Patent Applications – Structures, Trends and Recent Developments 2013

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0 Summary

Transnational Patent Applications

In the years 2010 and 2011, the decreasing trend of international patent filings that was encountered during the years of the economic crisis seems to have ended for nearly all countries and the numbers have stabilized or have even started to grow again. Yet, the number of filings mostly still remains at a lower level than in the years shortly before the recession.

Taking a closer look at the newly defined high-technology fields, the role of transnational patenting in high-technology has been slowly growing over the years, also in a long-term perspective. High-tech patents reach a rate of about 63% in total worldwide patenting in the year 2011, although some countries underwent a strict change of their profile in this respect. Finland and also Germany to some extent have slightly lost ground in high-tech patenting since the year 2002. Yet, Germany, Switzerland, Denmark and also Brazil are the countries that show the strictest focus on high-level technologies, while most of the other countries rather target leading-edge technologies.

When looking at Germany's country-specific technology profiles according to the new list of research-intensive industries and goods (NIW/ISI/ZEW-Lists 2012), Germany can be shown to be specialized, i.e. has comparative advantages, in three main areas: transport (automobiles and engines as well as rail vehicles), machinery and some areas of electrical engineering like power machines and power generation. Germany also has a very strong specialization within the new field of electrical equipment for internal combustion engines and vehicles. Comparative disadvantages reflected in negative specialization indices can be found in pharmaceuticals, biotechnology, information and communication technologies as well as optics and optical devices, meaning that Germany does not have strengths in these sectors in international technology markets.

Patent Filings targeting the German Market

The patent filings targeting the German market, i.e. all patents directly filed at the German Patent and Trademark Office (GPTO) or via the EPO system (including all applications to the EPO forwarded via the PCT-system), were also affected by the economic crisis, which is especially true for filings from the USA. Yet, also when looking at the patent filings targeted towards the German market, we find a rising trend of patent filings after the recession. Germany has by far the largest number of patent filings, which is to be expected as most countries file a large number of their patents first of all at the national office to secure their home market. The USA, closely followed by Japan, is the largest foreign applicant behind France, which also shows a strong orientation towards the German market, a large group of countries with less than 5.000 filings in 2010 can be identified. These are China, the UK, Switzerland, Sweden and Korea, with China having the largest growth of filings after 2002. The German profile is rather similar to the profile at the transnational level. Yet, it seems more balanced, i.e. it shows less strong positive but also less strong negative specializations within specific fields. However, this is also a result of the fact that the huge number of German filings is heavily influencing the total number of filings targeting the German market, which serves as the basis for the calculation of the specialization index. This high influence of German filings draws the German profile more to the centre of the distribution.

The Impact of the Financial Crisis on Patenting

Within this special section on the impact of the financial crisis on patent filings, we deal with the question which mechanisms within the innovation processes of firms, or on aggregate, whole innovation systems, are responsible for the decrease in patent filings during the years of the recession.

In our two-step analysis, looking at changes on the input side of the patent process, i.e. R&D expenditures, as well as at the output side, i.e. changes in patent strategy, we find that during the crisis, patent processes start to uncouple from the R&D process. This, however, is mostly a consequence of a decrease in R&D expenditures in external R&D projects. Yet, not only the input side in terms of R&D expenditures but also the adaptation of firms' patent strategies during the crisis serve as an explanation for the decrease in patent applications. Especially withdrawing and lapsing patents more frequently during times of crises seem to be prominent cost-saving strategies. The strategy of filing fewer patents also internationally, however, rather plays a minor role for companies in most of the countries under analysis.

Patents as Indicators for Researcher Mobility

Researcher mobility is a key issue in innovation. Through the mobility of researchers, e.g. in the form of employer exchange, long-term stays abroad or a change of location within an enterprise, innovation-relevant knowledge is exchanged and cooperative relations are established, so that international innovation potentials can increasingly be used.

In this year's study, the inventor information in patent documents was employed in order to draw a picture of the international mobility of researchers. This is a rather new, explorative approach to analyze the international mobility of researchers, which allows a systematic perspective on all mobile German researchers from different angles (countries, technology fields, firm size) with the help of only one integrated data source.

In sum, we find that nearly 6% of German researchers are internationally mobile, with the USA and Switzerland being the most attractive countries for German researchers to go to. The field comparison shows that, at least in absolute terms, researcher mobility is highest in pharmaceuticals and biotechnology, whereas relatively seen German researchers are

most highly mobile in ICT as well as in medical instruments. It seems that there is some kind of "brain drain" going on in these two fields, where Germany does not have its particular technological strengths. In fields where Germany has a rather strong technology base, i.e. mechanical engineering, researcher mobility is rather low in comparison. The analyses of intra- and extra-firm mobility show that mobile researchers most often change the company when going to a foreign country. Only 1.7% percent of inventors are mobile within their parent company, whereas about 5% change their employer.

1 Introduction

The technological performance of countries or innovation systems in general is mostly measured by patent applications as well as patent grants, which can be seen as the major output indicators for R&D processes (Freeman 1982; Grupp 1998). However, the methods and definitions applied for analyses using patent data do differ (Moed et al. 2004), which can be attributed to the increase of the body of literature in a field that steadily delivers new insights, knowledge and methods for researchers.

Still, patents can be seen and analyzed from different angles and with different aims. A technological view allows prior art searches as well as the description of the status of a technology. Seen from a micro-economic perspective, the evaluation of individual patents or the role of patent portfolios in technology-based companies might be in the focus. A macro-economic angle offers an assessment of the technological output of national innovation systems, especially in high-tech areas.

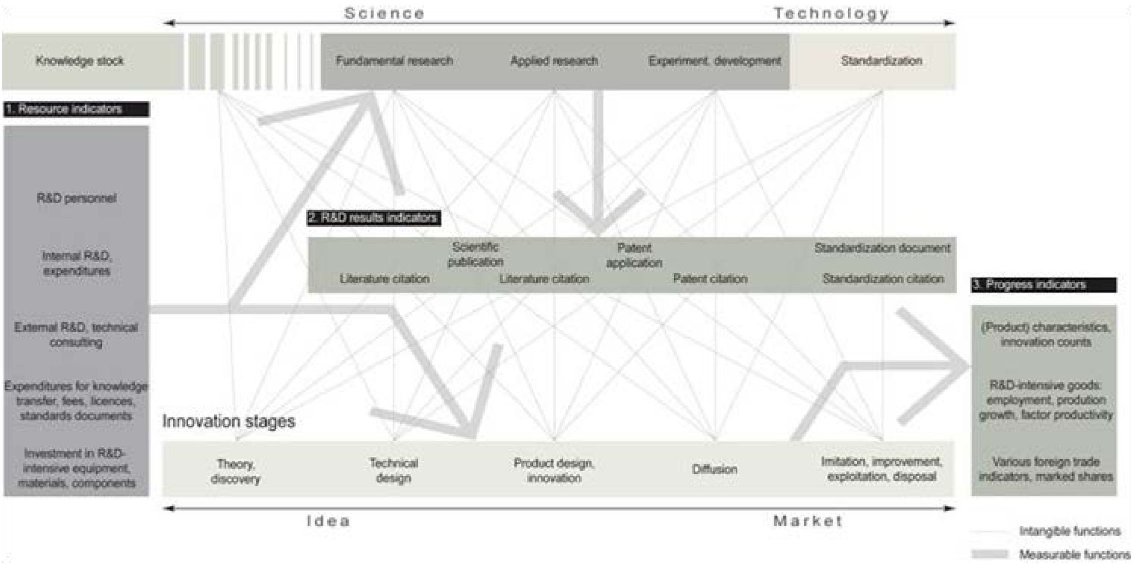
In this report, we focus on the macro-economic perspective by providing information on the technological capabilities and the technological competitiveness of whole economies. As already mentioned, patents are used as an output indicator of R&D processes. However, R&D processes can also be measured by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

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

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

different stages of the innovation process. A representation of innovation indicators and their relations are depicted in Figure 1.

Figure 1: Indicator System to analyse Innovation Systems Performance



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

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

This report gives a brief overview of the developments in transnational patent applications and patent applications targeting the German market since the early 1990s with a special focus on the recent trends and structures. In addition, in this year's report, the impact of the financial crisis of the years 2008 and 2009 on the patent activity of countries will be analyzed. Finally, we analyze researcher mobility with the help of inventor information in patent data, which is a rather new, explorative approach to gaining insights into the mobility of German researchers over time, countries and technology fields.

Section 2 first of all presents the data and methods applied for the analyses in the following chapters. Section 3 focuses on transnational patent applications and discusses total trends, growth rates, intensities (patents per 1 million workforce) and specialization indices, which are designed to reflect patent structures beyond size effects of countries and technology fields. Section 4 focuses on the analysis of patent filings targeted towards the German market, while section 5 is centered on the question if and how the economic crisis of the years 2008 and 2009 affected the patenting activity of countries. Finally, section 6 presents the analysis of researcher mobility via inventor information in patent data.

2 Data and Methods

The patent data for this study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from 83 patent authorities worldwide. Within this year's series, the new list of research-intensive industries and goods (NIW/ISI/ZEW-Lists 2012) will be used for the differentiation of 38 high-technology fields (Gehrke et al. 2013). This means that the high-technology sector was re-defined, implying that the field-specific analyses within this report will no longer be comparable to the analyses in the previous reports. However, we provide data from the beginning of the 1990s onwards, based on this new definition of high-tech fields.

By using PATSTAT as the basis of our analyses, we are able to apply fractional counting of patent filings. We do this in two dimensions: on the one hand, we do fractional counting by inventor countries and, on the other hand, we are also able to apply fractional counting to the 38 technology fields of the high-tech list, 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.

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

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

Besides patent filings, we extracted further patent indicators, as for example information on the legal status of patent applications or patent family size, for more in-depth analyses on the effect on the economic crisis on patenting activity.

In addition to analyzing the transnational patenting structures, patent applications that are targeted towards the German market are taken into account in this year's report. Here all patents are counted that reach the German Patent and Trademark Office (GPTO), whether they are directly filed at the GPTO or at the EPO (including all applications to the EPO forwarded via the PCT-system), excluding double-counts. As the lion's share of patents that are granted at the EPO also reach the German market – this is true especially for patents filed by German applicants but to a large extent also for foreign applicants – this method allows us to analyze all patents that are targeted towards protecting the German market. As we are interested in patent filings and not only grants, we use the application data of all EPO and PCT filings.

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

For the analyses of patents in different technological fields, patent specializations are calculated. For the analysis of specializations, the relative patent share (RPA[2]) is estimated. It indicates in which fields a country is strongly or weakly represented compared to the total patent applications. The RPA is calculated as follows:

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

where P_{kj} stands for the number of patent applications in country k in technology field j. Positive signs mean that a technology field has a higher weight within the country than in the world. Accordingly, a negative sign represents a below-average specialization. Hereby, it is possible to compare the relative position of technologies within a technology portfolio of a country and additionally its international position, regardless of size differences.

2 Revealed Patent Advantage

3 Trends of Transnational Patent Applications

Within this section, the recent trends of transnational patent filings since the beginning of the 1990s will be described. The analyses will be carried out for a selected set of technology-oriented countries[3], although, for reasons of presentation, not every country is displayed in each figure. Besides a country-specific view, we will also provide a distinction between low- and high-technology areas. High-tech is defined as technologies for which usually an average investment in R&D of more than 2.5% of the turnover is required. High-tech will further be differentiated by high-level and leading-edge technologies. While high-level covers technologies that require R&D expenditures between 2.5% and 7%, the leading-edge area covers technologies that are beyond 7% investment shares (Gehrke et al. 2013). In section 3.1, we will firstly discuss some broader country as well as technology-specific trends, while the differentiation of national technology profiles of Germany – looking at a list of 38 technology fields, according to the new high-tech definition – will be presented in section 3.2.

3.1 Trends and Levels of Patent Applications by Technology Areas

The absolute number of transnational patent applications by inventor countries is displayed in Figure 2. Although the USA encountered the largest decrease in transnational patent filings during the economic crisis of the years 2008 and 2009, it was, and still is the largest technology-providing country at the international level, closely followed by Japan and, with a given distance, Germany. In the years 2010 and 2011 we observe a recovery of US filings and a slight growth, yet the filings still are at a lower level compared to the peak in 2006. The filings of Japan seem to recover more quickly from the crisis, which is indicated by the larger growth rates compared to the US. Germany has the third largest number of transnational patent filings. Yet, although the number slightly rose between 2009 and 2010, it nearly remains constant between 2010 and 2011. Following behind these three countries, there is a large group led by China and Korea, at least after 2010. Both countries have grown strongly since the end of the 1990s and have managed to leave behind France and the United Kingdom in the total number of transnational applications. Sweden and Switzerland follow the UK with about 3.500 transnational filings each in 2011.

In general, we find a decrease in transnational patent filings during the years of the crisis for all of the analyzed countries. However, the US, as well as mostly US-oriented countries, have encountered the steepest decrease in transnational filings during this period. Yet, in 2010 and 2011 the number of patent applications at least stabilizes – at a lower lev-

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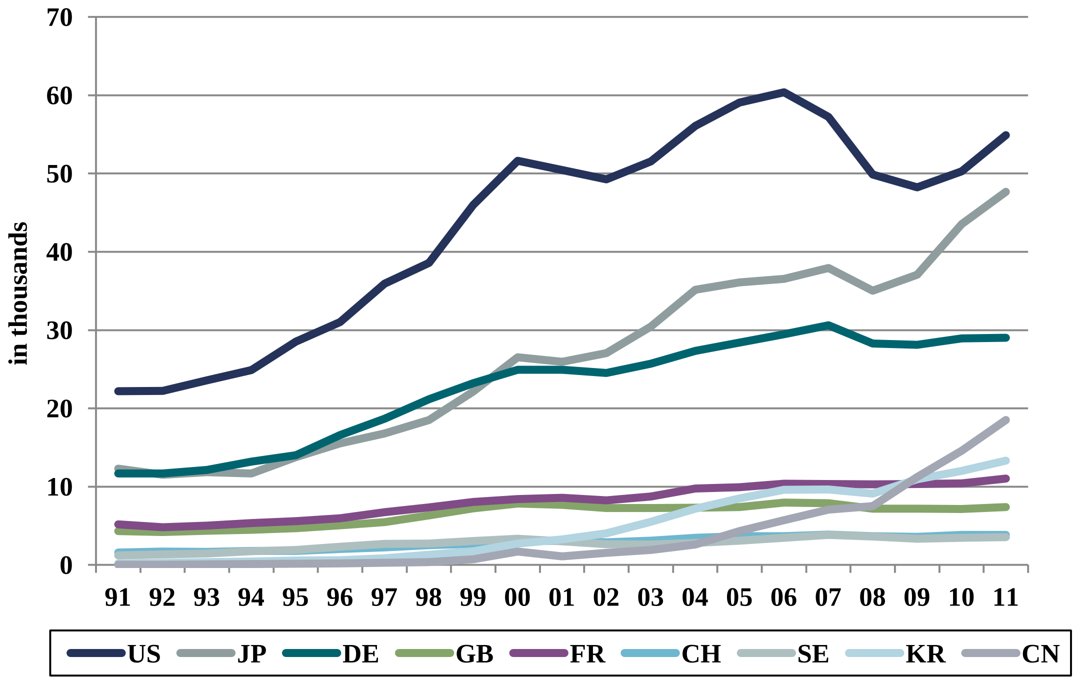
3 These are: Belgium, Denmark, Germany, Finland, France Israel, Italy, Japan, Canada, Korea, The Netherland, Austria, Poland, Sweden, Switzerland, Spain, United Kingdom, USA, Brazil, Russia, India, China, South Africa as well as the group of EU-28 member states.

el – for most of the countries. Yet, the next section is especially devoted to this topic, where more differentiated results will be presented.

Figure 2: Absolute number of transnational patent applications for selected countries, 1991-2011



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The absolute data, that has been presented so far, is of course affected by size effects. One adjustment to these size effects is shown in Table 1, where patent intensities per one million employees are displayed. This size adjustment sheds new light on the country ranks. Although the US is the largest country in absolute terms, it only scores thirteenth within our country set when looking at the patent intensities. Rather the smaller countries Switzerland, Finland and Sweden are at the top of the list of the technology-oriented countries analyzed here. Japan, Germany and South Korea are first among the larger countries in terms of absolute patenting. On the one hand, this is an expression of the strong technology orientation and the technological competitiveness of these countries. On the other hand, this is a sign of a clear and strict international orientation and an outflow of the export activities of these countries. Patents are an important instrument to secure market shares in international technology markets. With the perspective of this indicator, France, Great Britain and the EU-27/28 are in the midfield together with the USA.

