ECONSTOR

WWW.ECONSTOR.EU

Der Open-Access-Publikationsserver der ZBW – Leibniz-Informationszentrum Wirtschaft
The Open Access Publication Server of the ZBW – Leibniz Information Centre for Economics

Frietsch, Rainer; Neuhäusler, Peter; Rothengatter, Oliver

Working Paper

SME patenting: An empirical analysis in nine countries

Fraunhofer ISI Discussion Papers Innovation Systems and Policy Analysis, No. 36

Provided in Cooperation with:
Fraunhofer Institute for Systems and Innovation Research ISI

Suggested Citation: Frietsch, Rainer; Neuhäusler, Peter; Rothengatter, Oliver (2013) : SME patenting: An empirical analysis in nine countries, Fraunhofer ISI Discussion Papers Innovation Systems and Policy Analysis, No. 36

This Version is available at:
http://hdl.handle.net/10419/83977

Nutzungsbedingungen:
Die ZBW räumt Ihnen als Nutzerin/Nutzer das unentgeltliche, räumlich unbeschränkte und zeitlich auf die Dauer des Schutzrechts beschränkte einfache Recht ein, das ausgewählte Werk im Rahmen der unter
→ http://www.econstor.eu/dspace/Nutzungsbedingungen
nachzulesenden vollständigen Nutzungsbedingungen zu vervielfältigen, mit denen die Nutzerin/der Nutzer sich durch die erste Nutzung einverstanden erklärt.

Terms of use:
The ZBW grants you, the user, the non-exclusive right to use the selected work free of charge, territorially unrestricted and within the time limit of the term of the property rights according to the terms specified at
→ http://www.econstor.eu/dspace/Nutzungsbedingungen
By the first use of the selected work the user agrees and declares to comply with these terms of use.

ZBW Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Mitglied der Leibniz-Gemeinschaft

Fraunhofer ISI Discussion Papers *Innovation Systems and Policy Analysis* No. 36

ISSN 1612-1430

Karlsruhe, October 2013

SME Patenting – An Empirical Analysis in Nine Countries

Rainer Frietsch, Peter Neuhäusler, Oliver Rothengatter

Fraunhofer Institute for Systems
and Innovation Research ISI

Contents Page

1 Introduction 1

2 Literature and Theory 2

2.1 Literature and Theory 2

2.2 Indicators 7

3 Data and Methods 9

3.1 Data & Variables 9

3.2 Methods 12

4 Findings 13

4.1 Descriptive Results 13

4.2 Multivariate Results 17

5 Conclusion and Implications 21

6 References 23

Abstract

Empirical evidence shows that the distribution of patent applications is highly skewed in terms of company size, with a few large enterprises being responsible for the majority of patent applications. Small and medium-sized enterprises (SMEs), on the other hand, are important players in national innovation systems and are the subject of policy support in many countries.

Thus, this study examines the participation rate of SMEs in patenting activities in more detail, differentiating SME patent filings by country and technology area. The analyses are based on a unique, integrated and enriched patent data set of nearly 1.2 million patent applications, built upon PATSTAT data, separating companies into SMEs and large enterprises.

The results of descriptive and multivariate analyses reveal that SMEs file fewer international patents than multinational enterprises (MNEs). However, those SMEs which are active internationally even outperform their larger counterparts in terms of internationalization. It can further be observed that SMEs are more active in emerging technologies, have smaller inventor teams and smaller family sizes on average. Furthermore, patents filed by SMEs are withdrawn more frequently but refused less often. Patents of large firms, on the other hand, have a higher chance of being granted and are cited more frequently.

1 Introduction

Small and medium-sized enterprises (SMEs) have been shown to be important sources of employment growth and innovation (Audretsch 2001) and can be seen as key players in national innovation systems, thus being the subject of policy support in many countries. SMEs make up a major share of firms in national economies. For instance, in Germany, 99.3 percent of all companies are SMEs, employing more than 58 percent of the private sector's workforce, with a turnover of about 33.6 percent and about 13.9 percent investments in R&D. A similar picture can be drawn for the US, where small businesses represent 99.7 percent of all employer firms, employing 51 percent of the workforce and accounting for 51 percent of the private sector output (Mogee 2005).

