appropriate to let the patent law and the patent system fully take effect. This was and still is reason for international complaints on the Chinese IPR system. Changes have been made by the central government. Officials do not stop emphasising their efforts, which surely are there. International complaints are often concerned with the speed of adaptation and the formal regulations – for example the necessity to ask for international filing permission in case of inventions made in China. These are reasonable objections, but the main issue was and still is the enforcement of the IPR laws and especially the enforcement of the punishments in case of conviction (European Union Chamber of Commerce in China 2005; Ganea/Pattloch 2005). The punishment of infringement had increased in the course of the improvement of the patent system within the recent decade, but punishment of non-enforcement of court order still does not receive enough attention. The court decision is often ignored, not only in IPR disputes, but also in other civil law cases (Frietsch/Wang 2007).

The problem of enforcement starts at the courts. Until recently, only very few specialised patent courts were active and especially their experience was limited. Lawyers and first and foremost experienced patent judges were not available in China. Reasonable law suits with a predictable outcome that allows companies to balance risk and benefits beforehand were hardly existent. Even when the courts reach a decision, it might not be enforced (Bosworth/Yang 2000; Yang/Clarke 2005).

The problem continues with law enforcement, where regional interests of protecting local companies and enforcing the intellectual property rights of foreign technology owners, or even of Chinese companies from other regions or provinces often outweighs the legal enforcement implementation. The problem of counterfeiting made some Chinese and foreign firms organise themselves into associations, building networks with local authorities, to undertake additional private enforcement and push government to continue enforcement efforts (La Croix/Konan 2002). The regional differences in the implementation and application of laws, rules and regulations hamper a sound diffusion of technologies and products and make the situation unpredictable for enterprises, which intend to further increase their engagement. Also in this respect several efforts of governmental bodies like the SIPO were taken. In addition internationally collaborative projects like the "EU-China Project on the Protection of Intellectual Property Rights" (IPR2), which aims to improve "the effectiveness of intellectual property rights (IPR) enforcement in China"[6] have been jointly supported by Chinese and

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5 http://www.wipo.int/treaties/en/

6 See http://www.ipr2.org/

European authorities. Furthermore, the European Law School[7] in Beijing – with funding also from the European Commission – was established in 2009.

To sum up, the Chinese patent law has seen a considerably improvement in the recent decades since its introduction in the late 1970s. Especially the reforms introduced at the beginning of the new century before the WTO accession and the recent reform of the patent law in 2009 were the most influential changes. Clear improvements in the system in accordance with the demand to a patent law that is appropriate for a developing country, the Chinese government modernised its patent law step by step. Nowadays the IPR system is in formal accordance with worldwide standards in most respects – exemptions from this general statement included. For example, the obligation to seek approval of foreign applications for inventions completed in China is such an exemption. However, the legal and formal layout of the IPR system is not the biggest challenge but the law enforcement. Also here explicit efforts have been taken by the Chinese government and improvements are also visible. It will be interesting to see the consequences of the current granting practice of the Chinese patent office (SIPO), which grants the majority of the vast number of patent applications arriving at the office's doors. And SIPO grants them very quick, which raises doubts on the examination quality. It can be expected that this behaviour might take effects in the near future, when Chinese patent owners sue each other with a vast number of broad and sometimes essentially invaluable patents, but which might block others from being innovative.

4.1 Patent applications at the State Intellectual Property Office (SIPO)

The State Intellectual Property Office (SIPO) of China has seen an enormous rise of patent applications flooding in since the early 2000s. This rise is, on the one hand, a result of the increase in innovative and technological capabilities of Chinese companies and public research institutions. The enormous investments in R&D and in the science system in general show their effects on the output side of patents. On the other hand, this is a result of the discovery of IPR as well as the patent system in particular as an important mean to secure intellectual property. Without any doubt, many Chinese applicants and inventors also have high hopes concerning the economic benefit from the patent system, so the perception is that filing patents is one way in participating in the economic miracle and the overall economic growth of the Peoples Republic of China. Furthermore, there are many incentives in the Chinese system to file patents. This includes plans and guidelines of how many national or international patents should be filed by the country in total or by individual institutions. For example, the country's patent strategy, released in 2008, stresses the will of the Chinese government to catch-up with the leading patenting countries in terms of PCT applications. Accepting that such plans and policy goals have a stronger and more binding meaning than similar plans and strategies have in Western countries is key to understand the Chinese economic system as well as the innovation system in particular. Institutions are very obliged fulfilling the plans and there are sanctions and incentives that motivate institutions to achieve the goals. But at

7 See http://www.ecsl-beijing.eu/

the same time such announcements and plans come along with policies and investments that set the institutions and addressees of these policies and plans in the position to achieve these goals. There are several means in the systems that foster patent applications on the national but also on the international level. For example, students may graduate from their university by filing a patent– not necessarily an invention patent – instead of writing a thesis and in several institutions professors and researchers in public research get bonus payments for filing a patent.

The total number of invention patent applications has steadily grown since 2000 from a level of 51,747 to 391,177 applications in the year 2010, according to SIPO's official statistics.[8] This data counts the patents by their application date and includes patent applications that are not yet published or will even never be published as they were rejected or withdrawn before the 18 month publication period – though the share of never published applications is lower than, for example, at the EPO. The total number of more than 1.2 million patent applications that is sometimes reported in media and official statements to emphasise that SIPO is the largest patent office in world in terms of applications includes design and utility models, which are the majority of applications and which are of lower technical and scientific value. Furthermore, these latter kinds of patents are cheaper and faster to have and this is why they are attractive to several actors in the innovation system. The number of design and utility models filed by Chinese applicants has grown steeply while the filings from foreign applicants hardly increased. The number of design and utility models of foreign applicants is also rather low in general, which proves the restricted use and protection power of these kinds of patents. We limit our analyses to invention patents only (henceforth patents), as these are the more valuable and reliable filings. Furthermore, these filings are comparable to the patent applications on the transnational level so that the engagement of China abroad can be analysed. We use PATSTAT as a data source consistent with our other analyses in this report. However, this data is not completely congruent to the statistics published on SIPO's webpage.

The absolute number of patent applications at the SIPO by Chinese inventors as well as inventors from Germany, Japan and the USA in comparison is depicted in Figure 7. The growth of the Chinese applications is impressive and obvious, especially after 2004. This reflects the enormous upswing of applications that comes along with an enormous increase in the workload of the patent office. Invention patents demand the highest examination efforts and thereby increase the workload most. However, also the other kinds of patents, which were growing even faster, take attention of SIPO staff. Although SIPO has considerably increased the number of examiners, it still needs time to catch up with the workload. Examiners need to be hired, trained, and also should get time to gain work experience. The examination and granting practice, however, suggests that the average examination and granting process is rather quick, especially against this background of the steep increase in incoming filings. Explorative analyses of the legal status information of Chinese patents show that the majority of

8 http://english.sipo.gov.cn/statistics/index.html

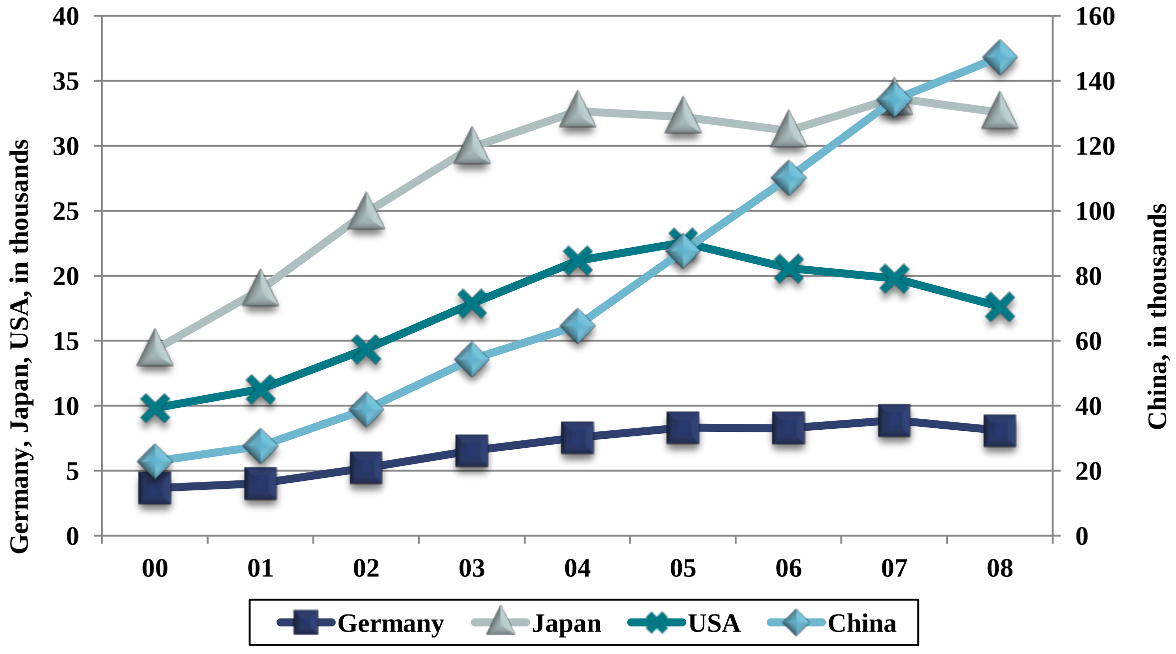
applications is granted and that the majority of them is processed within 2 years after filing. This is an impressive speed, but raises doubts on the quality of the examination process.

The patent law was changed in late 2009, taking effect in 2010. One of the main differences to the former patent law is the introduction of worldwide prior art instead of national prior art only. This might also have an impact on the workload and the duration of examination. One should expect that the examination process and therefore the time to grant will expand.

There is anecdotic evidence that several patents filed in China before 2009 would have not been grantable if a worldwide prior art would have been in force. It remains to be seen what happens to the patents filed after 2009. So far the indication is that the new patent law did not considerably slow down the growth of applications of Chinese companies and inventors, but maybe the effect on the grant rate will be visible soon.

Taking a look at the trends and levels of the foreign countries depicted in Figure 7 several striking results can be found. The Japanese have a clear and strong interest in the Chinese market, filing even almost twice as much patents at the SIPO than US-American inventors do, while on the transnational level (see previous chapter) the Japanese file almost half the number of patents of US-American inventors. Though the trend of the Japanese patent applications in China has slowed down after 2004 and the absolute number of applications per year even decreased between 2004 and 2006. The US-American applications also went down after 2005 and were still on a downward trend until 2008, which might be both an effect of the enchantment of the hype after China's WTO accession and the result of the financial crisis in the USA. The German patent applications to the SIPO follow a similar trend like the USA's, but on a lower level. German companies apply for less than 9,000 patents per year in China, which is less than 1/3 of their transnational filings.

Figure 7: Absolute number of patent applications in China (SIPO) of selected countries, 2000-2008



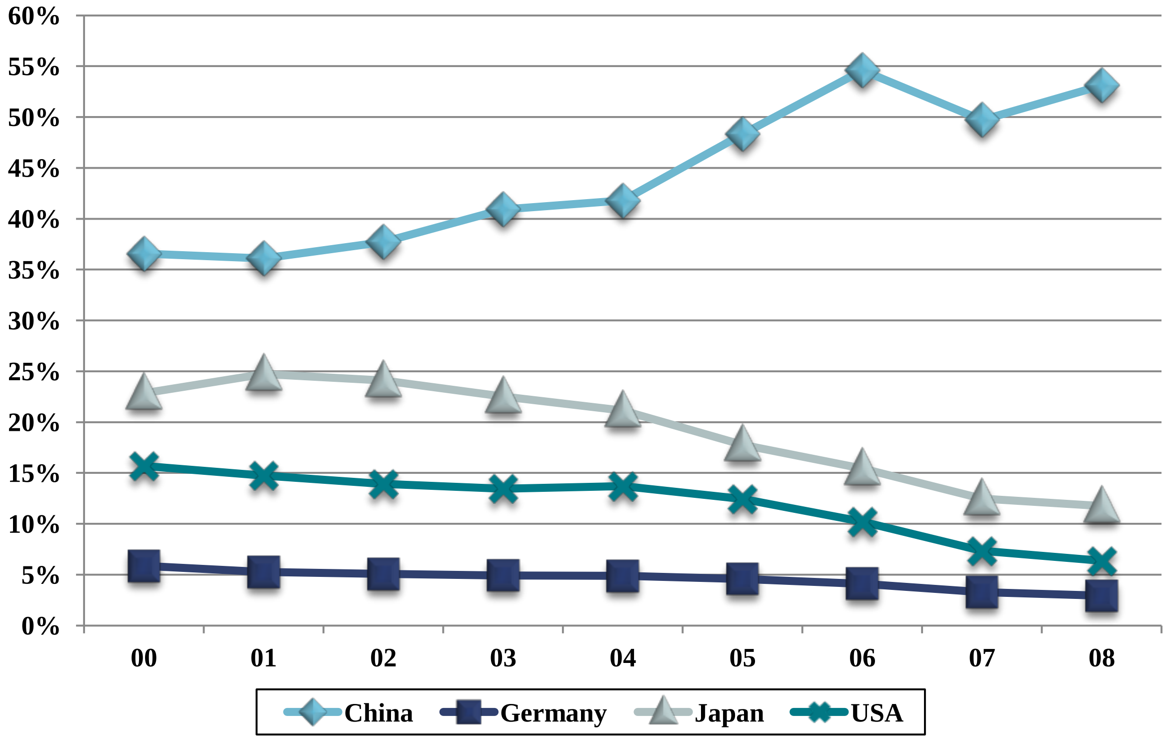
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

As Figure 8 shows, the shares of Chinese applications at SIPO were steadily increasing over time, while the shares of the other countries were decreasing in consequence. Until the priority year 2005, the majority of patent applications in China were filed by foreign companies and inventors, while since then Chinese applicants are responsible for the largest share of applications. China accounts for about 53% of all patent applications to the SIPO in 2008, Japan accounts for 12%, the USA for 6% and Germany for about 3%.

It is interesting to note that the shares of high-tech patents in all patents increased since 2000 (see Figure 9) for all countries under observation here, at least until the middle of this decade. China has the lowest share varying between 48% and 52%. South Korea has the highest shares in high-tech patents in their portfolio, reaching a level of more than 65% in 2007, followed by the USA and Japan. Germany has lower shares and especially shows a decrease since 2003. Obviously it is not only high-tech that Germany companies see worthwhile to be protected in China. As a matter of fact, there are at least two reasons to file patents in a country – either market access to sell goods and commodities based on these technologies or to protect the technology in case of production in the country. Both cases are relevant in China and the fact that Germany's shares of high-tech patent applications at SIPO decreased over time might also be driven by both kinds of motivations, but could indicate that low-tech production more and more moved to China in the last years (Kinkel et al. 2010; Kinkel/Maloca 2010), although this cannot be analysed in detail here and with the data at hand. This conclusion, however, is supported by the trends and the shares of South Korea, Japan and also the USA who – of course – also access China's market, but also use China as a production location especially for their high-tech products like mobile phones, computers and consumer electronics. Germany is not specialised in these areas, but more in medium-tech products like mechanical engineering, automobiles, and machines (which also account to the high-tech sector). However, these sectors also produce and invent technologies with lower R&D investment necessary and these products might be produced in China as well.

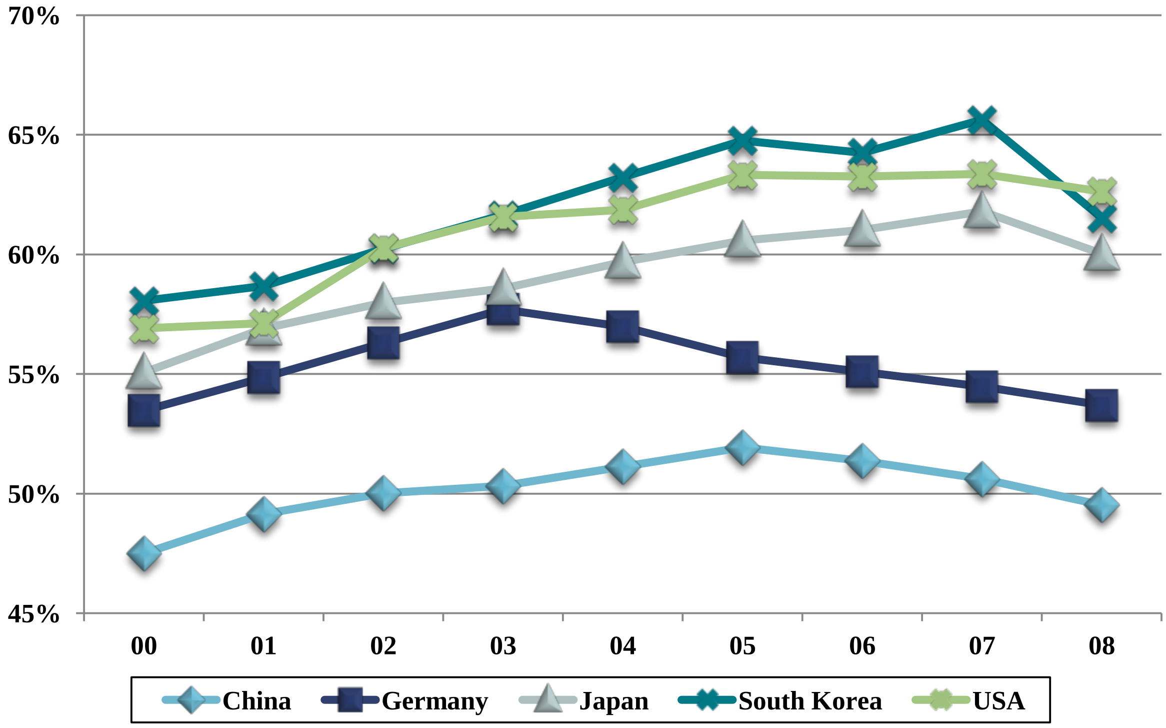
China's shares are lower than the shares of the other countries, which is to be expected based on the fact that SIPO covers the Chinese home market where patents are cheaper to have and easier to file than abroad for national inventors and applicants. On the other hand, it is surprising that the shares are only slightly lower than those of Germany, for example. Furthermore, given the enormous increase of patents in the period under observation here, it is astonishing that the share of high-tech patents did not decrease even more. It is often argued that the Chinese patents are of lower quality and of low technological content. The data presented here can hardly add substantial arguments to that discussion, but it can at least be seen that the technological areas where Chinese inventors file the patents are in no way only low-tech fields. This is not to neglect that many patents in China – and elsewhere in world – also in so called high-tech areas are invented and filed with only minor or even no research and development efforts or investments.