Table 1: Patent intensities (patent applications per 1m employment) and shares of technological areas, 2011

	Total	**Less R&D-intensive**		**High-Tech** of which are:		Leading-edge technologies		High-level technologies	
SUI	878	428	49%	470	54%	155	18%	315	36%
FIN	780	295	38%	481	62%	296	38%	186	24%
SWE	769	257	33%	522	68%	265	34%	257	33%
JPN	758	279	37%	492	65%	186	25%	305	40%
GER	731	316	43%	412	56%	130	18%	282	39%
DEK	664	248	37%	422	64%	119	18%	303	46%
ISR	655	211	32%	443	68%	247	38%	197	30%
KOR	549	193	35%	367	67%	177	32%	191	35%
AUT	517	257	50%	250	48%	77	15%	173	33%
NED	469	224	48%	245	52%	114	24%	131	28%
FRA	428	181	42%	253	59%	112	26%	141	33%
BEL	418	190	45%	230	55%	109	26%	121	29%
USA	392	137	35%	259	66%	127	32%	131	34%
EU-27/28	334	145	43%	190	57%	73	22%	117	35%
GBR	254	102	40%	151	59%	70	28%	81	32%
ITA	230	122	53%	117	51%	29	13%	87	38%
CAN	210	75	36%	137	65%	76	36%	61	29%
ESP	136	66	48%	72	53%	29	22%	42	31%
POL	98	46	47%	51	53%	22	23%	29	30%
RSA	25	15	58%	10	40%	3	12%	7	28%
CHN	24	6	26%	17	74%	12	49%	6	25%
RUS	17	9	50%	8	49%	4	23%	5	26%
BRA	8	4	51%	4	55%	1	14%	3	40%
IND	5	2	32%	3	68%	2	31%	2	37%

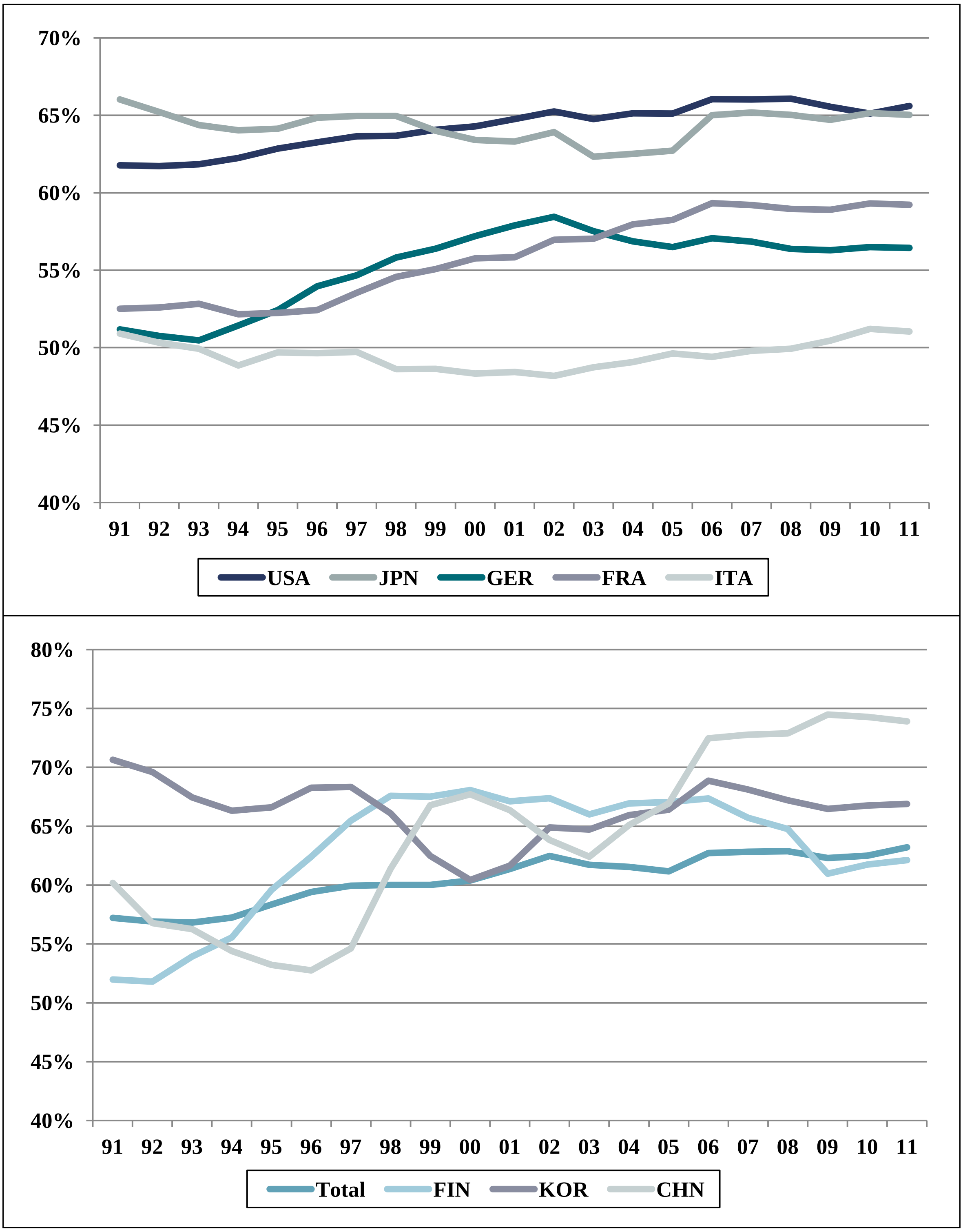
Source: EPO – PATSTAT; Fraunhofer ISI calculations.
Note: Due to missing data, the number of employees from the year 2009 had to be used for the calculations of the intensities in the case of FRA, CHN, BRA and RSA. For IND, the numbers for the year 2000 had to be employed. In a few cases, shares of patents in certain IPC-classes are assigned to leading-edge as well as high-level technologies, which might lead to double-counts. The shares therefore might slightly exceed 100%.

In addition to the general patent intensities, Figure 3 offers a differentiation of the patent intensities by technological areas and displays the respective shares on total patent filings. It is remarkable that especially Switzerland shows rather high activities in less R&D intensive fields. The same is true for Italy and the Netherlands, although especially the Netherlands are well-known for their high-tech company Philips. Also the BRICS countries Brazil, Russia and South Africa are very active in low-tech fields. China and India deviate from this pattern on the international floor with a low-tech share of only about 26% and 32%, respectively. China, however, especially shows large shares in leading-edge technologies, whereas in India the shares in leading-edge and high-level technologies are at a comparable level.

In addition, the USA, Japan, Korea, Canada, Sweden and Israel reach rather high shares of high-technology patents - according to the new definition of research-intensive industries and goods - between 65% and 68%. In the case of India, Canada and Israel, however, this can at least partly be explained by a high orientation towards the US market, which is the most important national market for high-tech products. The differentiation by leading-edge and high-level areas further qualifies these findings. The USA, Canada, Korea, Israel but also Finland and Sweden are filing many of their patents in leading-edge technologies. In consequence, these countries reach rather low shares in high-level technologies compared to the other countries. Germany and Switzerland, as well as Japan and Denmark are focused on high-level technologies, but reach comparably low shares in leading-edge areas.

Figure 3 shows the trends in high-tech shares within the national profiles of selected large countries. While the average share of total transnational high-tech patent applications rose from about 57% at the beginning of the 1990s to about 63% in 2011, some countries underwent a considerable change of their patenting in high-tech areas. The USA is at the top of the countries under analysis in this graph and reaches a rather stable share of high-tech patents at the transnational level. Although the trend has been slightly decreasing between 2008 and 2010, the share of high-tech patents slightly increased in 2011. Japan is the second most high-technology active country in terms of transnational patenting in the year 2011, at least for this selected country set. Japan, which had clearly lost ground and had lower shares of patenting activities in high-tech areas between 2003 and 2005, has managed to catch up with the USA on this indicator. France was able to increase its high-tech shares up to 2006, yet the share remains mostly stable from this year onwards, whereas Italy encountered a slight decrease in 2011, so that the gap to the other large innovation-oriented countries has grown. Germany scores fourth on this indicator compared to the countries analyzed within this figure behind Japan, the USA and also France after 2002 as the high-technology shares of Germany slightly decreased after 2002.

Figure 3: Shares of high-tech patent applications in total patent applications for selected countries, 1991-2011



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The lower panel of Figure 3 shows that the high-tech shares of Korea have been decreasing since 2006, although their absolute numbers have been increasing considerably. However, from 2009 onwards, we observe a stabilization in the high-tech shares of Korea. In the case of China, the number of filings has begun to grow from the year 2001 onwards when China joined the WTO and the TRIPS agreement. At least from 2003 onwards, also the high-tech shares have increased considerably. It is interesting to note that the Finnish trend is positive over the whole observation period, at least until 2006, and that this trend was accompanied by an increase in the absolute numbers of patent filings.

3.2 Technology Profiles and Specialisation Patterns

In this section, we provide a discussion of transnational patent applications by German inventors according to the new classification of 38 technology fields of the high-tech sector (Gehrke et al. 2013). We take a detailed look at the field-specific trends in Germany according to the new high-technology list and compare these trends to the earlier definition of high-tech sectors as provided in earlier reports of this series (see for example Neuhäusler et al. 2013).

The absolute number, specialization and the percentage growth of German transnational patent applications by technology fields are displayed in Table 2. It can be found that the two new fields of electrical appliances and electrical machinery, accessory and facilities reach rather high growth rates between 2001-2003 and 2009-2011. The same is true for aeronautics, which was the largest growing field in last year's report. These are followed by lamps and batteries as well as the rather small field of rubber goods, which also has been found to be growing strongly according to the earlier definition of high-tech sectors.

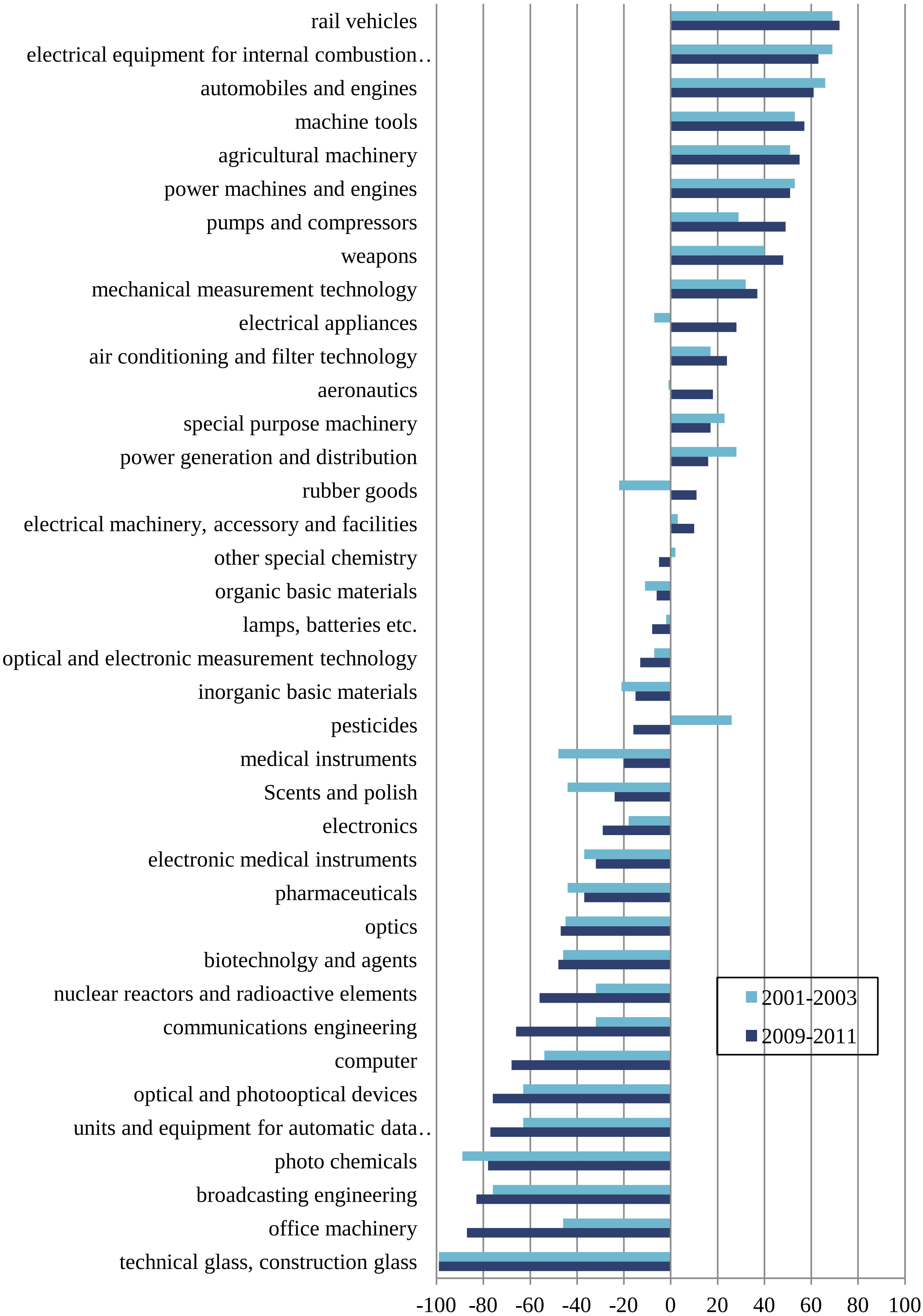
Among the fields that are growing most slowly in Germany are the two smallest fields, namely office machinery and photo chemicals, with only 50 and 3 transnational patent applications, respectively. Also pharmaceuticals, organic basic materials and biotechnology and agents as well as communications engineering and computers are slowly growing fields within the German technology profile. This first of all confirms the results from last year's study but also shows that most electronics related fields are growing rather strongly, whereas chemistry and pharmaceuticals as well as ICT related fields do not show very high growth rates within the German technology profile. The fields related to the mechanical engineering sector, where Germany is particularly strong, e.g. machine tools, agricultural machinery, automobiles and engines or special purpose machinery, show moderate growth rates in recent years, which also resembles the trends that have been found in earlier studies of this series.

Table 2: Transnational Patent applications of Germany according to the new definition of high-technology sectors (absolute, specialisation, and growth), 2009-2011

Technology Field	**Abs.**	**RPA**	**% Growth** (01-03=100)
electrical appliances	670	28	246,2
aeronautics	764	18	215,7
electrical machinery, accessory and facilities	593	10	198,1
lamps, batteries etc.	1838	-8	185,3
rubber goods	290	11	176,0
power generation and distribution	1896	16	175,1
rail vehicles	279	72	169,8
medical instruments	2619	-20	157,1
electronics	1591	-29	152,1
pumps and compressors	728	49	147,5
air conditioning and filter technology	1898	24	147,2
electronic medical instruments	880	-32	145,6
power machines and engines	3645	51	144,9
inorganic basic materials	430	-15	144,7
Scents and polish	44	-24	138,2
weapons	281	48	131,7
nuclear reactors and radioactive elements	21	-56	131,5
mechanical measurement technology	1107	37	127,9
agricultural machinery	503	55	127,4
optical and electronic measurement technology	2666	-13	118,6
electrical equipment for internal combustion engines and vehicles	1163	63	116,5
machine tools	2417	57	116,5
technical glass, construction glass	113	-99	115,8
units and equipment for automatic data processing machines	751	-77	109,3
optical and photooptical devices	66	-76	103,5
automobiles and engines	5228	61	96,2
broadcasting engineering	662	-83	95,4
optics	558	-47	94,2
special purpose machinery	3328	17	90,9
pesticides	507	-16	88,8
pharmaceuticals	1256	-37	84,7
other special chemistry	1026	-5	84,1
organic basic materials	1620	-6	80,7
communications engineering	3796	-66	79,5
computer	1685	-68	76,3
biotechnology and agents	1618	-48	72,7
office machinery	50	-87	46,5
photo chemicals	3	-78	14,4

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 4: Germany's technological profile, 2001-2003 vs. 2009-2011



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The specialization (RPA) of the German technology profile of the years 2001-2003 and 2009-2011 is displayed in Figure 4. Germany is specialized, i.e. has comparative advantages, in three main areas: transport (automobiles and engines as well as rail vehicles), machinery and some areas of electrical engineering like power machines and power generation.

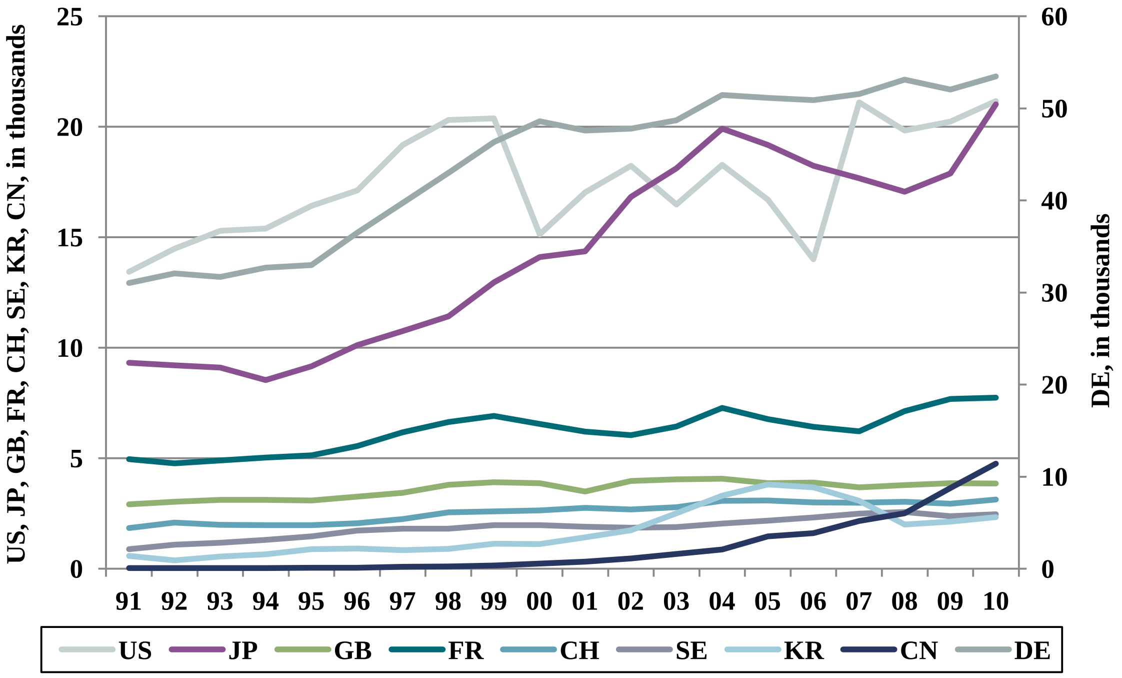
Germany also has a very strong specialization within the new field of electrical equipment for internal combustion engines and vehicles.