However, SMEs are facing a more and more severe technological competition – both at home and at an international scale. This technological competition and the globalization of value chains increase the necessity to secure IPR internationally. While large enterprises often act at their innovative and technological frontier, fully exploiting their technological capabilities, SMEs often have the potential for further increases.

In this paper, we attempt to analyze patterns in the patenting activities of SMEs compared to large firms in general. In particular, we want to explore in which respects the patent strategies between small and large firms differ, if and where sectoral differences exist and if there is a difference in the technological value of patents between small and large firms. This question is especially important in the light of the discussion on strategic patenting (Arundel/Patel 2003; compare for example Blind et al. 2006; Blind et al. 2009; Kortum/Lerner 1999), which has been found to be more and more extensively used from the beginning of the 1990s, resulting in backlogs at the patent offices, low-quality blocking patents and an overall increase of social costs, mostly coming from the private sector (Frietsch/Jung 2009). This can be seen as a major challenge for the patent system, thus being an important policy issue.

We base our analyses on a unique, integrated and enriched patent dataset, built upon the European Patent Statistical Database (PATSTAT), separating companies into SMEs and large enterprises. In total, we analyze nearly 1.2 million international patent applications between the years 2000 and 2008, differentiated by country, technological field and firm size.

The paper is structured as follows. Section 2 provides an overview on the literature and presents our hypotheses. Section 3 shows how we collected our data, explains the choice of our variables and presents the estimation methods for our multivariate analyses. Our descriptive as well as multivariate findings are presented in Section 4. Section 5 concludes.

2 Literature and Theory

2.1 Literature and Theory

SMEs play a critical role in national innovation systems, being not only essential but even a pushing factor for their structural rejuvenation. Although the number of patents per employee is larger for small than for large firms (Audretsch 2001), empirical evidence shows the distribution of patent applications is highly skewed in terms of company size. Large companies account for the lion's share of patent applications, which is even amplified when looking at patent filings at the international level (Blind et al. 2006; Frietsch 2007; Frietsch/Jung 2009; Hingley/Bas 2009; Mogee 2005). These patterns might emerge due to the differing role of small and large firms within innovation systems. While large firms have the advantages of employing large research facilities, also abroad, finance several R&D programs at a time, attract highly skilled personnel, bene-

fit from economies of scale and scope etc., SMEs have the organizational advantages of responding quickly and flexible to market needs.

This differing role in the overall innovation process gives rise to the question of why and especially how patent activities and strategies differ between small and large enterprises. One major difference, from which several additional assumptions about the patenting behavior of small and large businesses can be derived, is that SMEs face higher financial constraints than their large counterparts do (Breitzman/Hicks 2008; Mogee 2005). They do not have the necessary resources at their disposal and virtually possess less market power to enforce their rights (Neuhäusler 2012). The innovation process, from invention to commercialization, however, can be quite cost-intensive and is associated with a great deal of uncertainty, with costs arising a) at the *invention stage*, in terms of R&D expenditures for personnel and equipment, b) at the *patent process stage*, for patent application, translation, renewal or lawyer fees and c) at the *diffusion stage*, when it comes to being target of opposition or litigation or defending an infringed patent as well as commercializing a patent (or a product integrating the protected invention).[1]

SMEs' financial constraints and the high-cost of patenting, associated with uncertainty about the success of the developed inventions, may lead to differing patent strategies, different field specific engagement as well as differences in the (perceived) technological value of patents. The theoretical arguments regarding the different dimensions on which SMEs differ from their large counterparts will now be reviewed in more detail.