Figure 8: Shares of selected countries in total patent applications in China (SIPO), 2000-2008



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

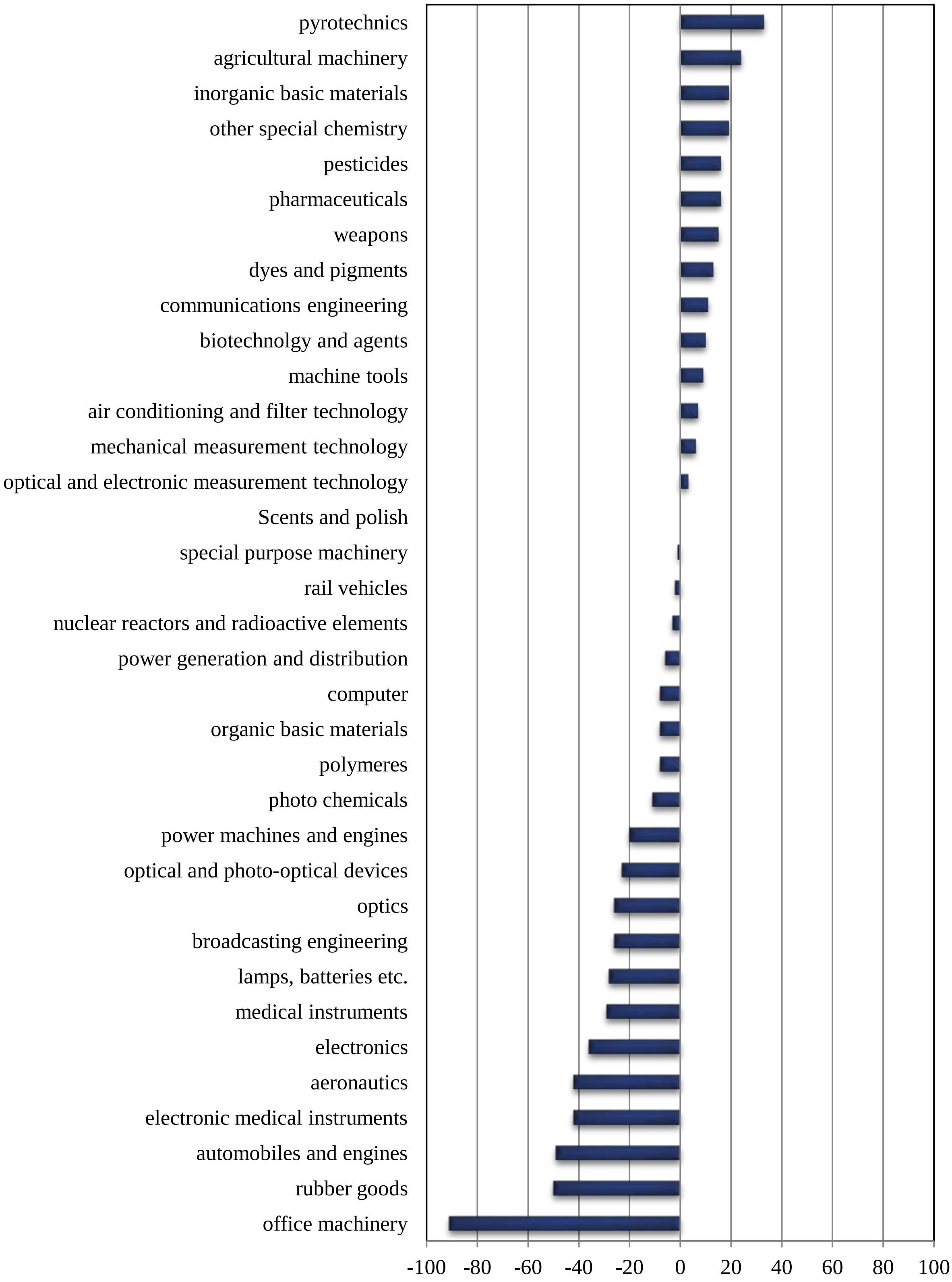
Figure 9: Share in high-tech patent applications in total patent applications at SIPO



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The Chinese patent profile (specialisation index) is depicted in Figure 10. Positive specialisation is visible in the areas of chemistry, pharmaceuticals, biotechnology, and some mechanical engineering fields, even though the index values are not very high, reflecting not outstanding comparative advantages in patenting. Chinese applicants have a profile that is very close to the average activity at the SIPO. This result is not very surprising, knowing that Chinese applicants account for more than half of all filings, therefore considerably shaping the benchmark of total applications in China. However, the result that there is almost no field or area of outstanding activity compared to the profile of foreign companies is also interesting in itself. On the other side of the distribution, there are a lot of areas where Chinese companies file relatively less patents than foreign applicants do, among them are automobiles or medical instruments – a finding that is consistent with another study on the Life Science sector in general in China (Frietsch/Meng 2010). It is interesting to see that also in the area of information and communication technologies (ICT), which belongs to the strengths of the Chinese patenting performance on the international stage (see the following section) and also the export performance, Chinese applicants are not able to gain comparative technological advantages even at their home market. Among these ICT fields, where Chinese reach indices below the average at SIPO, are broadcasting engineering or office machinery, but also computers and communication technologies only reach an average level. Also electronics or optical devices do not belong to their strengths.

Figure 10: China's patent profile at home (State Intellectual Property Office), 2006-2008

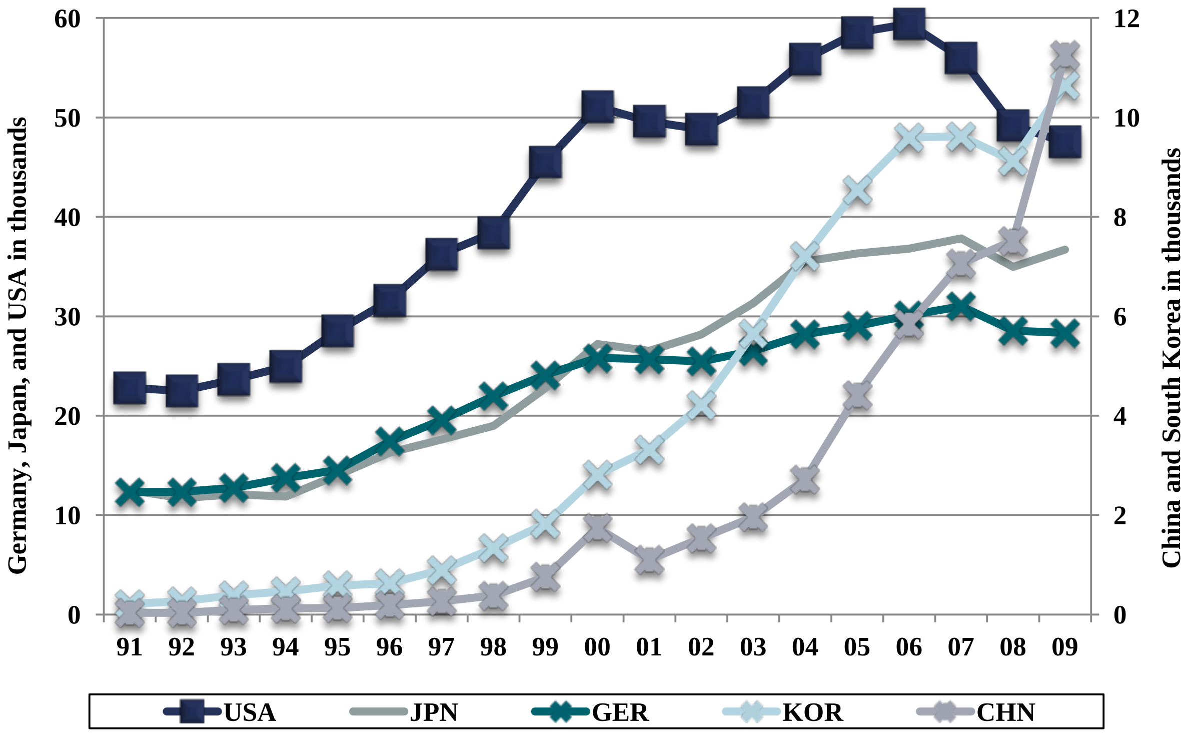


* Applicant country.
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

4.2 China's patent applications abroad – transnational patents

China's patent strategy[9] formulated in 2008 as well as the Medium to Long-term Plan on the Development of Science and Technology (SCPRC 2006) stresses the intention of the Chinese government to foster and increase the number of international patent applications, of PCT applications in particular. As Figure 11 shows, this policy was successful. Again, the absolute numbers of Chinese applications were growing considerably, especially after 2001. Meanwhile China files more patents on the transnational level than applicants from the United Kingdom, for example. Only South Korea, as another fast developing technology nation, shows a similar trend on a still higher level (Frietsch/Schüller 2010). The Chinese trend shows outliers in the years 1998 and 1999, where more patents were filed than in the years before and after. In these two years a Chinese company called Bio Window filed about 1,000 PCT patents. However, none of these patents made it to the regional or national phase at any patent office as they did not successfully pass the examination. Obviously this company tried to file already existing technology, not taking into account prior art. A positive formulation says they were inspired by the Human Genome Project (Frietsch/Wang 2007). So the statistics for 1998 and 1999 are heavily distorted by this activity and should therefore not be interpreted seriously, but treated as exceptional cases.

Figure 11: Absolute number of transnational patent applications

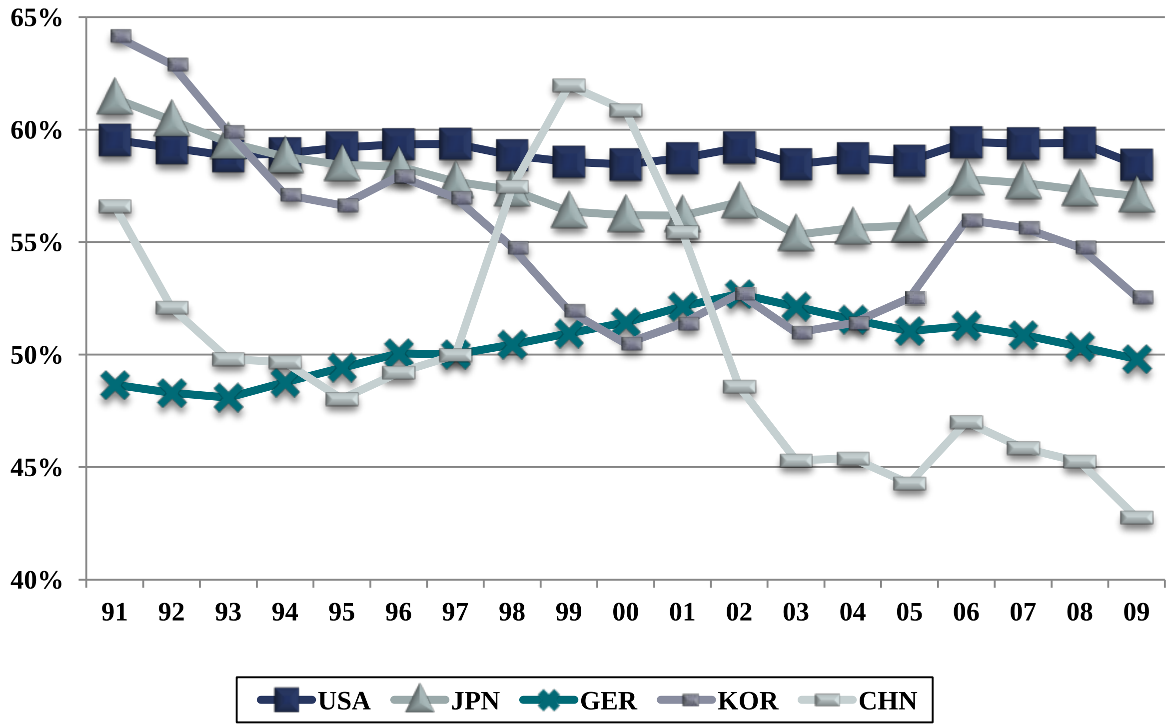


Source: EPO – PATSTAT; Fraunhofer ISI calculations.

9 http://english.gov.cn/2008-06/21/content_1023471.htm

It is interesting to note that the Chinese increase in the absolute number of patent applications comes along with a decrease of the shares of high-tech patents in their total patent applications (Figure 12). Excluding the two outlier years 1998 and 1999, a steady decrease of high-tech patents is visible, meanwhile reaching a much lower share than the most other industrialised countries. The shares of high-tech patents on the national level were shown to decrease as well (Figure 9). This is a surprising result as most countries file higher shares of high-tech patents on the transnational or international stage while at home the low-tech patents dominate the picture. Several explanations are at hand for this. For example, the lower engagement of SMEs on the international level – which have higher shares of low-tech activities. Higher investments – this is the definition of high-tech – require larger markets to regain these investments. Furthermore, on the international level it is the technological content and the technological competences that give the competitive edge and are therefore decisive for the success on international markets, while on national markets also the home base advantage and the market accession are easier to realise. So there is a high-tech filter at play when international technology markets are analysed.

Figure 12: Share of high-tech patent applications in total patent applications



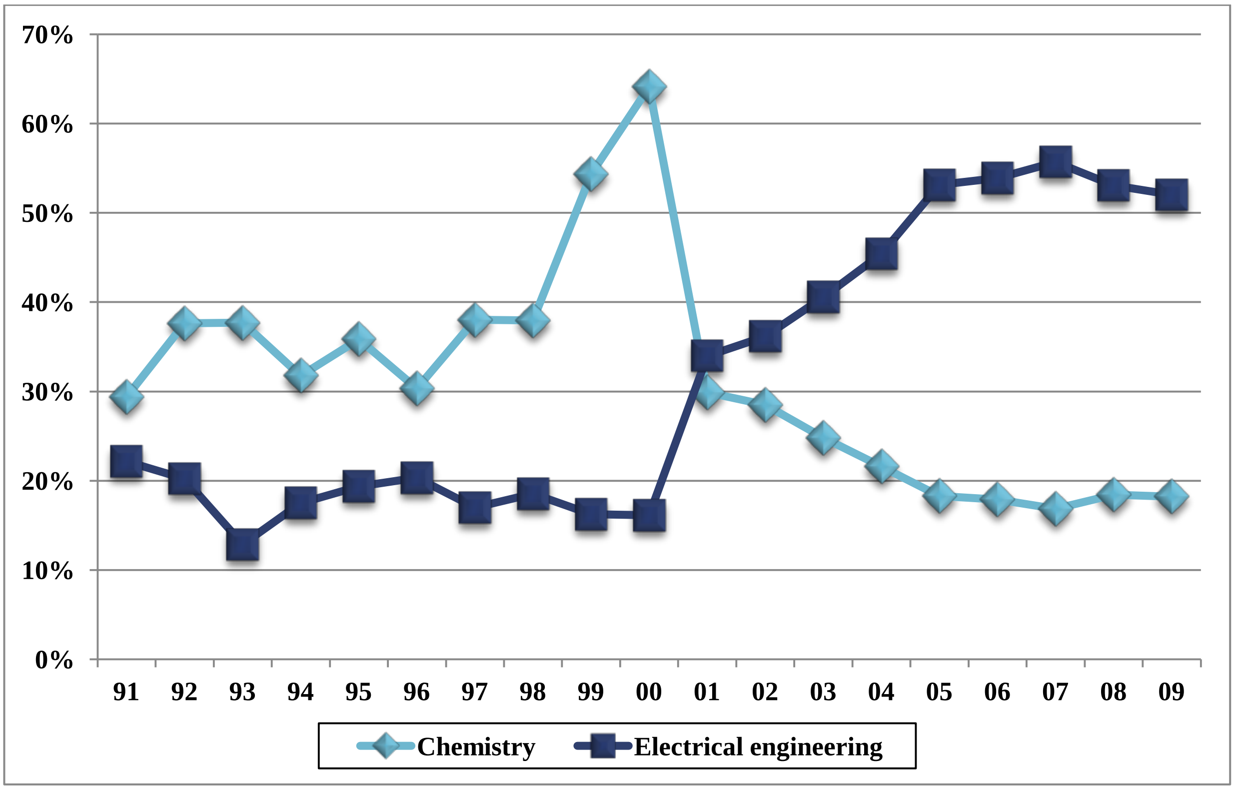
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The decreasing shares of Chinese high-tech patents on the international level are not a surprising result in general, but the level and the trend are interesting to note. At least two interpretations of this can be offered, which essentially are two sides of the same coin. On the one hand, the structure of Chinese patent applications on the international level has obviously changed considerably over time. Chinese companies need to register with the Ministry of Commerce (MOFCOM) to get approbation for exporting and internationalising. It seems that the structure of "who and what" gets approbation must have changed. On the other hand, the Chinese government and the Chinese companies have been very selective in what they offered on international markets at the beginning of the new century, but widened their scope in terms of technologies in the further course of the internationalisation. The comparative advantage of low labour costs was key to success in the ICT sector in the first half of the recent decade, coming along with building own technological competences in this area that are to some extent competitive on international markets. This comparative advantage also existed for low-tech areas, but was not backed by technological competences. Haier is the world's largest supplier of white goods – refrigerators, washing machines and the like, which are a typical low-tech area. Haier is able to protect its technological capabilities internationally and is meanwhile technologically competitive on the international stage.

