Academic Patents in Germany

Friedrich Dornbusch, Peter Neuhäusler

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Pariser Platz 6

10117 Berlin

http://www.e-fi.de/

Contact address and further information:

Dr. Peter Neuhäusler

Fraunhofer Institute for Systems
and Innovation Research ISI
Competence Center Policy and Regions
Breslauer Strasse 48
76139 Karlsruhe
Phone: +49-721-6809-335
Fax: +49-721-6809-176
E-Mail: peter.neuhaeusler@isi.fraunhofer.de

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0 Summary

Within this study, we compare the patenting activities by universities and public research institutes in Germany. The crucial problem hereby is that a large share of patent filings from universities is registered by companies and the university staff only appears as an inventor. Therefore, improved approaches, which are also able to detect patent filings that have not been formally submitted by universities themselves, are needed in order to correctly identify the amount of university patents. Within the course of this analysis, we take both viewpoints, i.e. the “applicants' perspective” and the extended perspective of “academic patents”, which takes university inventors into account.

Patents filed by research organizations, i.e. universities and public research institutes, account for about 5% of all EPO filings from German applicants. However, the number of patent filings, in absolute as well as relative terms, has increased over the last 20 years, which is even more pronounced for universities than for public research institutes. This has led to a convergence in the number of patent filings between universities and public research institutes in the recent years, which can be attributed to the abolishment of the “Hochschullehrerprivileg” (“professor's privilege”) in 2002 and the larger focus of German universities on commercializing their inventions. When taking a more differentiated look at the different public research institutes, it can be found that the Fraunhofer Society is responsible for the largest share of patent filings, followed by the Helmholtz Society and the Max-Planck Society. A differentiation by technological fields reveals that the field-specific profiles of universities and public research institutes in Germany complement each other. While universities are mostly focused on chemistry and related fields, the public research institutes have a larger focus on electrical engineering, instruments and mechanical engineering.

Yet, the contribution of universities and their employees to patented research is definitely underestimated by only accounting for university filed patents. Conservative estimations show that all patents with academic involvement (academic patents) account for 5.1% of all German applications at the EPO between 2001 and 2010. At the same time, university-owned patents accounted for round about 1.5%. Thus, our findings confirm that academic science significantly contributes to patenting activities and we find further support for the assumption that German scientific research has, even compared to other European countries, a strong effect on technological development. Secondly, we find that the overall amount as well as the shares of academic patents experienced comparatively low growth rates. Actually, between 2001 and 2005, they rather underwent a decline in absolute as well as relative terms. At the same time, university-owned patents experienced an impressive rise, initiated by the abolishment of the professors’ privilege (Hochschullehrerprivileg) in 2002. Remembering that university patents are a subsample of academic patents, differing dynamics between both samples raise further questions. A deeper look into the structures in academic patenting reveals that technology-specific activities leading

to academic patents in purely academic inventor teams (university-owned), privately owned (private applicants) and in collaborations with SMEs (SME-owned) are pretty similar in terms of technological fields. They seem to resemble the picture of science-driven technological development. The portfolio of large enterprises (LE-owned), however, is likely to reflect their own R&D activities with a stronger focus on engineering related areas. Public research institutes (PRI-owned) exhibit a similar portfolio to large firms, reflecting their heterogeneity and their stronger focus on electrical engineering, instruments and mechanical engineering even in collaboration with universities.

A detailed analysis of the trends and dynamic in the ownership structure in academic patents revealed three important findings. Firstly, other than previous approaches, we observe a slightly rising trend in academic patenting which is solely driven by the ever-increasing patenting activity not only by universities, but also by public research institutes. Secondly, we find that the largest share of academic patents is filed by large and small firms. Thirdly, however, firm filings in relative and absolute terms exhibit a negative trend. This goes hand in hand with increasing filing activities by universities and public research organizations. Nevertheless, it becomes obvious that, while small firms reveal a negative trend, large firms appear to be less sensitive and display a rather robust trend.

1 Introduction

The creation, diffusion and application of scientific and technological knowledge are crucial foundations of technological activities and key elements for the performance of national innovation systems. Basic scientific research hereby plays a significant role. Scientific achievements are mostly published in journals, so that other scientists can access them and consequently cite them if they deem them appropriate (Michels et al. 2013). Besides publications, however, patent filings are a major output of R&D activities of universities and public research institutes and can consequently be used to assess the technological output of these research organizations. Patents are filed to achieve temporary protection of technologically new products or processes on the market place (Schmoch 1997). Therefore, patents indicate an interest in the commercial exploitation of a new finding or a new technology. Compared to the publication of scientific results in scientific journals, they are more strongly focused on measuring an orientation towards the technological application of a given invention. By applying patent statistical indicators to measure the performance of German universities and public research institutes (PRI), we are able to assess the technology-oriented output of these research organizations.

In the recent years, knowledge and technology transfer from universities has been seen as an important approach towards the modernization of economic structures and the promotion the economic dynamics (Achleitner et al. 2009; Crespi et al. 2011; Egeln et al. 2007). A set of policy actions was undertaken to strengthen and improve the efficiency of technology transfer between university and industry. In doing so, universities were given a higher autonomy and flexibility, enabling them to introduce own regulations that apply to the management of technology transfer, contracts with industry and IPR. A complementary and important aspect has been seen in promoting patent filings from universities. Since the end of the 1990s, most European countries have been moving away from the individual ownership of academic patents towards systems of institutional ownership by the universities (Geuna and Rossi 2011). This trend was initiated based on the assumption that the levels of university patenting in Europe were low compared to the US. The Bayh-Dole Act, introduced in 1980 in the US, was seen as the main driver behind the growing patent portfolios of US universities. It acted as a prototype and role model for many European countries, even though the conclusions about its effect on knowledge and technology transfer were far from definite or conclusive (Kenney and Patton 2009; Mowery and Sampat 2004). Germany was one of the countries which introduced rules similar to Bayh-Dole and abolished the traditional professor's privilege (Hochschullehrerprivileg) in 2002. Since then, employee inventions are owned by the employing university and no longer by the inventors themselves. If, however, research is financed fully or partly by external contractors like private companies, it remains possible for parties to negotiate the allocation of patent rights between the university, the company and the individual inventor (Geuna and Rossi 2011).

The changes in the legal framework were accompanied with the establishment of "Patentverwertungsagenturen" (PVAs) (patent exploitation agencies). Their task and primary business model is to help universities and to act as a service provider for the assessment, filing, exploitation and commercialization of IPR. The universities remunerate the PVAs and are financially supported with a specific funding program (e.g. SIGNO Hochschulen).

Despite these quite extensive policy actions, still a large share of patent filings from universities is registered by companies and the university staff only appears as an inventor. Especially in Germany, a long tradition of university researchers to co-operate with industry is prevalent. These university-industry networks evolved under an IPR regime of individual ownership of academic patents – the professors' privilege. In sum, two types of governance in university-industry interactions can be observed (see also Geuna and Muscio 2009). The first is governed by individual and personal contractual interactions and is in place since the end of the 19th century. The second is constituted by the new elements in institutional structures (e.g. the establishment of liaison and technology transfer offices as well as patent exploitation agencies) that aim at mediating university-industry interactions as well as managing the ownership of IP resulting from collaborative, contractual or even purely academic research. The question how and if the emergence of the new governance mode influences the old one is still far from being resolved and requires further investigations. One perspective to contribute to this discussion is to analyze the structures and trends in academic patenting. Academic patents have a number of statistical applications. Firstly, they are not only key indicators of technology transfer activity, but also of university-industry ties, because they provide relational information on the institutional as well as individual level (Lissoni 2012). Yet, all analyses simply referring to the applicant criterion can be substantially misleading. Therefore, measuring and evaluating the effect of the politically driven initiatives from a short- as well as long term perspective became an important methodological challenge for scientists.

In recent years, basically two previous approaches have been applied to identify university-based patents. Firstly, searching academic titles (PROF, etc.) on official documents, even though this is no legal part of the name, helped to identify patents where Professors listed their title on a filing. This approach has been used several times by, e.g. Schmoch (2007) and up to now was the only solution to gain reliable estimates for Germany. However, a limitation of this approach is that it is limited to Germany and Austria, since only these countries commonly indicate the "Professor" title. Furthermore, it is limited to inventors declaring the title "professor". Other university staff members (e.g. assistants or PhD student) and professors not declaring their title are not found. This number of other academic inventors could consequently only be estimated. Furthermore, anecdotal evidence indicates a decrease of the title declaration. Secondly, a more recent and innovative approach matches existing staff lists of universities with the names of inventors listed on patents. This has been done for the US by Thursby et al. (2009) and by Lissoni et al. (2009; 2008) for France, Italy and Sweden in the KEINS project (Knowledge-based Entrepreneurship:

Innovation, Networks and Systems). However, an important limitation is that most countries (like Germany) do not keep comprehensive and up-to-date lists of university staff. Another problem is that such staff lists are usually limited to persons with an official function like tenured professors. Thus, there is the risk of missing certain groups of inventors.

Thus, for a correct detection of patterns and trends of patent applications from German universities, an improved approach is needed, which is also able to detect patent filings that have not been formally submitted by universities themselves. Our approach is based on the idea of checking the names of scientific authors, thus research-active university staff, and patent inventors. Within the course of this analysis, we are therefore able to take both viewpoints, i.e. the “applicants' perspective” and the extended perspective of “academic patents”, which take university inventors into account. This allows us to observe both sides of the same coin and enables us to detect possible special patterns that only become observable when both views are taken into account.

In section 2 of this report, we will give a more detailed overview of the databases and methods used within this study. In section 3, the results will be presented. We will first focus on the applicant perspective (section 3.1) and then go into more detail by taking into account those patent filings that have not been formally submitted by universities (section 3.2). Section 4 summarizes the findings from both approaches and discusses potential conclusions.

2 Data and Methods

In this section, the data used for the analyses as well as the methods are presented. We will first give a detailed overview of the data source and important definitions. Second, we will provide information on the two approaches that were chosen in order to identify patent filings from universities and public research institutes.

2.1 The Data

The patent data for this study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from 83 patent authorities worldwide. The 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, patent filings at the European Patent Office (EPO) will be analyzed. In a special analysis, we will additionally take a closer look at patent applications that are targeted towards the German market in order to get a more complete picture of the trends for Germany as a whole. Here, all patents that (sooner or later) 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, are counted. As the lion's share of patents from German applicants/inventors that are granted at the EPO also are targeted towards the GPTO (as a destination office), this method allows us to analyze all patents that are targeted towards protecting the German market.

In addition to the absolute numbers, patent intensities are calculated, which ensures better international comparability. The figures for the patent intensities are calculated as the total number of patent filings per 100 R&D employees (full-time equivalents) in the respective universities and public research institutes. The data on university employees were extracted from the German Federal Statistical Office (Statistisches Bundesamt 2013) as well as the Federal Report on Research and Innovation 2012 (Federal Ministry on Education and Research (BMBF) 2012). The data on employees from PRI also are based on the collection of the German Federal Statistical Office (Statistisches Bundesamt 2012). Gaps within the data for certain years were estimated on the basis of the values of the preceding and following years.

2.2 The identification of patents from universities and public research institutions

For the analysis of patents from universities, the definition of "university patents" is crucial. Thereby, it is especially important to differentiate patents filed by universities from

patents that are based on an invention made within a university. As a result of cooperative projects between research organizations and companies, or in the case of external R&D projects that are carried out by universities on behalf of and financed by companies, inventions arise for which a patent is filed by the company and not the university itself. Frequently, the university is not named on the filing as a patent applicant. While this is not necessarily an urgent matter for PRIs, as they tend to have stronger instruments and experience in the enforce of IPR, previous studies have shown, that for universities, a simple count of the patents, for which the university is named as the applicant, provides only a limited picture of the patent output from universities (c.f. Dornbusch et al. 2013; Lissoni et al. 2009; 2008). To draw a more complete picture of the patent output of universities, also inventions that were made within the university and for which a patent was filed by a company, need to be taken into account to cover the full inventive output of the respective university. Thus recent literature established a basic differentiation between patents filed by the university (in the following defined as "university patents") and patents filed by other applicant types, while university employees where involved in the invention leading to the patent (in the following defined as "university invented patents"). Both groups together are referred to as "academic patents" (c.f. Lissoni et al. 2008). Thus, university patents constitute a sub-sample of academic patents.

Within the course of this analysis, we will take both viewpoints and start by analyzing patents that were filed by universities (university-owned).

Identification of university owned patents by keyword searches

These were identified within the PATSTAT database with the help of a keyword search, including the names of the universities with different spelling variations and languages as well as a search for the names of the respective cities, also including spelling variations and languages. In the case of the Technical University of Munich, for example, patents are filed under the names "TECHNICAL UNIVERSITY OF MUNICH", "TECHNISCHE UNIVERSITAET MUENCHEN", or "TU MUENCHEN". Thus, in a first step, all patents filed by universities will be analyzed. In a second step, we will additionally use the inventor information on patent filings to identify inventors from universities. This novel approach will give us a more complete picture of the patent output of universities by taking those "patents with university involvement" into account. In a final step, we will compare both analytical approaches to see whether special patterns or trends can be identified that only become observable when both views are taken into account.