Internationalization

First of all, we take on an internationalization perspective. The application of a patent and the associated search for information, translation, as well as the costs to employ a patent lawyer or even maintain an in-house patent division are significant cost factors at the *patent process stage*, which are even amplified when it comes to filing patents in foreign jurisdictions (Hanel 2008). In addition, the commercialization of a technology to several different markets at the *diffusion stage* is a cost-factor, which should not be underestimated. New distribution channels have to be created, the firms have to increase their marketing investments and might have to build up supplier networks, increasing transaction costs. Because SMEs control fewer resources in general, they can thus be assumed to file fewer patents internationally than larger firms do, as they ap-

1 We are aware of the fact that innovation is not a linear process and costs may arise in other stages or feedback loops, too. We only concentrate on the ones relevant to patenting for the sake of simplicity.

proach fewer markets due to the market development costs. In addition, SMEs might file patents less broadly, in terms of the number of different patent offices that are targeted by one patent application. This already leads to our first two hypotheses:

H1a: *SMEs file less of their patents internationally than large firms do.*

H1b: *SMEs patent the same invention in fewer countries than large firms, i.e. they patent less broadly, and therefore have a smaller family size on average.*

The question of the internationalization of SMEs in terms of patenting can be seen as quite important from a policy perspective. A low degree of international patenting may be a disadvantage for small firms, since international patenting provides the applicant with more opportunities to license his technologies, arrange cross-licensing agreements or even partnerships, or enlarge his profits from technology investments (Chesbrough 2003).

Research Teams

In a second line of argumentation, we take on the productivity as well as the creativity perspective. From a productivity point of view, SMEs can be assumed to employ smaller teams of inventors on average, since smaller inventor teams mean fewer costs for developing an invention (*invention stage*). In a study of 8,300 PCT patent applications by US owned companies in the emerging field of nanotechnology, Fernández-Ribas (2010) found that SMEs tend to have smaller inventor teams than large firms. She therefore argues that SMEs tend to be more productive, at least in terms of the number of inventors per patent, due to their smaller team size on average. The costs of producing a technology are thus lower for SMEs. Furthermore, SME less often have a formal R&D department and even do not always have R&D personnel (Edler et al. 2003). This means that fewer people are concerned with creativity or research.

In addition, taking on the creativity perspective, it could be argued that a larger team of inventors reflects a larger breadth of the human capital and knowledge base. In this sense, a larger team of inventors should involve a larger set of skills (Guellec/van Pottelsberghe de la Potterie 2000; Van Zeebroeck et al. 2009). Because inventions basically are a combination of existing ideas (Schmoch et al. 1988), the larger skill-set should result in a (technologically) more valuable invention. Increasing the size of research teams is once again a strategy that seems to be easier to realize for large firms, because they simply can pick from a larger pool of employees and additionally have the resource base to maintain larger research teams. Both lines of argumentation lead to our second hypothesis:

***H2**: The inventor teams of SMEs are smaller on average than the inventor teams of MNEs.*

Defense

When it comes to the *diffusion stage,* SMEs first of all have been shown to have a lower capability of pursuing their IPR in case of infringements (Graham/Harhoff 2005). Additionally, the probability for patents to be opposed or litigated by a third party can be assumed to vary by firm size. Larger firms – relatively seen – are less often the target of patent litigation than SMEs (Bessen/Meurer 2005; Cremers 2004). The reason is the higher threat potential of large enterprises that is further increased by the presence of a large patent portfolio, which leads to greater experience or routine in patenting and in the enforcement of rights (Arundel et al. 1997). This can be seen as a major policy issue, since it might dissuade small firms from patenting (Cohen et al. 2000).