The trends of changing overall technological capabilities and orientation on the transnational level can also be seen in the broad shares of technological areas of patent filing. Figure 13 shows the shares of China's chemistry and ICT-related transnational patents since 1995. The role of chemistry clearly diminished over time (Frietsch/Wang 2009). In the 1990s the Chinese patent profile on the transnational level was dominated by chemistry patents and the like. It decreased from almost 40% in the 1990s to a level below 20% since the mid 2000s. At the same time the increase of electrical engineering patents is evident. The majority of them cover information and communication technologies. Especially after the year 2004, when Lenovo bought the PC branch from IBM, a boost of this area in the patent profile of China is visible. However, since 2007 also the share of electrical engineering is decreasing slightly. It remains to be seen if it further decreases in the future.

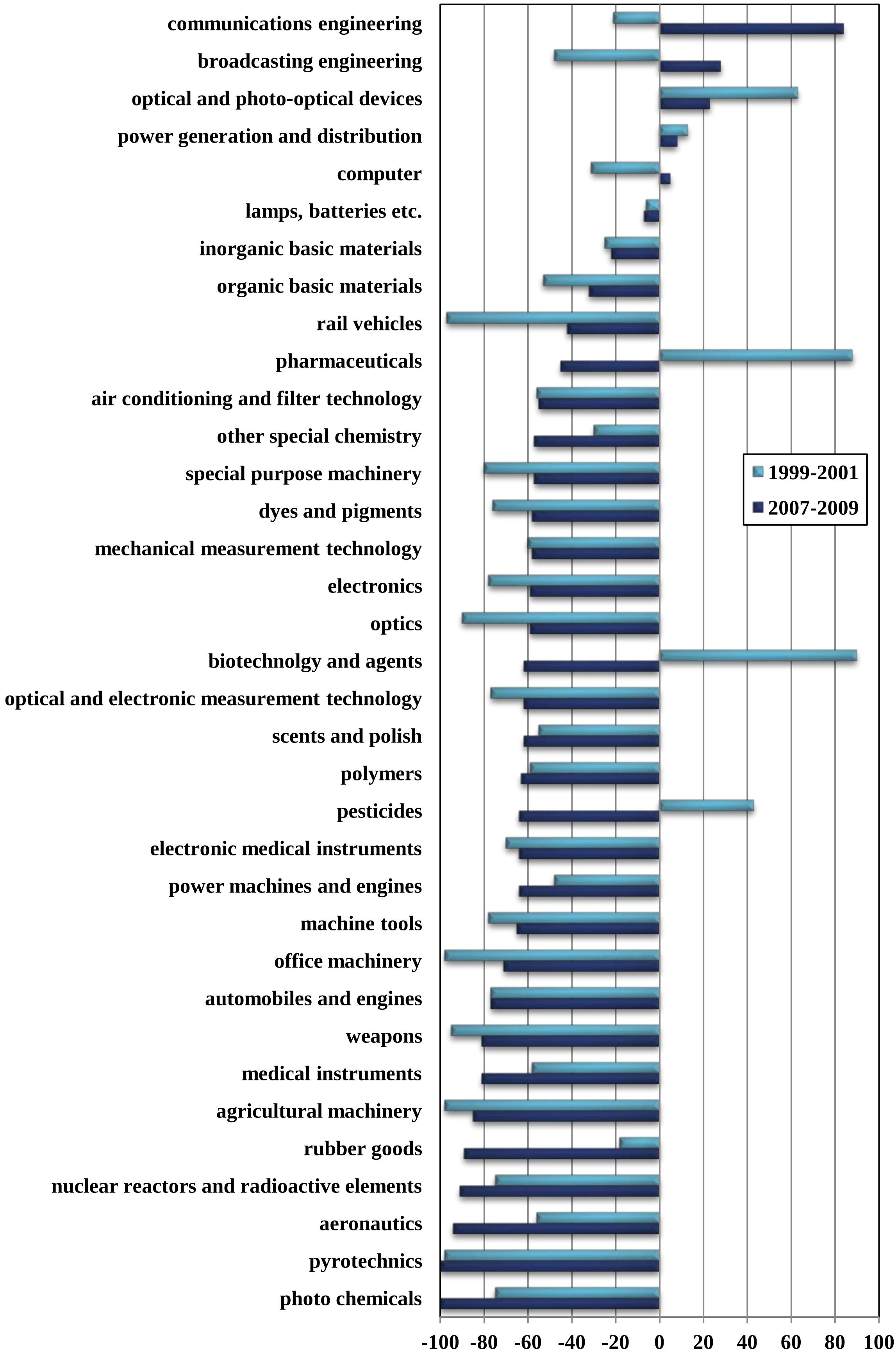
The total patent profile of China is displayed in Figure 14. Indeed, the profile has changed considerably over time as the comparison between the periods 1999-2001 and 2007-2009 show. In the current period communications and broadcasting engineering are the comparative advantages of Chinese patent output on the transnational level. Optical devices and power generation also belongs to the relative strengths of the Chinese innovation system. Computers and lamps and batteries are represented on the average in the Chinese profile. All the other fields do not belong to the comparative advantages. So the dominance of information and especially communication technologies is outstanding and evident. On the national level – this is just a reminder to the findings in the previous section – neither communication nor broadcasting engineering belongs to the comparative strengths of the Chinese innovation system. At home, chemistry, pharmaceuticals and some machinery fields were at the top, all of them not at the top on the international level. Next to the dominance of the information and communication technologies, which makes it hard to strive for any other area, two more conclusions can be drawn from this finding. On the one hand, the foreign market filter is at play, which results in a distinction between the national and the international profile. As discussed above, international markets are served with such goods and commodities where a strong competitiveness and a strong market position are reached – usually in high-tech fields. On the other hand, the MOFCOM filter seems to take effect, namely the fact that the Chinese governments picks the winners also to be successful on international markets. This conclusion is backed by the changing profile of Chinese patent applications on the transnational level over time – first chemistry, then information and communication technologies as well as electrical engineering. The question is what comes next?

Figure 13: Share of electrical engineering and chemistry patent applications of China (transnational patents)



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 14: China's patent profile abroad (transnational patent applications)



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

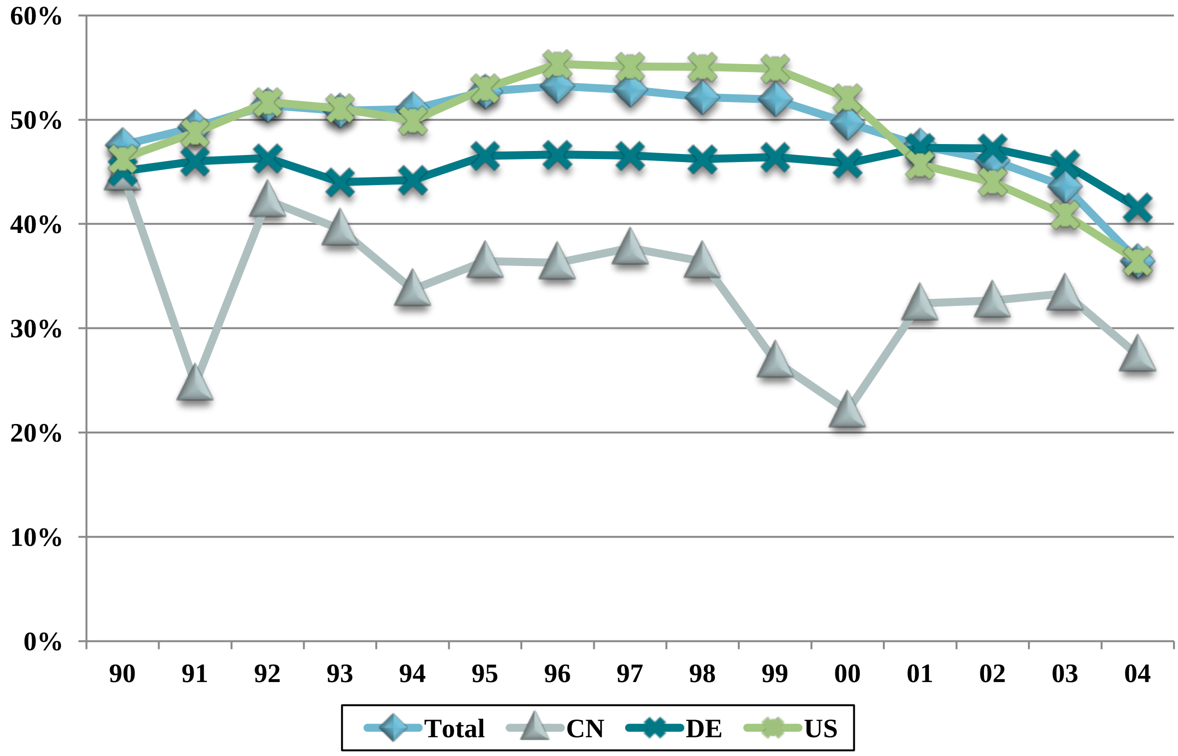
4.3 Citations in and of Chinese transnational patents

As indicated in the methodology chapter, patent citations might be used in two ways. On the one hand, forward citations can be interpreted as an indication of quality and backward citations can be seen as reflecting the technology context. The median age of the backward citations is used to calculate the total cycle time (TCT), which indicates how old the technologies are that a certain patent refers to. As we use transnational patents for this analysis, which essentially includes any family with at least an application at the EPO or via the PCT route, these two procedures are privileged also in terms of citations. To be more precise, the EPO patent citations are mostly introduced by the examiners and not by the applicant – this is different to the US patent system. Furthermore, examiners first of all use EPO patents for prior art searchers and in subsequent priorities they use USPTO and national European patent applications. This EPO effect is to some extent balanced by the inclusion of the PCT applications and the citations made there. USPTO patents play a major role in PCT citations, for example. However, Chinese national filings as well as Chinese applications entering the international stage via the PCT route are usually filed in Chinese. It takes some time to translate these applications into English, which is a disadvantage in terms of being cited. It takes about three to six months longer for Chinese applications than, for example, USPTO patent applications to be stored in the PATSTAT database that we use here. As PATSTAT is a copy of the database that is also used by the examiners in the EPO, the examiners also have later access to the Chinese patents than to the USPTO patents – and to the EPO patents anyway. This is at least a disadvantage for Chinese patents in terms of being cited. Given these restrictions, we analyse the citations of Chinese patents and discuss them in this section.

The forward citations – supposed to reflect patent quality – are displayed in Figure 15. The shares of cited applications in total applications for China follow a decreasing trend. Eliminating the priority years 1999 and 2000 from the interpretation due to the reasons mentioned the decreasing trend is visible, but not very pronounced. The shares decrease from about 38% in 1997 to about 33% in 2003. This was just when the absolute numbers of Chinese transnational patent applications began to rise steeply. The shares of applications that were cited within the first 4 years also decrease for the USA and for the total transnational patent applications in the same period of observation. Only the German curve shows an almost stable trend. As we use a 4 year citation window, data after 2004 cannot be used and even 2004 itself seems to be hardly interpretable.

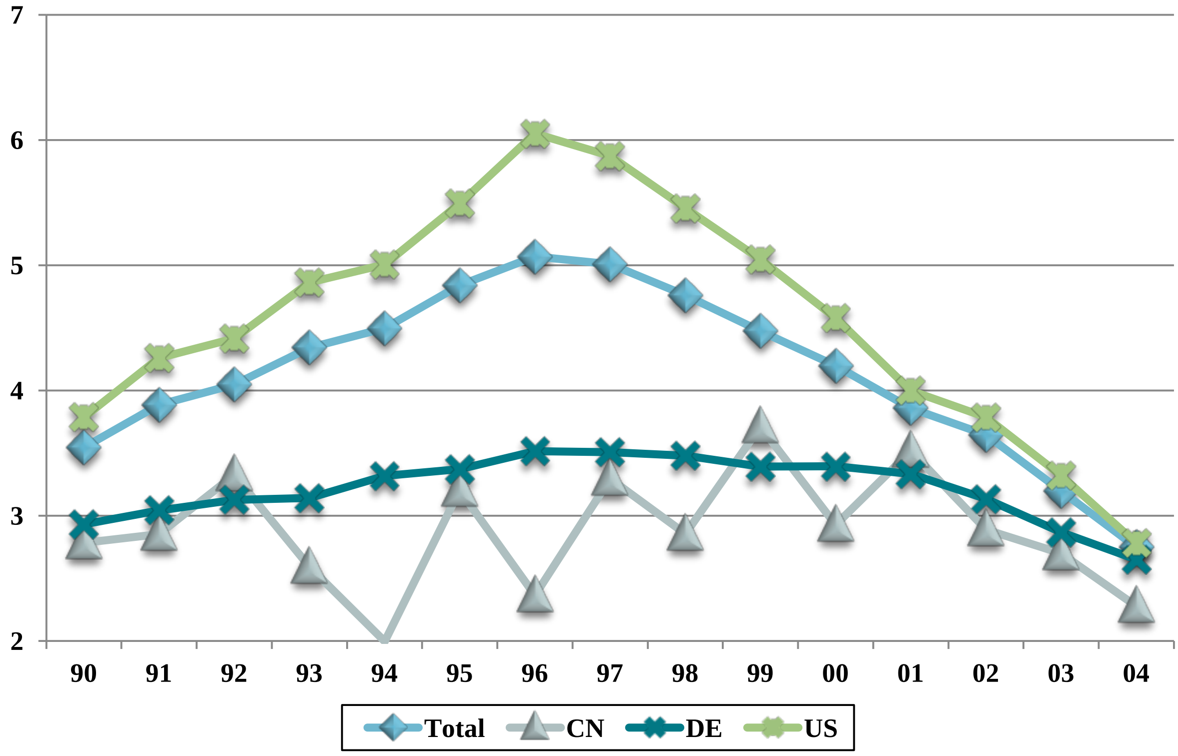
What is evident is that the share of Chinese patents that were cited is lower than the average of total patent applications as well as lower than the filings from the USA or Germany. When the average number of forward citations that a Chinese filing receives are analysed – given that it is cited at all – the differences to the other countries diminish (Figure 16). However, both indicators should be interpreted on the technology field level as there might be considerable differences in the profile of the countries that take a considerable effect due to differences in the average shares and numbers of citations per field.

Figure 15: Share of cited* transnational patent applications of all applications for selected countries, 1990-2004 (priority year)



* a 4 year citation window was applied
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 16: Average number of citations* per application



* a 4 year citation window was applied; only applications that were cited are taken into account.
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 17 depicts the results of an index calculation of the shares of cited Chinese transnational applications per technology field. The index simply divides the share of Chinese applications per field by the share of total applications per field. Any index value above one indicates higher shares for China than the average and the values below one indicate lower shares. Only scents and polish – a rather small field with only twelve Chinese applications and seven applications with citations in the period 2001-2004 – shows an index above one. So in all fields Chinese applications are less often cited than the average of total applications.

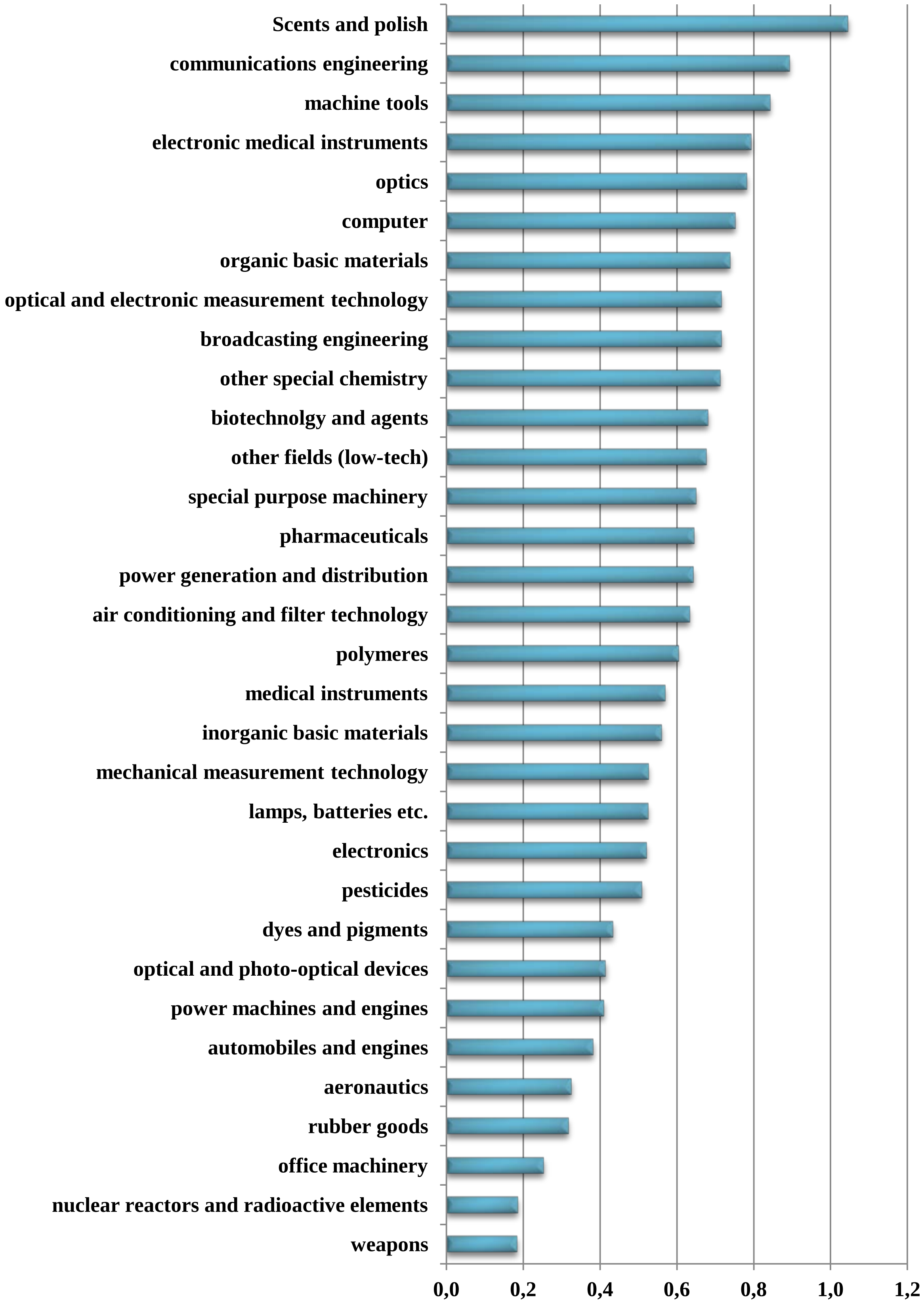
The average number of citations per cited application shows that only two areas, namely machine tools and pesticides, are cited above the average of total applications (Figure 18). However, the average citations for the large fields like communications engineering or computers as well as biotechnology and agents are rather close to the average so that the total citation rate is close to the average on the worldwide level.