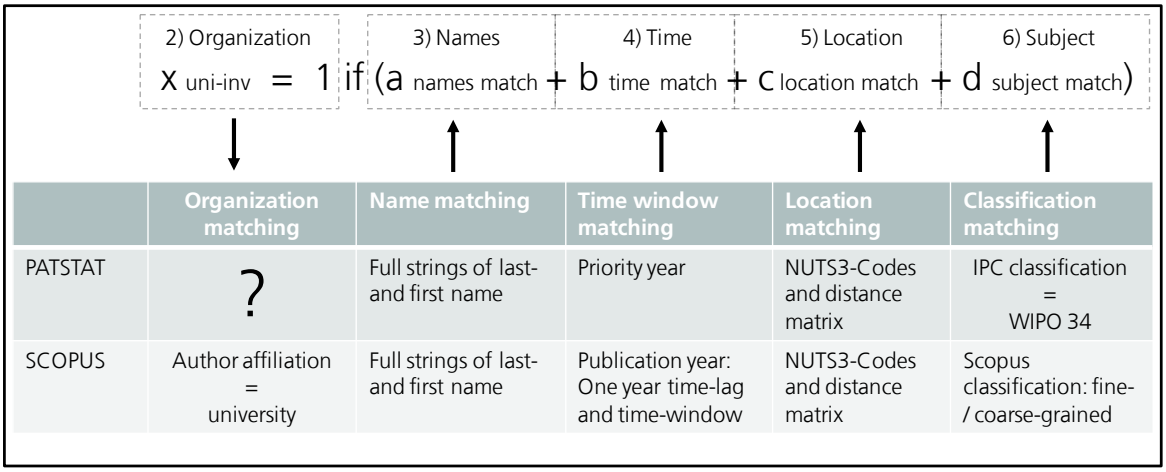
Identification of academic patents: A new large scale approach

The approach for the identification of the whole set of academic patents, including university-invented patents, is based on the examination of name matches of authors of scientific publications and inventors named on a patent filing. Patents do not indicate the employing institution of an inventor, while the publications list the authors' affiliation and enable us

to identify academic inventors and the patents they have contributed to. At the same time this also allows us to connect these patents to the publications of those university employees and academic authors. Thus, the individual academic authors (and inventors) are flagged and their uniquely assigned ID in Scopus serves us as a link between the patents and publications generated by theses individuals. A detailed description of the matching and its validation can be found in Dornbusch et al. (2013). However, we will briefly reflect on this method, in order to explain its application within the context of this paper. The analyses were performed with the Scopus database (2013 version) as Scopus, in contrast to WoS, provides full first names of authors as well as an author-affiliation-linkage for all publication years, which are necessary for the matching. This data was matched with PATSTAT.

The chosen approach exploits relatively large amounts of data and this raises the danger of erroneous matches between person names. This is mainly due to increasing numbers of homonyms, i.e. different persons having identical names. Therefore, the application of additional selection criteria is, as displayed in Figure 1, required in order to ensure an algorithm that matches inventor an author data as precisely as possible.

Figure 1: Selection criteria for academic patents



	Organization matching	Name matching	Time window matching	Location matching	Classification matching
PATSTAT	?	Full strings of last- and first name	Priority year	NUTS3-Codes and distance matrix	IPC classification = WIPO 34
SCOPUS	Author affiliation = university	Full strings of last- and first name	Publication year: One year time-lag and time-window	NUTS3-Codes and distance matrix	Scopus classification: fine- / coarse-grained

Source: Adapted from Dornbusch et al. (2013)

Based on a keyword search and manual correction, the German universities were identified and coded as such within Scopus. Their belonging publications, including the adhering bibliographic information, were stored in one and all EPO filings of German inventors were stored within another separate table. Accordingly, the author-/inventor names from these two tables are matched and, to ensure a high precision, complemented with additional selection criteria (c.f. Figure 1). In detail those were:

- The time window of two years with a one year delay of the patent filing was used to take account of the review process for journal articles. For example, the inventors named on a patent filing from the priority year 2006 were matched with the authors of the publication cohort from the years 2007/2008.

- A further selection criterion used is the match of the inventor address with the location of the university. Here, the NUTS3 code according to the NUTS classification (nomenclature des unités territoriales statistiques) of the OECD was applied. This is an advancement compared to the previously used postal codes as the later do not satisfactorily map functional relations between entities like the working and living places of inventors while NUTS-codes take these into account. To address the problem of rigid regional definitions, we additionally worked with a distance matrix, which also allows adjacent regions to be taken into account by the matching. As a standard, a distance of 30 km was used.
- In order to ensure a content-related correspondence between the matched documents, a concordance between technology fields, based on the existing WIPO35 classification (Schmoch 2008) and science fields within Scopus, was additionally employed (Schmoch et al. 2012).

For the evaluation of the alogorithm a *recall* and *precision* analysis has been applied (Baeza-Yates and Ribeiro-Neto 2011).[1] A precondition for this is to generate exact reference datasets. As for the *recall*, namely the estimate of the proportion of correctly identified documents in all documents, we identified the number of patents with universities themselves as applicants by simple keyword searches, as describe above, and calculated the share of correctly identified patents. The *precision* of the algorithm was validated by an online-survey covering authors for whom academic patents have been identified.[2] Due to the large datasets with imperfect data, 100% for both recall and precision are impossible. However, in order to obtain the best fit between the two, the F-score was calculated.[3]

Figure 2: Recall, precision and F-Score

Selection criteria: Full name +	**Recall**	**Precision**	**F-Scores**	
			R=P (F_1)	P>R ($F_{0,5}$)
Location*	0.71	0.77	0.74	0.76
Subject match	0.71	0.52	0.60	0.55
Location*, subject match	0.59	0.93	0.72	0.83

Source: Dornbusch et al. (2013)

*= Calculations were based on a match of two-digit postal codes, meanwhile NUTS3 Codes including a distance matrix are implemented.

It represents the harmonized mean between recall and precision. A set of different configurations have been tested and the relevant ones, for our purpose of this study, are displayed

1 Recall: CR/(CR + CM), where CR is Correct Recall and CM is Correct Missing (error type I or false negative); Precision: CR/(CR + IR), where IR is Incorrect Recall (errors type II or false positive).

2 The survey addressed 1681 persons with 2782 patent applications at the German patent office. 435 exploitable answers amounting to 678 patents have been received, equaling a response rate of 26%.

3 F-Score: Fß = (1+ß²) (p*r)/(ß²*p*r); p = precision = tp/(tp+fn) and r = recall = tp/(tp+fp) where tp means true positive, fn false negative and fp false positive.

in Figure 2.[4] The combination of full names with the location criterion as well as the subject match obviously achieves the best results (F-Score: 0.83), particularly when giving precision a higher priority over recall. However, as a concession to high precision we have to accept a reduced recall, i.e. the retrieved results are likely to underestimate the amount of academic patents.

Further data restrictions emerge from the publication database SCOPUS. Firstly, as previous analyzes showed, since 2001 the coverage of data on names, postal codes etc. is sufficient to provide comparable analyzes over time. Thus, we stick to the period from 2001 onwards. Secondly, we used the SCOPUS version 2013 where complete data is only available until publication year 2011. Data for 2012 is incomplete. As our matching requires a time-window of three years, we are restricted to the patent priority year 2009 and extrapolated data for 2010. We calculated the average growth rate over the previous three years.

4 Please compare Dornbusch et al. (2013) for a detailed discussion on the effects and the validation of the chosen selection criteria.

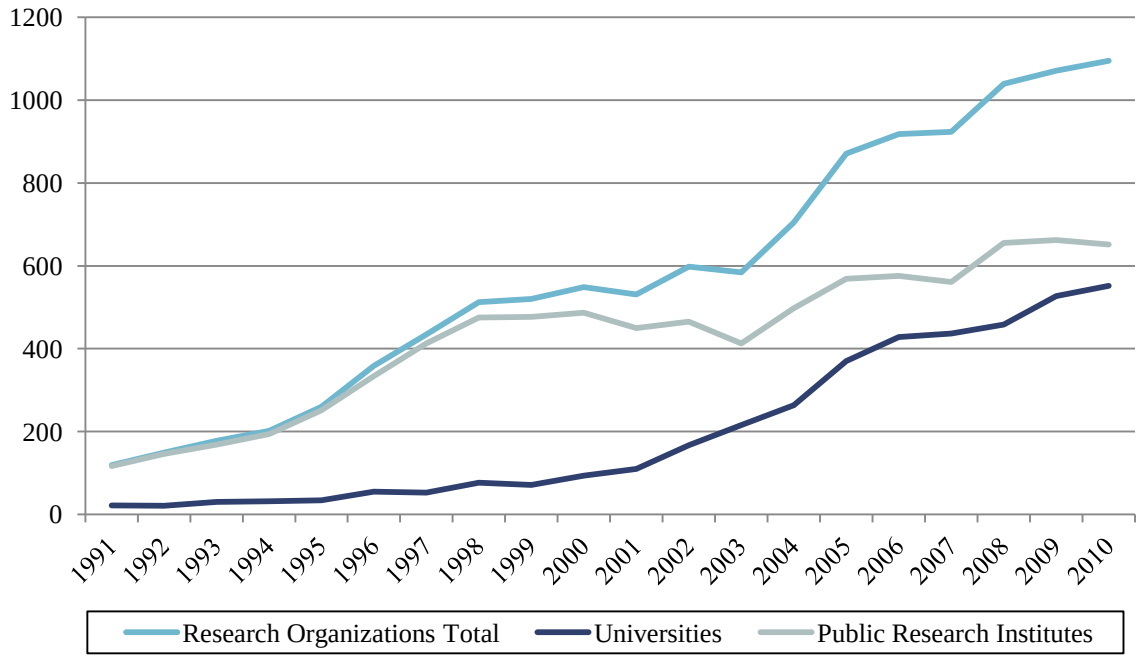
3 Trends in Patent Filings

Within this section, the trends in patent filings by universities and public research institutes in Germany will be presented. First of all, we will take on the applicant perspective and analyze trends in patents filed by universities and public research institutes. In the following sub-section, we will focus on academic patents by universities in order to provide a more complete picture of the trends in academic patenting.

3.1 Patents filed by Universities and Public Research Institutions

Patents filed by research organizations, i.e. universities and public research institutes, only account for a small share of patent filings in total. In only about 5% of all EPO filings from German applicants, a university or PRI is named as the patent applicant (Figure 5). This already reveals that patents are not the major innovative output of public research and that companies are responsible for the largest share of patent applications. However, the increase in patent filings, in absolute as well as relative terms, indicates that patenting has become more and more important for universities and PRI over the last 20 years.

Figure 3: Number of EPO filings by German research organizations, 1991-2010



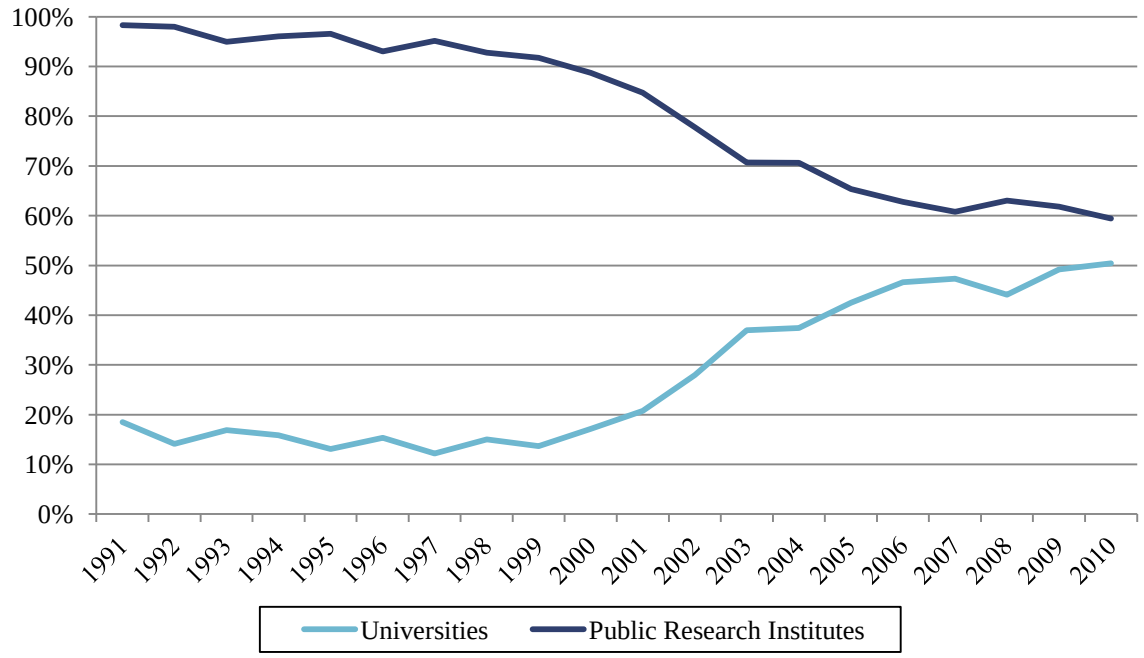
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Note: The sum of patents filed by universities and public research institutes might exceed 100% in certain years due to cooperative patent filings between universities and PRI.

Figure 3 presents the total number of patent filings by research organizations in total, as well as differentiated by universities and PRI. In the year 2010, research organizations were responsible for nearly 1,100 patent filings at the EPO, with 651 filings from PRI and 552 filings where universities are named as the patent applicant. The number of filings from research organizations has risen over the years. It is interesting to see that in the 1990s, filings from PRI have grown much faster than filings from universities. From 2000

onwards, however, higher growth rates can be observed by universities. This increased growth surely has to do with the legislation change of 2002 that was targeted towards promoting patent filings from universities and has led to a convergence in the number of filings from PRI and universities in the last few years.