An average activity rate in patenting can be found in the chemical sectors (organic materials, other special chemistry). Comparative disadvantages reflected in negative specialization indices can be found in pharmaceuticals, biotechnology, information and communication technologies as well as optics and optical devices, meaning that Germany does not have strengths in these sectors in international technology markets. All of these trends can be found in both time periods, i.e. the specialization profile of Germany is rather stable over time. Interesting trends, however, are that Germany was able to improve many of its already existing strengths at least slightly. However, this comes at the expense of a relative loss of positions in many areas of relative weakness, above all ICT and electronics. In addition, German inventors were able to gain ground in some of the areas of average activity in 2001-2003, especially in aeronautics, rubber goods, electrical machinery, accessory and facilities and electrical appliances, where also the largest growth rates could be observed (Table 2).

4 Patent Filings targeting the German Market

Transnational patents offer an assessment of the technological competitiveness of nations beyond home advantage effects, national idiosyncrasies and differing market orientations and are thus able to capture international patenting trends. Within this chapter, however, we take a different perspective by analyzing patent filings that are targeted towards the German market. More specifically, we analyze patent filings that are filed at the German Patent and Trademark Office (GPTO), no matter if they were filed directly at the GPTO or via the EPO system (including all applications to the EPO forwarded via the PCT-system), excluding double counts. Yet, this is associated with the assumption that all granted patents at the EPO are also forwarded to the GPTO, which, however, is true for the lion's share of granted patents at the EPO. By applying this method, we are able to make statements about all filings that are used to secure the German market, which, compared to the analysis of transnational filings above, resembles a market-related view on patent filings. We can thus assess the strength and the profile of Germany at the home market compared to other countries.

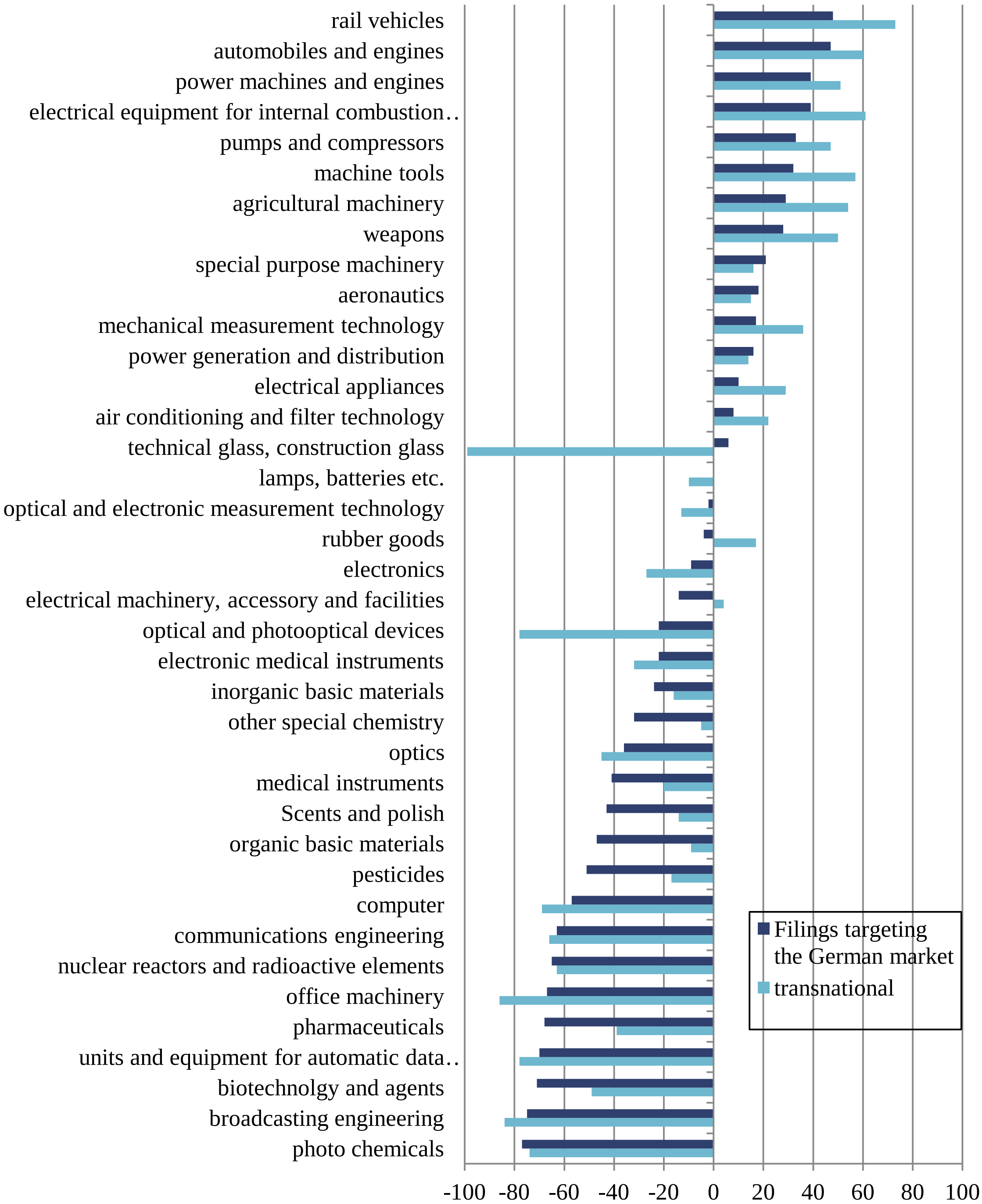
Figure 5: Total number of patent filings for the German market for selected countries, 1991-2010



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Figure 5 provides an overview of the total number of patent filings at the GPTO (directly filed at the GPTO as well as via the EPO system) between 1991 and 2010 differentiated by inventor countries. As we can see from the figure, Germany (displayed on the secondary y-axis) has by far the largest number of patent filings. This, however, was to be expected as most countries file nearly all of their patents at the national office first to secure their home market. The USA is the largest foreign patent applicant when looking at filings targeting the German market in 2010, closely followed by Japan. France is the fourth largest country in terms of patent applications targeted towards the German market, yet with only about a third of the number of filings of the USA and Japan. After France, a large group of countries with less than 5.000 filings in 2010 can be found. Among these countries are China, the UK, Switzerland, Sweden and Korea. China, however, also shows the largest growth of filings after 2002, which suggests that over the years the German market has become more and more important for inventions from China.

Figure 6: Technology profiles of Germany transnational filings (2009-2011) and filings targeting the German market (2008-2010)



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

As in the previous chapter on transnational patents, we will also focus on the German technology profile and compare it to its profile at the transnational level. The German profile is rather similar to the profile at the transnational level. Yet, the profile seems more balanced, i.e. it shows less strong positive but also less strong negative specializations within specific fields, which can be explained by different market orientations within different technology fields. However, this is also a result of the fact that the huge number of German filings heavily influences the total number of filings targeting the German market, which serves as the basis for the calculation of the specialization index. This large influence of German filings draws the German profile more to the centre of the distribution.

Especially within the group of mechanical engineering fields, Germany is less strongly specialized in filings targeting the German market as compared to the transnational level, although Germany still has its major comparative advantages within those fields. Within the fields of electrical engineering, e.g. broadcasting engineering, units and equipment for automatic data processing, office machinery, communications engineering, computers as well as electronics, Germany is slightly more specialized than at the transnational level. Yet, Germany does still not show positive specialization values within those fields. The most prominent differences between the two profiles can be found in the fields of electrical machinery, accessory and facilities, rubber goods and technical glass, construction glass. Especially the latter two fields are comparably small in terms of the absolute number of patent filings and, even more importantly, the absolute numbers are largely driven by German applicants, who are responsible for nearly a third of all patent filings in Germany within those fields.

5 The Impact of the Financial Crisis on Patenting

Within this section, the impact of the financial crisis of the years 2008 and 2009 on the patenting activity of different countries will be analyzed. In last year's study, we found that the number of international patent applications in many countries decreased during (or even before) the years of the crisis (Neuhäusler et al. 2013). The impacts of the crisis on patenting are particularly evident in countries that are highly active in the USA - including the United States itself - where the crisis originally started. In countries such as Germany or Japan, the crisis seems to affect patenting less severely, although a reduction in the international patent activity can also be observed particularly in 2008 (Frietsch et al. 2012).

However, it remains unclear what actually drives this decrease in international patent applications. In other words, the question which mechanisms within the innovation processes of firms, or on aggregate, whole innovation systems, are responsible for the decrease in patent filings during the years of the recession is still unanswered.

On the one hand, one can clearly argue that a decrease in R&D expenditures, indirectly affecting the output side of the innovation process, is responsible for the decrease in patent filings during the crisis. Analyses of earlier recessions revealed that firms decrease their investments in R&D during times of crises, which leads to prolonged innovation processes or delayed starts of R&D projects (Rammer et al. 2012). In the long run, the R&D expenditures of most industrialized countries are thus highly sensitive to economic developments (Schasse et al. 2012), although maintaining the given level of R&D expenditures can especially be seen as an advantage of Germany during the recent recession. Yet, also the R&D expenditures of the industry in Germany slightly decreased during the crisis, however not as strongly as in many other countries (Schasse et al. 2012).

Still, in sum, a decrease in R&D investments (input) necessarily leads to a lower number of inventions (output) for which a patent can potentially be filed. This should thus indirectly lead to a decrease in the number of patent filings during the years of the crisis.

In addition, a more direct effect on patenting activity emanating from the economic crisis, namely adopting a cost-saving patent strategy, can be assumed (Frietsch et al. 2012). The economic crisis thus has an influence on the output side of the innovation process itself. In order to decrease costs, firms might have especially changed their international patent strategy during the crisis, as the application and maintenance of patents, especially in several countries or at several patent offices, is associated with enormous costs.

It can thus be assumed that especially larger firms, which are responsible for the lion's share of international patent filings, have decided a) not to file their national patent applications (mostly at the home-market) also at an international level. Yet, also keeping patents within the system up to a possible grant and beyond is associated with a given amount of costs (examination fees, processing fees etc.) and therefore firms b) withdraw already filed patent applications or lapse already granted patents more often. Finally, firms might simply choose c) not to file patents for already generated inventions at all and/or delay the filing to a later point in time or to use less expensive ways of intellectual property protection, e.g. secrecy, in case this is possible for the respective inventions or technologies (Blind et al. 2003; 2006). All of these strategies are targeted towards saving costs that are associated with the patent process itself.

Especially the strategy of filing patents exclusively at the national level seems to be interesting for companies as patent-active companies file their patents - as soon as they have generated an invention that is worth patenting – in order to decrease the risk of losing their intellectual property to one of their competitors. This makes the strategy of filing patents at the home office comparably inexpensive, as national patent applications are less costly compared to filings at the EPO, via the PCT system or also at another national office, and at the same time less risky since intellectual property protection is secured at the home market.

All in all, this implies that the decrease in (international) patenting is assumed to depend on two mechanisms, which will be analyzed separately within this section in order to find out a) which of the two assumed effects actually is in place and b) which of the two assumed effects has a stronger influence on the patent activity of firms and, on aggregate, on countries.

5.1 Data and Indicators

Within this section, we will briefly describe the data and indicators used to analyze changes in patenting during the financial crisis that are associated with the decrease in R&D investments on the one hand and changes in patent strategies on the other.

5.1.1 Input Side Changes – R&D investments

In order to estimate the influence of a decrease in R&D investments on patent activity during the economic recession an integrated dataset of R&D expenditures and patent applications is necessary. In cooperation with the "Stifterverband für die Deutsche Wissenschaft", Fraunhofer ISI has created such a dataset, relating R&D expenditures and patent applications with the help of a probability matching at the firm level (micro data).[4] This integrated dataset allows us to perform differentiated analyses of R&D activities and patenting of German firms in the years 2007 and 2009, which helps us to answer the question if and how strongly a decrease in R&D expenditures affects the patent output of patenting firms during the crisis.

4 For details on the construction of the dataset please refer to Gehrke, B.; Cordes, A.; John, K. (NIW); Frietsch, R.; Michels, C.; Neuhäusler, P. (Fraunhofer ISI); Pohlmann, T. (TU Berlin); Ohnemus, J.; Rammer, C. (ZEW) (2014): Informations- und Kommunikationstechnologien in Deutschland und im internationalen Vergleich - ausgewählte Innovationsindikatoren, Studien zum deutschen Innovationssystem Nr. 11-2014, Berlin: EFI.

Table 3 Summary Statistics of the integrated R&D – Patent Dataset

Variable	Obs.	Mean	Std. Dev.	Min	Max
Sector (WZ08, 2-digit)	2414	23.13	8.81	1	50.00
Employees	2536	1241	7084	0	148938
Sales	2536	371559	2451490	0	55000000
Int. R&D exp.	2536	19390	123211	0	2156573
Ext. R&D exp.	2536	5895	62196	0	1266886
R&D exp.	2536	25285	176020	0	3122645
Patent applications	2536	12.57	99.10	0	2691.00
Forward citations	2536	4.92	45.08	0	1335.00
Patent intensity	2107	0.004	0.019	0	0.50
Citation intensity (R&D)	2107	0.001	0.009	0	0.27
Citation intensity (patents)	1899	0.399	1.501	0	45.00

Source: SV – Wistat, EPO – PATSTAT; Fraunhofer ISI calculations.

The dataset is in the form of a firm-level panel. However, not every company shows up twice in the dataset, i.e. for the years 2007 and 2009, implying that the panel is unbalanced. Besides descriptive statistics and analyses of correlations, multivariate statistical panel models for the years 2007 and 2009 will be applied, that allow us to estimate the effect of a decrease in R&D expenditures on patenting, controlling for firm size as well as sector specific effects. We thereby not only focus on the effect of R&D expenditures on patent applications and the change between 2007 and 2009, but also estimate models on patent intensity, defined as the number of patent applications per unit of R&D expenditure and its change over time. Since the dataset also includes information about patent forward citations, which are typically used to estimate the technological quality of patent applications (Albert et al. 1991; Trajtenberg 1990), we will also analyze the effect of decreasing R&D expenditures on patent quality during the crisis. In Table 3, the summary statistics for the dataset are presented.

5.1.2 Output Side Changes – Patent strategies

In order to analyze the influence of a change in patent strategies on patent activity during the crisis, several indicators based on the PATSTAT database will be analyzed. One specialty of this analysis is that events, e.g. the filing or the withdrawal of a patent, are under observation, which is why we do not analyze patents by priority year but by the year of the respective event, i.e. filing year, year of withdrawal etc.

Various dimensions of changes in patent strategy are in the focus of the analysis. First, this is the above-mentioned strategy of filing patents less frequently at an international level or with a broad market coverage, but more often at the respective national office and in core-markets, in order to protect one's own inventions with fewer costs. In order to find out if this strategy is actually more frequently used by patent applicants during the crisis, a newly developed indicator, namely the share of transnational patent filings on the number of distinct patent families[5] (including patent families with only one member, which are commonly referred to as "singletons" (Martinez 2009)) is calculated. Yet, as already stated above, there are other cost-saving strategies than just decreasing the number of international patent filings. One of these is to withdraw already filed patents or lapse already granted patents to save examination or maintenance costs. In order to capture these effects with the patent data at hand, two additional indicators are calculated and analyzed, which enables us to draw conclusions about such kinds of strategies during the crisis. This is first of all the share of withdrawn patents on the number of patent filings that are within the EPO system in a given year. In order to define the number of patents that are currently within the EPO system, first of all the stock of patent filings up to the year 1991 minus granted, withdrawn and refused patents was calculated. From 1992 onwards the difference of yearly inflows of patent filings and yearly outflows in terms of grants, refusals and withdrawals was calculated and added to the stock of patents within the EPO system before 1992. This indicator thus informs us whether the withdrawal shares actually increased during the crisis. Second, we calculate the yearly share of lapsed patents in the existing stock of granted patents. The basic method of calculating the stock of granted patents per year is similar to the withdrawal share. First, we calculate the stock of patent grants up to the year 1991 minus lapsed patents. From 1992 onwards the difference of yearly inflows of patent grants and yearly outflows in terms of lapses is added to the stock of patents within the EPO system before 1992. However, EPO patents are forwarded to the national offices after grant and maintenance fees have to be paid to the national offices. We thus decided to count a patent as lapsed when it has been lapsed at the German Patent and Trademark Office (GPTO) as we cannot control for the lapses at each office without double-counting. Yet, tests show that the share of lapsed patents is very similar when looking at lapse shares at the UK Intellectual Property Office (IPO) or the French Intellectual Property Office (INPI) compared to the GPTO.

Table 4 Summary Statistics for the Patent Dataset

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
Transnational share	27761	0.61	0.32	0.002	1
Withdrawal share	30810	0.05	0.08	0	1
Lapse share	25499	0.11	0.16	0	1
Technology field	37050	20.00	11.25	1	39
Country	37050	5.50	2.87	1	10
Year	37050	2001	5.48	1992	2010
Applicant type	37050	3.60	3.26	0	8

Source: EPO – PATSTAT; Fraunhofer ISI calculations.3

5 Patents for the same invention that are filed at several patent offices are commonly called patent families. A patent for the same inventions that is for example filed in Germany, the USA and Japan is called a patent family with three members.