***H3:** Patents filed by SMEs are opposed more frequently than patents filed by large enterprises.*

Motives

Due to the high costs for applying and renewing patents, SMEs can be assumed to use patents less often strategically in technology competition (*diffusion stage*) (de Rassenfosse 2010; Koehler 2011; Mogee 2005). Many small firms simply cannot afford a large patent portfolio, including patents for the purpose of blocking competitors. Additionally, most of the existing strategic motives for patenting are potentially more beneficial for large enterprises (Neuhäusler 2009). Blocking competitors, for example, is impossible until a firm has some patents at its disposal and has the (financial) capabilities to patent broadly (Blind et al. 2006). Besides using patents as a protection from imitation, which is still the main motive for small firms to file a patent (Blind et al. 2006; de Rassenfosse 2010), the literature shows that there are two strategic motives to patent that are potentially more beneficial for small than for large firms. The first one is to file a patent in order to gain access to the capital market, i.e. the banks (Rammer 2003; Rammer 2009) or venture capital, and attract investors (Hsu/Ziedonis 2008; Veer/Jell 2012). The second is to generate licensing revenues (Blind et al. 2006; de Rassenfosse 2010). These two strategic motives, however, require the patent to have a given technological height, an implementation and market potential, and it is not solely used for blocking purposes. Thus, since strategic patenting for SMEs only makes sense for patents that involve a considerable inventive step, whereas this is not a necessary precondition for patents that are filed to block competitors, SMEs can be assumed to file patents with a higher technological value on average than their large counterparts.

Another difference in the strategies between MNEs and SMEs can be found when looking at their closeness to science as measured by non-patent literature citations. Especially in science based industries, university spin-offs and high-tech companies more generally seem to be intensively engaged in science interactions (Rothaermel et al. 2007; Zucker et al. 2002), which implies that those firms also more often build on a scientific knowledge base. However, one could also argue that the larger resource base of MNEs allows them to build on scientific knowledge especially in order to gain access to non-core technologies, while small firms tend to focus on problem solving in core technological areas (Santoro/Chakrabarti 2002).

In sum, it can be assumed that patenting for strategic reasons is less likely to occur for SMEs, which should lead to a higher (technological) quality of SME patents on average.

H4: *Patents from SMEs are more valuable. Therefore, SME patent filings* ***a)*** *are granted more often,* ***b)*** *are cited more often by subsequent patents,* ***c)*** *cite more previous patents,* ***d)*** *cite more non-patent literature, than the patents from large and multinational enterprises do.*

Field specifities

Another topic we are concerned with, are the technology field specificities in patenting of large and small firms. Several studies show that SMEs are relatively more engaged in early phases of the technology development (Fernández-Ribas 2010; Schmoch 2007) and therefore tend to be more engaged in emerging fields with new ideas (Fernández-Ribas 2010). This is supported from a theoretical point of view, since established fields have a clearly defined market with high entry barriers, for example in terms of blocking patents, which deter market entry especially for small firms with only few financial resources (Blind et al. 2006). An additional theoretical argument comes from the theory of product cycles. Especially at the beginning of the product cycle, firms face other market participants in a technology (or quality) rather than a price competition. In later phases, when technologies mature, the technology competition regularly shifts to a price competition (Kleinknecht/Oostendorp 2002; Legler/Krawczyk 2006; Maskus/Penubarti 1995; Meyer-Krahmer/Dreher 2004; Utterback/Abernathy 1975). For SMEs, however, price competition is hard to face, since economies of scale cannot be realized in a large fashion. This means that they are either crowded out of the market or have to expand and become larger.

H5: *SMEs are more active in the emerging fields of nanotechnology, biotechnology, optics and renewable energies than their large counterparts.*

2.2 Indicators

In order to analyze the question of the lower degree of internationalization of SMEs in terms of patenting, the family size of a patent serves as a first indicator. It is determined by the number of countries or patent offices, at which the same patent has been applied at (Putnam 1996; Schmoch et al. 1988). Therefore, it provides information about the number of markets that are sought to be secured by the applicant to sell his invention.

In order to indicate the amount of R&D personnel needed to generate an invention that can later eventually be patented, similar to the work of Fernández-Ribas (2010), we use the average number of inventors per patent. This gives us an indication of the team size needed for the development of a particular piece of technology inside a company and serves as a proxy for the breadth of the human capital and knowledge base underlying an invention.