Figure 4: Shares of filings by universities and public research institutes in all filings by research organizations, EPO, 1991-2010



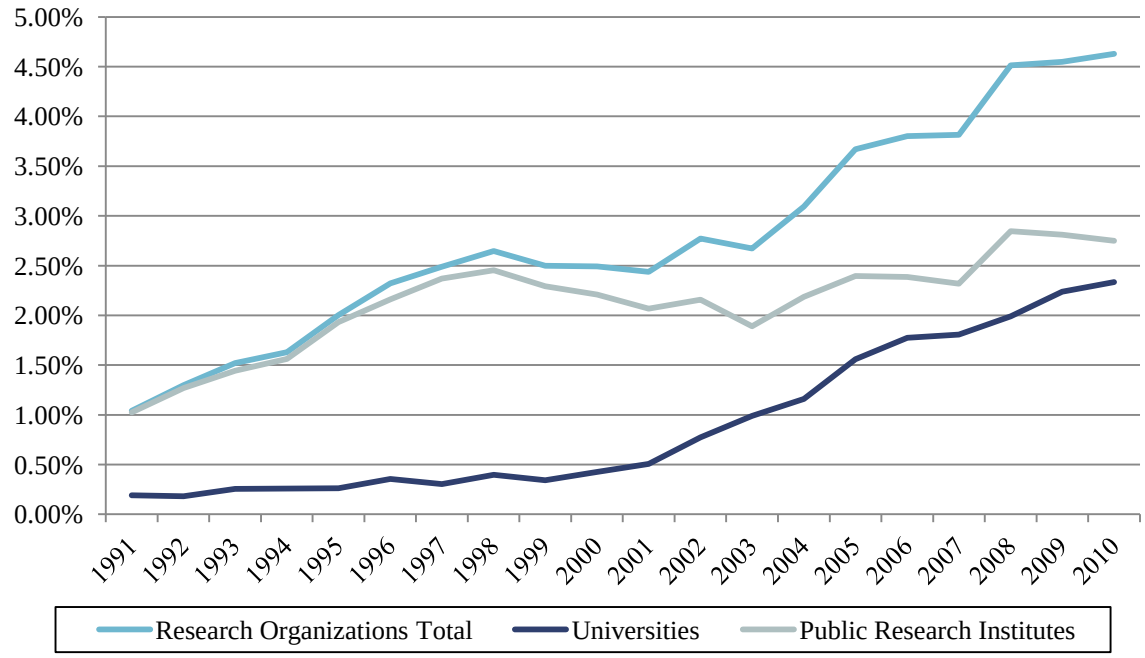
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Note: The shares might exceed 100% in certain years due to cooperative patent filings between universities and PRI.

These trends are also resembled in the shares of filings by universities and public research institutes in total filings by German research organizations (Figure 4 and Figure 5). Whereas in 1991 the largest share of filings from public research came from PRI, this has changed massively over the last 20 years. Nearly half of all filings from public research are now filed by universities, with a major growth of these shares from the year 2000 onwards.

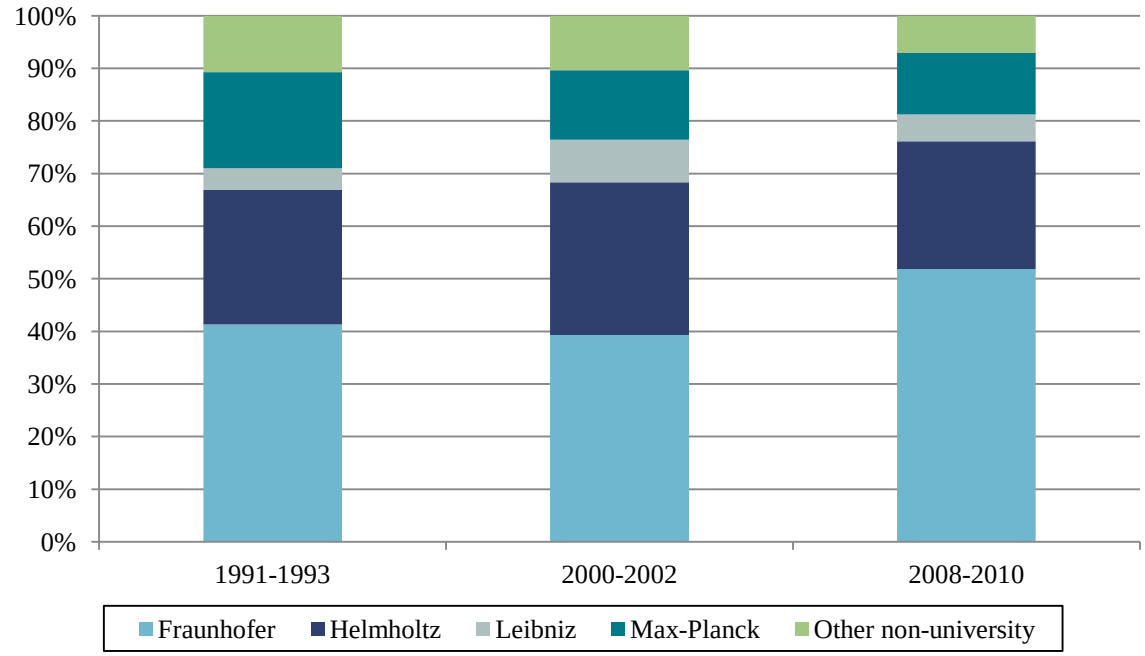
Before we take a closer look at the number of patents filed by the single universities, it is interesting to see which of the PRI make up for the largest share of patent filings. This is illustrated in Figure 6. The Fraunhofer Society is responsible for the largest share of patent filings within the comparison of the public research institutes. This is as expected, as the Fraunhofer institutes are focused on applied research and their role within the German science system is to serve as a link between basic research and its application in industry.

Figure 5: Shares of filings by universities and public research institutes in total filings by German applicants, EPO, 1991-2010



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Figure 6: Shares of filings by public research institutes in all PRI filings, EPO

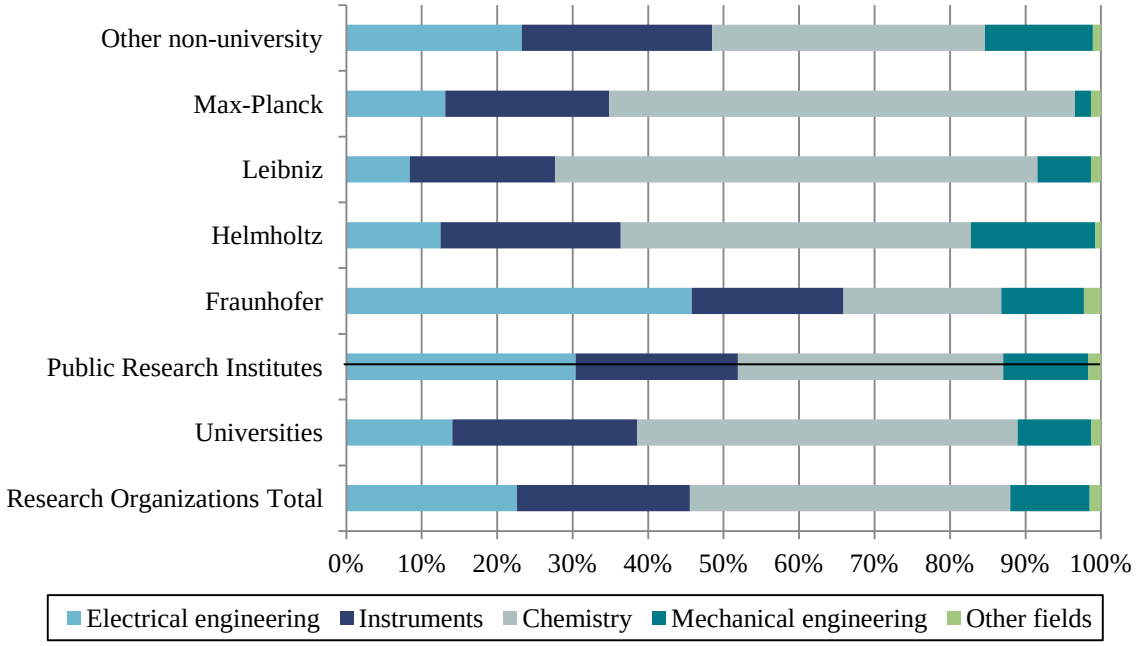


Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Nevertheless, it is interesting to note that Fraunhofer has increased it its shares between 2000-2002 and 2008-2010 and is responsible for nearly 52% of all patent filings by public research institutes. This increase in the shares comes at the expense of the second largest player in terms of patent filings within the PRI, namely the Helmholtz Society. The Helmholtz Society, whose role is to pursue more long-term oriented research, accounted for nearly 30% of all PRI filings in the period 2000-2002. This share has declined to 24% in

the period 2008-2010. The shares of the Max-Planck Society, which is rather strongly focused on basic science within Germany, also have decreased between these two time periods. In the period of 1991 to 1993, Max-Planck has been responsible for 19% of the PRI's patent filings. This share decreased to 13% in the period 2000-2002 and 12% in 2008-2010. The Leibniz Society is smallest in terms of patent filings. In the last observation period, the Leibniz institutes accounted for 5% of all EPO filings from public research institutes.

Figure 7: Field-specific shares of EPO filings by research organization, 2008-2010



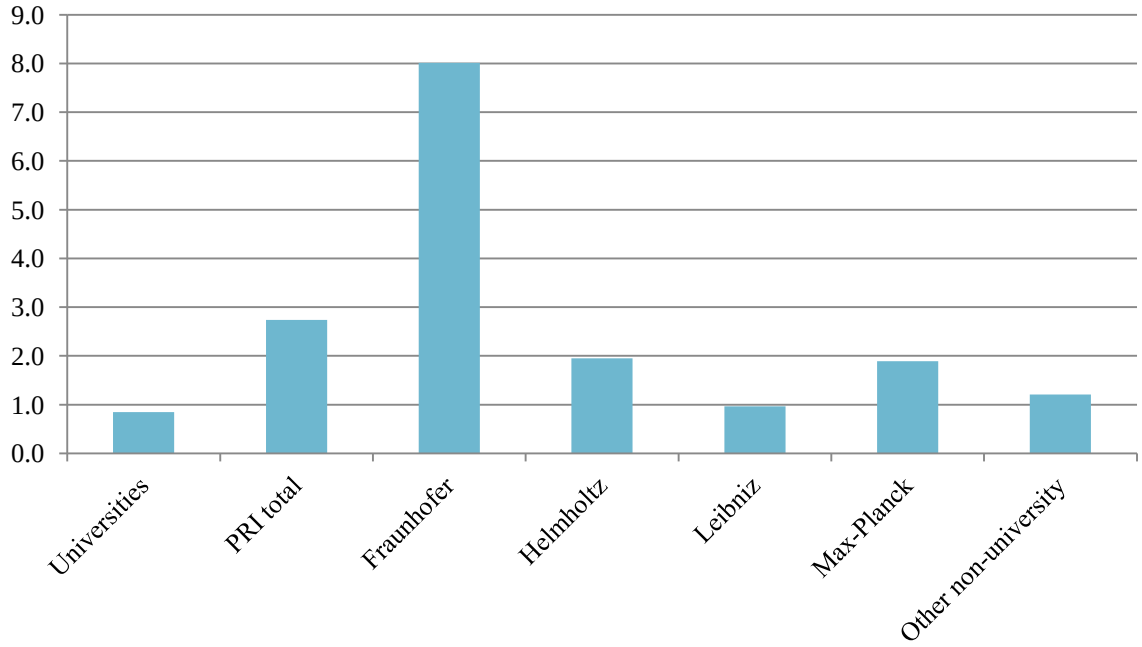
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Figure 7 shows the field-specific shares of EPO filings. This gives us an idea in which technological fields universities and public research institutes in Germany are mostly active in terms of patenting. In sum, the field of chemistry has the highest share within the portfolio of the German research organizations in total, followed by the field of instruments and electrical engineering. Besides the residual category of “other fields” the lowest share can be found for the field of mechanical engineering. When looking only at the universities, it can be found that the shares within the field of chemistry as well as instruments are even higher than in the total average, whereas the field of electrical engineering has a smaller share. This picture is basically turned around when looking at the PRI. Here, the shares in chemistry, and to some extent also instruments, is smaller than in the overall comparison, while electrical engineering has a larger share. It thus seems that the profiles of universities and public research institutes in Germany complement each other.

Taking a more detailed look at the single public research institutes reveals that the Fraunhofer Society is most highly specialized in electrical engineering, while the Helmholtz Society has the largest shares in mechanical engineering. The field of chemistry is especially dominant within the profiles of the Leibniz Society and the Max-Planck Society. Although

the profiles of the two institutions are rather similar, the Max-Planck Society is somewhat more specialized in electrical engineering while the Leibniz Society shows a larger focus on mechanical engineering. In the remaining "other non-university" institutes, the portfolio is more or less balanced.