Yet, it is possible that those patent strategies differ between different countries, technology fields as well as between different types of applicants (SMEs, large firms, universities, public research institutes, single inventors) due to differences in resource constraints. Thus, we have created a dataset that allows us to estimate multivariate panel models at the level of countries and high-technology fields – in addition to descriptive statistics – on the three outcome indicators described above controlling for field and country[6] specific effects as well as effects that might be moderated by the type of the patent applicant[7]. With the help of those models, differentiated conclusions about the influence of the crisis on different patent strategies can be drawn.

In sum, this two stage analysis allows us to assess, at least for Germany, which of the two mechanisms (direct vs. indirect) exerts a stronger influence on patenting during the economic crisis. An overview of the variables used for our analyses can be found in Table 4.

5.2 Results of the Analyses

This section presents the results of the analyses on the impact of the financial crisis on patenting activities. First, we will focus on the question if and how the R&D downturn during the crisis affects patenting activities. Second, the results of the change in patent strategy on patent output will be presented.

5.2.1 The effect of R&D on patenting during the crisis

To get a first impression of the impact of the financial crisis on R&D expenditures, and, in turn, the patent activities of German firms, Table 5 shows the correlation coefficients between R&D expenditures and patent applications as well as forward citations and their changes between 2007 and 2009. As we can see from the table, the correlation between the total R&D expenditures and the number of patent applications decreases between 2007 and 2009. This can be seen as a first indication of our assumption that the crisis affects the input of the innovation process in terms of R&D expenditures and accordingly also the output. In 2009, the patent process can be shown to be more uncoupled from the R&D process than it was in 2007. Interestingly, this decrease of the correlation between total R&D expenditures and patent filings can be attributed to a decrease in the correlation between external R&D expenditures and patent filings, whereas the correlation between internal R&D expenditures and patents nearly remains unchanged.

6 The countries covered by the sample are CH, DE, FI, FR, GB, IT, JP, NL, SE and the US.

7 We control for several types of patent applicants, namely SMEs (less than 500 employees), large firms (more than 500 employees), universities, public research institutes and single inventors.

Table 5 Correlation Analysis

		Internal R&D expenditures	External R&D expenditures	Total R&D expenditures
No. of patent filings	2007	0.754***	0.569***	0.726***
	2009	0.758***	0.405***	0.678***
No. of forward citations	2007	0.725***	0.444***	0.668***
	2009	0.697***	0.548***	0.678***

Significance level: ***p<0.01, **p<0.05, *p<0.1.

Source: SV – Wistat, EPO – PATSTAT; Fraunhofer ISI calculations.

When looking at the number of forward citations to patents, which can be seen as an indicator of patent quality (Albert et al. 1991; Trajtenberg 1990), we find a slight increase in the correlation coefficient between 2007 and 2009. This increase can also be attributed to projects financed by external R&D. In the case of internal R&D expenditures, the correlation slightly decreases. In sum, this means that firms mostly seem to decrease their external R&D activities during the crisis.

Table 6 Multivariate Results I

	Number of patent applications XT negative-binomial, RE			**Number of FW-citations** XT negative-binomial, RE		
	Coef.		Std. Err.	Coef.		Std. Err.
R&D expenditures	0.0013	***	0.0001	0.0017	***	0.0002
2009 Dummy	-0.0969	***	0.0355	-2.6619	***	0.1309
R&D expenditures*2009 Dummy	-0.0001	**	0.00004	-0.0002	**	0.0001
Firm Size Dummy	1.1351	***	0.0684	1.9411	***	0.1449
Constant	0.5838	***	0.0953	-0.2937		0.2740
Sector Dummies	YES			YES		
No. of obs.	2370			2370		
No. of groups	1633			1633		
LR chi2/Wald chi2	611.44			1502.91		
Prob > chi2/Wald chi2	0.000			0.000		
Pseudo R2	0.042			0.019		

Significance level: ***p<0.01, **p<0.05, *p<0.1.

Note: Coefficients for "R&D expenditures" and "R&D expenditures*2009 Dummy" multiplied by 1,000.

Source: SV – Wistat, EPO – PATSTAT; Fraunhofer ISI calculations.

When analyzing these trends via a multivariate regression model, similar effects can be observed. Using the number of transnational patent filings as the dependent variable and R&D expenditures, a dummy for the year 2009 (as compared to 2007) as well as the interaction term between R&D expenditures as explanatory variables controlling for firm size - coded 0 for firms with less than 500 employees - and sectors, we find that there is a positive relationship between R&D expenditures and patents, which is as expected.[8] For the year 2009, we find a significantly negative effect compared to 2007, which is the base outcome for this dummy variable, implying that the number of patent applications is decreasing between 2007 and 2009. Most interesting for our question, whether a decrease in R&D expenditures has led to the decrease in patent filings, is the interaction effect between R&D expenditures and the year 2009, whose coefficient shows a significantly negative sign. This means that at least a part of the decrease in patent filings during 2007 and 2009 can be attributed to a decrease in R&D expenditures, although other factors are at play here, which is shown by the significantly negative effect of the dummy variable for the year 2009.

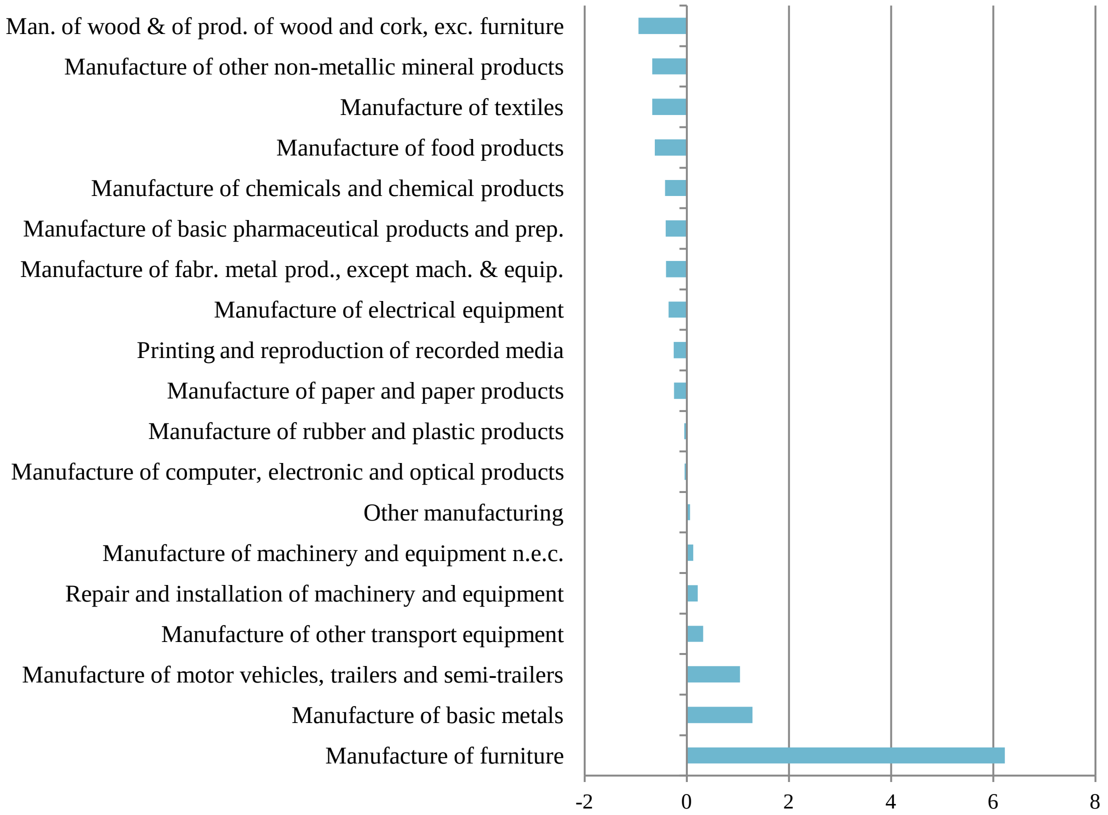
In sum, we can state that there is an effect of a decrease in R&D expenditures on the decrease in patent filings, although the effect is not overly large. We observe exactly the same pattern for the forward citations, too, implying that a higher amount of R&D leads not only to a significant increase in patent filings but also to an increase in patent quality. The dummy variable for the year 2009 as well as the interaction term also show negative signs in this model and the effects are more strongly pronounced than in the model on patent filings. Thus, the decrease in R&D during the crisis slightly decreases the patent filings but even more so the patent quality, as indicated by a decline in patent citations.

Figure 7 now shows the growth of the patent intensity – calculated as the number of transnational patent filings by unit R&D expenditure – between 2007 and 2009. As we can see from the figure, the patent intensity decreases or stays at a comparable level in the manufacturing sector between 2007 and 2009. Yet, there are some exceptions to this pattern. Mostly the mechanical engineering related sectors, especially the transport sector but also the basic materials industry, even show growing patent intensities during this time period. The largest growth can be found for the manufacture of furniture, although this is a rather small industry in terms of total R&D expenditures. It thus seems that in most sectors, a decrease in R&D expenditures also leads to a decrease in patent filings. When we take a closer look at this effect by estimating a multivariate random-effects panel model with the patent intensity as the dependent variable and sector-specific controls as well as a control variable for firm size (coded 0 for firms with less than 500 employees), we see that on average the patent intensity decreases between 2007 and 2009 (Table 7).Yet, the effect is not significant in the OLS model and only marginally significant in the Tobit model. As for the citation intensity – calculated as the number of patent forward citations divided by the R&D expenditures – some more stable effects can be observed. Here, we also find that on average the citation intensity decreases between 2007 and 2009. The effect is stable over both model specifications and shows a larger coefficient than for the patent intensity. This confirms the results from the previous model. Although the decrease of R&D expenditures

8 In previous analyses with this dataset, we have found that not using a time lag between R&D expenditures and transnational patents delivers results with the highest explanatory power. This is why we have decided not to use a time lag between R&D expenditures and patent filings for the analyses at hand.

during the financial crisis affects a company's patent output on average, the negative effect is more strongly pronounced when looking at patent quality rather than quantity. However, due to the timeliness of R&D expenditures and patent filings, the effects of the economic crisis on patent intensity are hard to validate and interpret.

Figure 7 Growth of the patent intensity between 2007 and 2009, by sector, industry only



Source: SV – Wistat, EPO – PATSTAT; Fraunhofer ISI calculations.
Note: Calculations only for sectors that state a given patent intensity in 2007 and 2009.

In sum, we can state that during the crisis, patent processes start to uncouple from the R&D process, although this is mostly a consequence of a decrease in R&D expenditures in external R&D projects. This might be an effect of lowering especially variable costs (external R&D) while keeping the fixed costs (internal R&D) at a similar level. Firms might have learned from the new economy crisis to keep up a certain level of R&D capacities in order to be prepared for the periods after the crisis, e.g. by not having increased search costs. The models also show that at least a part of the decrease in patent filings of German firms between 2007 and 2009 can be attributed to a decrease in R&D expenditures, which confirms our hypothesis, although the effect is not overly large. As for the patent quality, on the other hand, the effect is more strongly pronounced, implying that a lower amount of R&D leads not only to a significant decrease in patent filings but also to a decrease in patent quality. However, the models also show that the decrease in R&D expenditures is not the only factor that leads to a decreasing patent output during the crisis. These factors might be associated to changes in the firms' patent strategy, which will be analyzed in the next section.

Table 7 Multivariate Results II

	Patent intensity						Citation intensity					
	XT OLS, RE			XT Tobit, RE			XT OLS, RE			XT Tobit, RE		
	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
Firm Size Dummy	-0.004	***	0.001	-0.0002		0.001	-0.001	*	0.001	0.010	***	0.002
2009 Dummy	-0.001		0.001	-0.002	†	0.001	-0.002	***	0.000	-0.018	***	0.001
Constant	0.005	***	0.001	-0.001		0.001	0.002	***	0.000	-0.017	***	0.002
Sector Dummies	YES			YES			YES			YES		
No. of obs.	2017			2017			2017			2017		
No. of groups	1414			1414			1414			1414		
LR chi2/Wald chi2	94.37			--			40.04			--		
Prob > chi2/Wald chi2	0.000			--			0.6005			--		
Pseudo R2	0.047			0.000003			0.020			0.009		

Significance level: ***p<0.01, **p<0.05, *p<0.1, †=marginally significant.

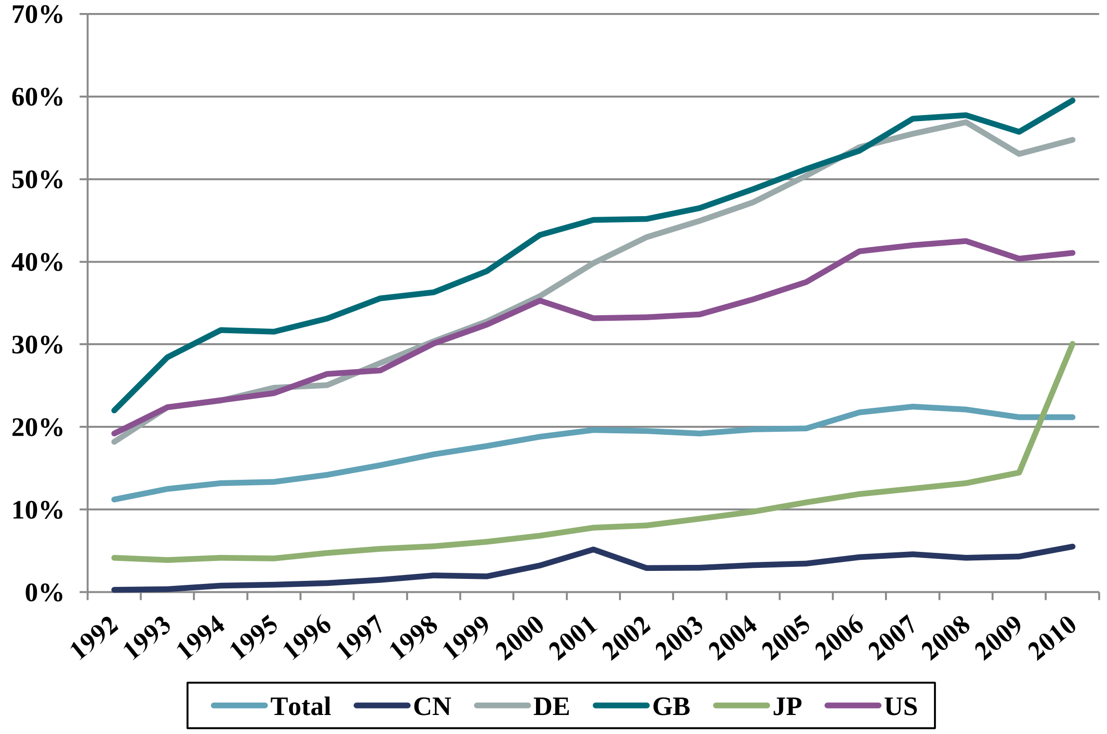
Source: SV – Wistat, EPO – PATSTAT; Fraunhofer ISI calculations.

5.2.2 The effect of changing patent strategies on patent output

Within this section, we will analyze the effect of changes in patent strategy during the crisis on the patent output of countries (as an aggregate of all patent filings within the country, which mostly come from industry). As already stated in the introduction, we can assume that firms have adopted a cost-saving patent strategy during the crisis, which consequently influences their output in terms of patent filings. However, we do not know what kind of strategies firms exactly follow in order to save patenting costs. We thus make three assumptions about reasonable cost-saving strategies that firms might follow during the crisis and then test these assumptions via descriptive as well as multivariate analyses.

As we can observe that especially transnational patent activities are declining for most countries during the crisis, a first cost-saving strategy of firms could be to file their patent applications only at the home-market and not at an international level. This saves the costs of a rather expensive international filing but still has a rather low risk as intellectual property protection is secured at least at the home market. In order to test this assumption, we calculated the share of transnational patent filings by application year on the number of patent families (including "singletons") of a country. By applying this indicator and analyzing it over time, we are able to find out if the share of international filings (via the PCT and/or EPO system) on all patent filings of firms (national at the home-market, national at a foreign market or transnational) have decreased during the crisis. This gives us an indication of "international orientation" of the firms in terms of their patent strategy.

Figure 8 Share of transnational patent filings on patent families, by filing year, 1992-2010



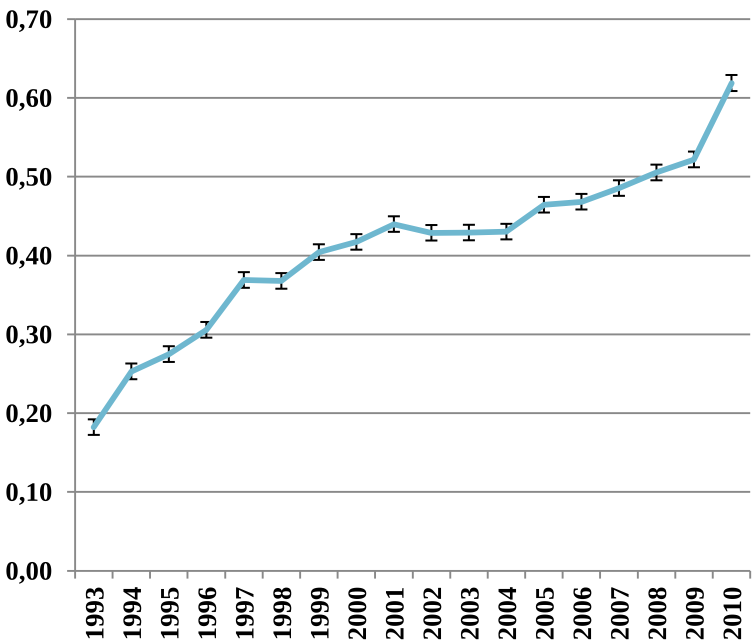
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

The share of transnational patent filings on the number of patent families is plotted graphically in Figure 8. As we can see, the share is mostly rising over the years for all analyzed countries, although the growth is highest in the 1990s. After the year 2001, where we encountered the new economy crisis, we can observe a slowdown in this growth and the share remains rather stable until 2005. Afterwards, we find a slight increase until 2006 and once again a slowdown of the growth from 2007 onwards when the financial crisis started. This effect confirms our hypothesis at least partly, although the effect is not that strongly pronounced. Especially for the US we find the expected pattern. Also for the UK and Germany the effects are as expected. Yet, for China and Japan, we do not find the assumed decrease in international filings.