In sum, the analyses of the forward citations do not clearly indicate a lower quality level of the Chinese patents, given the fact of delayed visibility and therefore "citeability" of the Chinese documents. Differences are measurable by using the share of cited documents in total documents. When the average number of citations is taken into account, the differences almost diminish, although only a few fields are cited above the worldwide average level.

The so called backward citations – the documents that Chinese patents cite – are displayed in Figure 19. Also in this case an index is calculated, benchmarking the Chinese median age of cited patents against the total median age per technology field. Values below one indicate a technology cycle time that is shorter than in the case of total patent applications in that field. Index values above one point to longer cycles, respectively. The interpretation is the shorter the cycle time, the shorter is the technology path that the citing document follows and the "newer" is the technology.

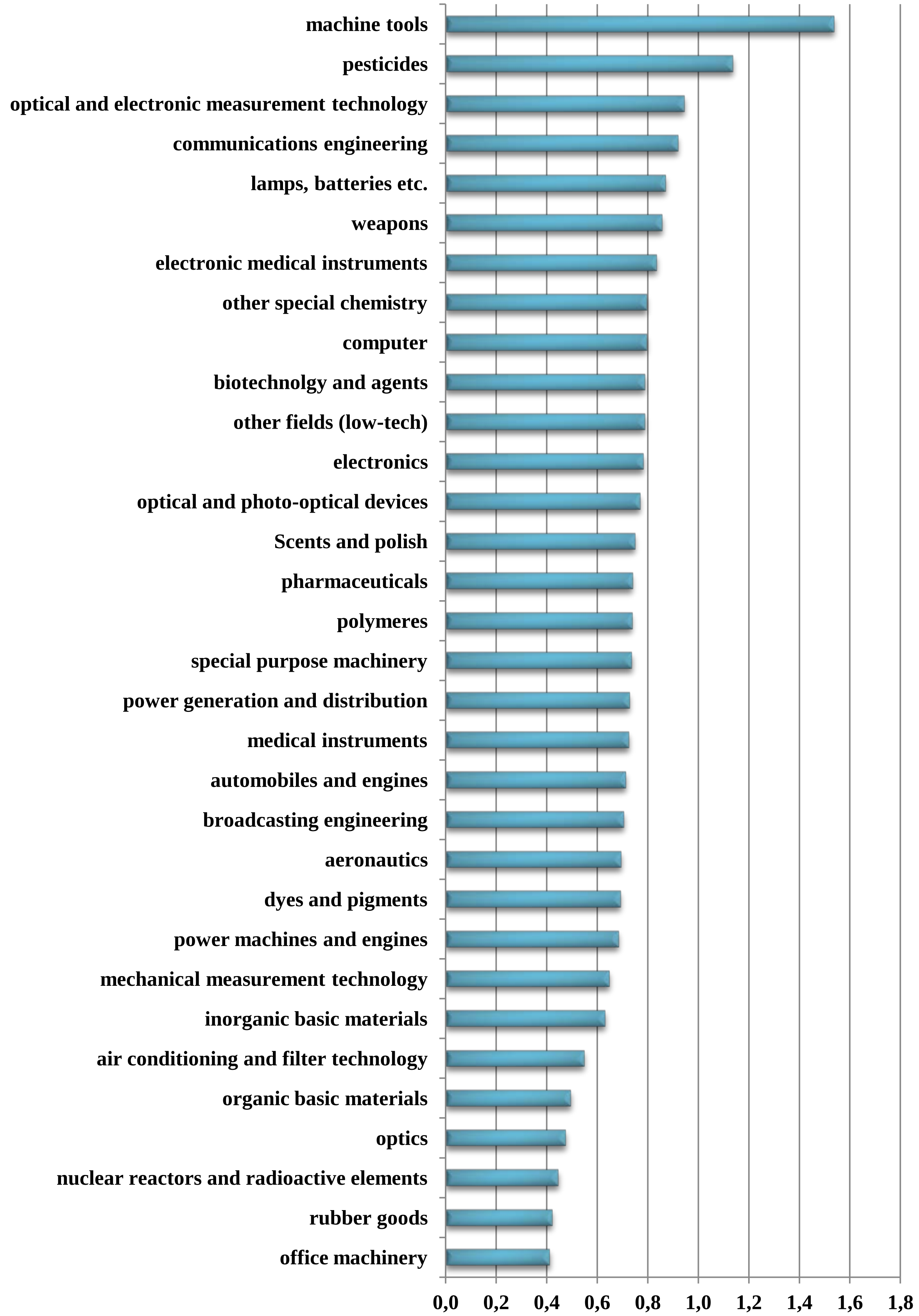
As can be seen in Figure 19, the majority of technology fields have cycle times that are below the worldwide average; among them are broadcasting and communications engineering and also most optical fields. Pharmaceuticals, biotechnology as well as computers show a TCT hat is identical to the worldwide average, while fields like electronics, machine tools, organic basic materials or pesticides are well above the worldwide TCT. It is interesting that machine tools were the most frequently cited patents of Chinese applications and in parallel this is among the fields that cite rather old technologies. However, one has to keep in mind that the forward citations refer to a period at the beginning of the decade, while the backward citations are more up to date referring to a period at the end of the decade. Structural changes within the field of machine tools might have occurred since the beginning. Machine tools are also insofar interesting as this is an area of specialisation of German industry and complaints about counterfeiting as well as a quick catching-up based on the imitation strategy were articulated here and there. It remains to be seen – once the recent applications are processed by the patent offices – if these applications have higher rejection rates and what their probability and duration of being maintained is.

Figure 17: Index of shares of cited* transnational patent applications of all Chinese applications by technological fields, 1990-2004 (priority year)



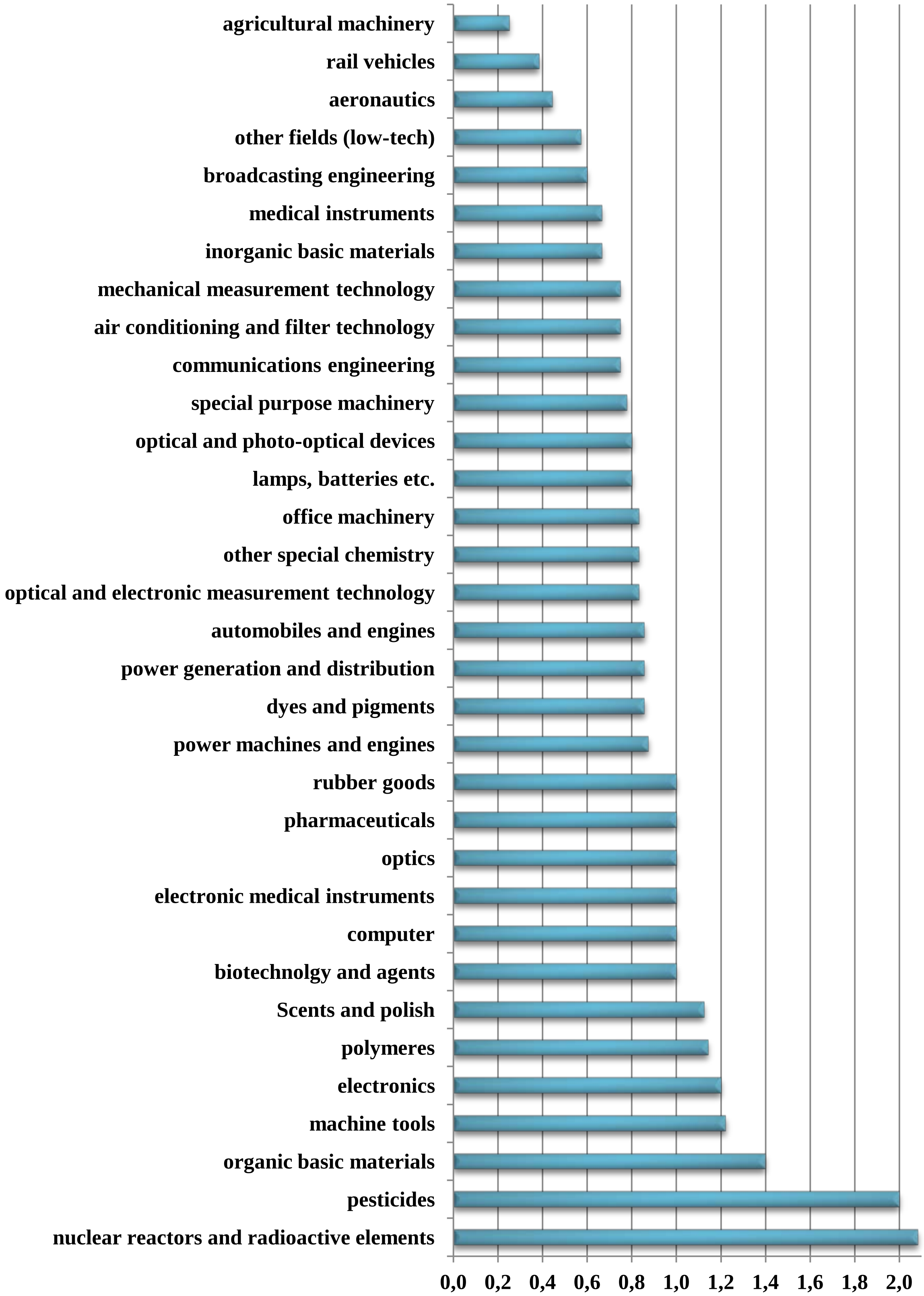
* only applications that were cited are taken into account; the following fields are not depicted as no applications were filed by Chinese applicants: agricultural machinery, pyrotechnics, photo chemical, rail vehicles.
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 18: Average number of citations* per Chinese application by technological fields



* only applications that were cited are taken into account; the following fields are not depicted as no applications were filed by Chinese applicants: agricultural machinery, pyrotechnics, photo chemical, rail vehicles.
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 19: Total cycle time (median age of cited patents) for Chinese transnational applications by technological fields, 2007



* the following fields were excluded as no applications were filed by Chinese applicants: weapons, pyrotechnics, photo chemicals.
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

5. Patent Families – Applying Weights to Account for Differences

5.1 Introduction

In the context of national innovation systems, the main intention of patent analyses is to provide a comparative assessment of the technological competitiveness of those systems. Patents still are the most important indicator for the output of technological invention processes. They indicate stronger efforts in R&D activities and therefore a higher innovative output. However, several studies have found that the distribution of the economic value of patents is extremely skewed, meaning that patents considerably vary in their value (see for example Gambardella et al. 2008).

The economic value of patents is not determined solely by the characteristics of a single patent, but by various factors of a technology or a firm and its interactions with competitors and markets. This means that the economic or commercial value of individual patents can hardly be derived from the information contained in a single patent document. In addition, the economic benefits of a technological product can hardly be assigned to one single patent, as this product is usually the result of several technologies implemented in one device, machine etc, which is therefore often protected by a large number of patents (Frietsch et al. 2010b). In sum, simple patent counts could give a distorted picture of the technological basis of a country.

In the empirical literature a multitude of indicators are proposed to predict the economic value of patents. These mostly are more advanced patent indicators, relating, for ex-ample, to patent citation measures, the size of inventor teams and even legal events, such as oppositions (see for example Harhoff et al. 2003). Another important indicator of patent value is the average family size of patent portfolios or profiles (of countries, technology fields or companies), which is in the focus in this analysis. 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). For each of these countries, however, application and maintenance fees have to be paid to the respective offices. Moreover, additional costs could emerge for the enforcement of patent rights in various countries. Therefore, 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 bear additional costs for the protection of his invention in the respective market. In this sense, it is assumed that a patentee only files a patent abroad, if he expects a corresponding profit with the sale of the protected technology. In more simple words, a large patent family means greater market coverage which is associated with preliminary and running expenses (Frietsch et al. 2010b).

The average size of a patent family has shown to be a handy indicator of the economic value of patent portfolios at the firm level (compare for example Neuhäusler et al. 2011). At the country level, however, the family size has a very restricted predicting power (Frietsch et al. 2010b). The reasons for this are at least twofold. First, technologies have a different propensity to internationalisation, which means that for example ICT and pharmaceuticals are more internationally oriented – and therefore have a higher average number of family members – than for example machinery or automobiles (Blind et al. 2003). Countries with a higher orientation to ICT or pharmaceuticals thus reach higher average family sizes than engineering-oriented countries. Second, and even more important, the individual family members target markets of very different value, in terms of size or strength of the targeted market. For example a patent family targeting the US, Japanese and German market might be more valuable in terms of market coverage than a patent filed in five smaller European countries. This results from the difference in the market size of those countries which is why calculating the average family size or summing up the family members does not seem appropriate in the value discussion, at least at the country (Frietsch et al. 2010b).

Our approach to address this gap is to weight the members of patent families from different countries before calculating the average family size to account for the market potential or the value of the market in which the patents of these families were filed. These weighting factors range from GDP to local competition measures and will be described in more detail in the next paragraph. This approach yields two significant contributions. First, it will be possible not only to count the number of worldwide patent families by country but to weight this count according at which office those patents have been filed. Second, it is possible to calculate a weighted average family size by country, which could serve as an improved indicator of the value of a patent portfolio at the country level.[10]

5.2 Construction and Implementation of the Weighting Factors

In order to assess the market strength of each country, six different measures were calculated and implemented in our version of the PATSTAT database. These are summarized in the following table (Table 3).

Table 3 Overview of the weighting factors

Name	Description	Source
GDP	Gross Domestic Product	(The World Bank 2011)
POP	Population Size	(United Nations Population Division 2009)
CI	The Global Competitiveness Index	(World Economic Forum 2010)
LOC	Intensity of local competition	(World Economic Forum 2010)
PARK	Strength of patent systems	(Ginarte/Park 1997; Park 2008)
IMP	Imports	(United Nations Commodity Trade Statistics Database 2011)

We decided to introduce multiple weighting factors, since all of those factors capture the market size or market value of the targeted economies in a different manner. In the following sections we will show how the countries rank in terms of their weighted family count, depending on the weighting factor that is applied. In addition, we will perform bivariate and multivariate analyses to find out how similar these measures are to each other and which one could serve as an improved indicator of the value of a patent portfolio at the country level in terms of its ability to explain export streams.

10 These analyses are based on former analyses carried out in 2010 (Frietsch et al. 2010b).

To normalize these weighting factors on a range from 0 to 1, they were defined as the share on world's total for each indicator by country and year. In the case of CI, LOC and PARK, which are index variables and a total number does not exist, each country's value was divided by the maximum value on the scale of those measures. If data on some years was missing, the respective fields were filled with data from preceding or following years. This is especially problematic for CI, LOC and PARK. The PARK indicator is only available for the years 1995, 2000 and 2005. CI and LOC values are only available for the year 2010.

These weights were then included into our version of PATSTAT. For each patent office and each year from 1990 onwards a weighting factor was assigned. A challenge is the treatment of EPO and PCT patent applications, since a patent application at these offices does not necessarily mean that all contracting member states of these international patent offices are targeted by one application (in fact, most patents only designate a chosen set of national offices). In order to calculate the different weighting factors for the EPO, first of all the average weight for all EPO contracting states was calculated for each of the weighting factors (e.g. GPD, IMP etc.). In a second step, this average EPO weight was multiplied by the average family size of all patent applications with at least one EPO member, indicating of how many countries are targeted by one EPO application on average.[11] This way, we capture the average market coverage of an average EPO patent application. A similar approach was chosen for the PCT applications, based on the average of values of a set of countries[12]. By calculating the weights for EPO and OECD in this manner it is assured that EPO and PCT patent applications are neither over- nor undervalued.

To finally calculate the weighted family counts and weighted average family size by each weighting factor, each individual family member is multiplied by the weight given to the respective patent office it has been filed. The results of these calculations are then summed up for each family and counted (or averaged in case of the average family size) by country in a final step. The unweighted family count is calculated accordingly, except that each family member is just counted once per family, without applying the weights. Additionally, we excluded the so-called "singletons" (Martinez 2009; Martínez 2010), which are patent families that consist of only one family member, to focus solely on patent families with at least one member in another country as otherwise the pure national patent applications at large national offices (USPTO, SIPO, KIPO, JPO) would dominate the picture and distort our analysis. In other words, the home advantage (Frietsch/Schmoch 2010b) of large countries would bias the results. At this point, it is important to mention the difference between absolute family counts and the average family size of a country's patent profile. Although weighted by the market

11 An option to this approach would have been to weight EPO and PCT applications by zero, since all of these applications are forwarded to national offices at a given point in time. This however, would have limited our analyses to the 1990s since it takes some time for PCT applications to be forwarded and EPO applications to be granted. Nevertheless, it has to be mentioned that with the chosen approach at least some of the family members could be weighted twice, once for EPO or PCT and once for the respective national office; a problem that becomes more serious the farther we go back in time.