To differentiate between technologically more or less valuable patents, several indicators have been proposed in the literature. A first and very straightforward indicator is the grant of a patent, which provides information if a patent has met the criteria of novelty, inventive step and commercial applicability (Frietsch et al. 2010). This is not the case for refused patents, clearly indicating that the given patent application did not meet the regular conditions for being granted. Things are a little more complicated when it comes to withdrawn patents, since a withdrawal can indicate different things. Of course, it may only be an anticipation of a future refusal (compare for example Harhoff/Wagner 2009). On the contrary, withdrawn patents can also have had a strategic (e.g. blocking value) during their lifetime, and can therefore be seen as strategic patent applications. However, the decision to withdraw a patent could simply reflect a successful product portfolio management of a firm.

In addition, citation based indicators are often used to indicate the technological value of patents. Patent forward citations are especially prominent in the literature. It is assumed that the number of forward citations (citations a patent receives) measures the degree to which a patent contributes to a further development of advanced technologies, and thus can be seen as an indicator of technological significance (Albert et al.

1991; Deng et al. 1999; Narin et al. 1987; Trajtenberg 1990).[2] Backward citations (citations a patent makes), on the other hand, refer to previous patents and are mostly used as an indicator of technological breadth or background of an application and can give hints on the scope of a patent (Frietsch et al. 2010; Harhoff et al. 2003). However, one could also argue, that backward citations give proof of some stock of existing knowledge a patent application draws upon. Thus, a smaller number of references made to previous patents implies that the patent at hand builds on a small stock of existing knowledge and can therefore be considered as more original or novel (Fernández-Ribas 2010; Rosenkopf/Nerkar 2001). Finally, references to non-patent literature (NPL-citations) can be used to indicate the closeness to science or basic research of a firm's R&D activities (Deng et al. 1999). A closer linkage to science can be assumed to heighten the technological value of a patent.

In order to shed more light on the question if SME patents are challenged by third parties more often than the patents filed by large firms, opposition or litigation data can be employed. In contrast to the US, where infringed patents often are litigated on court, at the EPO, any third party may file an opposition against a granted patent within a period of nine months after grant.[3] Based on the findings from the existing literature, it can be argued that SMEs are more often target of opposition or litigation because of their lower bargaining power.

However, there is a caveat about using the oppositions as an indicator of the lower bargaining power in patent negotiations, at least when analyzing SME patent filings, since opposition (or litigation) history has also been shown to reflect the technological value of a patent (Harhoff et al. 2003; Harhoff/Reitzig 2004; Lanjouw/Schankermann 1998; van der Drift 1989). The basic argument is that opposing a patent is subject to significant additional costs, for which companies should only be willing to pay if they see a reasonable restriction of their (economic) room to maneuver by the contested patent. In addition, an appeal against a patent means that at least two parties conduct research for exactly the same piece of technology, or are at least active on similar mar-

2 As a specific feature of the EPO, patent citations are categorized into different types. First of all, there are citations which are particularly relevant regarding the assessment of the novelty or the inventiveness of the application (invention) examined. These can be called the "relevant" citations with the codes X or Y (European Patent Office 2012). In order to find out if firm size affects different kinds of citations in a differently, we differentiated citations by their kinds in the course of the analyses.

3 In the course of the Leahy-Smith America Invents Act (AIA) signed into law in 2011, post-grant review procedures were introduced at the USPTO, which came into effect in 2012. These procedures are similar to the opposition procedures at the EPO and might reduce patent litigation on court within the US in the future.

kets. Therefore, the costs and risks associated with the dispute signal the existence of a market for the patented invention (Van Zeebroeck 2009b).

Thus, from both perspectives (technological value and bargaining power), it could be argued that SME patents are more often opposed than patents filed by large firms with the opposition indicator not being able to differentiate between the two effects. Nevertheless, we keep the indicator in our sample to at least gain some insight on the structural effect of firm size on oppositions in our multivariate modeling, maybe coming back to this particular problem another time.[4]

3 Data and Methods

3.1 Data & Variables

The data we use for the study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT), which provides information about published patents collected from 81 patent authorities worldwide. The patent data applied here follow the concept of transnational patents, recently suggested by Frietsch and Schmoch (Frietsch/ Schmoch 2010), which is able to overcome the home advantage and unequal market orientations of domestic applicants, so that a comparison of technological strengths and weaknesses between countries becomes possible. In detail, all PCT applications and all direct EPO applications without precursor PCT application are counted. This excludes double counting of transferred Euro-PCT applications. Put more simply, all patent families with at least a PCT application or an EPO application are taken into account.