The effects of the multivariate model with the share of transnational patent filings on the number of patent families as a dependent variable as well as control variables for countries, technology fields and the size of the patent applicant (Figure 9) show a similar trend.[9] We observe a drop in the share after 2001, which is also significant as the F-Test compared to the year 2000 shows. However, we do not find the expected decrease in the share between 2007 and 2009 when controlling for country-, size- and field-specific differences. The share rather seems to even slightly increase within this time period.

9 The full results of the models can be consulted in Table 8 in the annex.

Figure 9 Development of the coefficient (incl. standard errors) of filing year in the multivariate model on the share of transnational patent filings on patent families, 1993-2010, base year 1992



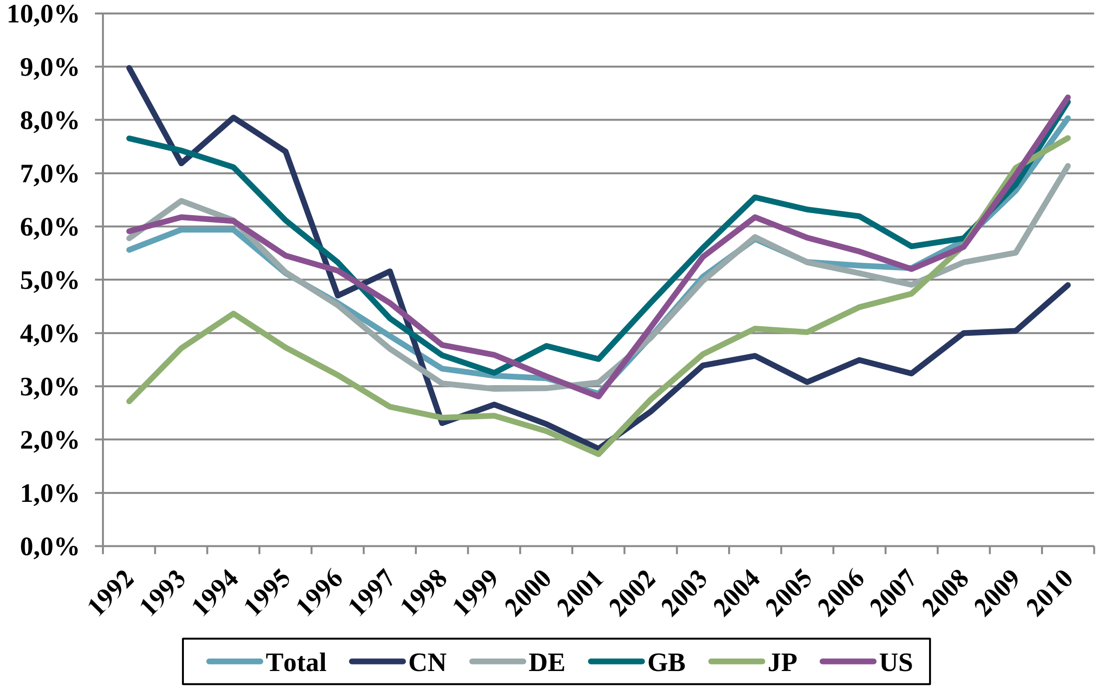
Year	F-Test (compared to previous year)
1994	50.1***
1995	4.73**
1996	9.36***
1997	39.83***
1998	0.01
1999	13.6***
2000	1.72
2001	5.34**
2002	1.28
2003	0.00
2004	0.01
2005	12.05***
2006	0.15
2007	3.11*
2008	4.03**
2009	2.76*
2010	90.81

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Note: Tobit panel-model, marginal effects, dV: share of transnational patent filings on patent families, iVs: filing year (base: 1992), technology fields, type of patent applicant, countries.

In sum, we can state that we can only partly confirm the hypothesis of a decrease in international compared to national patent activities. Also a slight decline in international patent activities can be found during the recession, it seems that companies, in order to save costs, rather delay the patent filing in general, or not file their patent at all, rather than filing a patent at the home-market and not at the international level. Only for some countries, for example the USA, which has a very large domestic market, this seems to be a suitable strategy.

Figure 10 Share of withdrawn patents in the EPO patent stock, by year of withdrawal, 1991-2010

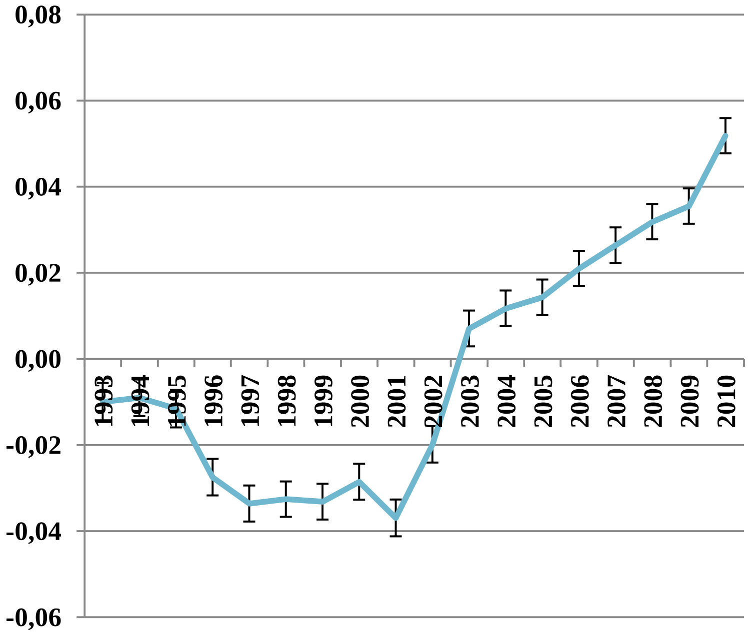


Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Yet, also keeping patents within the system up to a possible grant is associated with a given amount of costs (examination fees, maintenance fees etc.) and therefore firms might withdraw already filed patent applications more often than usual during times of crises. This is the second cost-saving strategy that is under analysis here, which will be analyzed by the development of the share of withdrawn patents in the EPO patent stock over time (Figure 10). As we can see from the figure, the share of withdrawn patents is declining in the 1990s for all of the analyzed countries, implying that within this time period, patents are more and more kept within the EPO system up to a possible grant. Yet, from 2001 to 2004, i.e. within the period of the new economy crisis, the withdrawal share is rising in each of the countries under analysis. From 2004 onwards, we observe a decline in this ratio until 2008, when the share of withdrawn patents once again drastically increases. This pattern can be seen as a confirmation of our hypothesis. During both economic crises, the share of withdrawn patents increases and decreases afterwards.

Also when looking at the multivariate model, where we control for countries, technology fields and the size of the patent applicant, a similar trend can be observed (Figure 11). Especially during times of the two economic crises, we find a drastic increase in the coefficient. The F-Test shows that these effects are significant on a yearly basis only for the crisis of the new economy as well as for the year 2010 (as compared to 2009). However, when grouping the years according to the times of the crises, i.e. 1990-2000, 2001-2003, 2004-2007, 2008-2010, we find significant differences between all the groups.

Figure 11 Development of the coefficient (incl. standard errors) of withdrawal year in the multivariate model on the share of withdrawn patents in the EPO patent stock, 1993-2010, base year 1992



Year	F-Test (compared to previous year)
1994	0.05
1995	0.37
1996	14.76***
1997	2.42
1998	0.07
1999	0.02
2000	1.47
2001	4.48**
2002	18.04***
2003	47.74***
2004	1.5
2005	0.46
2006	3.35*
2007	2.16
2008	2.16
2009	0.96
2010	19.77***

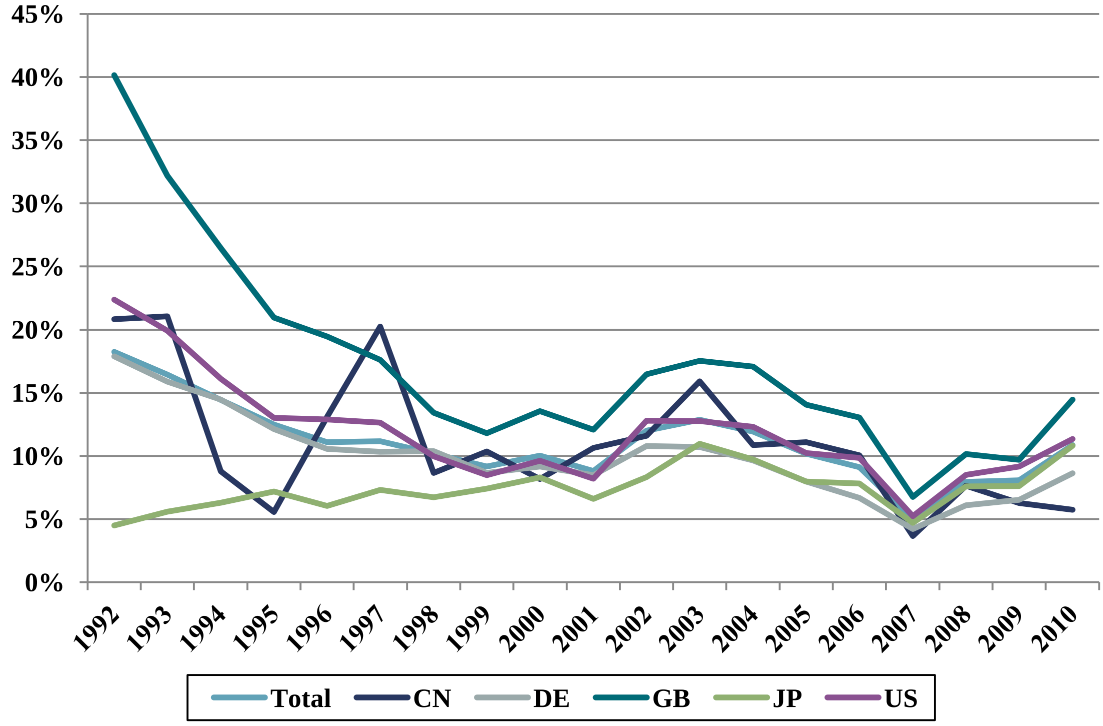
Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Note: Tobit panel-model, marginal effects, dV: share of withdrawn patents in the EPO patent stock, iVs: withdrawal year (base: 1992), technology fields, type of patent applicant, countries.

It thus seems that withdrawing patents that are already within the system but not yet granted seems to be a very suitable and commonly used cost-saving strategy for firms, which is applied especially during times of economic crises, where cost-saving strategies become more important. This makes sense from a company point of view since a once filed patent becomes state-of-the-art, which makes it impossible for other companies to file a patent for the same invention. In addition, the patent has an option value until it is withdrawn from the system, which often is sufficient especially in very fast-paced technology fields.

The final cost-saving strategy of companies that we analyze here is to lapse already granted patents more often than usual during times of crises. For each granted patent, maintenance fees have to be paid to the respective national offices, which can be very expensive especially when maintaining a patent at a large number of national offices. The share of lapsed patent filings in the stock of granted EPO patents is plotted in Figure 12.

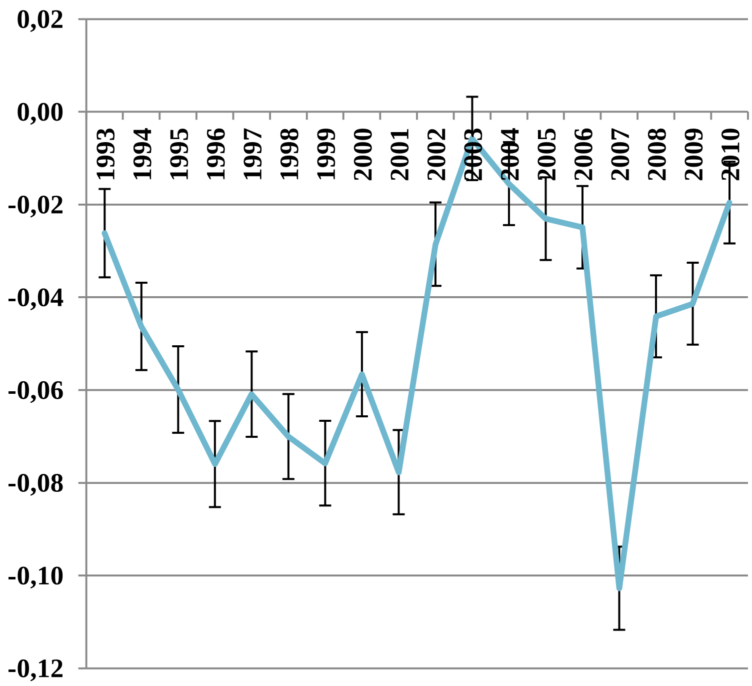
Figure 12 Share of lapsed patent filings in the stock of granted EPO patents, by year of the lapse, 1991-2010



Source: EPO – PATSTAT; Fraunhofer ISI calculations.

As we can see from the figure, the share of lapsed patents is declining over the 1990s, with the exception of Japan. This trend is in accordance with the withdrawal shares shown above. Until the year 2000, firms have thus more commonly kept their patents within the system, before as well as after grant. From 2001 until 2003, the share of lapsed patents is increasing and once again declines afterwards. From 2007 onwards, however, the shares are increasing again. This pattern could also be observed for the shares of withdrawn patents and indicates that lapsing patents in order to save costs also seems to be a suitable patent strategy.

Figure 13 Development of the coefficient (incl. standard errors) of lapse year in the multivariate model on the share of lapsed patent filings in the stock of granted EPO patents, 1993-2010, base year 1992



Year	F-Test (compared to previous year)
1994	4.70**
1995	2.25
1996	3.24*
1997	2.94*
1998	1.11
1999	0.45
2000	5.09**
2001	6.26**
2002	34.73***
2003	7.67***
2004	1.42
2005	0.87
2006	0.05
2007	92.58***
2008	53.19***
2009	0.12
2010	7.75***

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

Note: Tobit panel-model, marginal effects, dV: share of lapsed patent filings in the stock of granted EPO patents, iVs: lapse year (base: 1992), technology fields, type of patent applicant, countries.

The period-specific effects from the multivariate model, where we control for countries, technology fields and the size of the patent applicant, point into a similar direction to what could be shown by the descriptive analysis (Figure 13). During both economic crises, we find a drastic increase in the coefficient, implying that the share of lapsed patents increases during the recessions, keeping all other factors constant. The F-Tests show that these effects are significant on a yearly basis for both economic crises. Also when grouping the years according to the times of the crises, we find significant differences between all the groups.

In sum we can state that both strategies, i.e. withdrawing and lapsing patents more frequently during times of crises, are prominent in order to save costs. The strategy of filing patents less frequently also internationally, however, does not seem to play a major role for most of the countries under analysis. Patents rather seem to be filed with a delay or maybe not even filed at all during the economic recession. Patents that are already within the system, however, are withdrawn (before grant) or lapsed (after grant) more frequently.

5.3 Conclusions

Within this section, we focused on the impact of the financial crisis of the years 2008 and 2009 on the patenting activity of different countries. We followed a two-step approach in order to find out if the decline in patent activities could solely be attributed to changes at the input side of the patent process, i.e. a decrease of R&D expenditures during the recession, or if special cost-saving patent strategies are additionally able to explain the decline in the patent output of countries.

What we find is that during the crisis, patent processes start to uncouple from the R&D process. This can mostly be seen as a consequence of a decrease in R&D expenditures in external R&D projects. A part of the decrease in patent filings of German firms during 2007 and 2009 can thus be attributed to a decrease in R&D expenditures, which confirms our hypothesis, although the effect is not overly large. As for the patent quality, on the other hand, the effect is more strongly pronounced. However, the models also show that the decrease in R&D expenditures is not the only factor that leads to a decreasing patent output during the crisis. The further analyses show that changes in the patent strategy of the firms serve as an explanation for the decrease in patent applications during the recession. Especially withdrawing and lapsing patents more frequently during times of crises are prominent cost-saving strategies. The strategy of filing patents less frequently also internationally, however, rather plays a minor role for most of the countries under analysis. Patents rather seem to be filed with a delay or maybe not even filed at all during the economic recession. Patents that are already within the system, however, are withdrawn (before grant) or lapsed (after grant) more frequently.

The analysis has thus provided us with a detailed view on the factors that are driving the decrease in patent filings during the economic recession. We have learned that both, a decrease in R&D expenditures as well as a change in patent strategies, are behind the decrease in patent filings. This has two kinds of implications. The first one is associated with the measuring of innovative activities via patent indicators during times of recession, especially as patent processes seem to have uncoupled from R&D expenditures and patent strategies are adapted. Measuring innovative activities solely by patents could lead to a distorted picture of the innovative output of companies and firms especially during recessions. Thus, especially for analyses of technological performance of countries during crises, an innovation indicator system, including several input as well as output-related indicators for innovation should be applied to draw a complete picture. When using patent indicators alone as a measure of innovative output, this has to be kept in mind for the interpretation of these indicators. The second implication is that R&D is not the only factor that drives the decrease in patent filings. Firms are well able to develop differentiated cost-saving patent strategies, which increase their room to maneuver also when costs have to be cut in order to stay competitive, at least for a certain amount of time. This implies that firms, at least in Germany, have been able to cope with the crisis while maintaining a certain level of innovative potential.