12 This set of countries covers all OECD member states as well as BRICS and EU-27.

size of the target country, the absolute number of patent families a country files is still dependent of the size and technological performance of the filing countries, i.e. a large and technology oriented country like the US will file a larger number of patent families than a smaller country like for example Luxembourg or Belgium, since also the absolute number in patent filings from these countries largely differs. The average family size, on the other hand, is not affected size effects of the filing country and is therefore assumed to vary much stronger according to the weighting factor that is being applied. Additionally, the average family size gives a stronger indication of the degree of internationalisation of a country's patent profile as it shows how many markets on average are targeted on average. In order to account for those differences, several analyses based on both measures will be performed.

For further analyses it also has to be mentioned, the individual family members by country are weighted according to the national market. When we analyse the data, the countries indicate the location of the invention and not the location of the family member. Furthermore, we chose the year 2002 as the final year for our analyses to assure that our calculations are based on complete patent families with no family members missing.[13]

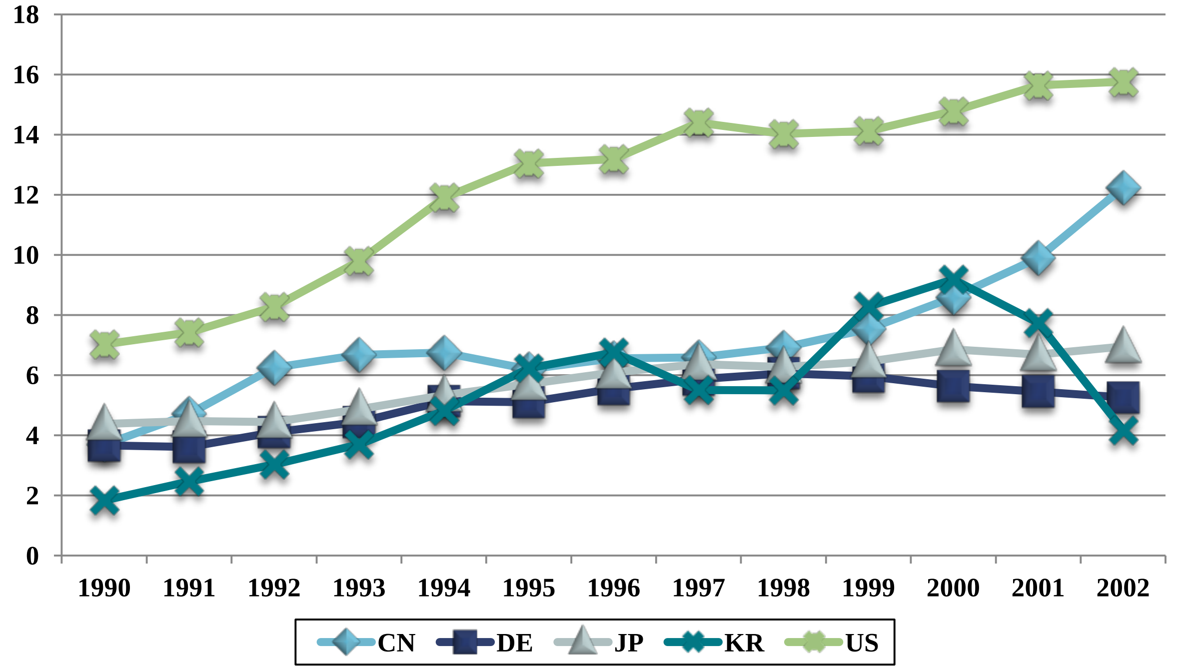
5.3 Country Comparisons

To get a first impression on patent families and their development over time, Figure 20 and Figure 21 show the unweighted share of patent families by country on all patent families worldwide from 1990 to 2002.

As can be seen from the Figure, the largest share of worldwide patent families comes from the US, followed by Japan, Germany and Korea. Also China claims a high share of patent families with a massive increase from 1997 onwards. The rest of the countries remain on a similar level over the years, with a share of worldwide patent families below 2%.

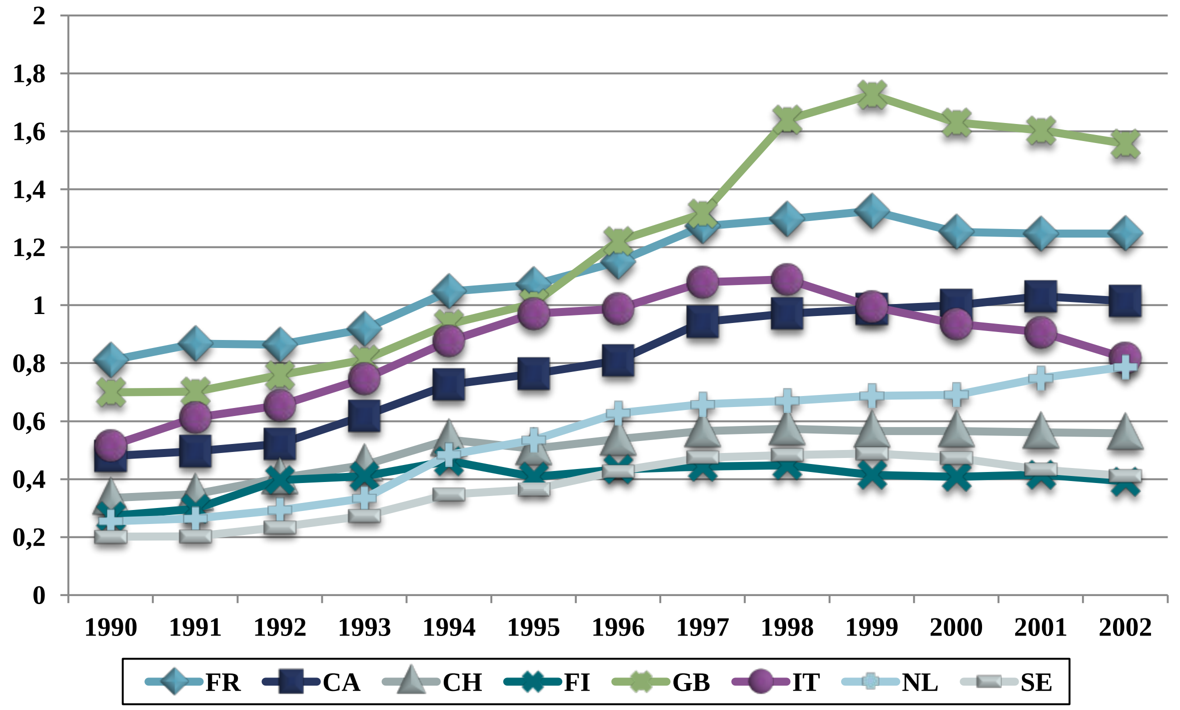
13 Due to the priority concept and the possibility of filing patents via PCT procedures it could take up to about four years from the date of priority filing in a given country until patents from the same family are published in other countries. Additionally, patent applications at the EPO are forwarded to the designated national offices after being granted, where they then count as individual family members, which takes about five years on average (Frietsch et al. 2010b).

Figure 20 Share of patent families by country on all patent families worldwide, unweighted, countries with large family sizes only, in %, 1990-2002



Source: EPO-Patstat, own calculations.

Figure 21 Share of patent families by country on all patent families worldwide, unweighted families, countries with small family sizes only, in %, 1990-2002

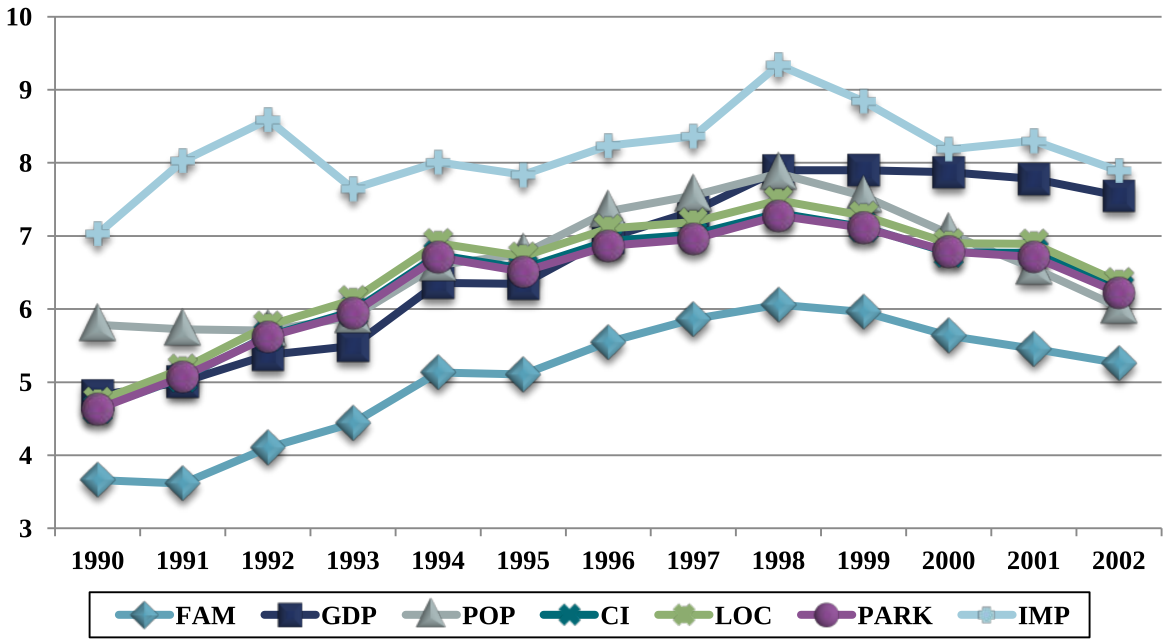


Source: EPO-Patstat, own calculations.

To compare the different weighted family counts, Figure 22 shows the share of German patent families[14] on all patent families worldwide by each weighting factor. The shares all follow a similar trend over the years. During the 1990s one can observe a rise in the share of German patent families, which could be associated with the known phenomenon of the patent surge during this decade. From 1998 onwards, however, the share of German patent families on all patent families stagnates or even declines, depending on the chosen weighting factor. This could be explained by the fact that for example China and South Korea increasingly entered the international patenting scene, leading to a stagnation or decline in the share on overall patent families for other countries (compare Figure 20 above).

An even more interesting result that can be observed when looking at Figure 3 is that Germany performs better when weighting the family members by market size com-pared to the unweighted family count (FAM). This means, that German patents are mostly filed in large markets (in terms of GDP, population etc.). This is especially true for the family size weighted by the imports of the respective target countries, implying that German patents are mostly applied for in countries with a large import amount. This confirms former findings that patents structure and secure export markets (Blind/Frietsch 2003; Blind/Frietsch 2006; Frietsch et al. 2010b).

Figure 22: Share of German patent families on all patent families worldwide, by weighting factor, in %, 1990-2002

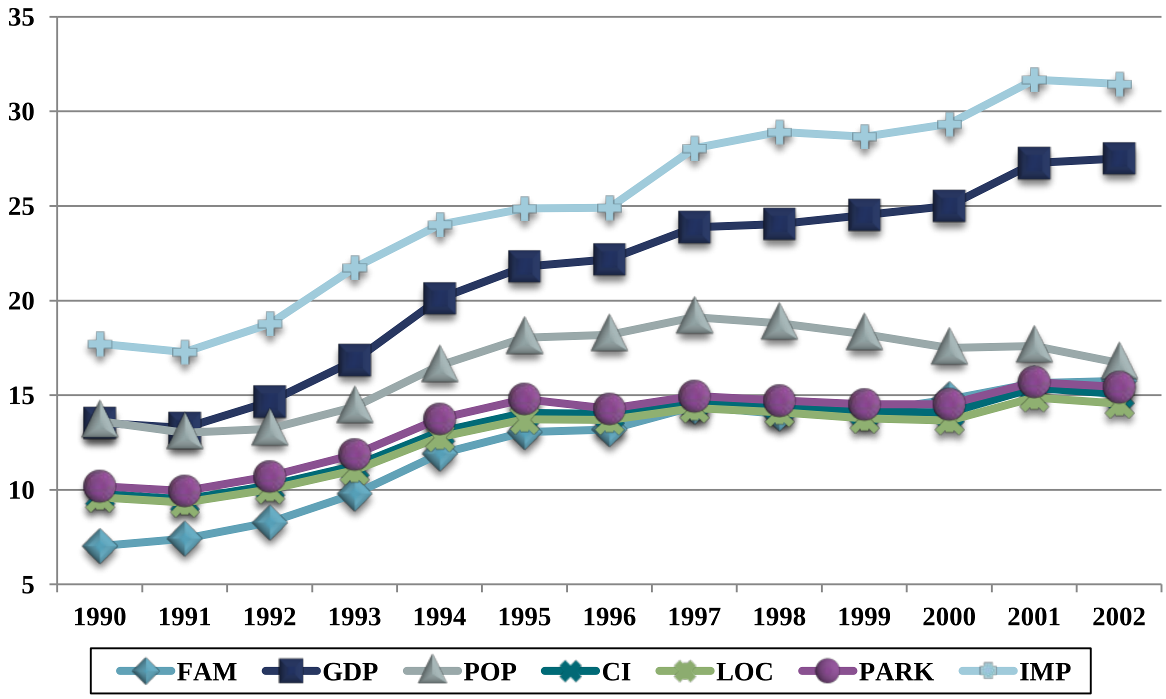


Source: EPO – PATSTAT, own calculations.
Note: The values for CI and LOC in this calculation are very similar, which is why the values for CI are hardly visible.

14 Just for clarification, it has to be stressed that Germany is here defined by the location of the invention and not by the office where the patent is filed. In other words, Germany here means patents invented in Germany and filed abroad.

Figure 23 shows the share of US patent families on all patent families worldwide by each weighting factor. It can be observed, that the share of US patent families on worldwide patent families is higher than the German share, with a rising trend from 1990 onwards. However, the patterns regarding the different weighting factors look quite similar. Also the US performs better when weighting the family members by market size compared to the unweighted family count. The share of worldwide patent families for the US is highest when weighting the family members in terms imports and GDP of the respective target countries. This shows that US patents, as well as its German counterparts are mostly filed in large markets. At this point, it has to be taken into account that the US itself has a large domestic market, both in terms of imports and GDP, which could be interpreted as some kind of home-field advantage, especially when these two weights are applied. When looking at the population weighted family size, however, a decline in the share of US on worldwide patent families can be shown, which can at least partly also be attributed to the rise in Chinese and South Korean patent applications.

Figure 23 Share of US patent families on all patent families worldwide, by weighting factor, in %, 1990-2002

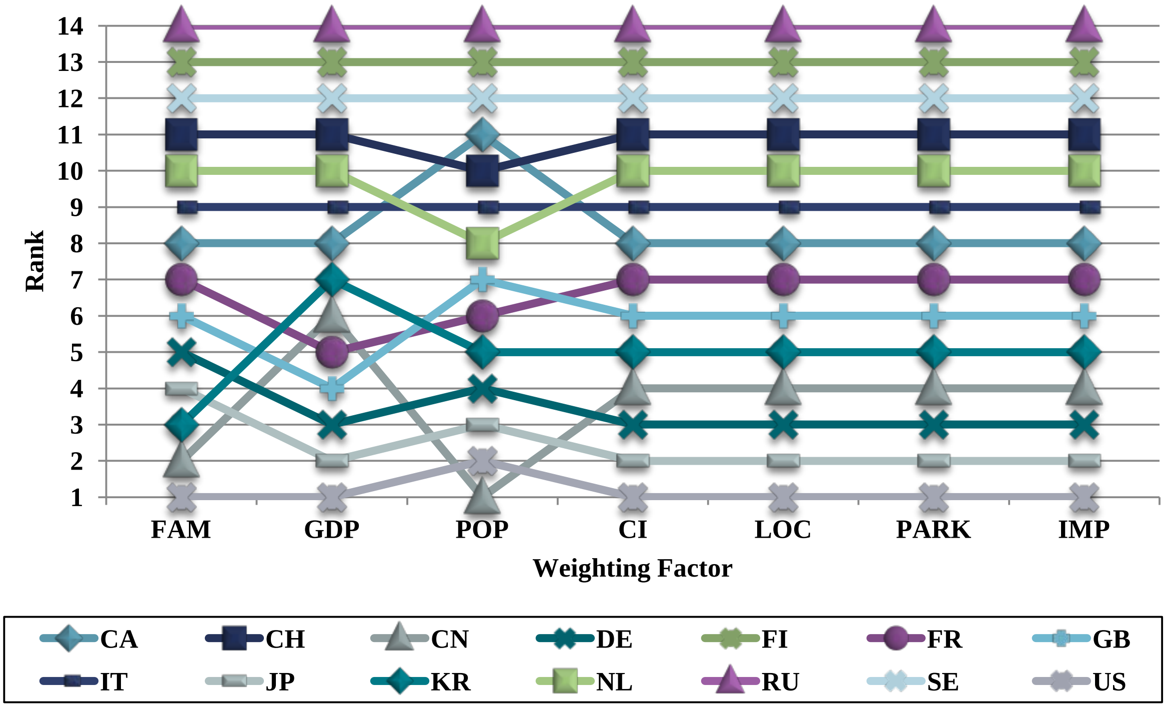


Source: EPO – PATSTAT, own calculations.

To allow for an easier comparison across countries over the different weighted family counts, Figure 24 shows a country ranking according to the percentage share on worldwide patent families by weighting factor for the year 2001. It can be stated that the rank for each country only changes slightly by the different weighting factors. The United States rank first in their worldwide share of patent families, except for the population weighted family size. Japan scores second on most indicators, followed by Germany. The most striking results can be found for China. They score fourth when weighting their family counts by CI, LOC, PARK or

IMP, but first when the population weighted family size is taken into account and sixth, when looking at the GDP weighted family counts. However, it can be assumed, that all patents that China files at foreign patent offices are also filed at SIPO. Since China has a very large population, a Chinese family member is evaluated very highly when applying the population weight. On the other hand, China scores less good in terms of GDP, which leads to a much lower ranking of the number of Chinese patent families when the GDP weight is applied. This effect is mostly responsible for the change in rankings between the countries on the GDP and population weighted family sizes.