Figure 8: Patent intensities (patents per 100 R&D employees, full-time equivalents) by research organizations, EPO, 2008-2010



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

In Figure 8, patent intensities, i.e. the number of EPO patent filings per 100 R&D employees (full-time equivalents), for universities as well as public research institutes are plotted. This allows us a comparison of universities and PRI beyond size effects, since the number of patent filings is normalized based on the size of the given research organization. Although universities file a larger number of patents than the single public research institutes, their patent intensity, at least in terms of patents where the university is named as an applicant, is rather low. The intensity of PRI is nearly three times as high as the patent intensity of universities. Yet, this is mostly driven by the Fraunhofer Society, which by far is most patent-intensive. As already stated above, Fraunhofer institutes are highly focused on applied research, which explains the high patent intensity compared to the other PRI. The Fraunhofer Society is followed by the Helmholtz Society with a patent intensity of 1.95, i.e. within the period 2008 to 2010, 1.95 patents per 100 R&D employees were filed. The Helmholtz Society is followed closely by the Max-Planck Society with a patent intensity of 1.89. Besides the residual category of "other non-university" research institutes, the Leibniz Society scores last on this indicator with a patent intensity of 0.97.

Table 1: EPO filings and patent intensities (patents per 100 R&D employees) by university applicants, 2008-2010

Rank	University	Number of EPO filings 2008-2010	University	Patent intensity 2008-2010
1	Karlsruher Institut fuer Technologie	121	Karlsruher Institut fuer Technologie	3.54
2	Universitaet Freiburg (i.Br.)	121	Universitaet Luebeck	2.92
3	Technische Universitaet Dresden	76	Universitaet Freiburg (i.Br.)	2.11
4	Technische Universitaet Berlin	72	Technische Universitaet Hamburg-Harburg	2.05
5	Technische Universitaet Muenchen	70	Technische Universitaet Berlin	1.94
6	Universitaet Heidelberg	63	Medizinische Hochschule Hannover	1.75
7	Universitaet Erlangen-Nuernberg	59	Technische Universitaet Dresden	1.33
8	LMU Muenchen	58	Universitaet der Bundeswehr Hamburg	1.24
9	Universitaet Muenster	53	Technische Universitaet Darmstadt	1.14
10	Charite - Universitaetsmedizin Berlin	50	Charite - Universitaetsmedizin Berlin	1.13
11	Universitaet Hamburg	44	Technische Universitaet Muenchen	1.12
12	Universitaet Mainz	42	Universitaet Marburg	1.08
13	Universitaet Bonn	40	Universitaet Erlangen-Nuernberg	1.08
14	Universitaet Duisburg-Essen	40	Universitaet Duisburg-Essen	1.03
15	Medizinische Hochschule Hannover	36	Universitaet Muenster	0.99
16	Universitaet Wuerzburg	33	Universitaet Mainz	0.99
17	RWTH Aachen	32	Universitaet Heidelberg	0.94
18	Technische Universitaet Darmstadt	30	Universitaet des Saarlandes	0.87
19	Universitaet Giessen	28	Universitaet Bonn	0.86
20	Universitaet des Saarlandes	27	Technische Universitaet Braunschweig	0.85
21	Universitaet Jena	27	Technische Universitaet Kaiserslautern	0.80
22	Freie Universitaet Berlin	26	Universitaet Hamburg	0.80
23	Universitaet Kiel	24	Universitaet Ulm	0.79
24	Universitaet Koeln	23	Universitaet Wuerzburg	0.77
25	Universitaet Marburg	23	LMU Muenchen	0.77
26	Universitaet Leipzig	22	Universitaet Giessen	0.74
27	Universitaet Stuttgart	22	Universitaet Hannover	0.73
28	Universitaet Hannover	20	Technische Universitaet Chemnitz	0.72
29	Universitaet Tuebingen	19	Universitaet Jena	0.71
30	Universitaet Ulm	19	Freie Universitaet Berlin	0.70
31	Technische Universitaet Braunschweig	18	Universitaet Kassel	0.63
32	Technische Universitaet Hamburg-Harburg	16	Brandenburgische Technische Universitaet Cottbus	0.61
33	Universitaet Duesseldorf	16	Universitaet Stuttgart	0.58
34	Universitaet Frankfurt a.M.	16	RWTH Aachen	0.57
35	Universitaet Kassel	13	Universitaet Kiel	0.57
36	Universitaet Regensburg	13	Universitaet Leipzig	0.56
37	Ruhr-Universitaet Bochum	11	Universitaet Koeln	0.55
38	Technische Universitaet Chemnitz	11	Universitaet Duesseldorf	0.55
39	Universitaet Bremen	11	Universitaet Konstanz	0.53
40	Universitaet Goettingen	11	Universitaet Greifswald	0.53
41	Universitaet Magdeburg	11	Universitaet Magdeburg	0.51
42	Humboldt Universitaet Berlin	10	Universitaet Potsdam	0.49

Rank	University	Number of EPO filings 2008-2010	University	Patent intensity 2008-2010
43	Technische Universitaet Kaiserslautern	10	Universitaet Bremen	0.49
44	Universitaet Dortmund	10	Universitaet Tuebingen	0.44
45	Universitaet Greifswald	10	Universitaet Paderborn	0.44
46	Universitaet Potsdam	10	Technische Universitaet Bergakademie Freiberg	0.41
47	Universitaet Rostock	9	Universitaet Dortmund	0.40
48	Universitaet Konstanz	8	Universitaet Frankfurt a.M.	0.39
49	Universitaet Luebeck	7	Universitaet Rostock	0.39
50	Universitaet Paderborn	6	Universitaet Regensburg	0.39
51	Brandenburgische Technische Universitaet Cottbus	5	Humboldt Universitaet Berlin	0.35
52	Universitaet Halle	5	Ruhr-Universitaet Bochum	0.30
53	Technische Universitaet Bergakademie Freiberg	4	Universitaet Goettingen	0.28
54	Universitaet Bielefeld	4	Universitaet Lueneburg	0.26
55	Universitaet der Bundeswehr Hamburg	4	Universitaet Siegen	0.21
56	Universitaet Siegen	3	Universitaet Bielefeld	0.20
57	Universitaet Bayreuth	2	Universitaet Halle	0.18
58	Universitaet Lueneburg	2	Technische Universitaet Clausthal	0.16
59	Universitaet Oldenburg	2	Universitaet Oldenburg	0.14
60	Technische Universitaet Clausthal	1	Universitaet Bayreuth	0.13
61	Universitaet Augsburg	1	Universitaet Hohenheim	0.10
62	Universitaet Hohenheim	1	Universitaet Wuppertal	0.07
63	Universitaet Wuppertal	1	Universitaet Augsburg	0.07

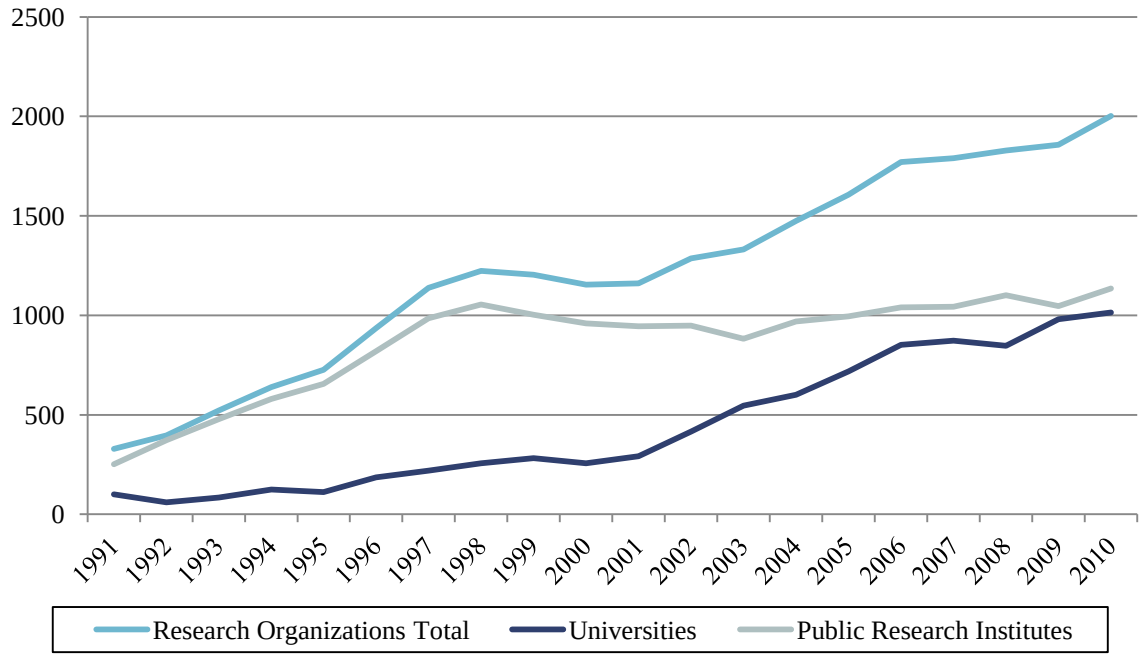
Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Note: The figures for R&D personnel in full-time equivalents by single universities are not available. Therefore, the figures for R&D personnel in absolute numbers were employed.

Table 1 provides a detailed overview on the number of EPO filings and patent intensities for the single German universities in the period 2008 to 2010. Since figures for R&D employees by universities are not available in full-time equivalents, the absolute number of researchers per university has been used for the calculation of the patent intensities. This leads to an underestimation of the patent intensities compared to Figure 8, yet does not influence the comparison between the single universities.

The “Karlsruhe Institut für Technologie (KIT)” has filed the largest number of patents within this time period and also has the highest patent intensity in comparison. It is followed by the University of Freiburg with the same number of filings between 2008 and 2010 but a somewhat lower patent intensity. In terms of the number of EPO filings, the technical universities of Dresden, Berlin and Munich score among the top 5 on this indicator. This is different for the patent intensity, where the comparably small Universities of Luebeck and the Technical University Hamburg-Harburg are among the top 5 universities. Although both universities comparably file a small number of patents – 16 in the case Hamburg-Harburg and 7 in the case of Luebeck – they both show high patent intensities due to a comparably small number of R&D employees.

Figure 9: Number of filings by German research organizations targeting the German market (EPO+GPTO), 1991-2010



Source: EPO – PATSTAT; calculations by Fraunhofer ISI

Before digging deeper into the academic patents by universities, i.e. additionally taking into account patent filings from universities where the university staff only appears as an inventor and the university itself not as an applicant, we will take a final look at the filings from universities and PRI targeting the German market. Here, all patents that (sooner or later) reach the German Patent and Trademark Office (GPTO), whether directly filed at the GPTO or at the EPO are counted. The trends we can observe here basically resemble the trends in EPO filings from Figure 3, although at a higher level. In the year 2010, research organizations were responsible for about 2,000 patent filings targeting the German market, with 1,135 filings from PRI and 1,014 filings where universities are named as the patent applicant. Once again, we can observe the impact of the legislation change of 2002 on the number of patents filed by universities. When comparing the figures to the ones observed in Figure 3, we also find that the GPTO still is a very prominent patent office for filings from universities and PRI. Only slightly more than 50% of all filings from research organizations are filed at the EPO, the other half is filed at the national office.

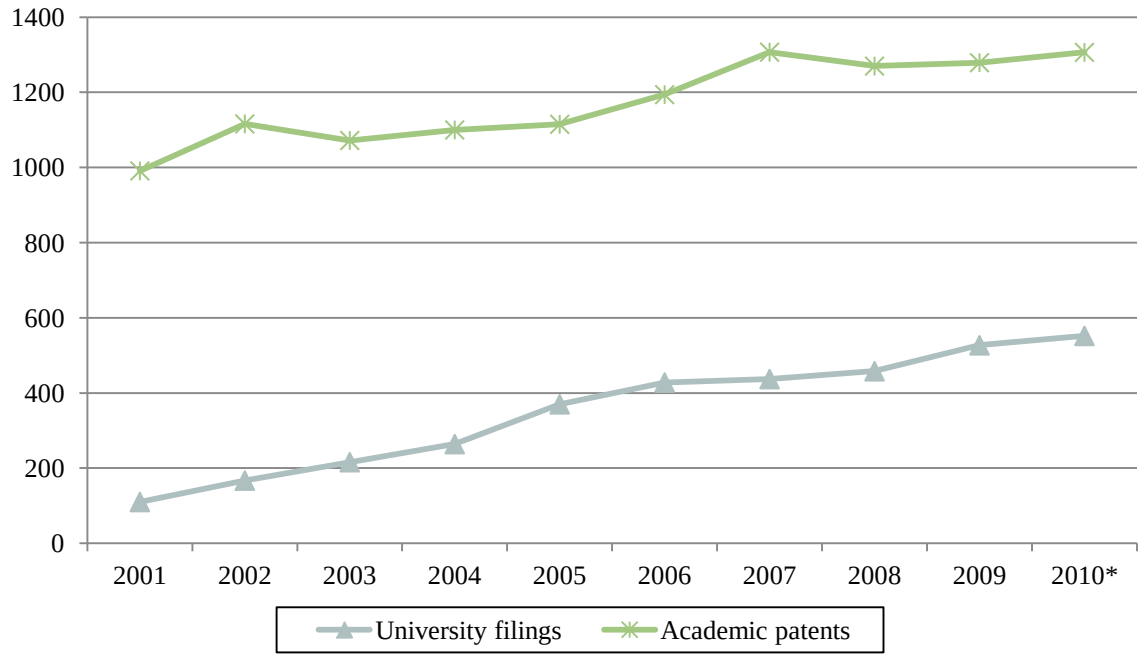
3.2 Academic Patents

After having gained a general view on the patented research output from public research organizations, the following section will aim to shed further light into academic patenting activities by universities, i.e. we will additionally take the hidden share of the academic contribution to technological development (as measurable by patents) into account.

Basic findings: What about academic patenting in Germany?