All the patents in the dataset are counted according to their year of worldwide first filing, the so-called priority year. This is the earliest registered date in the patent process and is therefore closest to the date of invention. We included all patent filings from the priority years 2000 to 2008.

Our analysis focuses only on patent filings from companies. The differentiation by the type of the applicant, i.e. whether it is a small or medium sized enterprise (SME) or a

4 A similar argumentation can also be made for the family size, since it can also be interpreted from a patent value point of view. The basic argument from this perspective is that an applicant should only be willing to bear the additional costs for filing his patent in several jurisdictions if he expects a correspondent profit (Frietsch et al. 2010). However, we believe that this argument does not make too much sense when it comes to the differentiation between small and large firms in terms of patent activity per se, because of the overwhelming cost-saving argument and can therefore be disregarded in this context.

large multinational enterprise (MNE) was done manually for all countries used in this analysis. In a first step, companies were separated from individuals and academic applicants in the patent data. Applications for which the applicant and the inventor name were identical were identified as patent applications by individual inventors and were excluded from this analysis. Next, the legal status of an applicant (e.g. Inc., AG, GmbH, S.R.L etc.) was used to identify companies. For the remaining records a manual check was carried out to identify them as academic/non-profit organizations or classify them as individuals or companies. In a second step, the differentiation between SMEs and MNE was performed for those applicants, which were classified as a company in the first step. To simplify this procedure, applicants with less than four patent filings in a three-year time window between the priority years 1996 and 2008[5] were in general classified as SMEs. We verified this simplifying assumption by drawing a sample of this group and checking them manually. We found errors and misclassifications in less than 5 percent of the examined cases and therefore accepted our procedure. For the remaining applicants, information on the number of employees was used. The name of the applicant in the PATSTAT database was compared with the names of companies from Hoppenstedt (Germany), Amadeus (Europe), Hoovers (USA, Japan) databases and complemented with information from internet searches where necessary. Again, this comparison was done manually. Applicants with more than 500 employees and more than three patent filings in a three-year time window between the priority years 1996 and 2008 were classified as MNEs. 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.

The information on the type of the applicant is available only for nine countries, namely Finland, France, Germany, Great Britain, Japan, Netherlands, Sweden, Switzerland and the USA. The countries are differentiated by the country where the applicant is located. This means that each patent is assigned to the country from which the patent has been filed, implicitly accounting for the fact that larger firms might apply all their patents for example from the country where their headquarters or main research facility is located. Therefore, a patent filed by a US applicant is counted as a patent originated from the USA.

---

5 Clearly, this could lead to distortions especially in the earlier years of our analysis, since the time period for the applicant type definition is shorter than the full time period under analysis. We used the information on the applicants gained from this period and also the same definition of applicants also for the period 1985 to 1995. However, we decided to analyze data as far back as 1985 since we believe that timing effects are important and checks have proved that distortions are limited.

Technologies are differentiated by high-technology fields, including a residual low-tech area (Legler/Frietsch 2007) and emerging technologies. Emerging technologies are defined in terms of the International Patent Classification (IPC) in the fields of optics, renewable energies, nanotechnology and biotechnology. For our further analyses, we added additional indicators that are commonly used to indicate a patent's technological value, e.g. forward citations. In order to get insights into differences in the closeness to science between SMEs and MNEs, we also added the references made to non-patent literature. We further add information on the legal status of patent filings, which indicates if a patent has been granted, withdrawn, refused or opposed during the examination process. For the definition of the legal status of a patent application, the Patent Register Service (PRS) codes were employed, which are assigned to each patent application by the EPO. The data for the legal status of patent filings refer only to direct filings at the EPO, since the World Intellectual Property Organization (WIPO), where PCT-applications are filed, only forwards patents to the respective national offices and is not responsible for patent examination.