6 Patents as Indicators for Researcher Mobility

Empirical findings on the nature and extent of the mobility of researchers and other skilled workers are not yet available in a systematic manner. While there is a variety of studies that focus on the external migration of German researchers/highly-qualified personnel abroad (brain drain), the immigration of foreign researchers/highly qualified personnel to Germany (brain gain) or the remigration of German researchers/highly skilled personnel from abroad (brain circulation), these mostly use different data sources and/or analyze only subpopulations of international migration flows (see for example Cañibano et al. 2008; Criscuolo 2005; Dietz et al. 2000; Jöns 2011, Moed et al. 2013).

Due to this data gap, the Expert Commission Research and Innovation has announced a "feasibility study on the mobility of researchers and innovation", whose goal was to examine different methods of measurement of the mobility of researchers in terms of their suitability for a long-term indicator system and also to propose new methods. While the feasibility study only discusses methodological issues, the Indicator Studies 2014 will provide empirical results based on several innovative approaches. Within this chapter, the inventor information in patents will be used in order to draw a picture of the international mobility of researchers. This is a rather new, explorative approach[10] to analyze the international mobility of researchers, which allows a systematic analysis of all mobile German researchers from different angles (countries, technology fields, firm size) with the help of only one integrated data source.

Researcher mobility is a key issue in innovation. This is not least due to the internationalization strategy of the federal government and the Framework Programme for internationalization of the German Federal Ministry of Education and Research (BMBF), which essentially aims to strengthen cooperation with the scientifically best in the world and to make the global innovative potential available for Germany. Through the mobility of researchers, e.g. in the form of employer exchange, long-term stays abroad ("sabbatical") or a change of location within an enterprise, innovation-relevant knowledge is exchanged and cooperative relations are established, so that international innovation potentials can increasingly be used.

As it can be assumed that knowledge is exchanged in any cooperation, the analysis of collaborations through international researcher mobility also allows statements about international knowledge flows. Thereby, it can be assumed that mostly tacit or experiential know-

10 Recently, the World Intellectual Property Organization (WIPO) published a study that also uses inventor information in patents to analyze researcher mobility over time. However, the authors used a slightly different method for the identification of mobile researchers by using information on inventor nationality and residence in PCT applications (Miguélez/Fink 2013). In addition, Jaffe et al. (1993) and Jaffe and Trajtenberg (1999) have used the citation information in patents to analyze international knowledge flows.

ledge (Polanyi 1985) is exchanged, which will later explicitly be stated in the form of a patent application.

Analyzed over time, the cooperation structures resulting from international researcher mobility indicate the internationalization of research and development activities. This provides information about which countries can already be considered as attractive research partners for Germany and with which countries cooperation needs to be improved.

Researcher mobility, however, is a complex term that includes several forms of "mobility". Besides the general notion of "moving" to another country, researchers can change their location but remain within the same company, e.g. in the form of a sabbatical or a longer-term relocation (intra-firm mobility). However, another dimension to the mobility of researchers is the exchange between companies, e.g. a researcher changes permanently to an employer located in another country (extra-firm mobility). To examine the various facets of the mobility of researchers, three separate patent analyses will be performed. Within the next sections, first of all the general trends in international researcher mobility will be analyzed. In the two following sections, a differentiation between researchers that are internationally mobile within their company and researchers that leave their company will be provided. Yet, first of all, some methodological issues will be discussed.

6.1 Methodology

In general, the methodology of analyzing researcher mobility by patents is based on a unique identifier for inventors named on patent filings, which is included in the PATSTAT database. Whenever an inventor is named on a patent application, he or she is assigned a standardized inventor ID within the database.[11] As soon as he or she files another patent he or she will be assigned the same inventor ID that can be used to track the inventor's patenting behavior over time.[12]

For our analyses, all German inventors of all German firm applicants of the priority year 2000 were followed over time (until the year 2009) and it was checked if these inventors state a foreign address on their patent filings in one of the following years. The country information of these addresses provides evidence whether a researcher who was located in Germany in the year 2000 files a patent from a foreign country in the following years, which allows conclusions about his or her international mobility. In order to identify whether a patent applicant is a firm and to differentiate whether an applicant is a small or medium-sized enterprise (SME) or a large enterprise (LE) a manual classification of applicant types was employed (see Frietsch et al. 2011). Applicants with more than 500 em-

11 As for the assignment of the inventor ID to the inventor's name, a standardized name cleaning procedure is used, i.e. spelling variations are taken into account.

12 We performed manual checks on these inventor IDs within external databases, e.g. EPO's Espacenet, which showed that the inventor ID can reliably be used to identify inventors over time.

ployees and more than three patent filings in a three-year time window between the priority years 1996 and 2008 were classified as LEs. The number of 500 employees corresponds to the German SME definition (Günterberg/Kayser 2004). The remaining applicants with more than three patent filings in the given time window and less than 500 employees were classified as SMEs.

As in the previous sections, transnational patent filings serve as the basis for this analysis. Yet, our analyses are twofold. First of all, we concentrate on researcher mobility between 2000 and 2009 in total, i.e. we want to answer the question where mobile researchers most frequently relocate to. This means that all inventors of the year 2000 that state a foreign address on a patent filing between 2000 and 2009 will be analyzed, regardless whether they change the patent applicant (i.e. the firm) or remain with the same applicant but file their patents from another country. These analyses will give us a general overview of researcher mobility between 2000 and 2009 (section 6.2). In a second step, we will differentiate between researchers that move to a different country but remain with their parent company, i.e. in the form of a sabbatical or a longer-term relocation (intra-firm mobility), and researchers who file a patent from another country with another patent applicant, i.e. by permanently changing to an employer located in another country (extra-firm mobility). Here, the focus is on the question whether mobile researchers move to foreign patent applicants or remain with their parent company. (section 6.3).

Using patents for the identification of researcher mobility, however, is also associated with certain limitations. A *mobile researcher* can only be identified as such if he files a patent from a foreign country after the year 2000. In case the researcher does not file a patent, he does not show up in the database and thus cannot be identified. This limits the analysis to researcher mobility of actively patenting researchers. Another problem emerges for the identification of the intra- and extra-firm mobility of researchers. Although we use a harmonized patent applicant name (Du Plessis et al. 2009; Magerman T. et al. 2009; Peeters B. et al. 2009) to identify the affiliation of inventors to a given patent applicant, we cannot make sure if a researcher actually leaves the enterprise (including all of its affiliates) or simply moves to a subsidiary or affiliated firm and therefore at least remains attached to his or her original employer. Thus, we can only estimate the share of mobile researchers that stay within the same firm, but not if they stay within the enterprise including all of its affiliates. However, we control for this effect by analyzing researcher mobility within the Siemens AG, for which a list of keywords is used to identify the firm as well as its (current) affiliates and subsidiaries.

In sum, using the inventor information in patents as an innovative method of analyzing researcher mobility allows an identification of mobile researchers, which can be analyzed from the perspective of the most central target countries, i.e. the countries that are most attractive for German researchers, as well as from the perspective of technology fields[13]. This, in turn, indicates cooperation structures that evolve by the international mobility of researchers and of the internationalization of German R&D activities.

6.2 General Structures in International Researcher Mobility

Within this section, we will analyze the general cooperation structures resulting from international researcher mobility over time, by target country and by different technology fields.

For the year 2000, a total of 28,503 distinct German inventors transnational of patent filings from all German patent applicants can be identified. Of these 28,503 inventors, 1,674 filed a patent with a foreign inventor address between 2000 and 2009, which results in a share of 5.9% in total. These mobile researchers file a total of 7,384 patents between the years 2000 and 2009. When differentiating the mobile researchers by filing with German and non-German patent applicants between 2000 and 2009, it can be found that 2.9% of the mobile researchers file their patents from a foreign address but remain with a German applicant. 4.2% of the mobile researchers file their patents from a foreign address and a non-German applicant is stated on the patent application.[14] This can be seen as a first indication that the mobility of researchers more often occurs between firms than within, which will be analyzed in more detail in section 6.3. However, we have to keep in mind that researchers might change to another firm that is affiliated to the enterprise of origin.

Figure 14 presents these trends over time, i.e. the annual share of mobile researchers (2000-2009) in all researchers named on German patent filings of the year 2000. With the help of this graph, it can be shown in which year (after 2000) most of the researchers leave Germany. In addition, the graph shows which share of researchers stays with a German firm after 2000 and which share changes to a foreign firm.

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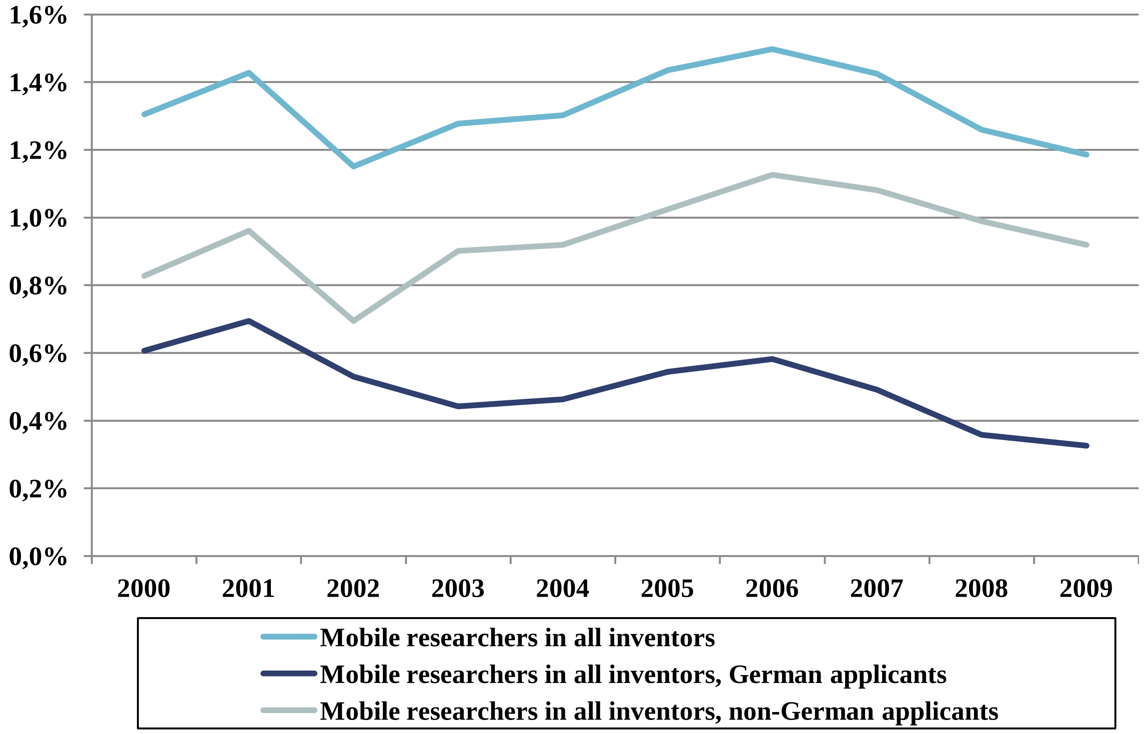
13 As for the technology field differentiation the 38 high-technology fields (Gehrke et al. 2013) will be employed.

14 Mobile researchers might change their address more than once between 2000 and 2009, which results in double counts within the analyses. Thus, these figures do not add up to 5.9%.

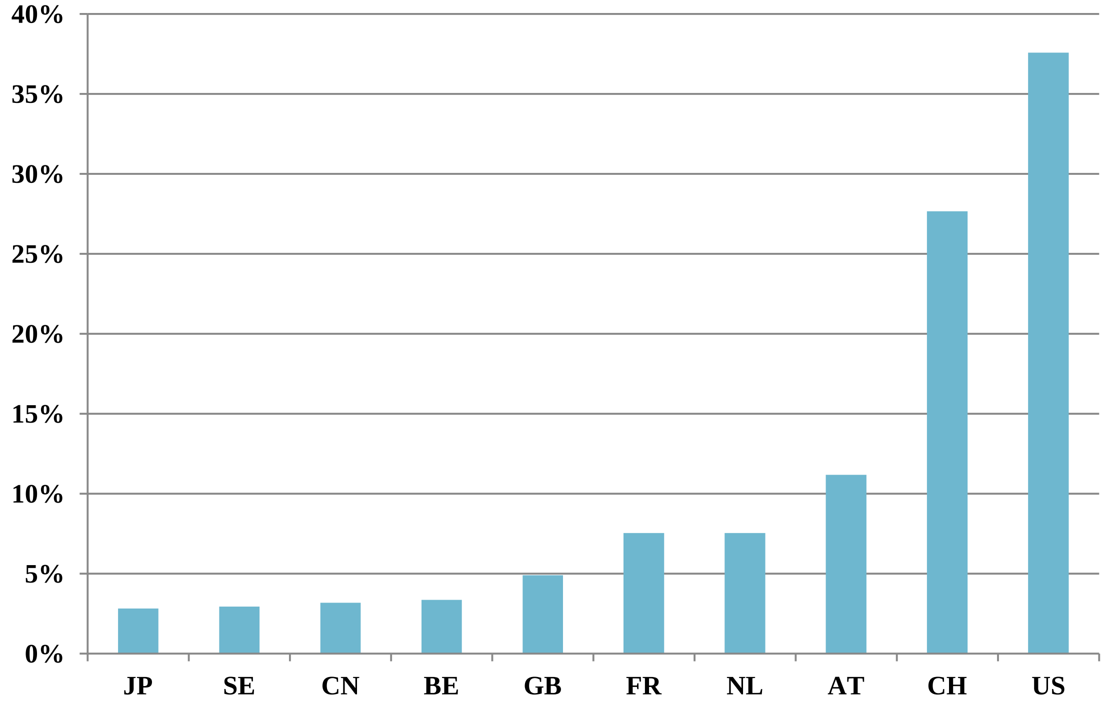
Figure 14 Share of mobile researchers, 2000-2009



Source: EPO –PATSTAT, Fraunhofer ISI calculations.

As can be seen from the figure, researcher mobility is comparably high in the year 2001, followed by a rather steep decrease in the year 2002. From 2003 onwards, the share of mobile researchers increases up to 1.5% in the year 2006. From then on, we once again observe a slight decrease in researcher mobility. A similar trend can also be observed for researchers that wander off to non-German applicants. As for the German applicants, the trend seems a little more stable, i.e. the decrease in the year 2001 as well as the following increase are not that clearly visible.

Figure 15 Share of mobile researchers by target (inventor) country, Top-10 countries, 2000-2009

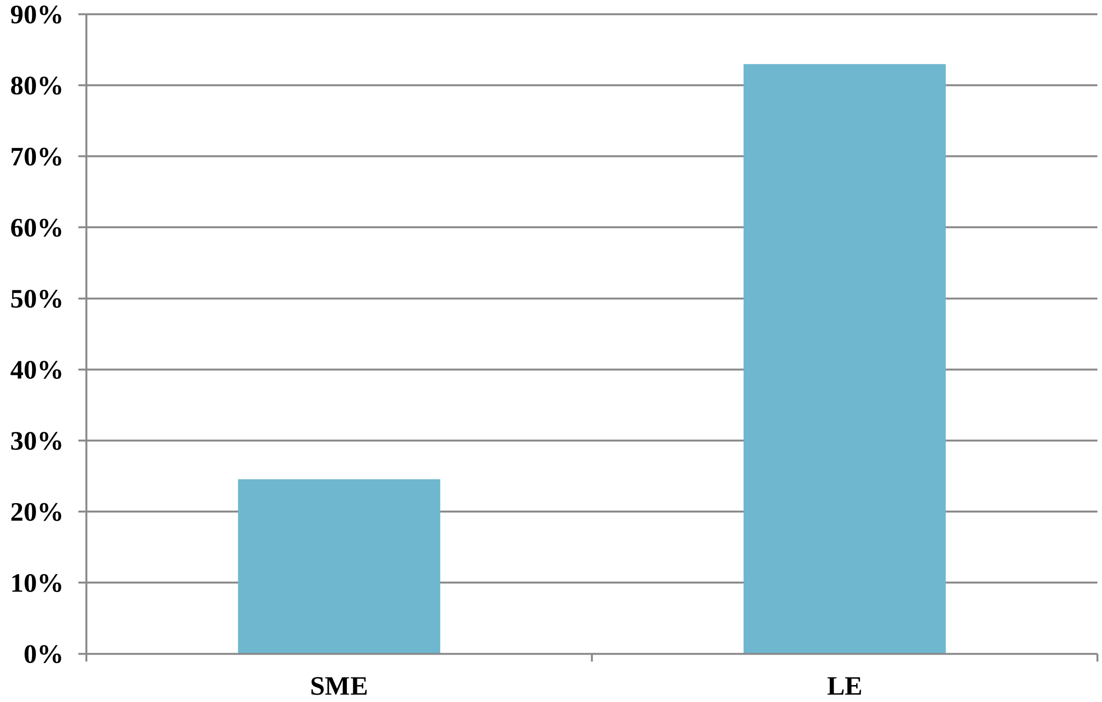


Source: EPO –PATSTAT, Fraunhofer ISI calculations.

Another question within this framework is to which country mobile researchers relocate most frequently. In other words, which are the most interesting target countries for mobile researches from Germany? Figure 15 thus shows the share of mobile researchers (2000-2009) by target country in all mobile researchers for the Top10 target countries. As we can see, the USA is with 38% the most attractive target country for mobile researchers after the year 2000. It is followed by Switzerland, where about 28% of all mobile researchers move to. The next most attractive countries are Austria, the Netherlands and France, although the shares are rather low compared to Switzerland and the US, i.e. 11%, 8% and 8%, respectively. Japan, Sweden, China, Belgium and Great Britain are at similar levels with values between 3% and 5%.