Figure 10 provides an indication on the possible dimension of this methodological issue. Displayed are the numbers of university filings (as presented in the previous section) compared to the number of academic patents, as identified by the algorithm (described in section 2).

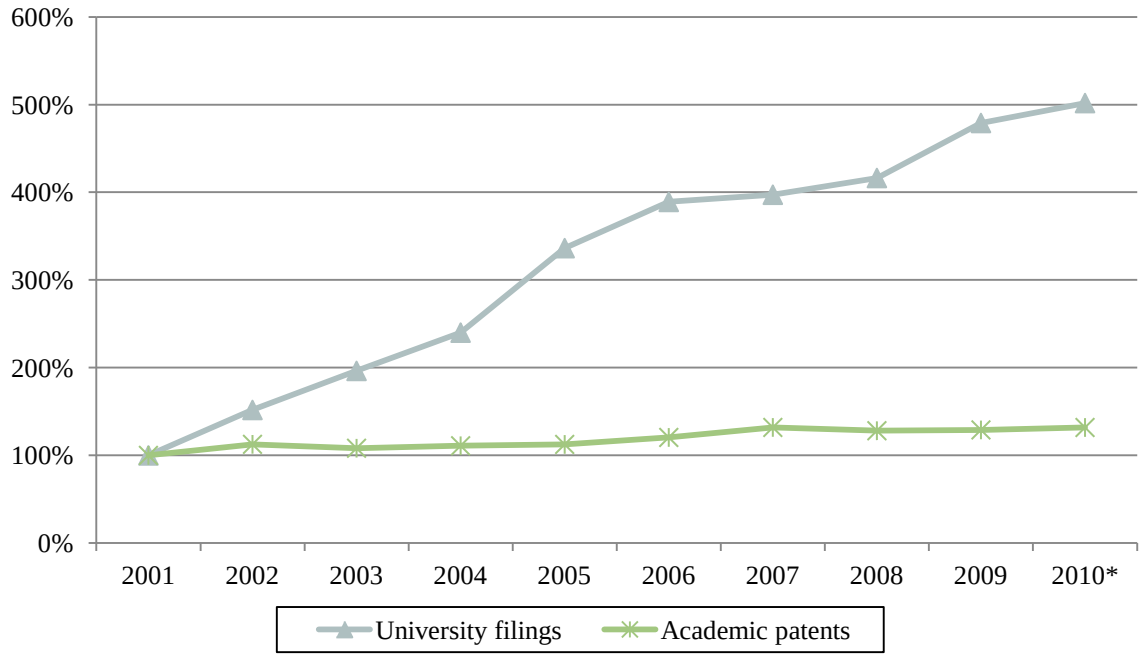
Figure 10: Number of academic patents from German universities, EPO, 2001-2010



Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI
*extrapolated (average growth rate over three preceding years)

It becomes evident that the overall amount of academic patents indeed is much larger than that of university filings. Applications of academic patents as well as university patents have been rising since 2001. Nevertheless, university filings underwent a remarkable increase since 2001. Academic patents fluctuate on a rather stable level until 2005. The numbers show a slight increase by 13% in this time span. From 2005 onwards, again a slight increase in relation to 2001 can be observed. In the end, a gain of 32% compared to the base year 2001 can be found.

Figure 11: Relative development of academic patents compared with patents filed by universities, EPO, 2001-2010 (base year 2001 = 100)

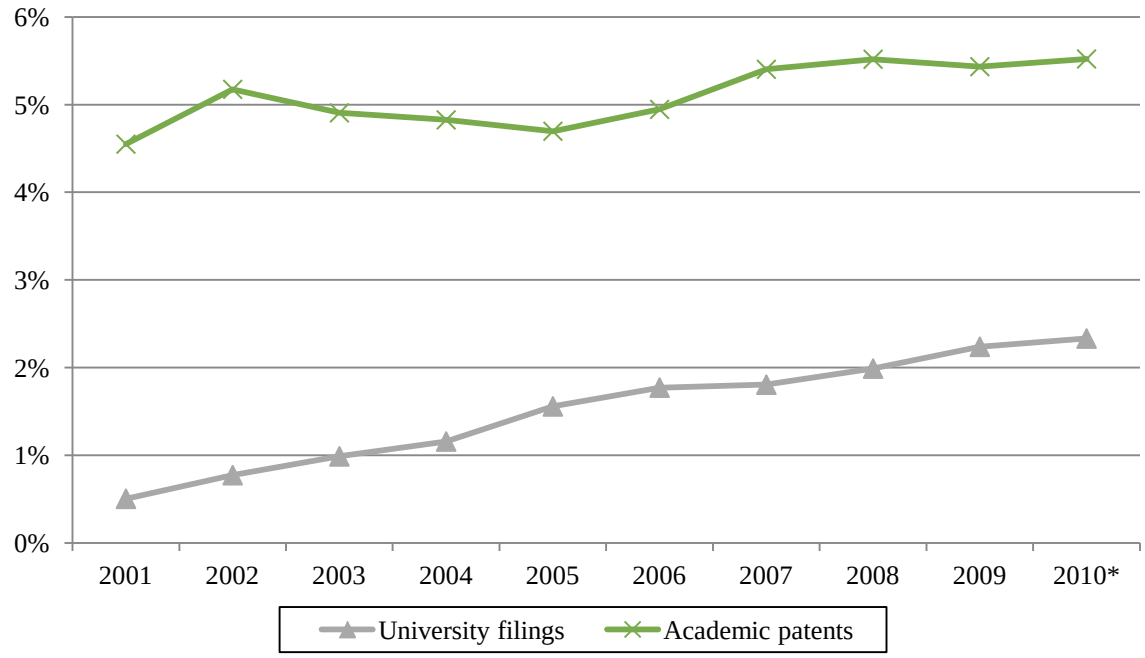


Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI
*extrapolated (average growth rate over three preceding years)

Taking both figures together, we can firstly assert that the contribution of universities and their employees to patented research is definitely underestimated by only accounting for university filed patents. Secondly, we find that the trend in academic patenting is strongly driven by increasing efforts of German universities to claim IP on inventions made by their employees.

However, what does this mean for technological development in Germany, or more prosaically, how important is the contribution of academic science to patented inventions in terms of quantities? Furthermore, what does this mean in relation to other countries? Figure 12 displays the annual shares of all academic patents compared to university-owned patents among the overall appearance of EPO filings by German applicants.

Figure 12: Comparing shares of academic patents and shares of filings by German universities in total filings of German applicants, EPO, 2001-2010



Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI

* extrapolated (average growth rate over three preceding years)

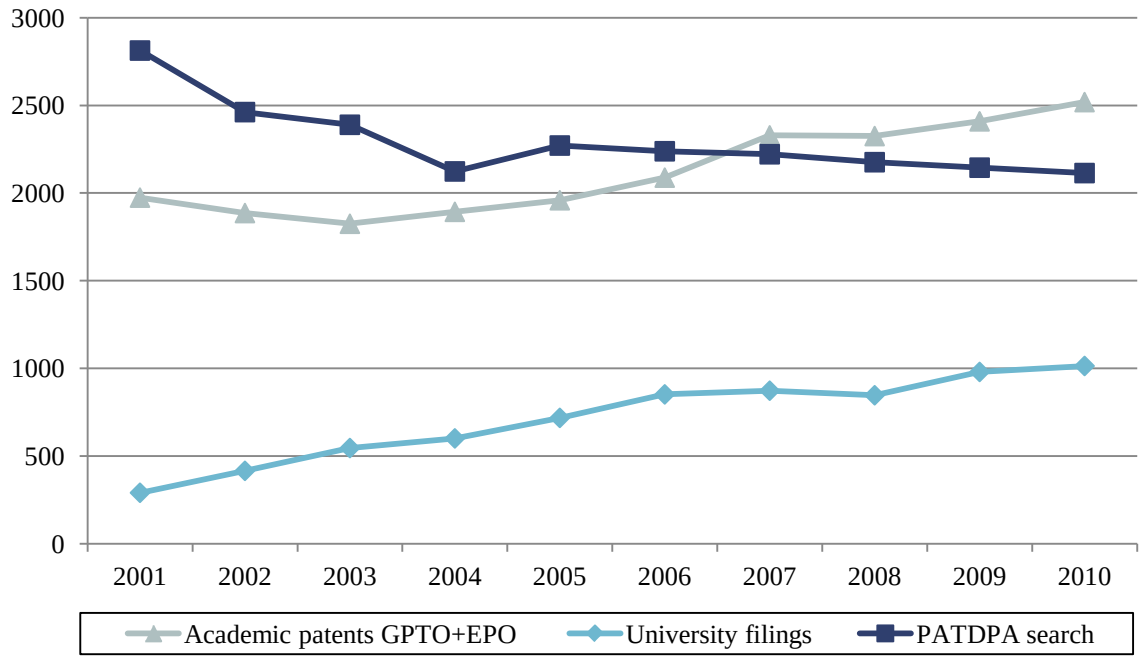
The results indicate that each year, academics contributed from 4.5 up to 5.5% to all patented inventions. Previous studies by Lissioni et al. (2009; 2008; 2012) estimated that academic patents in European countries (namely France, Italy, Netherlands and Sweden) on average accounted for round about 4% of all EPO patents by domestic inventors between 1994 and 2002. However, those numbers resulted from rather conservative estimations. In a more recent follow-up study, Lissoni et al. (2013) provide more up-to-date and thus comparable estimates for Italy. They show for 2001 to 2006 that the share of academic patents in Italy ranges from 5.1 to 5.5% (lower bound) and 6.6 to 6.9% (upper bound).

Our estimation for Germany shows that academic patents on average over the years accounted for 5.1% of all German filings at the EPO, while for university-owned patents this is 1.5%. Taking a closer look at the observations, we find opposing trends from 2002 to 2005. While universities steadily expand their share from 0.5% in 2001 to 2.2% in 2010, the shares of academic patents shows a decrease between 2002 and 2005. From 2005 onwards, however, the shares recover and grow to 5.5% in 2010.

Finally, before moving ahead towards a more fine-grained analysis of the main technological content, actors and ownership relations behind academic patenting, we take brief look on the combined offices (EPO+ GPTO) (Figure 13). Here, all patents that (sooner or later) reach the German Patent and Trademark Office (GPTO), whether directly filed at the GPTO or at the EPO are counted. For university-owned patents, the picture for both offices resembles the findings with respect to EPO filings (compare section 3.1). However, for academic patents, we observe partly different trends and dynamics (see Figure 13). Accounting for both offices, the estimated totals experience a slight downturn between 2001

and 2002. The numbers decrease from ca. 2,000 patents in 2001 to ca. 1,900 patents in 2002. From 2002 onwards the numbers are pretty much comparable to those at the EPO.

Figure 13: Number of academic patents from German universities, (EPO+ GPTO), 2001-2010



Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI
*extrapolated (average growth rate over three preceding years)

The shares of academic patents at both offices (Figure 14) closely resemble the picture derived from the totals on academic patenting at both offices. The shares of academic patents are comparable to those at the EPO.

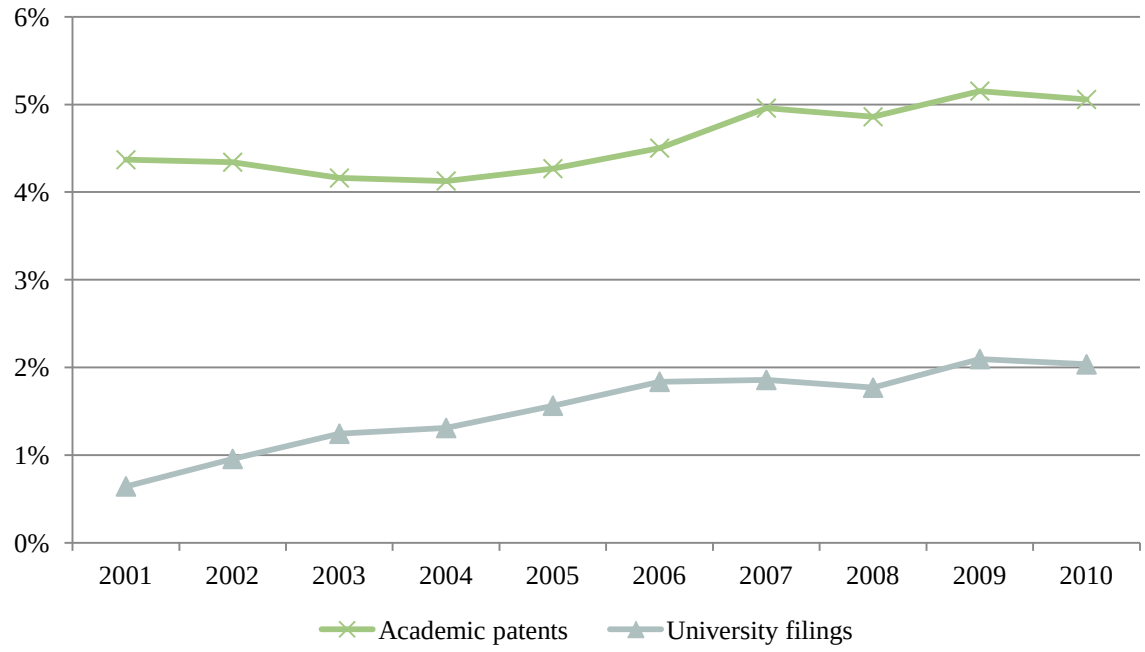
We compare our results from Figure 13 to previously published numbers on academic patenting in Germany (Cuntz et al. 2012; Expertenkommission Forschung und Innovation (EFI) 2012) based on searches for the professors title in the PATDPA database provided by STN[5]. The numbers are at a similar level compared to our approach. However, although we observe a similar downturn of the numbers on academic patents from 2001 to 2003, our approach suggests increasing numbers from 2003 onwards, while previous estimations indicated an ongoing decreasing trend.