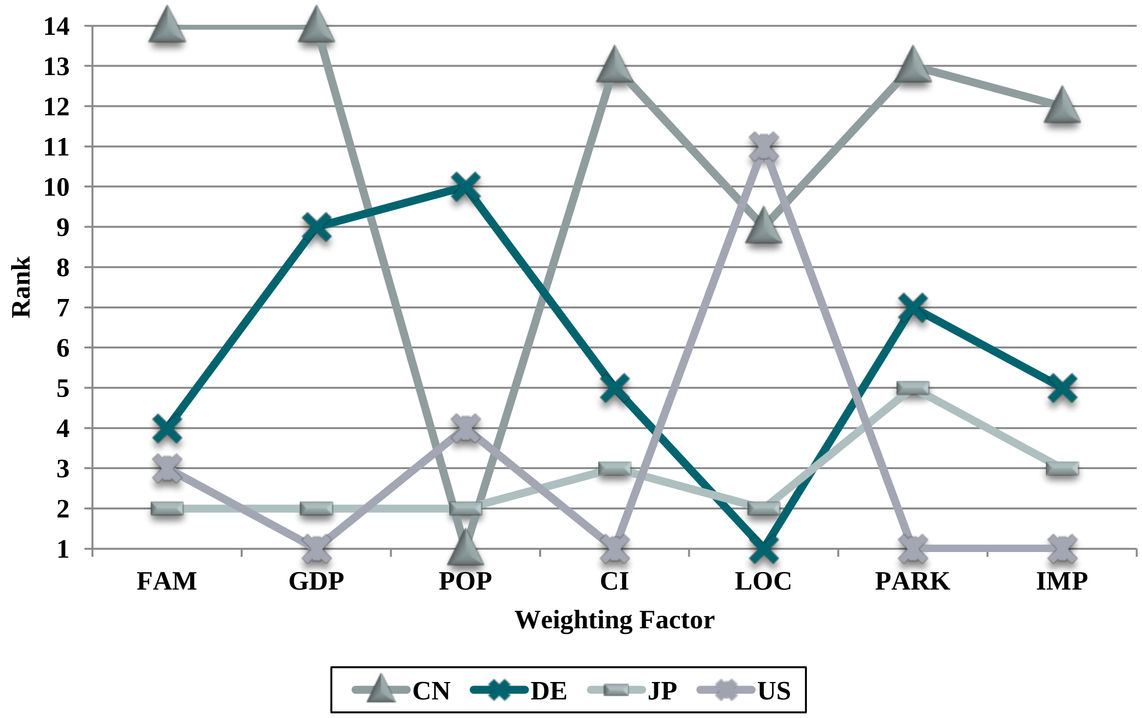
Figure 24 Country ranking according to the share of the countries' patent families on all patent families worldwide, by weighting factor, 2001



Source: EPO – PATSTAT, own calculations.

The ranking based on absolute family counts, however, still includes effects that can be attributed to the size of a country in terms of patent applications. Therefore, Figure 25 shows a country ranking by the average family size of the countries by weighting factor. Here the picture looks more complicated. The country rankings show a much higher variation depending on the applied weighting factor. However, the US and Japan still dominate the overall picture, ranking first or second, respectively, on most of the weighting factors. Germany seems to be relatively weak when the GDP and population weights are applied, but is stronger when looking at the CI, LOC or IMP weighted average family sizes. China again takes a very special position, with even more pronounced effects than in the ranking for the weighting number of patent families.

Figure 25 Country ranking according to the average family size, by weighting factor, 2001



Source: EPO – PATSTAT, own calculations.
Note: Since the country ranking by average family sizes if varies largely, only a limited number of countries is shown for reasons of visibility.

5.4 Weighted families and the ability to forecast export streams

To find out how much the weighted family counts actually differ, additional bivariate and multivariate analyses will be presented in the following. The methodology and dataset construction is based on former analyses carried out by Fraunhofer ISI in 2010 (Frietsch et al. 2010b). However, the construction of the dataset will be outlined briefly. In the former analyses it could be shown that patent families had no significant impact on the association between patents and exports, or in other words, had no significant additional explanatory power to estimate the export value of countries by technology fields. The conclusion was that the average family size of a patent cannot serve as a patent value indicator at the country or field level, due to the heterogeneity of the individual family members in terms of market size or market value that they represent. Our current approach takes the conclusions of these analyses one step further by examining if a weighted family size can serve as a better indication of patent value at the country level.

5.4.1 Data and methodology

The patent data were extracted from the "EPO Worldwide Patent Statistical Database" in its September 2009 version (henceforth, PATSTAT). For each of 35 high technology fields (Legler/Frietsch 2007) and one residual low-tech area, the annual sum of EPO patent applications filed by each country was counted.[15] To this dataset we added the unweighted and weighted average family sizes of each inventor country as well as additional patent value indicators that are common sense in the literature, like patent forward citations. If the EPO search report referred to the PCT document, we also included PCT citations. All patent data reported are dated by their priorities, i.e. the year of worldwide first filing.

The export figures used for further analyses were extracted from the United Nations Commodity Trade Statistics Database (COMTRADE). Trade data in COMTRADE is aggregated by commodity groups, meaning that a concordance between the technology classification for patents (IPC) and the commodity classification (Standard International Trade Classification Revision 3 or SITC3 for short) had to be applied. This concordance table was constructed according to the definitions in Legler and Frietsch (2007). Additionally, we collected information on GDP, inhabitants, exchange rates, purchasing power parities (PPP) etc from OECD databases (OECD Stats) and matched it to our dataset. In order to achieve a comparable basis over countries and years, we converted the export figures to constant US dollars for the year 2000. The final dataset includes 6084 units (36 technology fields multiplied by 13 countries) for 13 years from 1990 to 2002 (Frietsch et al. 2010b). Due to data availability Russia had to be excluded from the following analyses.

To estimate the effects of the different weighted average family sizes on exports, panel regression estimations are conducted, where the absolute export volumes serve as a dependent variable. Several models, differing by weighting factor, were fitted. In addition to the models which only included the family size indicators as a potential explanatory variable (besides the number of patents by country and field and GDP per capita as a control variable) a second set of models was fitted, which also included the average number of forward citations (using a four year citation window), backward citations and the share of grants on applications for each technology field and country. In order to not only analyze the effects of the different weighted average family sizes on absolute exports but also in relative terms, all the analyses were repeated for the trade balance (defined as exports minus imports) per patent application. This variable does not only allow to evaluate the export amount of countries but also to balance trans-shipment effects, i.e. countries having a large export amount due to their high amount of imports, which have been found to influence the export amounts of some countries like Ireland or Belgium.

Hausman tests were applied to test for unobserved heterogeneity and in all models it was possible to accept the null hypothesis of no difference between the coefficients in the fixed and the random effects model. An additional Breusch and Pagan Lagrange multiplier test for random effects finds significant differences across units and thus is in favour of the random effects over an OLS regression model. Therefore, we only report the results of the random effects models.

15 EPO applications were chosen for this analysis in order to focus on a consistent and homogeneous patent system including patent citations.

5.4.2 Bivariate and Multivariate Results

Before digging into the multivariate analyses, the different weighted family counts and average family sizes are compared by applying a pair wise correlation analysis Table 4. When looking at the family counts by different weights, it can be observed that they are highly correlated. This means that they are largely interchangeable, which is in line with the results of the country rankings above.[16] This effect is not that strongly pronounced for the average family sizes by country, meaning that the correlations between the average family sizes by weighting factor are much lower than for the absolute family counts. However, this difference can largely be attributed to a difference in the level of the two indicators, which largely results from the size difference of the countries in the sample. Nevertheless, also when average family sizes are compared, it can be observed that CI, LOC and PARK are highly correlated. Especially for CI and LOC this is not very surprising because LOC is a component of CI.[17] The high correlation between GDP and IMP can probably be attributed to the fact that they are best able to mirror the size and performance of the national economies, especially against the background that our sample largely includes innovation oriented countries. Interestingly, none of the weighted average family sizes is highly correlated with the unweighted family size, implying that at least for the average family size the weighting of the individual family members by market size makes a difference. The following multivariate analyses will show if the weighted family size can be used as an indicator of patent value in terms of exports at the country and technology field level.

Table 4 Pair wise Correlations between the Family Counts and Average Family Sizes, by weighting factor

	Family Counts							Average Family Size						
	FAM	GDP	POP	CI	LOC	PARK	IMP	FAM	GDP	POP	CI	LOC	PARK	IMP
FAM	1							1						
GDP	0.878*	1						0.125*	1					
POP	0.889*	0.646*	1					-0.197*	-0.306*	1				
CI	0.968*	0.950*	0.794*	1				0.100*	0.420*	-0.035*	1			
LOC	0.971*	0.948*	0.803*	0.999*	1			0.090*	0.266*	0.087*	0.963*	1		
PARK	0.955*	0.963*	0.760*	0.997*	0.995*	1		0.191*	0.631*	-0.522*	0.776*	0.667*	1	
IMP	0.902*	0.996*	0.679*	0.958*	0.950*	0.969*	1	0.073*	0.891*	-0.236*	0.446*	0.299*	0.608*	1

Significance Level: *p<0.05
Source: EPO – PATSTAT, own calculations.

16 Excluding China and Korea from the bivariate correlation analysis reveals even larger correlations for the weighted family counts.

17 Similar results can be found when conducting an exploratory factor analysis using principal component factors. For the family counts only one factor is extracted. When using the different average family sizes, however, three factors are extracted, with CI, LOC and PARK loading high on one common factor. The same is true for GDP and IMP.

The random effects models on the influence of the different weighted average family sizes on absolute export amounts show that the unweighted family size exerts no significant influence on the absolute exports of countries by technology fields, neither in the model excluding, nor including additional patent value indicators (Table 5). This is as expected, keeping in mind the results of our previous study (Frietsch et al. 2010b).

The number of patent applications influences exports positively, which is also not surprising and has been found in our previous models using a very similar dataset.

The more interesting effects appear when looking at the weighted average family sizes. It can be shown, that the weighted average family sizes by GDP and by IMP exert a significantly positive influence on absolute exports. This effect even holds when other patent value indicators are taken into account as control variables. The other weighted family sizes (POP, CI, LOC) do not show any significant impact on a country's exports, except the PARK weighted indicator in the model including the other value indicators. These results show that the weighted average family size by GDP or imports is able to serve as an indication of patent value at the country and technology field level. However, the two measures are highly correlated, which means that choosing one of the two is sufficient. Given the availability and accessibility, the GDP indicator might be more handy than the import indicator so that we suggest to use the former one.

The same analysis is now repeated for the trade balance per patent application as a dependent variable. Here some different effects can be shown. In this model, all of the weighted family sizes, except the one weighted by the population, exert a significantly positive influence on the trade balance per patent application. The same is true when additionally controlling for the other patent value indicators in the models. This means that the weighted average family size does not only affect absolute exports but also in relative terms. However, the R^2 values of the models show that the explained variance of the model on trade balance per patent application is much lower than in the model on absolute exports.

Taken together the results of both models, it can be shown that the weighted average family size by GDP or imports is able to serve as a robust indication of patent value at the country and technology field level. Using the other weights also shows some positive effects, but only in the model on the trade balance per patent application. However, GDP and imports are highly correlated, which means that choosing one of the two is sufficient. Given the availability and accessibility, the GDP indicator might be handier than the import indicator so that we suggest using the former one.

Table 5 Random Effects Models on the influence of the different weighted average family sizes on absolute exports

dV: Exports absolute	Excluding additional value indicators							Including additional value indicators						
	M1a	M2a	M3a	M4a	M5a	M6a	M7a	M1b	M2b	M3b	M4b	M5b	M6b	M7b
Avg FAM Size	-56.54							-58.86						
	(47.78)							(50.93)						
Avg GDP Size		23173.9***							41853.02***					
		(4446.83)							(5826.21)					
Avg POP Size			-12878.41							-3908.72				
			(12834.88)							(15539.12)				
Avg CI Size				-429.57							2915.02			
				(1619.8)							(5985.34)			
Avg LOC Size					-745.65							-2508.36		
					(1511.60)							(5809.98)		
Avg PARK Size						1611.67							11162.77***	
						(1278.27)							(3161.24)	
Avg IMP Size							75473.31***							127044.37***
							(8460.08)							(11127.33)
# Patent App.	9.24***	9.24***	9.22***	9.22***	9.22***	9.23***	9.25***	9.23***	9.22***	9.21***	9.22***	9.21***	9.22***	9.25***
	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)	(0.14)
Avg # FW-Cit.	--	--	--	--	--	--	--	-30.81	4.27	-34.96	-34.59	-34.74	-29.19	22.91
								(62.43)	(62.29)	(62.33)	(62.33)	(62.33)	(62.28)	(61.83)
Avg # BW-Cit.	--	--	--	--	--	--	--	-40.19	-21.65	-43.79	-42.5	-44.32	-38.44	-34.94
								(37.24)	(37.09)	(37.15)	(37.2)	(37.18)	(37.12)	(36.72)
Grant Share	--	--	--	--	--	--	--	1794.79**	2696.69***	1741.16**	1758.32**	1835.60**	1571.84**	1608.57**
								(721.61)	(729.5)	(741.89)	(723.62)	(731.28)	(723.35)	(713.62)
Control Variable	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country Dumies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Field Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
R^2 within	0.7776	0.7785	0.7775	0.7775	0.7775	0.7776	0.7804	0.7779	0.7799	0.7779	0.7779	0.7779	0.7783	0.7829
N	6012	6012	6012	6012	6012	6012	6012	5718	5718	5718	5718	5718	5718	5718

Significance Levels: ***p<0.01, **p<0.05, *p<0.1; Note: Coefficients for country dummies, field dummies, and GDP per capita are omitted for simplicity.
Note: The number of observations differs between the models with and without additional value indicators due to the citation window used in the case of forward citations.
Source: EPO – PATSTAT, own calculations.

Table 6 Random Effects Models on the influence of the different weighted average family sizes on the trade balance per patent application

dV: Trade Balance per	Excluding additional value indicators							Including additional value indicators						
patent application	M1c	M2c	M3c	M4c	M5c	M6c	M7c	M1d	M2d	M3d	M4d	M5d	M6d	M7d
Avg FAM Size	1.22**							1.58***						
	(0.52)							(0.52)						
Avg GDP Size		145.99**							132.37**					
		(59.28)							(60.35)					
Avg POP Size			33.85							160.58				
			(156.99)							(160.29)				
Avg CI Size				257.78***							228.67***			
				(61.84)							(61.67)			
Avg LOC Size					241.39***							213.15***		
					(59.45)							(59.87)		
Avg PARK Size						199.89***							181.97***	
						(32.64)							(32.56)	
Avg IMP Size							450.48***							357.28***
							(116.34)							(115.99)
# Patent Applications	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Avg # FW-Citations	--	--	--	--	--	--	--	-5.55***	-5.31***	-5.44***	-5.40***	-5.46***	-5.34***	-5.27***
								(0.64)	(0.65)	(0.64)	(0.64)	(0.64)	(0.64)	(0.64)
Avg # BW-Citations	--	--	--	--	--	--	--	-0.52	-0.36	-0.42	-0.35	-0.36	-0.35	-0.41
								(0.38)	(0.38)	(0.38)	(0.38)	(0.38)	(0.38)	(0.38)
Share of Grants	--	--	--	--	--	--	--	29.19***	32.32***	31.21***	27.38***	25.09***	25.97***	28.93***
								(7.44)	(7.56)	(7.65)	(7.46)	(7.54)	(7.45)	(7.44)
Control Variable	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Field Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
R^2 within	0.0645	0.0646	0.0636	0.0665	0.0663	0.0698	0.0661	0.0796	0.0789	0.0783	0.0804	0.0802	0.0832	0.0797
N	5718	5718	5718	5718	5718	5718	5718	5718	5718	5718	5718	5718	5718	5718

Significance Levels: ***p<0.01, **p<0.05, *p<0.1; Note: Coefficients for country dummies, field dummies, and GDP per capita are omitted for simplicity.

Source: EPO – PATSTAT, own calculations.

5.5 Conclusions

The aim of this analysis was to weight the number of patent families from different countries, since a more simple count of patent families by country or technology field might not be able to capture the size or strength of the market in which the patents of these families were filed. This weighted family size indicator is supposed to give a more refined picture of the world-wide patent applications by countries or technology fields. In addition, the weighted average family size could serve as an improved indicator of the value of a patent portfolio at the country level.

Our results show, that there are at least some differences in the number of patent families by country, depending on the chosen weight for the family counts. Germany, for example, performs better compared to a non-weighted family count no matter which of the weighting factors is chosen. China on the other hand, performs worse when GDP weighted families are counted but much better when population weighted families are in the focus. This result seems quite reasonable since China, as well as most other countries, files most of its international patents also at the home market.

Apart from these deviations, a ranking of the countries by the different weighted family counts shows only minor differences in rank, no matter which weight is chosen. This, however, is different when using the average family sizes of the countries to perform the ranking because the average family size is independent of the size of the filing country.