In sum, this leaves us with a final sample of nearly 1.2 million patents – about 350.000 in the case of the legal status analyses[6] – from 2000 to 2008, differentiated by firm size, technology field and the country of the applicant.

Table 1 Overview of the variables and summary statistics (about here)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Applicant Type	1199711	0.73	0.44	0	1
Granted (Dummy)	345914	0.31	0.46	0	1
Withdrawn (Dummy)	345914	0.24	0.43	0	1
Refused (Dummy)	345914	0.02	0.12	0	1
Withdrawn or Refused (Dummy)	345914	0.26	0.44	0	1
Opposed (Dummy)	345914	0.01	0.11	0	1
Family Size	1127038	4.70	3.08	2	45
# NPL citations	1199711	1.59	12.25	0	8936
# BW citations	1199711	5.96	7.53	0	399
# FW citations	1199711	0.90	2.52	0	313
# XY citations	1199711	0.32	1.09	0	177
# AXY citations	1199711	0.47	1.31	0	178
# Inventors	1199711	2.73	1.93	0	99

Source: EPO – PATSTAT, own calculations

6 Besides the fact that the legal status of patent filings refer only to direct filings at the EPO there is still missing information on the legal status for those filings which are still pending in the patent process, where no decision on the outcome of the examination has yet been taken by the EPO.

We now briefly turn to the variables to be used in our multivariate analyses (Table 1). Following the theoretical discussion from Section 2, we use different kinds of variables as response variables in our models, with the applicant type as an explanatory variable in each model, as well as dummy variables to control for country- and field-specific effects. The applicant type variable is coded 0 for SMEs and 1 for large firms and thus serves as our company size indicator.

Relating to the discussion on the legal status of patent filings, dummy variables were created, which indicate if a patent has been granted (coded 1 for yes, coded 0 for no), withdrawn, refused during or opposed after examination process.

The citation variables, as well as the number of inventors, all are count variables. In the case of forward-citations, including the A, X and Y citations, which are analyzed separately, a four-year time window was used. This time window assures that all patents have the same amount of time to be cited. Not using a time window would lead to higher citation counts for older patents, as they had a longer time period to be cited, which would cause a systematic bias. A time-window is not necessary for the analysis of backward- and NPL-citations, since those references are made to previous documents and thus they are not biased by timing effects. Another variable analyzed is the family size of a patent application, or of an invention, to be more precise. It is defined as the number of distinct patent offices where the patent was filed, excluding the so-called "singletons", which are patent applications filed at only one patent office in total (Martinez 2009; Martinez 2010). Therefore, the family size variable is also a count variable, however, excluding zero and one counts, which means that it is a censored count variable, which requires certain estimation methods (see the description in Section 3.2).

3.2 Methods

Different types of models with the dichotomous firm size as an explanatory variable – as well as dummy variables to control for country- and field-specific effects – were fitted in order to test our hypotheses.

To analyze the effects on the legal status variables in more detail, logistic regressions were employed, since the outcome variables are dichotomous, i.e. a patent was granted or not, withdrawn or not etc. In the logit model, the log odds of the outcome are modeled as a linear combination of the predictor variables (Long 1997). For the analyses of citations, family size and the number of inventors, negative binomial regression models were used, because these variables are in the form of count data. Several kinds of count models exist to address this problem, with the Poisson and the negative binomial regression model probably being the most prominent. The Poisson distribu-

tion, however, assumes that mean and variance of the response variable are the same (Long 1997). If the variance is much larger than the mean, the model underestimates the variance and standard errors of the Poisson regression, leading to overly large z-values. A large difference of the mean and variance of those variables can already be observed in Table 1. This overdispersion can be accounted for by a negative binomial regression model, which adds an overdispersion parameter alpha reflecting the unobserved heterogeneity between observations (Long/Freese 2003). A likelihood ratio test on this parameter showed that the negative binomial distribution in this sample is not equivalent to a Poisson distribution and therefore the negative binomial regression model is most suitable for this analysis.