An explanation might be that the "old" approach, as it relied on the assumption that most professors indicate their title on the filing, overestimated this share and thus underestimated the true contribution of academic inventors to patenting. Furthermore, the share of academic inventors without a professor's title might be higher than assumed. In line with this, regarding the different observed dynamics between both approaches, a possible explanation has been discussed by Cuntz et al. (2012). They argue that the share of non-

5 Values for 2009 and 2010 extrapolated with the average growth rate over the preceding three years.

professorial academic staff among university employees rose significantly faster than the share of professors. Additionally, there might be, as anecdotal evidence suggests, a reduced tendency of professors to indicate their title on patent filings. We conclude, firstly, that the search for the professor's title provided a rather conservative estimation which, secondly, suffers in that it has difficulties in mapping recent developments and changes in public research.

Figure 14: Comparing shares of academic patents and shares of filings by German universities in total filings of German applicants, (EPO+ GPTO), 2001-2010



Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI
* extrapolated (average growth rate over three preceding years)

In conclusion, taking the previous remarks and findings to together, a set of aspects and issues deserves further attention and should be highlighted here. Our findings confirm that academic science significantly contributes to technological advancements in Germany. We find support for the assumption that German scientific research has, even compared to other European countries, a strong effect on technological development. Nevertheless, remembering that university patents are a subsample of academic patents, the differing dynamics between both samples raise further questions. While university-owned patents experienced an impressive rise, initiated by the abolishment of the professors' privilege (Hochschullehrerprivileg) in 2002, university-invented patents, and respectively other applicants must have lost shares in academic patenting. Additionally, the slump in shares of academic patents after 2002 at the EPO and in totals as well as shares at the EPO+GPTO is noteworthy. Taken together, this still calls for a better understanding of the dynamics in academic patenting and the intended as well as unintended implications that recent governmental initiatives had on university-industry collaborations. Frank et al. (2007), for

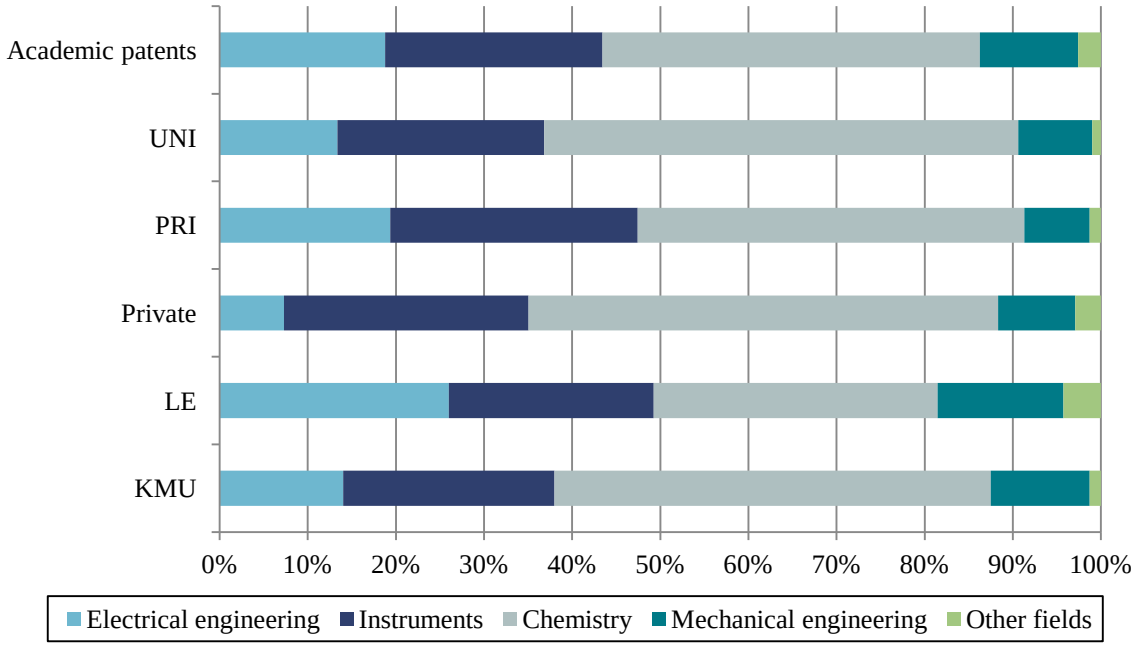
example, raise the issue that the enforced involvement of PVAs is often perceived as disturbing, by both - universities and firms.

In order to gain additional insights into the structures underlying academic patenting actives in Germany, the following section will provide a set of descriptive analyzes on the technological content, the single universities and ownership relations.

Academic patenting in Germany: What is invented, who invents it and who owns it?

Figure 15 shows the field-specific shares of EPO filings among all academic patents as well as differentiated by applicant types in academic patenting. The academic inventors' contribution to patenting, independent from the ownership, is strongest in the field of chemistry (including the strongly science-based life sciences). It is followed by instruments and electrical engineering. The lowest share can be found for the field of mechanical engineering, despite "other fields" which is a residual category. When dividing the academic patents by their different applicant types the observed patterns do not depart much. However, some differences deserve to be mentioned. University-owned (UNI) as well as privately-owned (Private) shares within the field of chemistry are comparably high. At the same time, they file less in electrical engineering. The portfolio of public research institutes (PRI), when university scientists are involved, is similar to that that of all filings by public research institutes as presented in section 3.1. In doing so, they maintain higher shares in instruments and electrical engineering than other applicant types. Interesting findings can be derived from the filings by large enterprises (LE) and SMEs.

Figure 15: Field-specific shares of EPO filings by research organization, 2007-2009



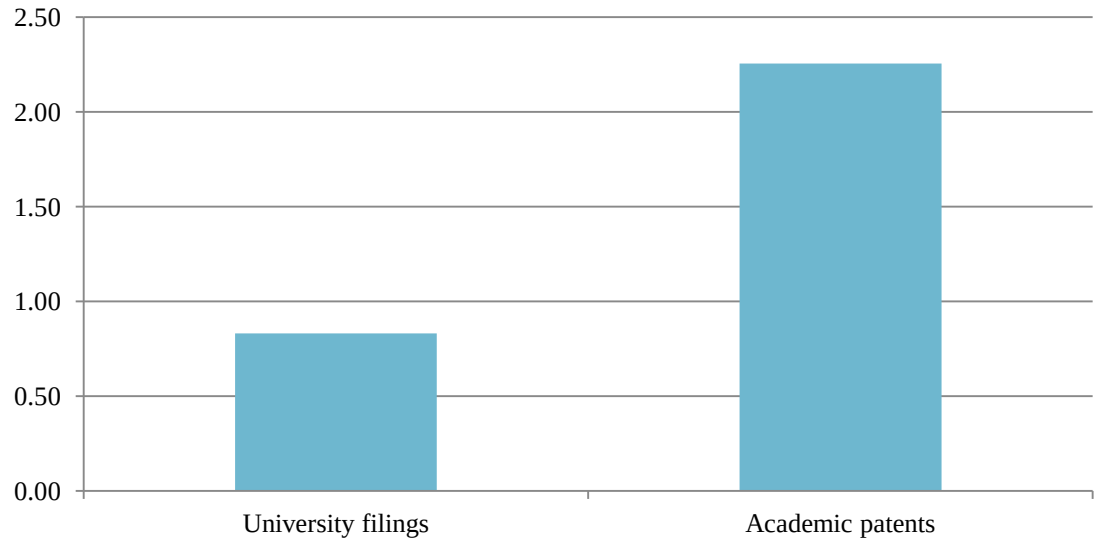
Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI

*extrapolated (average growth rate over three preceding years)

Large firms have a more balanced portfolio of patented technologies to which academic inventors contributed to. In doing so, they own higher shares in engineering than in other categories, particularly in electrical engineering. Chemistry, however, is a relatively small field for academic involvement in large firms' inventive activities. SMEs technological portfolio with academic inventors' contribution closely resembles the picture of university-owned and purely academic patents.

In sum, the overall picture derived from these figures is largely comparable to that found in other European countries (c.f. Lissoni 2012) as well as in the US (c.f. Thursby et al. 2009). Nevertheless, the share of academic patents in engineering and instruments is comparably high in Germany. Additionally, the differentiation by type of ownership provides interesting insights into technology-specific collaboration patterns between academic inventors and other actors in the German innovation system. We find that purely academic (UNI), privately owned (private) and patents owned by SMEs (SME) are pretty similar in terms of technological fields. They seem to resemble the picture of science-driven technological development. The portfolio of large enterprises (LE), however, is likely to reflect their own R&D activities which are more balanced and have a stronger focus on engineering related areas. Public research institutes, as shown in section 3.1, are very heterogeneous. Unsurprisingly, this is reflected in the breadth of the technological portfolio of research conducted in collaboration with universities.

Figure 16: Academic contribution to patenting compared to university filing in intensities (patents per 100 R&D employees, full-time equivalents), EPO, 2007-2009



Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI

Moving to Figure 16, we notice that the patent intensities, i.e. the number of EPO patent filings per 100 R&D employees (full-time equivalents), are significantly higher when academic patents are counted. This means that the contribution of academic inventors' to the technological development is about 2.7 times higher compared to counting university-filed patents. Furthermore, when normalizing by the size of the university, we find that their

patent intensity, in terms of patents where university staff is named as inventors, gets comparable to the output of other research organizations (compare Figure 8). Except for the Fraunhofer Society, which by far is most patent-intensive and highly focused on applied research, these numbers suggest that universities (on average) contribute to the largest number of patents where academic science is involved.

Table 2 shows how the number of patents with academic inventors' contribution is distribute among single universities. Displayed is the number of EPO patents that emerged with at least one academics contribution in the period 2007 to 2009. Furthermore the rank for each university in university-owned patents (c.f. Table 1) is displayed *(in brackets)*. As already stated above, the absolute number of researchers per university has been used for the calculation of the patent intensities.

Table 2: Academic patents and patent intensities (patents per 100 R&D employees) by employing university, EPO, 2007-2009

Number of EPO filings				**Patent intensity**		
Rank	**University**	**Academic patents 2007-2009**	***Rank uni-owned***	**University**	**Academic patents 2007-2009**	***Rank uni-owned***
1	TU Muenchen	448	*(5)*	HU Berlin	9.27	*(51)*
2	Charite	306	*(10)*	TU Muenchen	7.82	*(11)*
3	LMU Muenchen	282	*(8)*	FU Berlin	7.64	*(30)*
4	FU Berlin	271	*(22)*	Charite	6.98	*(10)*
5	HU Berlin	251	*(42)*	U Jena	6.83	*(29)*
6	U Jena	243	*(21)*	MH Hannover	6.26	*(6)*
7	U Heidelberg	231	*(6)*	TU Darmstadt	5.97	*(9)*
8	U Erlangen-Nuernberg	185	*(7)*	U Luebeck	5.96	*(2)*
9	TU Dresden	158	*(3)*	TU Clausthal	4.45	*(58)*
10	TU Berlin	152	*(4)*	TU Berlin	4.37	*(5)*
11	TU Darmstadt	145	*(18)*	KIT	4.15	*(1)*
12	KIT	133	*(1)*	TU Ham.-Harb.	3.92	*(4)*
13	U Stuttgart	128	*(27)*	LMU Muenchen	3.85	*(25)*
14	MH Hannover	123	*(15)*	U Erlangen-Nuernberg	3.68	*(13)*
15	RWTH Aachen	111	*(17)*	U Heidelberg	3.62	*(17)*
16	U Mainz	98	*(12)*	U Stuttgart	3.56	*(33)*
17	U Duesseldorf	97	*(33)*	U Hannover	3.43	*(27)*
18	U Tuebingen	94	*(29)*	U Duesseldorf	3.35	*(38)*
19	U Freiburg (i.Br.)	93	*(2)*	TU Ilmenau	2.98	*(--)*
20	U Hannover	91	*(28)*	TU Dresden	2.97	*(7)*
21	U Duisburg-Essen	90	*(14)*	TU Braunschweig	2.88	*(20)*
22	U d. Saarlandes	73	*(20)*	U Marburg	2.86	*(12)*
23	U Regensburg	67	*(36)*	U Duisburg-Essen	2.78	*(14)*
24	TU Braunschweig	62	*(31)*	U Ulm	2.60	*(23)*
25	U Ulm	60	*(30)*	U d. Saarlandes	2.55	*(18)*
26	U Koeln	59	*(24)*	TU Kaiserslautern	2.52	*(21)*
27	U Bochum	58	*(37)*	U Mainz	2.46	*(16)*
28	U Marburg	57	*(25)*	U Dortmund	2.38	*(47)*
29	U Hamburg	56	*(11)*	TU Freiberg	2.23	*(46)*
30	U Dortmund	55	*(44)*	U Tuebingen	2.22	*(44)*
31	U Wuerzburg	54	*(16)*	U Mannheim	2.20	*(--)*
32	U Frankfurt a.M.	51	*(34)*	U Konstanz	2.17	*(39)*