The importance of the US and Switzerland can be interpreted as a sign of internationalization of German researchers, i.e. they relocate to the US and Switzerland more frequently. Yet, it might also have to do with the management strategy of German firms, gaining more and more affiliations in the US and Switzerland and partly moving their research centers there (Belitz et al. 2006). Third, at least in the case of Switzerland, this might also resemble commuting effects, i.e. researchers that live at the border to Germany and commute between their home and their workplace in Switzerland or vice versa.

Figure 16 Share of mobile researchers by SMEs and LEs, 2000-2009



Source: EPO –PATSTAT, Fraunhofer ISI calculations.

Note: The shares of mobile researchers from SME and LE applicants exceed 100% as some researchers might a) file a patent from a German SME and LE in the year 2000 or b) file a co-patent with an SME/LE applicant, respectively.

Apart from country-specific effects, i.e. the question where mobile researchers go to most frequently, it is also interesting which type of company these researchers come from. Is researcher mobility more common in small or in large firms?

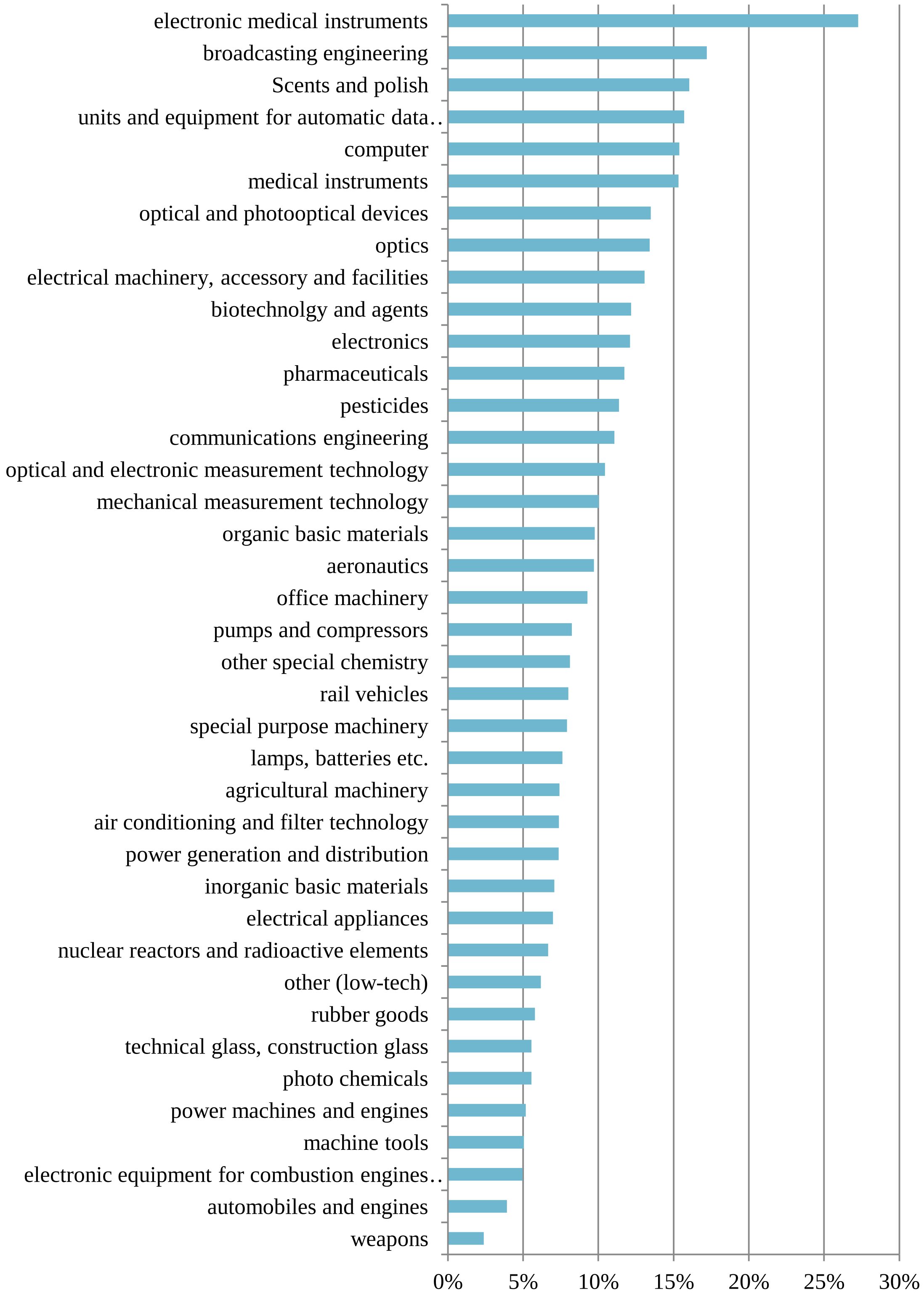
The answer to this question can be found in Figure 16, which shows the share of mobile researchers (2000-2009) differentiated by the type of the patent applicant (SME vs. LE) in all mobile researchers. We can see that researchers from LEs are more often mobile than researchers from SMEs. Whereas only about 25% of researchers that move to another country come from SMEs, 83% come from LEs. This implies that researchers in German LEs are more often mobile than in SMEs, which might be due to their stronger international orientation, a higher probability of moving to a foreign subsidiary or simply reflecting the higher turnover of personnel in LEs.

However, this graph still represents an absolute view, which is not independent of size effects, i.e. a larger number of researchers, in absolute terms, is employed in large firms. When calculating the share of mobile researchers from SMEs in all researchers from SMEs of the year 2000, it can be found that 8.19% of all SME inventors are internationally mobile between 2000 and 2009. For LEs this share is only about 6.19%.

In Figure 17 and Figure 18, we will now concentrate on the field-specific trends in international researcher mobility. Figure 17 first of all shows the share of mobile researchers in all researchers of the year 2000 by technology field. With the help of this graph, we can identify in which fields researcher mobility, relatively seen, is most highly pronounced, absent size effects of the respective fields in terms of patenting. As we can see from the figure, researchers are by far most highly mobile within the field of electronic medical instruments. About 27% of all researchers of the year 2000 within this field move to another country within the years 2000 to 2009. It is followed by broadcasting engineering and scents and polish, where shares of 17% and 16%, respectively, can be reached. Also within the fields of automatic data processing, computers and medical instruments, researcher mobility is comparably high. It thus seems that German researchers are especially mobile in ICT-related fields as well as fields related to medical instruments. In the fields of weapons, automobiles and engines, machine tools etc. researcher mobility is rather low. Thus, the fields of mechanical engineering, where Germany has its technological strengths, do not have a high researcher mobility in general. It rather seems that in fields where Germany does not have its technological strengths, researchers more often move to different countries. This indicates some sort of "brain drain", at least if these mobile researchers move to different companies and do not stay within the parent firm.

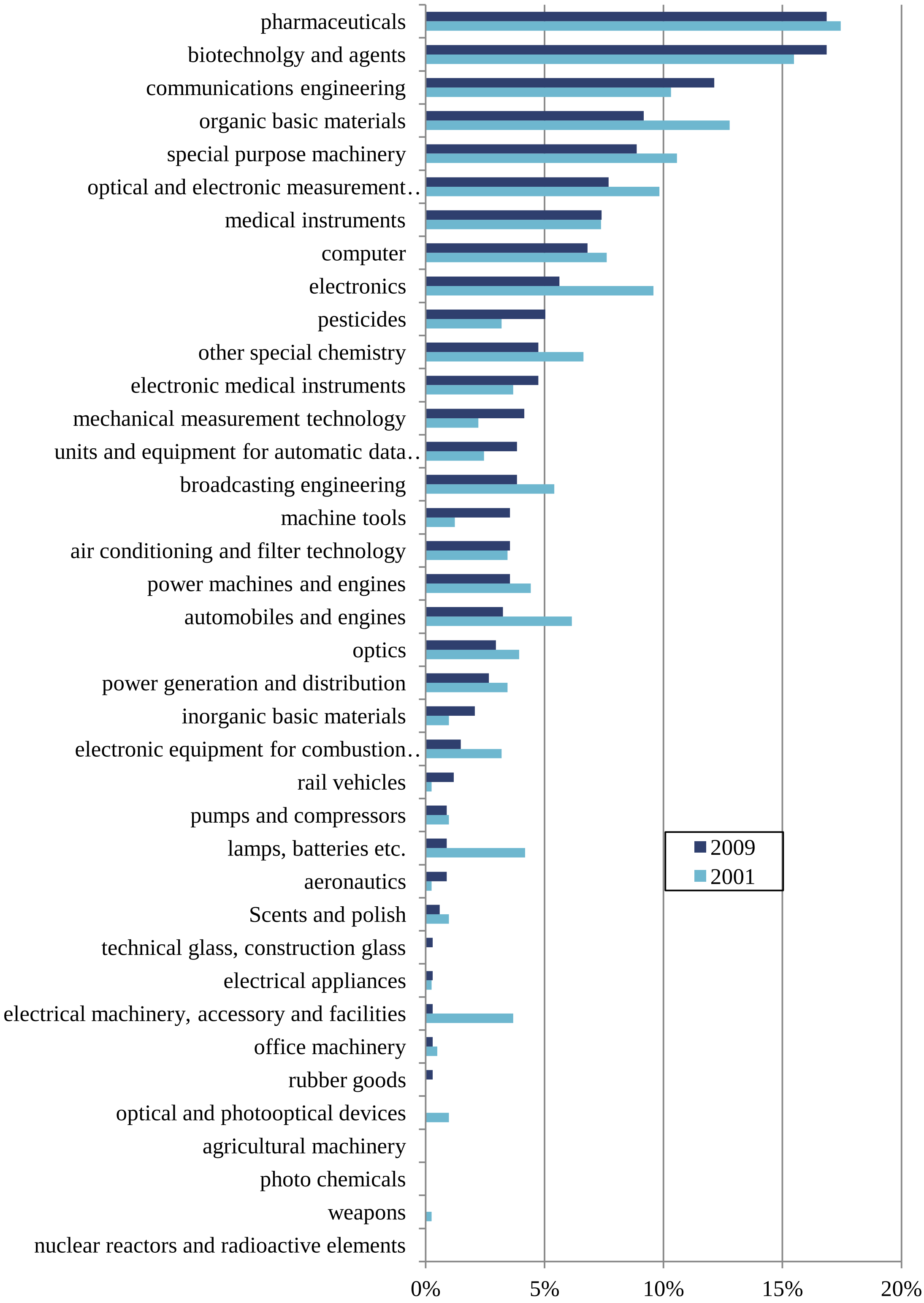
In Figure 18, we now take on another field-specific perspective. The figure shows the share of mobile researchers by technology field in all mobile researchers of the respective year. Thus, this, so to say, resembles the absolute perspective, which, however, is not independent of size effects within the respective fields. When looking at the figure, it can be found that especially pharmaceuticals and biotechnology are the fields where researcher mobility is highest. In the fields of nuclear reactors, weapons and photo chemicals, researcher mobility is rather low. However, these fields can also be seen as comparably small in terms of absolute patenting activity. The comparison over the two analyzed time periods shows that researcher mobility has increased especially in biotechnology, communications engineering, pesticides and machine tools, whereas it has decreased in organic basic materials, electronics and automobiles and engines.

Figure 17 Share of mobile researchers (2000-2009) in all inventors of the year 2000, by technology field



Source: EPO –PATSTAT, Fraunhofer ISI calculations.

Figure 18 Share of mobile researchers by technology field in all mobile researchers, 2001 and 2009



Source: EPO –PATSTAT, Fraunhofer ISI calculations.

6.3 Intra- and Extra-Firm Mobility

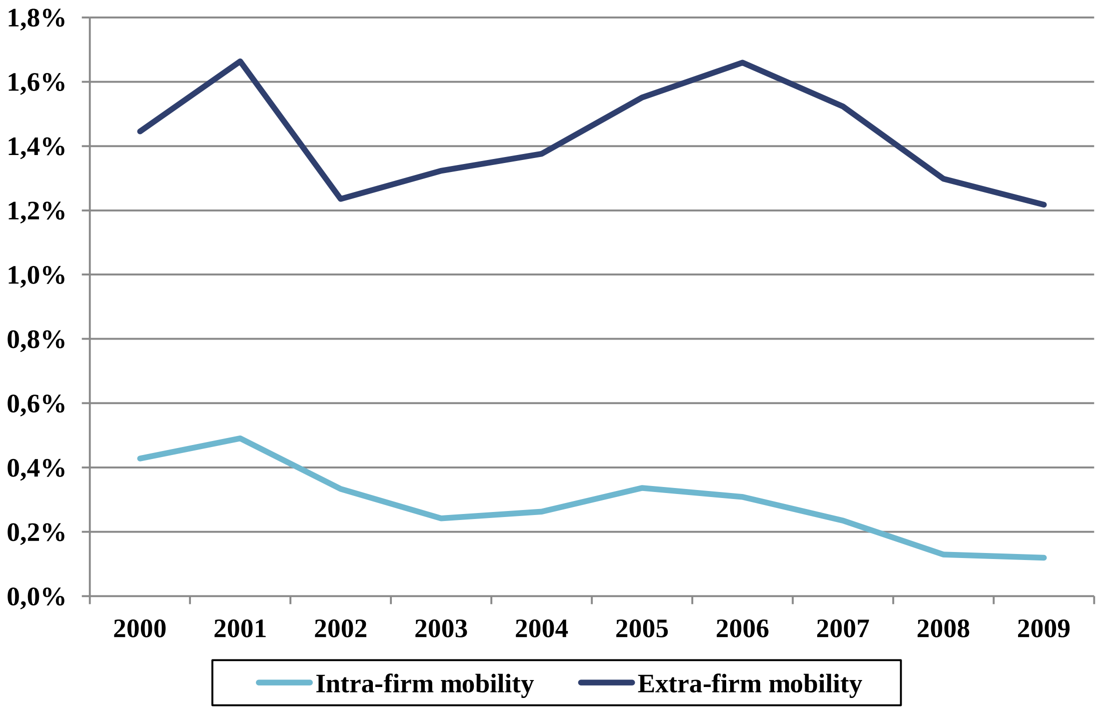
Based on the findings of the general trends of international researcher mobility, within this section, we will present the results of the analyses of intra- and extra firm mobility. Methodologically, intra- and extra-firm mobility is defined via the harmonized patent applicant name in PATSTAT (Du Plessis et al. 2009; Magerman T. et al. 2009; Peeters B. et al. 2009). A researcher that changes his or her address to a foreign country and remains with the same (harmonized) patent applicant is defined as being mobile within the firm (intra-firm mobility) whereas a researcher that changes his or her address to a foreign country and also changes the patent applicant compared to the year 2000, i.e. in this case, the firm, is defined as being internationally mobile outside of his or her original company (extra-firm mobility).

From the 28,503 distinct German inventors of the year 2000, 481 filed a patent with a foreign inventor address and remained with the same applicant, while 1,423 mobile researchers have changed the patent applicant in the subsequent years. This results in a share of 1.7% intra-firm and a share of 5% extra-firm mobility. The researchers that are mobile within their firm are responsible for 1,623 patent applications between 2000 and 2009. The researchers, who are mobile extra-firm, file a total of 6,265 patents within the same time period. Counted per capita, researchers who leave their parent company thus are more patent active in the period 2000 to 2009 than their counterparts that remain with their original company (4.40 vs. 3.37 patents, respectively).

As already stated in the methodology section, for the distinction of intra- and extra-firm mobility, we cannot make sure if a researcher actually leaves the enterprise (including all of its affiliates) or simply moves to a subsidiary or affiliated firm and therefore at least remains attached to his or her original employer. In order to qualify our findings in regard to this issue, for one German enterprise, namely the Siemens AG, we gathered all the information on subsidiary names from the Creditreform Amadeus company database. This enables us to draw a picture of international intra- and extra-firm researcher mobility including subsidiary information and compare these results to our more general findings. In sum, we find that within the Siemens AG, 28.6% of the researchers of the year 2000 are mobile intra-firm (including subsidiaries) between 2000 and 2009. When calculating the same ratio for all mobile researchers we have identified in our sample, we find that 28.7% of these researchers are mobile within the parent company. We thus conclude that using the harmonized applicant name for the identification of intra- and extra-firm mobility delivers rather robust results.

When analyzing the trends of intra- and extra-firm mobility over time (Figure 19), it can first of all be found that over all years, the share of extra-firm mobility is higher than the share of intra-firm mobility. About two thirds of mobile researchers thus change the company when relocating to another country, about one third is mobile within the parent company. Secondly, we can see that from the year 2002 onwards, the share of extra-firm mobility increases up to a peak in 2006, whereas intra-firm mobility rather shows a decreasing trend over the years. Consequently, the difference between intra- and extra-firm mobility rises over the analyzed time period. In 2009, 1.1% of all inventors from the year 2000 are mobile extra-firm whereas only 0.1% are mobile intra-firm.