To analyze this pattern in more detail, additional bivariate correlation analyses were conducted, which show that the weighted and also the unweighted family counts are highly correlated, meaning that descriptive statistics based on absolute (weighted or unweighted) family counts are barely affected by the chosen weighting factor, except some country idiosyncrasies. When looking at the average family size, which is supposed to be used as a patent value indicator at the country level, however, some larger differences between those weights can be revealed. To finally get an impression about which weight is suitable for the patent value analyses, some multivariate analyses, building on a previous study conducted by Fraunhofer ISI in 2010, were conducted. With the help of the multivariate models it can be shown, that the unweighted average family size as well as most of the weighted average family sizes show no effect in explaining absolute exports by countries. When taking into account a relative measure, namely the trade balance per patent application, most of the indicators show a significant influence. The GDP and import weighted family size, however, lead to robust results over both models, which is why they seem to be able to act as an indicator of patent value at the level of countries and technology fields. Nevertheless, one has to keep in mind that these two measures are highly correlated, and also show similar results in their predicting power when they are applied in the regression approach. Therefore, any of them could be used. We opt for the GDP weighting indicator as this is handier due to availability and accessibility.

In sum, the analysis has shown that the unweighted family size is of not very much use as a patent value indicator at the country level, whereas the GDP and imports weighted family sizes are able to add predicting power. They are even robust when controlling for other value indicators that are prominent in the empirical literature.

6. Growth trend of the IPC-Classes and Structures of the growth drivers – an IPC-Group and Subgroup Analysis

6.1 Introduction

Forecasting the future relevance and the possible development of technological fields can be seen as a major issue of innovation research since the identification of those promising areas in terms of technological development are supposed to be a basis of economic activities (Frietsch et al. 2011). Therefore, these promising fields may be a focus of special awareness and supportive activities, especially against the background that patent output indeed are related to market success and returns on investments, or to put it in other words, patents can be seen as value-oriented (see for example Bessen 2009; Frietsch et al. 2011; Hall et al. 2005; Neuhäusler et al. 2011).

Therefore, a substantial growth of patent applications in a certain technological field in the last decade indicates that relevant market returns were generated in that field. Additionally, it can be stated that the competition in this market is largely based on technological innovation increasing the probability that the relevance of this field will persist at least in the next decade (Frietsch et al. 2011).

In our last year's report we set out to identify those promising fields and grouped them into three size classes in order to achieve comparable growth rates over the years, assuring that large technological fields were only compared to their large counterparts. This was done to avoid the problem that small fields tend to have higher growth rates than larger ones, for purely mathematical reasons (Frietsch et al. 2011).

This year's analysis is supposed to pick up the results from the preceding analyses and take them one step ahead by taking a deeper look into the structure of the IPC subclasses and to identify the essential growth drivers, i.e. specific technologies that are responsible for largest share of the growth within technological fields in more detail.

6.2 Methodology

As for last year, the growth in the number of patent applications by technological field is defined by their indexing in the 8th edition of International Patent Classification (IPC). The IPC is revised steadily, reclassifying patent applications if new codes are introduced. This reclassification is also realised in a backward direction, meaning that older patent applications are adapted to the revised classification as well as the new ones. A specific advantage for this analysis is that all applications are indexed by patent examiners who are experts in their fields, assuring a very high quality compared to other classification, for instance of journal publications (Frietsch et al. 2011). The IPC is built up hierarchically and consists - in descending order - of sections, classes, subclasses, main groups and subgroups. The respective hierarchical level corresponds to the number of digits of the encoding, where four digits correspond to the subclasses (World Intellectual Property Organization (WIPO) 2006).

For the present analysis, we only focus on subclasses that were identified as being "large sized and having the highest growth rates in the last decade" (Frietsch et al. 2011), since these can be assumed to show a higher variation in the activities of the different subclasses. In essence, this means that the analysis of subclasses is now taken to a deeper level. More technically spoken, our investigation now refers to the most detailed level of “main groups” and “sub-groups” of the IPC, meaning 8-10 digits, as compared to the last year's study, which was performed on the basis of IPC 4-digit subclasses.

In the first part of this section we analyze the growth of those subgroups in terms of all transnational patent applications and then turn our focus to a comparison with the growth shares for transnational patent applications from Germany. In a final step, the growth shares in subgroups are disentangled by different types of applicants, i.e. multinational enterprises (MNEs), small and medium sized enterprises (SMEs), public research institutes and universities.

An overview of the subclasses that are to be analyzed in more detail below can be found in Table 7. It shows the results of the top five of the analysis for large sized IPC subclasses between 1997 and 2007 (priority years). In both analyses, the IPC subclass, groups and subgroups were determined in terms of transnational patent applications (Frietsch/Schmoch 2010a).

Table 7 Large IPC subclasses with the highest growth in the last decade

Rank	Code	Present size	Annual growth factor	Content
1	G06Q	3,480	1.14	Data processing methods
2	H01M	2,480	1.10	Batteries, fuel cells
3	H04L	10,472	1.10	Digital transmission of information
4	F21V	1,078	1.10	Features of lightening devices
5	H04W	4,371	1.11	Wireless communication networks

Source: (Frietsch et al. 2011).

Before digging deeper into the analyses, it has to be mentioned that there are huge size differences between the groups and subgroups for different subclasses. For example, the IPC subclass G06Q has seven groups and no subgroups whereas subclass H01M has 8 groups consisting of 181 subgroups. This means that the range of distinct technologies in the field H01M (batteries, fuel cells) is much wider than in the field G06Q (data processing methods), which has to be taken into account for further analyses.

6.3 Subgroup analysis at the transnational level

To identify the specific groups and subgroups, which can be seen as growth drivers in their respective subclasses at the transnational level, they were ranked according to their share of growth in the decade 1997-2007. The detailed IPC-Group-/Subgroups of the chosen IPC-subclasses, including their overall growth share, are shown in the following tables.[18] These tables always show the number of subgroups with an aggregated share of growth of at least 70 percent in the given subclass. Furthermore, a of "concentration measure" is introduced, which is calculated as the share of subgroups reaching a growth share of at least 70% on all subgroups in a given subclass, therefore ranging from 0 to 1. With the help of this measure it can be identified how concentrated or diversified a subclass is. Subclasses having a concentration value of below 0.5 can be interpreted as being relatively more concentrated or focused on just a few subgroups containing the majority of patent applications, whereas subclasses with values above 0.5 can be seen as more or less diversified.

Table 8 IPC-Group-/Subgroups with the highest share of growth within the field of data processing methods (G06Q)

Subclass G06Q (Data processing methods)			
Rank	**Code**	**Share of growth**	**Content**
1	G06Q 30/00	35%	Commerce e.g. marketing, shopping, billing, auctions or e-commerce
2	G06Q 10/00	23%	Administration, e.g. office automation or reservations; Management, e.g. resource or project management
3	G06Q 50/00	21%	Systems or methods specially adapted for a specific business sector, e.g. health care, utilities, tourism or legal services

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The IPC subgroups with the highest share of growth within the field of data processing methods (G06Q) are depicted in Table 8. Subclass G06Q has seven subgroups in total and it can be observed that three subgroups are responsible for 77% of the growth in this particular subclass, implying that the patent applications within this subclass are focused on these three subgroups. Therefore, data processing methods for commerce, administration and those specially adapted for a specific business sector, like health, can be seen as the major growth drivers within this subclass. When additionally taking into account subgroup G06Q 40/00 (not shown), which refers to data processing methods for finance, even 94% of growth within this subclass are covered. Yet, since this subclass is comprised of only seven subclasses it reaches a concentration measure of only 0.43, showing that the concentration in this subclass is not overly high. However, it has to be taken into account that seven subgroups are in fact quite a small number per subclass, each of the other subclasses under analysis here consist of more than 100 subgroups.

18 Subgroups form subdivisions under the main groups, have the same number of digits. Therefore, they can be treated as being on the same hierarchical level, which is why both are referred to as subgroups in the remainder of this section.

Table 9 IPC-Group-/Subgroups with the highest share of growth within the field of batteries, fuel cells (H01M)

Subclass H01M (Batteries, fuel cells)			
Rank	**Code**	**Share of growth**	**Content**
1	H01M 8/04	15%	Fuel cells; Manufacture thereof auxiliary arrangements or processes
2	H01M 8/10	13%	Fuel cells with solid electrolytes
3	H01M 8/02	9%	Fuel cells; Details
4	H01M 10/36	6%	Secondary cells; Accumulators
5	H01M 8/24	4%	Grouping of fuel cells into batteries, e.g. modules
6	H01M 8/00	4%	Fuel cells; Manufacture thereof
7	H01M 8/06	4%	Fuel cells; Combination of fuel cell with means for production of reactants or for treatment of residues
8	H01M 4/86	3%	Electrodes; Inert electrodes with catalytic activity, e.g. for fuel cells
9	H01M 8/12	3%	Fuel cells; operating at high temperature, e.g. with stabilised ZrO2 electrolyte
10	H01M 2/10	3%	Constructional details, or processes of manufacture, of the non-active parts; Mountings; Suspension devices

Source: EPO-Patstat, own calculations.

When looking at subclass H01M, covering batteries and fuel cells, a more differentiated picture can be revealed (Table 9). Here it is ten subgroups being responsible for at least 70% of growth within this subclass. However, it has to be taken into account that this subclass covers 181 subgroups, leading to a concentration measure of 0.06. Therefore, this subclass can be seen as highly concentrated on a few subgroups which mostly are directly connected to fuel cells or secondary cells and less on hybrid cells or electrodes.

Table 10 IPC-Group-/Subgroups with the highest share of growth within the field of digital transmission of information (H04L)

Subclass H04L (Digital transmission of information)			
Rank	**Code**	**Share of growth**	**Content**
1	H04l 29/06	21%	Arrangements, apparatus, circuits or systems; characterised by a protocol
2	H04l 12/56	15%	Data switching networks; Packet switching systems
3	H04l 12/28	13%	Data switching networks; characterised by path configuration, e.g. LAN [Local Area Networks] or WAN [Wide Area Networks]
4	H04l 12/24	7%	Data switching networks; Arrangements for maintenance or administration
5	H04l 27/26	7%	Modulated-carrier systems; Systems using multi-frequency codes
6	H04l 29/08	5%	Arrangements, apparatus, circuits or systems; Transmission control procedure, e.g. data link level control procedure
7	H04l 1/18	4%	Arrangements for detecting or preventing errors in the information received; Automatic repetition systems, e.g. van Duuren system

Source: EPO-Patstat, own calculations.

The subclass "Digital transmission of information" (H04L) is even larger than H01M in terms of the number of subgroups, consisting of 197 in total. Within those 197 subgroups, seven subgroups account for at least 70% of the share of growth in H04L, resulting in a concentration value of 0.04. Thus, the growth of H04L therefore is even slightly more concentrated on the growth of only a few subgroups than H01M is and therefore only has few growth drivers. Namely these are mostly connected to data switching networks and protocol and transmission control procedures. Although being already highly concentrated, especially protocol arrangements or apparatus fulfil an outstanding role in this subclass, being responsible for about 21% of growth.

Table 11 IPC-Group-/Subgroups with the highest share of growth within the field of features of lightening devices (F21V)

Large subclass F21V (Features of lightening devices)			
Rank	**Code**	**Share of growth**	**Content**
1	F21V 29/00	15%	Cooling or heating arrangements
2	F21V 33/00	8%	Structural combinations of lighting devices with other articles
3	F21V 7/00	8%	Reflectors for light sources
4	F21V 8/00	7%	Use of light guides, e.g. fibre optic devices, in lighting devices or systems
5	F21V 5/00	6%	Refractors for light sources
6	F21V 19/00	6%	Fastening of light sources or lamp holders
7	F21V 5/04	4%	Refractors for light sources; of lens shape
8	F21V 29/02	4%	Cooling or heating arrangements; Cooling by forcing air over or around the light source
9	F21V 23/00	4%	Arrangement of electric circuit elements in or on lighting devices
10	F21V 3/00	3%	Globes; Bowls; Cover glasses
11	F21V 7/04	3%	Reflectors for light sources; Optical design

Source: EPO-Patstat, own calculations.

In the field of "Features of lighting devices" this outstanding role can be attributed to the subclass "cooling or heating arrangements", accounting for nearly twice as much of the growth than the secondly ranked subgroup. In total, it is eleven subgroups accounting for at least 70% of the share of growth in this subclass. Again taking in account the number of different subgroups in the subclass, which is 124, the calculated concentration measure takes a value of 0.09. This means that also the growth in F21V is concentrated on the growth of only a few subgroups, it is still slightly more diversified than H01M and H04L.

Table 12 IPC-Group-/Subgroups with the highest share of growth within the field of Wireless communication networks (H04W)

Large subclass H04W (Wireless communication networks)			
Rank	**Code**	**Share of growth**	**Content**
1	H04W 4/06	4%	Services or facilities specially adapted for wireless communication networks; Selective distribution of broadcast; Services to user groups; One-way selective calling services
2	H04W 72/12	4%	Local resource management, e.g. selection or allocation of wireless resources or wireless traffic scheduling; Wireless traffic scheduling
3	H04W 36/14	4%	Handoff or reselecting arrangements; Reselecting a network or an air interface
4	H04W 4/00	4%	Services or facilities specially adapted for wireless communication networks
5	H04W 72/04	3%	Local resource management, e.g. selection or allocation of wireless resources or wireless traffic scheduling; Wireless resource allocation
6	H04W 4/02	3%	Services or facilities specially adapted for wireless communication networks; Services making use of the location of users or terminals
7	H04W 88/06	3%	Devices specially adapted for wireless communication networks, e.g. terminals, base stations or access point devices; adapted for operation in multiple networks, e.g. multi-mode terminals
8	H04W 36/00	3%	Handoff or reselecting arrangements
9	H04W 52/02	3%	Power management, e.g. TPC [Transmission Power Control], power saving or power classes; Power saving arrangements
10	H04W 48/16	3%	Access restriction; Network selection; Access point selection; Discovering; Processing access restriction or access information
11	H04W 76/02	2%	Connection management, e.g. connection set-up, manipulation or release; Connection set-up
12	H04W 84/18	2%	Network topologies; Self-organising networks, e.g. ad hoc networks or sensor networks
13	H04W 8/26	2%	Network data management; Network addressing or numbering for mobility support
14	H04W 48/18	2%	Access restriction; Network selection; Access point selection; Selecting a network or a communication service
15	H04W 12/06	2%	Security arrangements, e.g. access security or fraud detection; Authentication, e.g. verifying user identity or authorisation; Protecting privacy or anonymity; Authentication
16	H04W 36/08	2%	Handoff or reselecting arrangements; Reselecting an access point
17	H04W 74/08	2%	Wireless channel access, e.g. scheduled or random access; Non-scheduled access, e.g. random access, ALOHA or CSMA [Carrier Sense Multiple Access]
18	H04W 72/00	2%	Local resource management, e.g. selection or allocation of wireless resources or wireless traffic scheduling

Note: In this table, only the subgroups accounting for at least 50% of the share of growth in this subclass are shown for reasons of better visibility. The rest of the subgroups mostly account for only 1% of growth.
Source: EPO-Patstat, own calculations.

When finally looking at the last subclass under analysis here, namely "Wireless communication networks" (H04W), which is being analysed here, a slightly different pattern can be revealed. In sum, 32 subgroups are responsible for at least 70% of the share of growth in H04W, resulting in a concentration value of 0.15. This is quite low compared to H01M, H04L and F21V. Furthermore, it also becomes obvious from the table that no dominant or outstanding subgroup can be identified. The subgroup ranking first only accounts for 4% in the growth of this subclass, whereas the value of the first ranked subclass exceeded a growth share of 15% in the other subclasses analysed. Therefore, this subclass can be seen as quite diversified compared to the other subclasses.

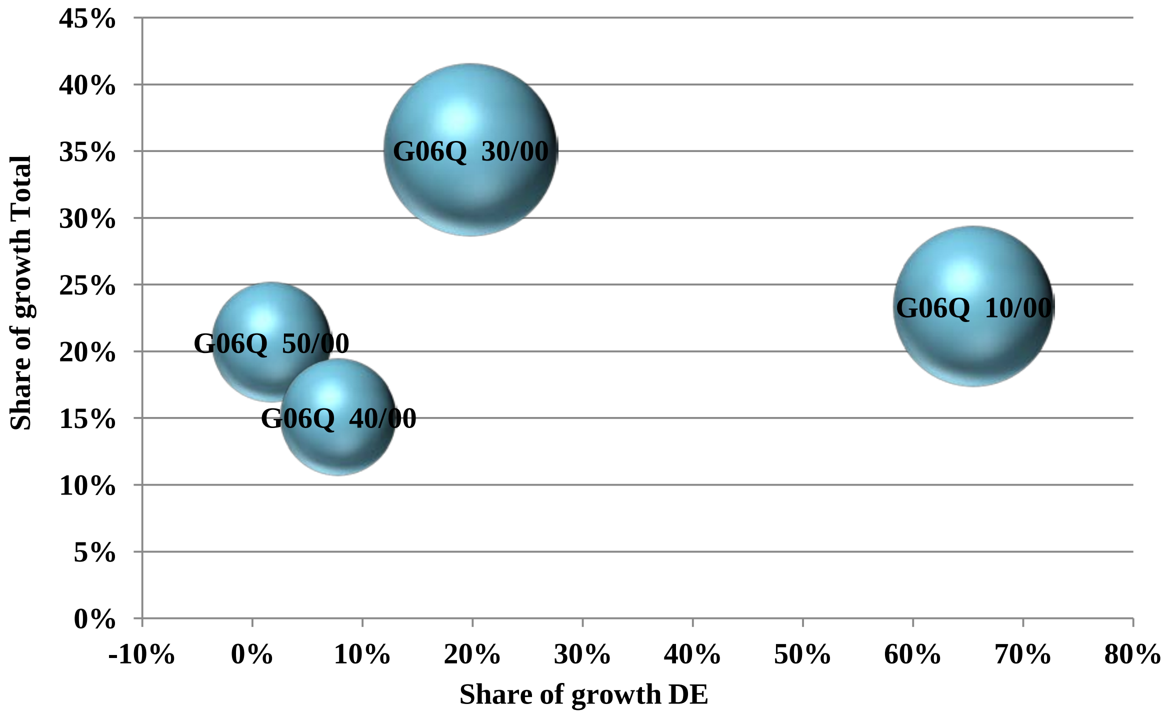
6.4 Comparison to the German development

In this section, we set the focus on analyzing how the overall growth shares within given subclasses at the total transnational level compare to the share of growth in the given subgroups for transnational patent filings only from Germany. In other words, we set out to draw a more refined picture of the German case.