Number of EPO filings				Patent intensity		
Rank	**University**	**Academic patents 2007-2009**	***Rank uni-owned***	**University**	**Academic patents 2007-2009**	***Rank uni-owned***
33	U Kiel	51	*(23)*	U Regensburg	2.14	*(50)*
34	U Muenster	43	*(9)*	RWTH Aachen	2.12	*(34)*
35	U Potsdam	37	*(46)*	U Potsdam	2.00	*(42)*
36	U Halle	35	*(52)*	U d. Bw. Hamburg	1.95	*(8)*
37	U Leipzig	34	*(26)*	U Freiburg (i.Br.)	1.75	*(3)*
38	U Goettingen	32	*(40)*	U Bochum	1.72	*(52)*
39	U Konstanz	32	*(48)*	U Koeln	1.53	*(37)*
40	U Bonn	31	*(13)*	TU Chemnitz	1.46	*(28)*
41	U Rostock	30	*(47)*	U Rostock	1.38	*(49)*
42	TU Kaiserslautern	29	*(43)*	U Wuerzburg	1.34	*(24)*
43	TU Clausthal	27	*(60)*	U Halle	1.31	*(57)*
44	TU Ham.-Harb.	26	*(32)*	U Frankfurt a.M.	1.31	*(48)*
45	U Mannheim	26	*(--)*	U Wuppertal	1.29	*(62)*
46	TU Ilmenau	25	*(--)*	U Kiel	1.28	*(35)*
47	U Giessen	21	*(19)*	U Hohenheim	1.22	*(61)*
48	U Magdeburg	21	*(41)*	U Bayreuth	1.10	*(60)*
49	TU Chemnitz	20	*(38)*	U Hamburg	1.05	*(22)*
50	TU Freiberg	19	*(53)*	U Magdeburg	1.04	*(41)*
51	U Kassel	18	*(35)*	U Greifswald	0.94	*(40)*
52	U Bremen	18	*(39)*	U Kassel	0.92	*(31)*
53	U Greifswald	17	*(45)*	U Leipzig	0.91	*(36)*
54	U Bayreuth	16	*(57)*	U Goettingen	0.88	*(53)*
55	U Wuppertal	16	*(63)*	U Muenster	0.85	*(15)*
56	U Luebeck	14	*(49)*	U Bremen	0.83	*(43)*
57	U Hohenheim	12	*(62)*	U Bonn	0.73	*(19)*
58	U Paderborn	9	*(50)*	U Paderborn	0.71	*(45)*
59	U Bielefeld	8	*(54)*	U Giessen	0.57	*(26)*
60	U Siegen	7	*(56)*	U Siegen	0.52	*(55)*
61	U d. Bw. Hamburg	6	*(55)*	U Bielefeld	0.45	*(56)*
62	U Augsburg	4	*(61)*	TU Cottbus	0.40	*(32)*
63	U Osnabrueck	4	*(--)*	U Osnabrueck	0.34	*(--)*
64	TU Cottbus	3	*(51)*	U Augsburg	0.31	*(63)*
65	U d. Bw. Muenchen	1	*(--)*	U Vechta	0.30	*(--)*
66	U Passau	1	*(--)*	U Weimar	0.17	*(--)*
67	U Weimar	1	*(--)*	U Eichstätt - Ingolstadt	0.15	*(--)*
68	U Eichstätt - Ingolstadt	1	*(--)*	U Passau	0.14	*(--)*
69	U Vechta	1	*(--)*	U d. Bw. Muenchen	0.14	*(--)*

Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI

Note: The figures for R&D personnel in full-time equivalents by single universities are not available. Therefore, the figures for R&D personnel in absolute numbers were employed.

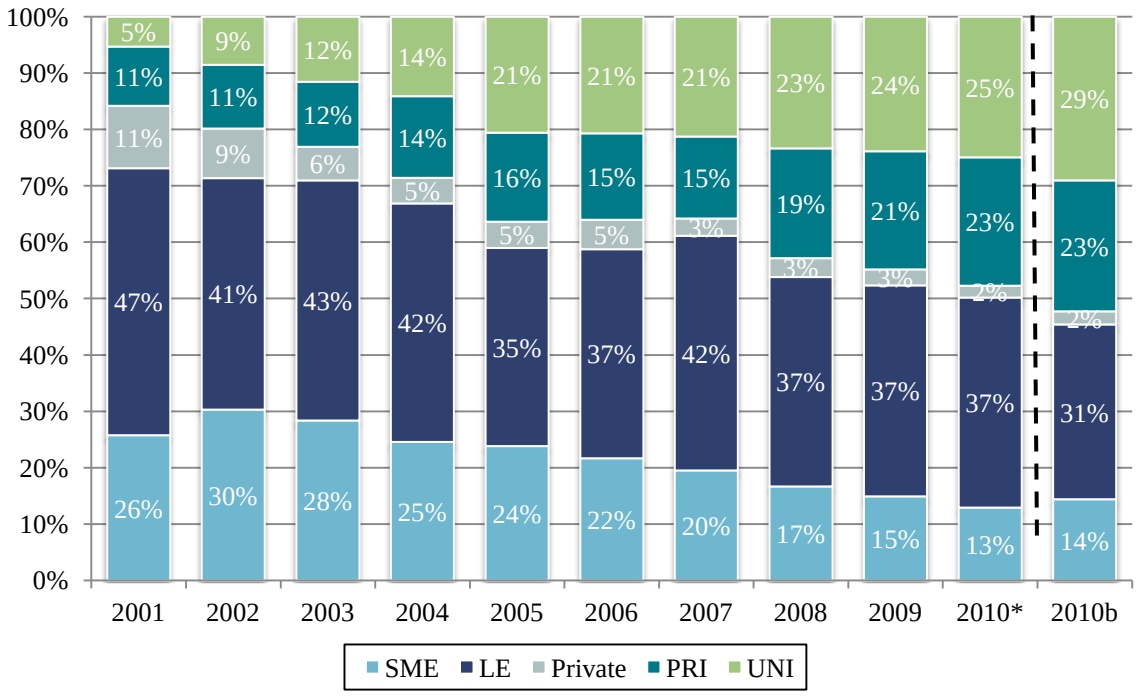
Table 2 demonstrates that the universities with the highest numbers of university-owned patents are not necessarily those with the highest number of university-invented patents, too. The "Karlsruhe Institut für Technologie (KIT)", for example, has filed the largest number of patents and also has the highest patent intensity. Yet, it ranks 12th in numbers as well as intensities when academic patents are counted. Also the University of Freiburg, 2nd in numbers and 3rd in intensities in university-owned patents, looses significantly and ranks 19th in absolute and 37th in terms of intensities when looking at academic patents. The "Technische University München", now ranks first in numbers and is followed by "Charité

Berlin", "Ludwigs-Maximilians-Universität München (LMU)", "Freie Universität Berlin" and the "Humboldt Universität Berlin". This picture changes for the patent intensities. Here we find that smaller universities gain a "small size advantage" and rank higher. The top five in terms of intensities, however, are "Humboldt Universität Berlin", "Technische University München", "Freie Universität Berlin", "Charité Berlin" and "Universität Jena".

A striking finding is that particularly universities in Munich and Berlin show high numbers of academic patents. At this point, it should be mentioned that double counts are possible and that in large research clusters such as Munich and Berlin close and organizational boarder-crossing networks are likely to exist. This is particularly the case when universities share and co-operate in medical facilities such as e.g. the Charité University Hospital in Berlin. Anyway, the figures show that large technical universities and universities with huge medical facilities (e.g. Charité, Heidelberg, LMU), located in large agglomerations, generate the largest numbers of academic patents.

As stated in the previous section, university-owned patents experienced an impressive rise, initiated by the abolishment of the professors' privilege (Hochschullehrerprivileg), in 2002. At the same time, the overall amount as well as the shares of academic patents experienced comparatively low growth rates. Actually, between 2001 and 2005, they rather underwent a decline in totals as well as shares. One question emerging from these findings is how these dynamics are reflected within the ownership structures in university-invented patents. In other words, when university-owned patents grew at such rates, other applicants must have lost shares in academic patenting.

Figure 17: Ownership of academic patents in shares, EPO, 2001-2010



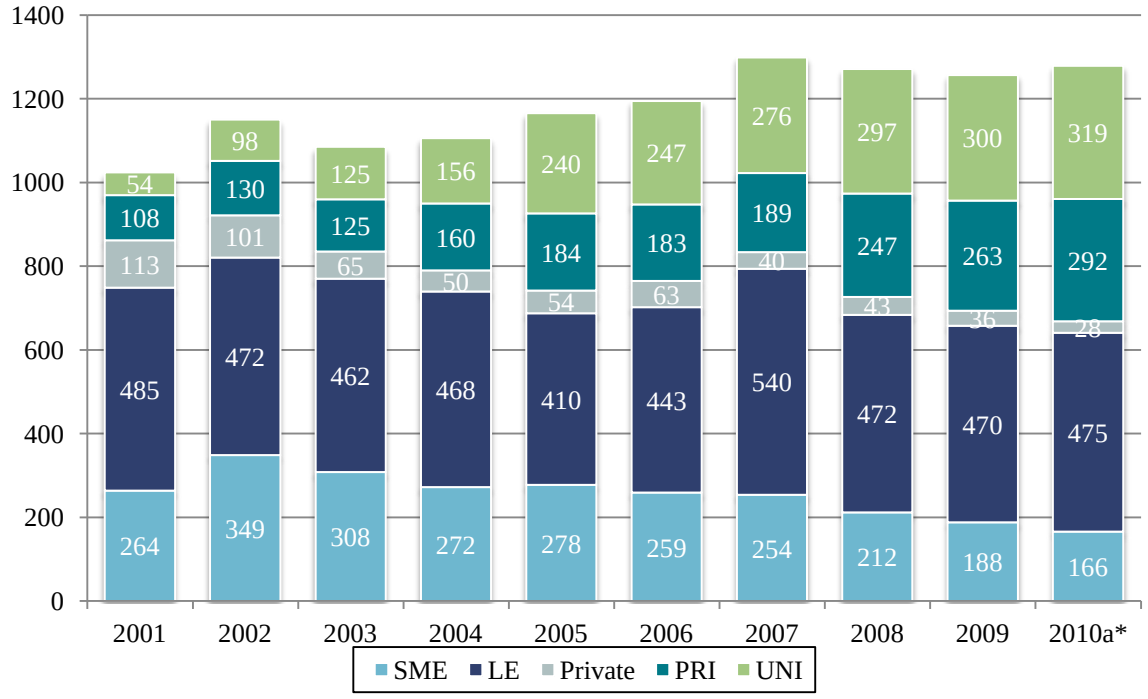
Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI
*extrapolated (average growth rate over three preceding years)

Figure 17 displays the shares of ownership in academic patenting at the EPO. As explained in section 2, the priority year 2010 is, due to data restrictions, not complete. Thus we extrapolated the values for 2010 by using the average growth rates over the last three years. The resulting value is presented as “2010a” in the figure. However, we additionally display the directly retrieved values, constituting 65% of the totals in the preceding year, as 2010b. We include these numbers because they indicate a particularly strong increase in university-owned patents. At the same time, the shares for large firms are significantly reduced. However, as data on 2010 is incomplete, we refrain from a deeper interpretation.

Figure 17 reflects the increasing share of university-owned patents (UNI). Starting at five% in 2001, universities rapidly increased their shares to 21% in 2005 and 25% in 2010. Obviously, since the abolition of the professors’ privilege German universities increasingly exerted property rights on the inventions made by their employees. Interestingly, this is also the case for public research institutes (PRI) at the EPO, where PRIs increase their shares from 11% in 2001 to 23% in 2010. At the same time the shares of privately owned academic patents are significantly reduced from 11 to 2%. Thus, parts of the expanding filing activities by universities as well as public research organizations obviously lead to minimized shares of academic patents owned by individual university employees.

The second striking finding from Figure 17 is that the main share of academic patents is filed by large and small firms. However, this share has been decreasing from over 70% in 2001 to round about 50% in 2010. In doing so, three phases can be distinguished. At first (2001 till 2004) a slight decline in corporate filings is observable. In 2005 the share drops under 60% and stabilizes till 2007. From 2008 onwards the shares further decrease. The differentiation between SMEs and larges firms (LE) shows that the share of SMEs has been constantly sinking from 30% in 2002 to 13% in 2010. It is obvious that these developments go hand in hand with the increasing filing activities by universities and public research organizations.

Figure 18: Ownership of academic patents in absolute numbers, EPO, 2001-2010



Source: EPO – PATSTAT, SCOPUS-Elsevier; calculations by Fraunhofer ISI

Note: The sum of patents filed by different applicant types might exceed 100% in certain years due to cooperative patent filings.

*extrapolated (average growth rate over three preceding years)

However, decreasing shares do not necessarily mean that the total number of corporate filings decreased. Figure 18 shows the numbers of academic patents by applicant type filed at the EPO. More or less stable numbers in terms of firm-owned academic patents, with two peaks in 2002 and 2007, can be found. The numbers are largely stable for large firms. Small firms, however, significantly and constantly lose ground from 2002 to 2010. The rise in overall academic patenting is related to patents filed by public research (UNI & PRI). This results from a sinking tendency for firms to file academic patents, while universities and public research institutes steadily increase their patenting activity. However, while large firms' filing activities in academic patenting recover and stabilize, the small firms' downward trend continues.

Two main findings that can be drawn from the remarks above are:

- Firstly, a slightly rising trend is observable in academic patenting and this is caused by the ever-increasing patenting activity not only by universities, but also by public research institutes.
- Secondly, firm filings in shares as well as in totals are negatively affected. This is mostly attributable to the negative trend found for small firms, while large firms appear to be less sensitive and display a more robust trend.