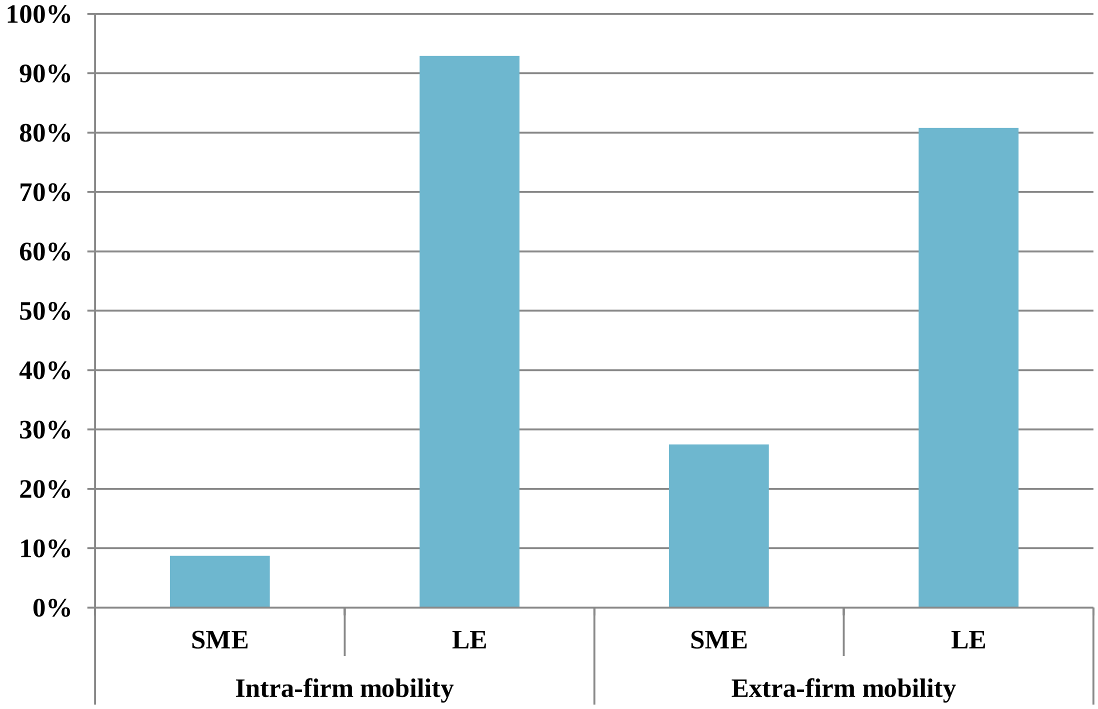
Figure 19 Share of mobile researchers, intra- and extra firm, 2000-2009



Source: EPO – PATSTAT, Fraunhofer ISI calculations.

Looking at the firm-size specific shares of mobile researchers (Figure 20), which shows the share of mobile researchers (2000-2009) differentiated by the type of the patent applicant (SME vs. LE) in all mobile researchers in intra- and extra-firm mobility, we can see that researchers from LEs are more often mobile than researchers from SMEs. This confirms the trends found in Figure 16, but additionally shows us that this is true for intra- as well as extra-firm mobility. Yet, it can also be shown that for SMEs extra-firm mobility is by far more common than intra-firm mobility. This makes sense, as large enterprises more commonly operate research facilities etc. in foreign countries, whereas this is a rare phenomenon in the case of SMEs.

Figure 20 Share of mobile researchers by SMEs and LEs, intra- and extra-firm mobility, 2000-2009



Source: EPO –PATSTAT, Fraunhofer ISI calculations.

Note: The shares of mobile researchers from SME and LE applicants exceed 100% as some researchers might a) file a patent from a German SME and LE in the year 2000 or b) file a co-patent with an SME/LE applicant, respectively.

However, once again this graph is not independent of size effects, i.e. a higher number of researchers in total is employed in large firms, which is why the shares of mobile researchers are naturally higher. When calculating the share of extra-mobile researchers from SMEs out of all researchers from SMEs of the year 2000, it can be found that 7.85% of all SME inventors are mobile extra-firm between 2000 and 2009. For large enterprises this share is only about 5.05%. This is in accordance with the general trend. Yet, when calculating the same share for intra-firm mobile researchers, it can be observed that only 0.55% of all SME inventors are mobile intra-firm between 2000 and 2009, whereas this share is about 2.05% for LEs. In sum, this means that in general SME researchers, relatively seen, are more mobile than LE researchers. This, however, is only true for extra-mobile researchers. Intra-firm mobility occurs more commonly in large firms, also from a relative point of view.

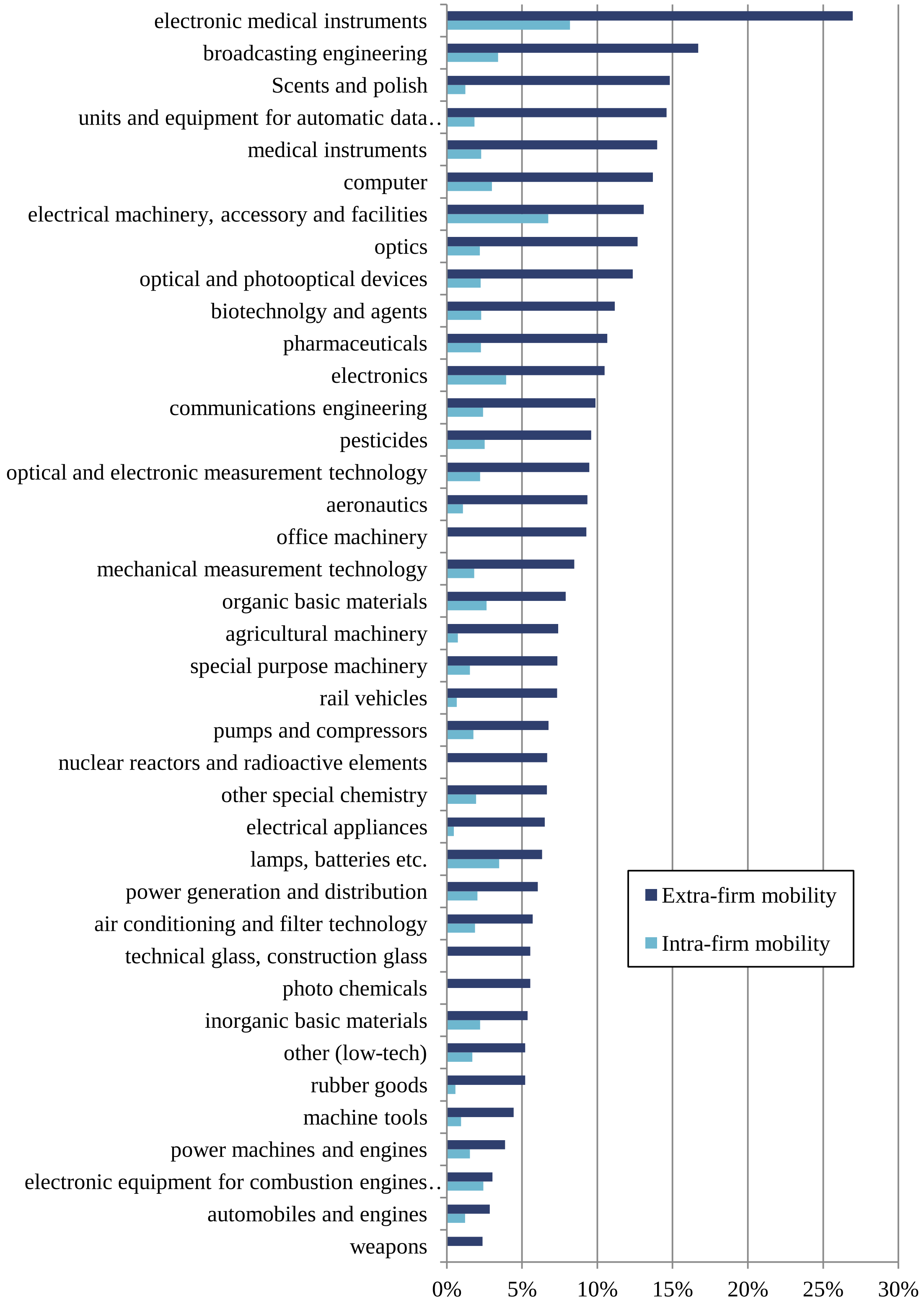
In Figure 21 and Figure 22, we look at the field-specific trends in intra- and extra-firm mobility. As in the previous section, we first of all focus on the most important fields in terms of researcher mobility in a relative perspective, i.e. in which fields the researcher mobility, relatively seen, is most highly pronounced (Figure 21).

In Figure 21, we can see that extra-firm mobility is most prominent in electronic medical instruments, broadcasting engineering and scents and polish. Since extra-firm mobility constitutes the larger part of researcher mobility in general, we can state that the trends found in Figure 17 are mostly driven by extra-firm mobile researchers, although also intra-firm mobility is highly important in electronic medical instruments. Intra-firm mobility generally seems to play a major role within the fields of electrical engineering. We find rather high shares in electrical machinery, accessory and facilities as well as electronics and lamps and batteries. Relatively seen, intra-firm mobility of German researchers thus is highly prominent in electrical engineering.

Figure 22 shows the share of mobile researchers by technology field in all mobile researchers, differentiated by extra- and intra-firm mobility. This once again resembles the absolute perspective, which is dependent on the size of the respective field in terms of patenting activity. As for the shares of researchers that are mobile extra-firm, the figure closely resembles the trends we have seen in Figure 18. This, however, is not surprising since extra-firm mobility is more common than intra-firm mobility, which also drives the shares in Figure 18. Extra-firm researcher mobility is highest in pharmaceuticals, biotechnology and communications engineering, whereas researchers in the fields of nuclear reactors, weapons and photo chemicals are not mobile at all.

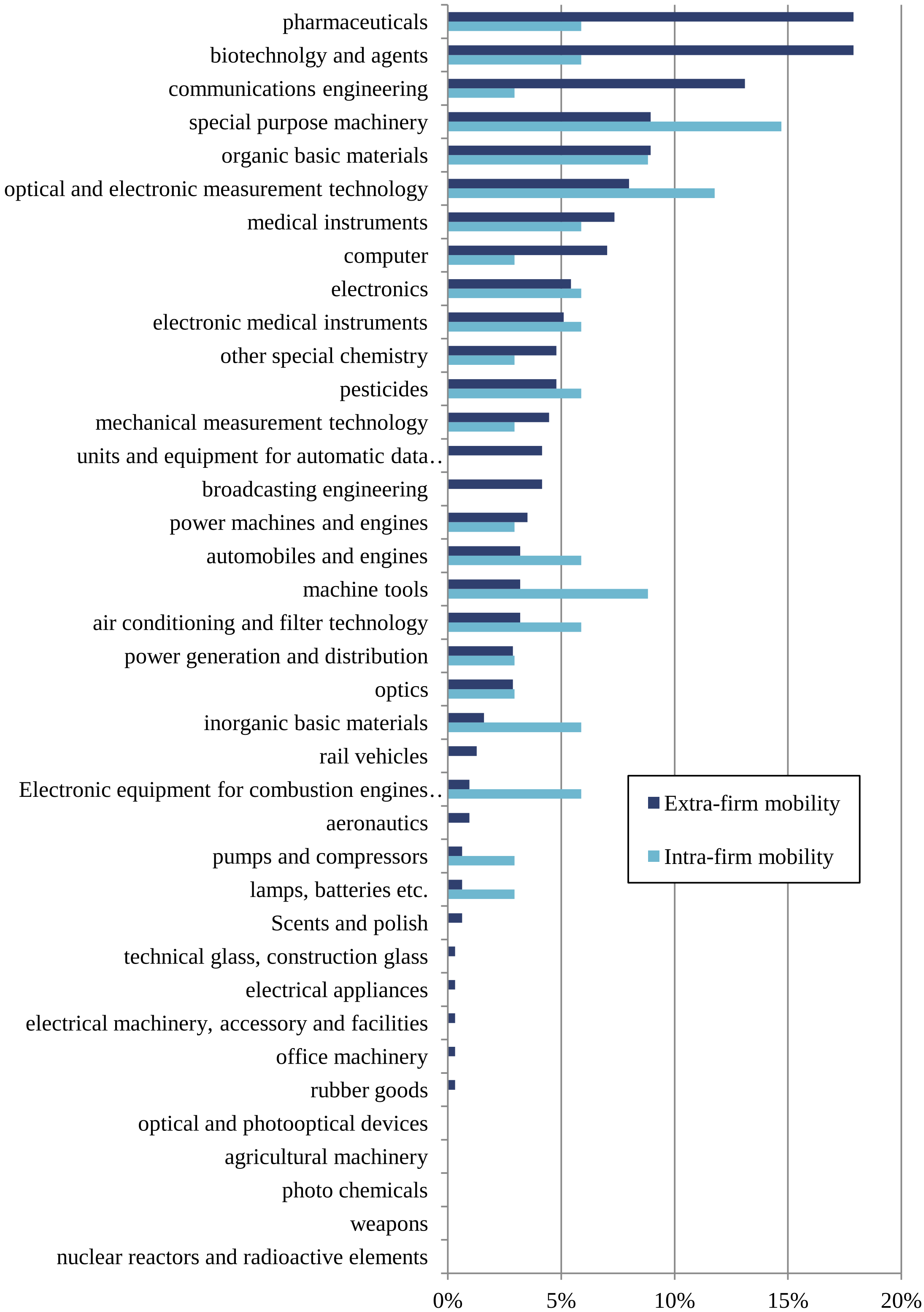
Most interestingly, however, are the numbers for intra-firm researcher mobility. Intra-firm mobility is highest in the fields of special purpose machinery, optical and electronic measurement technology, machine tools and automobiles and engines. Thus, it seems that researcher mobility within German firms most often takes place in the mechanical engineering fields, at least in absolute terms.

Figure 21 Share of mobile researchers (2000-2009) in all inventors of the year 2000, extra- and intra-firm mobility, by technology field



Source: EPO –PATSTAT, Fraunhofer ISI calculations.

Figure 22 Share of mobile researchers by technology field in all mobile researchers, extra- and intra-firm mobility



Source: EPO –PATSTAT, Fraunhofer ISI calculations.

6.4 Conclusions

Within this analysis, international researcher mobility was analyzed via changes in inventor addresses on patent filings. Although this method has certain weaknesses, i.e. we can only identify inventors/researchers who are actively patenting, it provides a precise identification of mobile researchers and opens avenues for further research on cooperation structures that evolve via international researcher mobility.

In sum, we find that nearly 6% of German researchers are internationally mobile. Over the years, a peak in researcher mobility in the years 2001 and 2006 can be identified, while the numbers are slightly decreasing up to the year 2009. As for the target countries, we find that at least in recent years, the USA and Switzerland are the most attractive countries for mobile researchers to go to. The field comparison shows that, at least in absolute terms, researcher mobility is highest in pharmaceuticals and biotechnology, whereas relatively seen German researchers are most highly mobile in ICT as well as in medical instruments. It seems that there is some kind of "brain drain" going on in these two fields, where Germany does not have its particular technological strengths. In fields where Germany has a rather strong technology base, i.e. mechanical engineering, researcher mobility is rather low in comparison.

The analyses of intra- and extra-firm mobility show that mobile researchers most often change the company when going to a foreign country. Only 1.7% percent of the inventors are mobile within their parent company, whereas about 5% change their employer. Over the years, extra-firm mobility even seems to become more prominent among researchers, whereas intra-firm mobility looses importance. However, intra-firm mobility is highest within the mechanical engineering fields (in absolute terms) and highly prominent in electrical engineering (in relative terms), whereas extra-firm mobility most often occurs in sectors like pharmaceuticals or biotechnology.

7 Annex

Table 8 Multivariate Results III

	Share: Transnational filings/patent families			Share: Withdrawn patents/EPO filing stocks			Share: Lapsed patents/EPO grant stocks		
	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
1993	0.182	***	0.010	-0.010	**	0.004	-0.026	***	0.010
1994	0.253	***	0.010	-0.009	**	0.004	-0.046	***	0.009
1995	0.275	***	0.010	-0.012	***	0.004	-0.060	***	0.009
1996	0.306	***	0.010	-0.027	***	0.004	-0.076	***	0.009
1997	0.369	***	0.010	-0.034	***	0.004	-0.061	***	0.009
1998	0.368	***	0.010	-0.033	***	0.004	-0.070	***	0.009
1999	0.404	***	0.010	-0.033	***	0.004	-0.076	***	0.009
2000	0.417	***	0.010	-0.029	***	0.004	-0.057	***	0.009
2001	0.440	***	0.010	-0.037	***	0.004	-0.078	***	0.009
2002	0.429	***	0.010	-0.020	***	0.004	-0.029	***	0.009
2003	0.429	***	0.010	0.007	*	0.004	-0.006		0.009
2004	0.430	***	0.010	0.012	***	0.004	-0.016	*	0.009
2005	0.464	***	0.010	0.014	***	0.004	-0.023	**	0.009
2006	0.468	***	0.010	0.021	***	0.004	-0.025	***	0.009
2007	0.485	***	0.010	0.026	***	0.004	-0.103	***	0.009
2008	0.505	***	0.010	0.032	***	0.004	-0.044	***	0.009
2009	0.522	***	0.010	0.035	***	0.004	-0.041	***	0.009
2010	0.619	***	0.010	0.052	***	0.004	-0.020	**	0.009
Constant	0.213	***	0.012	0.078	***	0.005	0.183	***	0.011
Field Dummies	Yes			Yes			Yes		
Country Dummies	Yes			Yes			Yes		
Applicant Type Dummies	Yes			Yes			Yes		
Number of obs.	27761			30810			25499		
LR chi2	28329.68			5071.12			2297.52		
Prob > chi2	0.000			0.000			0.000		
Pseudo R2	0.7465			-0.3619			0.2505		

Significance level: ***p<0.01, **p<0.05, *p<0.1. Tobit panel-models, marginal effects. The base year for the time-dummies is 1992.

Source: EPO – PATSTAT; Fraunhofer ISI calculations.

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