To do this, the following figures show the share of growth within the subgroups that have been identified as major growth drivers on the overall transnational level in the analyses above, compared to transnational applications from Germany only. The growth share of German applications is shown at the abscissa, the overall transnational level at the ordinate. The size of the bubbles indicates the present size of the subgroups in terms of the overall number of transnational patent applications (an average of 2006 and 2007). This way, we can show how the growth of subgroups in total compares to the growth of fields for applications from Germany. Since H04W is a quite diversified field, it has to be left out of this kind of analysis due to reasons of presentation.

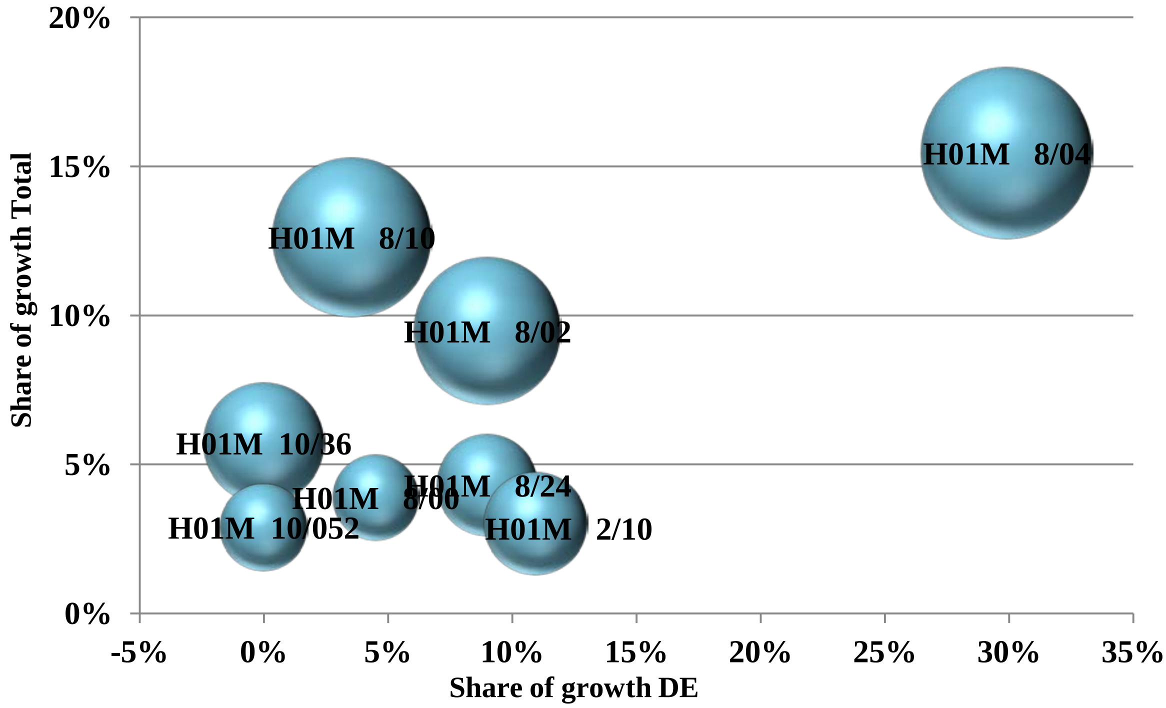
When looking at Figure 1, an interesting effect becomes directly visible. Namely, subgroup G06Q 10/00, which covers data processing methods for administration, shows a way larger growth in the German case than at the total transnational level and is for itself responsible for nearly 70% of the growth of subclass G06Q. At the overall level, data processing methods for commerce have shown an about 10% higher growth share than those for administration. Therefore, it can be stated that within subclass G06Q, Germany is highly concentrated on one single subgroup, however bearing in mind that G06Q consists of only seven subgroups in total.

Figure 26 Comparison of subgroup growth shares between German and overall transnational applications within the field of data processing methods (G06Q)



Source: EPO-Patstat, own calculations.

Figure 27 Comparison of subgroup growth shares between German and overall transnational applications within the field of batteries, fuel cells (H01M)

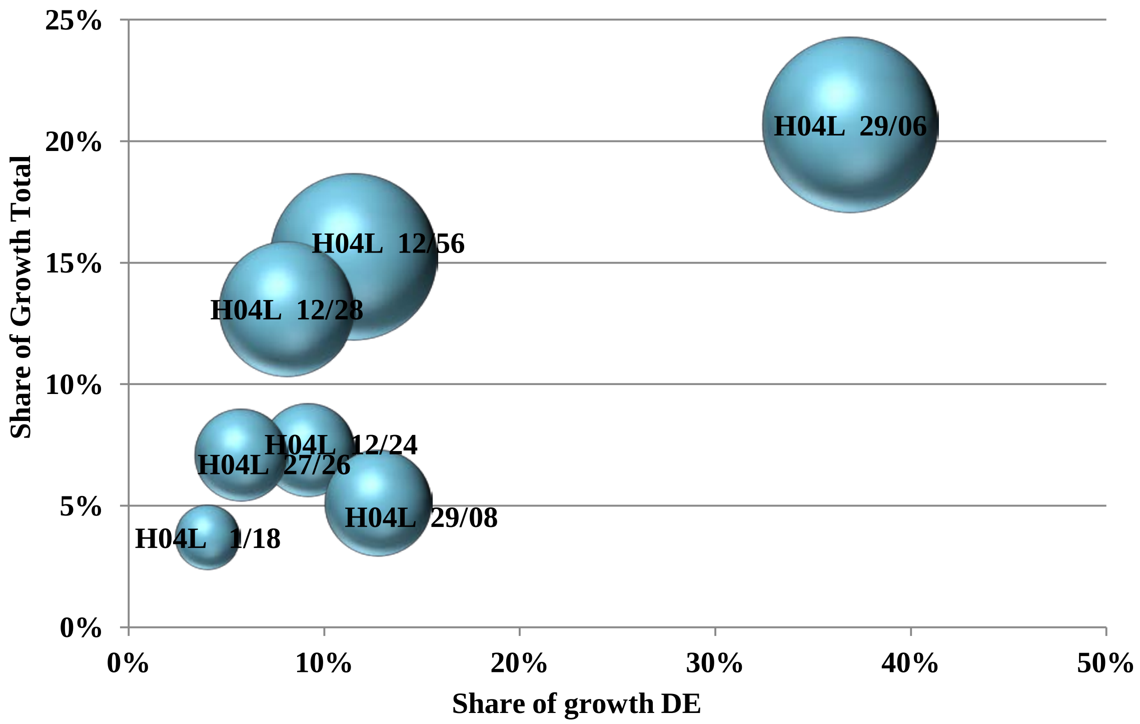


Source: EPO-Patstat, own calculations.

In the field of batteries and fuel cells, a similar outstanding role of one single IPC subgroup for the German case can be found. Namely, this is the manufacturing of auxiliary arrangements or processes for fuel cells, e.g. for control of pressure (H01M 8/04). Although this is a technology with high growth shares at the overall level, too, Germany seems to have a special focus on this particular subgroup. In other words, 30% of the growth of the subclass H01M from Germany is due to growth in the manufacturing of auxiliary arrangements or processes for fuel cells only. Therefore, also this subclass can be seen as even more concentrated in the German case than at the overall transnational level. Yet, it has to be taken into account that the growth in other subgroups is more evenly spread over the different subgroups in the case of Germany.

A very similar pattern as in the case of H01M can be observed for the field of digital transmission of information (H04L) (Figure 28). Again, one subgroup, namely arrangements, apparatus, circuits or systems characterised by a protocol (H04L 29/06) takes an outstanding role. This is also true for the overall transnational level, yet it is much more strongly pronounced in the German case. 37% of growth in this subclass can be attributed to this particular subgroup, whereas this is only 21% at the overall level. However, again it can be observed that the growth in other subgroups is more evenly spread over the different subgroups in the German case.

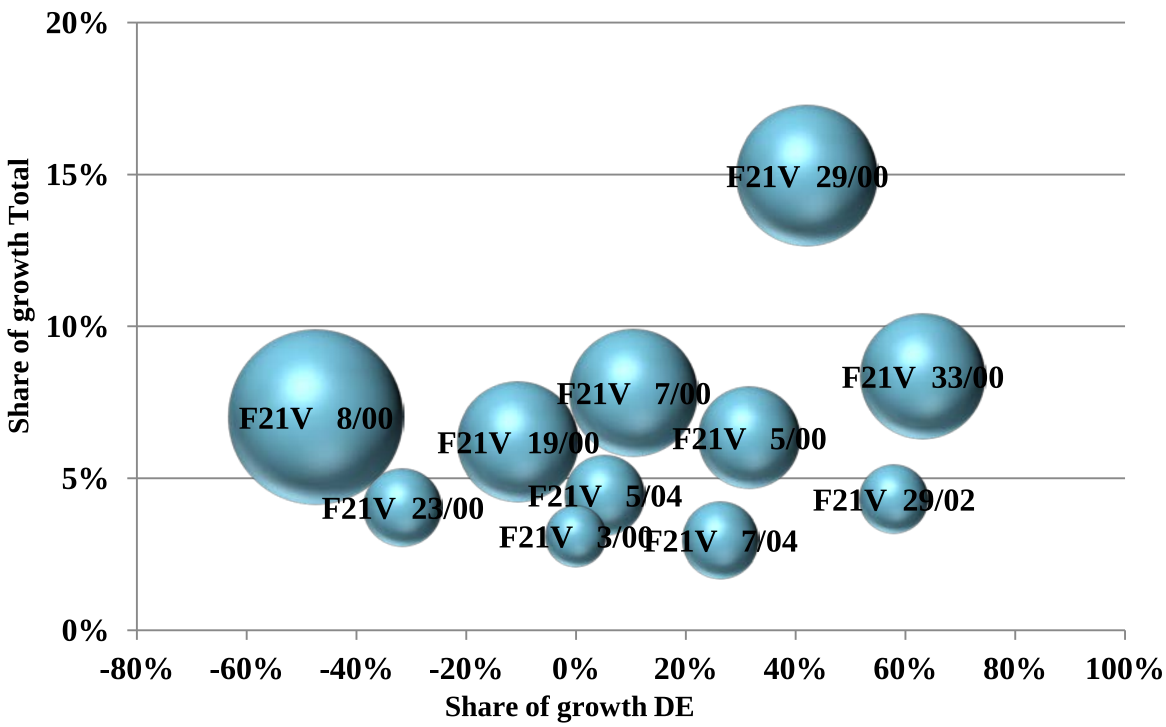
Figure 28 Comparison of subgroup growth shares between German and overall transnational applications within the field of digital transmission of information (H04L)



Source: EPO-Patstat, own calculations.

A totally different pattern can be revealed in the field of features of lightening devices (F21V). This is the only technology field where subgroups did not grow, but actually decline in Germany over the last decade. This is most strongly pronounced in the use of light guides, e.g. fibre optic devices, in lighting devices or systems, which still is a strongly growing and large field at the international level. On the other hand, Germany seems to be more strongly focused on cooling and heating arrangements and structural combinations of lighting devices with other articles, which are growing with much lower pace at the international level.

Figure 29 Comparison of subgroup growth shares between German and overall transnational applications within the field of features of lightening devices (F21V)



Source: EPO-Patstat, own calculations.

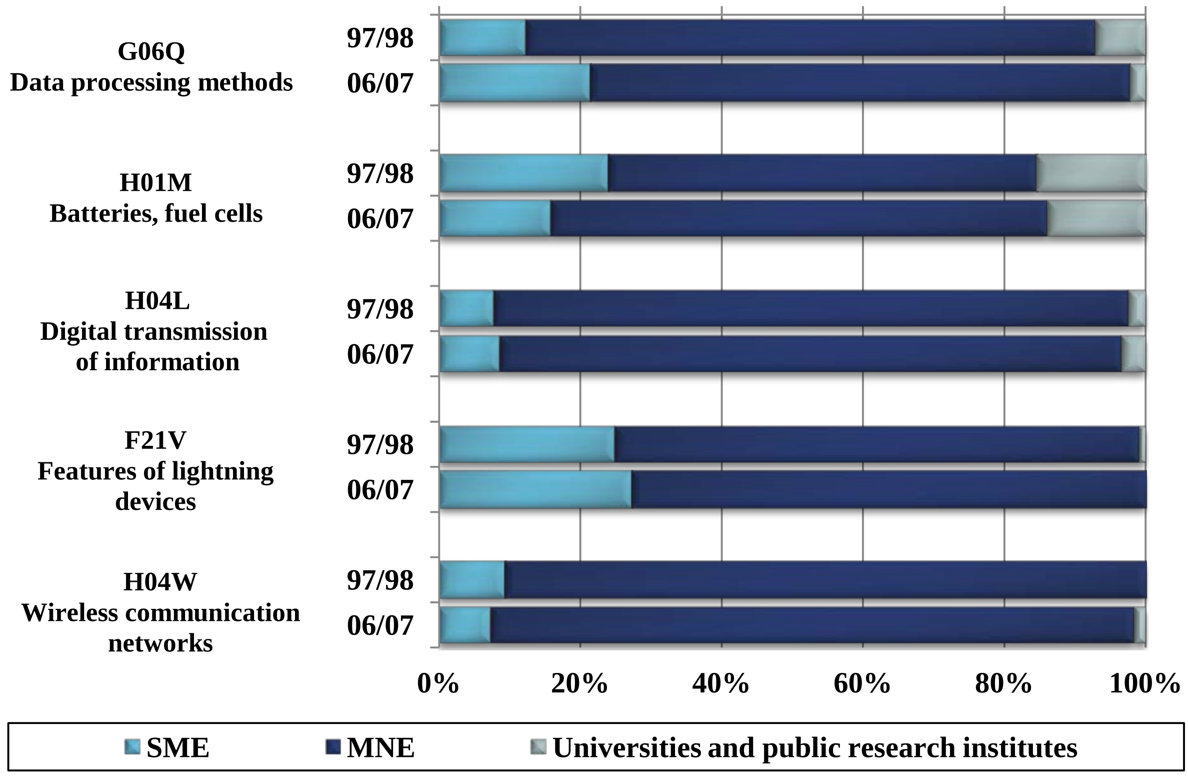
6.5 Differentiation by applicant type

The final Figure of this section turns the focus away from analysing the different subgroups to find out which types of applicants, i.e. SMEs, MNEs and universities and public research institutes, are responsible for the growth of the different subclasses.

As expected, all of the analysed subclasses are dominated by MNEs, as they are responsible for the largest share of patent applications in general. However, some interesting trends can be revealed. First of all, it is interesting to note that three out of five fields show an increasing share of patent applications from SMEs over the two time periods. This is especially true for the field of data processing methods, where the share of SME applications has almost doubled. Also the subclasses "digital transmission of information" and "features of lightening devices" show an increasing share of SME patents in the region of one the three percentage points. For wireless communication networks and batteries and fuel cells a contradictory effect becomes visible. In those two fields, a decline in the share of SME patent applications can be observed, which is even more pronounced in the field of batteries and fuel cells. Yet, this is not overly surprising since it can be assumed that especially fuel cells and batteries gained increased importance for automotive firms in the last decade, an industry where many large multinationals are located.

When looking at the share of patent applications from universities and public research institutes taken together, it can be revealed that they are also most active in battery and fuel cell technology, with a share of patent applications between 13 and 15%. In all other fields, the share of patent applications from universities and public research institutes is considerably lower. Only the field of data processing methods still reaches a share of about 7% in the period 1997 and 1998. However, a large decline in this share over the years can be observed, which can also be attributed to an increasing importance of this field for large car manufacturers in the last decade.

Figure 30 Large IPC subclasses with the highest growth of transnational applications in the last decade in two time periods, differentiated by applicant type



Source: EPO-Patstat, own calculations.

6.6 Conclusion

The aim of this analysis was to identify and analyse the specific technologies, which can be seen as the essential growth drivers within quickly growing technology fields. Thereby, we built upon last year's analysis where the fastest growing technological fields in terms of IPC subclasses where identified. This year we went one step further to take a closer look at the IPC subgroups which can be held responsible for the growth in these subclasses, focussing only on subclasses that a comparably large in terms of the number of patent applications within these subclasses.

In sum, it can be stated that the growth in most subclasses under analysis here is largely born out of high growth rates of only a few subgroups within these 4-digit subclasses. This implies, that forecasting the future relevance or development of technological fields has to be carried carefully at a much disaggregated level to draw refined conclusions about essential growth drivers within technology fields. Concentration measures, like the very straightforward and simple one given above, can at least shed some more light on the specific developments in technological fields, which in turn can give rise to special awareness and supportive activities from a policy perspective.

When comparing the overall level of transnational patent applications to the German patent filings only, it can be revealed that most of the analysed IPC subclasses are strongly concentrated to only one particular subgroup in the German case. This means that applications from Germany can be seen as more concentrated to a single piece of technology than it is the case at the overall transnational level. What we can additionally observe, is that applications from Germany are mostly filed in large IPC subgroups in terms of overall transnational applications, implying that Germany operates at the technological frontier in major technologies and not only in niches. However, given that the distribution of growth is more evenly spread over the different subgroups, taken aside some outstanding particular technologies, it can be stated that also "smaller" technologies, in terms of their present number of patent applications, are not neglected in the German patent profile when it comes to the largest growing technological fields at the international level.

Finally, the analysis of the types of applicants in the given subclasses revealed that MNEs are responsible for the most of the patent applications in all of the analysed subclasses. However, especially in the field of data processing methods an increase in SME patents becomes obvious. On the other side, especially batteries and fuel cells are more and more patented by large firms, which is probably caused by an increased importance of this particular technology for automotive firms in the last decade.

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