4 Summary and conclusions

The aim of this study was to identify and to compare the trends and dynamics behind the patenting activities by universities and public research institutes in Germany. In doing so, the main intention was to add to a comprehensive picture of the contribution of academic research to patenting activities. Here, two different methodological approaches have been applied.

Firstly, by searching for applicant names listed on patent filings, we identified those documents that are owned by universities or other public research institutions:

- The results show that patents filed by research organizations, i.e. universities and public research institutes, account for about 5% of all EPO filings from German applicants. However, the number of patent filings, in absolute as well as relative terms, has increased over the last 20 years, which is even more pronounced for universities than for public research institutes. This has led to a convergence in the number of patent filings between universities and public research institutes in the recent years, which can be attributed to the abolishment of the “Hochschullehrerprivileg” (“professor's privilege”) in 2002 and the larger focus of German universities on commercializing their inventions and innovations.
- When taking a more differentiated look at the different public research institutes, it can be found that the Fraunhofer Society is responsible for the largest share of patent filings within the comparison of the public research institutes, followed by the Helmholtz Society and the Max-Planck Society. A differentiation by technological fields reveals that the field-specific profiles of universities and public research institutes in Germany complement each other. While universities are mostly focused on chemistry and related fields, the public research institutes have a larger focus on electrical engineering, instruments and mechanical engineering.

Secondly, however, a major problem regarding research and inventive activities conducted at universities is the identification of university-based filings that have not been applied for by the universities themselves, but by other organizations (enterprises, research institutes, single inventors). Analyses that disregard this share of university-invented patents will substantially underestimate the true contribution of academic inventors and consequently miss large parts of the picture. Therefore, an improved approach, which is also able to detect patent filings that have not been formally submitted by universities themselves, has been applied. In doing so, we complement above findings by gaining further insights on the hidden contribution of academic inventors on patented technological development:

- Taking the results together, we assert that the contribution of universities and their employees to patented research is definitely underestimated by only accounting for university filed patents. Our estimations show that all patents with academic involvement (academic patents) account for 5.1% of all German applications at the EPO between 2001 and 2010. At the same time university-owned patents accounted for round about 1.5%. Thus, our findings confirm that academic science significantly contributes to patenting activities and we find further support for the assumption that German scientific research has, even compared to other European countries, a strong effect on technological development.

- Secondly, we find that the overall amount as well as the shares of academic patents experienced comparatively low growth rates. Actually, between 2001 and 2005, they rather underwent a decline in totals as well as shares. At the same time, university-owned patents experienced an impressive rise, initiated by the abolishment of the professors' privilege (Hochschullehrerprivileg) in 2002. Remembering that university patents are a subsample of academic patents, the differing dynamics between both samples raise further questions.
- A deeper look into the structures in academic patenting reveals that technology-specific activities leading to academic patents in purely academic inventor teams (university-owned), privately owned (private applicants) and in collaborations with SMEs (SME-owned) are pretty similar in terms of technological fields. They seem to resemble the picture of science-driven technological development. The portfolio of large enterprises (LE-owned), however, is likely to reflect their own R&D activities with a stronger focus on engineering related areas. Public research institutes (PRI-owned) exhibit a similar portfolio to large firms, reflecting their heterogeneity and their stronger focus on electrical engineering, instruments and mechanical engineering even in collaboration with universities.
- Regarding role of single universities in academic patenting we find a skewed distribution. Particularly large technical universities and universities with huge medical facilities (e.g. Charité, Heidelberg, LMU), located in large agglomerations, generate the largest numbers of academic patents.
- A detailed analysis of the trends and dynamics in the ownership structure in academic patents revealed two important findings. Firstly, other than previous approaches, we observe a slightly rising trend in academic patenting which is solely driven by the ever-increasing patenting activity not only by universities, but also by other public research institutes. Secondly, we find that the main share of academic patents is filed by firms. Thirdly, however, firm filings in shares as well as in totals exhibit a negative trend. This goes hand in hand with increasing filing activities by universities and public research organizations. Nevertheless it becomes obvious that, while small firms reveal a negative trend, large firms appear to be less sensitive and display a rather robust trend.

Overall, we conclude that recent trends in academic patenting are strongly driven by increasing efforts of German universities to claim IP on inventions made by their employees. However, other than previous approaches, our findings do not suggest a decreasing trend in academic patenting. We rather find that academic inventors' contribution to patenting activities has been rising over the last decade. This might reflect increasing public investments, basically by increasing the volume of public and competition-based third-party funding, in university research. The same accounts for public research institutions and their increasing patent portfolios.

At the same time, the last decade was characterized by increasing efforts of policy makers to induce a stronger and more efficient system for technology transfer between particularly universities, partly public research institutions and firms. These initiatives were accompanied by a set of bylaws and the funding as well as establishment of institutionalized technology transfer infrastructures. A new type of governance in university-industry interactions emerged. Taken together, these policy actions, aiming at the promotion of structured

knowledge transfer in Germany, obviously lead to increasing efforts of universities to exert IP on inventions made by their researchers. The efficiency and economic value of these initiatives (for both the universities as well as socio-economic welfare), however, remains disputable and are still in need for further discussion. Yet, this is not subject to this study and requires further research (compare e.g. Cuntz et al. 2012). One often discussed aspect is that the enforced involvement of PVAs in collaborations between university and industry is often perceived as disturbing, by both - universities and firms.

Our results indeed show, that the share of firm-owned patents from collaborative or contractual research slightly decreased over time. The main driver here, however, has been significantly reduced filings by SMEs. Thus, one might conclude that the networks between academic and large firms are more or less unaffected by the new legislation as well as increasing efforts by universities to exert control over the IP generated by their staff. At the same time SMEs might simply have a weaker bargaining position in negotiations with universities. Another, however, at least equally likely assumption is that small firms and academic start-ups might prefer licensing agreements, where the university is the owner of a patent, over own filings. SMEs often eschew from filing on their own, because they avoid the often related risk and high costs associated with patent ownership (filing, maintenance and litigations). Thus, it might be economically and managerially more reasonable for them to let the university file the patent/the patents. This might especially be the case when university TTOs and patent officers act rather supportive and in favor of the respective enterprise, when it comes to licensing negotiations. A final explanation could be that SMEs simply reduced their collaborative research activities with universities. This could have been triggered by an increasing orientation towards basic research in universities. The more scientifically advanced and basic, the less the likelihood that SMEs, due to a lack of absorptive and R&D capacities, can profit from academic research results. Anyway, further investigations are needed to clarify these points.

Additionally, figures on the total amount of private R&D investments to universities indicate a strong and steady increase from round about 450 Mio. Euro in 1999 to ca. 1.100 Mio. Euro in 2009 (Stifterverband für die Deutsche Wissenschaft 2012). This indicates rising interactions between university and industry and therefore it is quite surprising to observe (slightly) decreasing firm-owned university-invented patents. At the same time, a main implication of recent changes in research funding is the strengthened orientation of universities towards basic research, while public research institutions seem to develop a stronger specialization into their traditional mission-orientation (e.g. “Exzellenzinitiative” and “Pakt für Forschung und Innovation”) (compare e.g. Frietsch and Schubert 2012 for a discussion). Especially in universities, the emerging incentives towards basic research are likely to work at the faculty level as they directly address the research agenda of individual academic chairs. As a result they might simply be more active in collaborative research activities with firms that are less relevant for patentable research results. In sum, our results and above remarks highlight that there is still need for a better understanding of the dy-

namics in academic patenting and the intended as well as unintended implications that recent governmental initiatives had on university-industry collaborations.

Finally, an interesting finding with regard to the German research landscape is the increasing share of university-invented patents filed by public research institutions. This could, firstly, indicate an increasing tendency of public research organizations to exert IPR on research conducted in collaboration with universities. In doing so, an increasing entrepreneurial orientation and strengthened positions in IPR (universities as well as public research institutions) could be assumed. However, the emerging question would be: If this is the case for universities as well as public research institutes - Is this raising potential for conflicts? Secondly, the finding could also be interpreted as an increasing tendency to collaborate and that universities and public research institutions, besides their mission-orientation, build joint forces. Nevertheless, both points deserve future analyses.

5 References

Achleitner, A.-K., Allmendinger, J., Grupp, H., Luther, J., Soete, L., Llerena, P., Schmoch, U., Stenke, G., Meurer, P. and Ulbricht, L. (2009): *Gutachten zu Forschung, Innovation und Technologischer Leistungsfähigkeit, EFI-Gutachten 2009*. Berlin: Expertenkommission Forschung und Innovation (EFI).

Baeza-Yates, R. and Ribeiro-Neto, B. (2011): *Modern Information Retrieval - The concepts and technology behind*: Pearson Education Limited.

Crespi, G., D'Este, P., Fontana, R. and Geuna, A. (2011): The impact of academic patenting on university research and its transfer. *Research Policy*, 40, 55-68.

Cuntz, A., Dauchert, H., Meurer, P. and Philipps, A. (2012): *Hochschulpatente zehn Jahre nach Abschaffung des Hochschullehrerprivilegs* (= Studien zum deutschen Innovationssystem No. 13-2012), Expertenkommission Forschung und Innovation (EFI) (Hrsg.). Berlin.

Dornbusch, F., Schmoch, U., Schulze, N. and Bethke, N. (2013): Identification of university-based patents: A new large-scale approach. *Research Evaluation*, 22, 52-63.

Egeln, J., Gehrke, B., Legler, H., Licht, G., Rammer, C. and Schmoch, U. (2007): *Bericht zur technologischen Leistungsfähigkeit Deutschlands 2007*. Berlin: BMBF.

Expertenkommission Forschung und Innovation (EFI) (Ed.) (2012): *Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit 2012*. Berlin: EFI.

Federal Ministry on Education and Research (BMBF) (2012): *Federal Report on Research and Innovation 2012*, Berlin: Federal Ministry on Education and Research (BMBF).

Frank, A., Meyer-Guckel, V. and Schneider, C. (2007): *Innovationsfaktor Kooperation. Bericht des Stifterverbandes zur Zusammenarbeit zwischen Unternehmen und Hochschulen*. Essen: Edition Stifterverband.

Frietsch, R. and Schubert, T. (2012): Public research in Germany: Continuity and change. In: Fraunhofer ISI (Ed.): *Innovation system revisited - Experiences from 40 years of Fraunhofer ISI research*. Stuttgart: Fraunhofer Verlag, 65-84.

Geuna, A. and Muscio, A. (2009): The governance of university knowledge transfer: A critical review of the literature. *Minerva*, 47, 93-114.

Geuna, A. and Rossi, F. (2011): Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy*, 40, 1068-1076.

Kenney, M. and Patton, D. (2009): Reconsidering the Bayh-Dole Act and the Current Univer-sity Invention Ownership Model. *Research Policy*, 38, 1407-1422.

Lissoni, F., Lotz, P., Schovsbo, J. and Treccani, A. (2009): Academic patenting and the professor's privilege: Evidence on Denmark from the KEINS database. Science and *Public Policy*, 36, 595-607.

Lissoni, F. (2012): Academic patenting in Europe: An overview of recent research and new perspectives. *World Patent Information*, 34, 197-205.

Lissoni, F., Llerena, P., McKelvey, M. and Sanditov, B. (2008): Academic Patenting in Europe: New Evidence from the KEINS Database. *Research Evaluation*, 17, 87-102.

Lissoni, F., Pezzoni, M., Potì, B. and Romagnosi, S. (2013): University Autonomy, the Professor Privilege and Academic Patenting: Italy, 1996–2007. *Industry & Innovation*, 20, 399-421.

Michels, C., Fu, J., Neuhäusler, P. and Frietsch, R. (2013): *Performance and Structures of the German Science System 2012* (= Studien zum deutschen Innovationssystem No. 6-2013), Expertenkommission Forschung und Innovation (EFI) (Hrsg.). Berlin.

Mowery, D.C. and Sampat, B.N. (2004): The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments? *Journal of Technology Transfer*, 30, 115-127.

Schmoch, U. (2007): *Patentanmeldungen an deutschen Hochschulen* (= Studien zum deutschen Innovationssystem No. 10-2007). Bonn, Berlin: BMBF.

Schmoch, U. (1997): Indicators and the relations between science and technology. *Scientometrics*, 38, 103-116.

Schmoch, U. (2008): Concept of a Technology Classification for Country Comparisons: Final Report to the World Intellectual Property Organisation (WIPO). Geneva: World Intellectual Property Organization.

Schmoch, U., Dornbusch, F., Mallig, N., Michels, C., Schulze, N. and Bethke, N. (2012): *Vollständige Erfassung von Patentanmeldungen aus Universitäten*. Bericht an das Bundesministerium für Bildung und Forschung (BMBF), revidierte Fassung. Karlsruhe: Fraunhofer ISI.

Statistisches Bundesamt (2012): *Finanzen und Steuern - Ausgaben, Einnahmen und Personal der öffentlichen und öffentlich geförderten Einrichtungen für Wissenschaft, Forschung und Entwicklung*, Fachserie 14, Reihe 3.6, Wiesbaden: Statistisches Bundesamt.

Statistisches Bundesamt (2013): *Personal an Hochschulen 2012*, Fachserie 11, Reihe 4.4, Wiesbaden: Statistisches Bundesamt.

Stifterverband für die Deutsche Wissenschaft (2012): *FuE-Datenreport 2012. Analysen und Vergleiche*. Essen: Stifterverband.

Thursby, J., Fuller, A.W. and Thursby, M. (2009): US faculty patenting: Inside and outside the university. *Research Policy*, 38, 14-25.