A specialty occurs for the family size variable, since it is a zero-truncated variable, i.e. zero counts are not possible. Therefore, we ran a zero-truncated negative binomial regression model for this specific variable, because ordinary negative binomial regression would try to predict zero counts even though there are no zero values, leading to biased estimates. Again, a likelihood ratio test showed that the zero-truncated negative binomial model is preferred to a zero-truncated Poisson model in this sample.

In a second set of analyses, SME patent filings in different technological fields will be analyzed in more detail. In order to stay consistent with our previous models, the field variables were used as dependent variables, with firm size as an explanatory variable. We differentiate the patents in our dataset as belonging to a high-technology field (coded 1) or not (coded 0) as well as belonging to an emerging field (coded 1) or not (coded 0). For a more detailed overview of SME patenting in emerging fields, we further ran more specific regressions for four emerging fields, namely biotechnology, nanotechnology, renewable energies and optics. Country specific effects were also controlled in all of those models. Since the technology field variables all are dummy variables, we again employed logistic regression models.

4 Findings

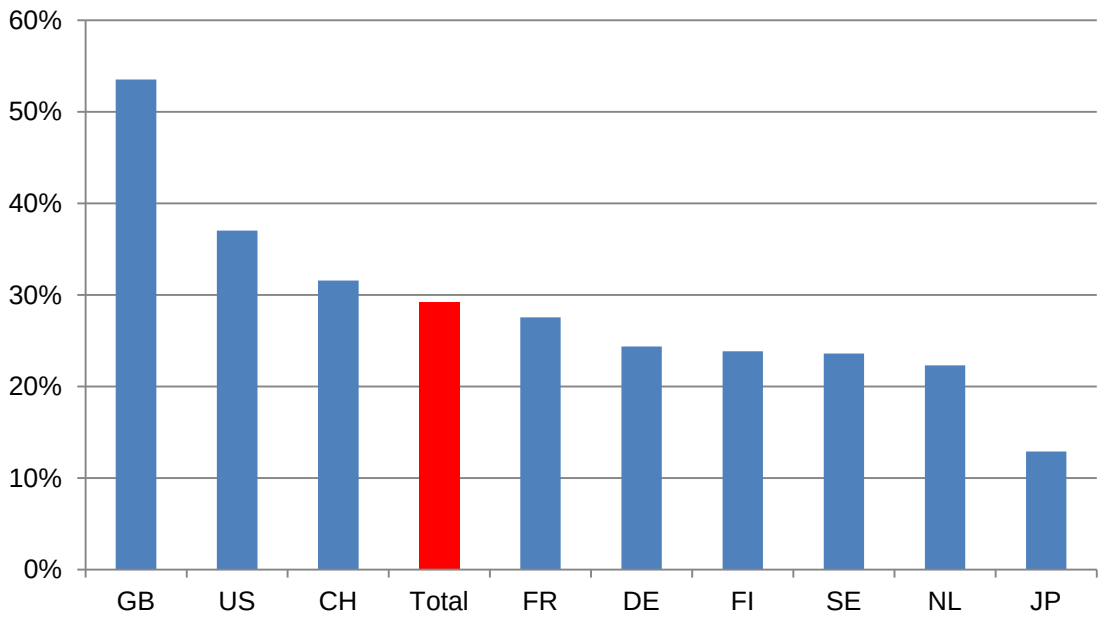
In order to test our hypotheses on the structural differences in patenting between SMEs and large enterprises, Section 4.1 first presents our descriptive findings. Section 4.2 presents the results of our multivariate models.

4.1 Descriptive Results

Figure 1 shows the shares of transnational SME patents compared to the share of transnational patents by large firms. In total, nearly 30 percent of all transnational patents are filed by SMEs. When looking at the country-wise patent filings, however, a

more differentiated pattern can be revealed, which can be attributed to the industry structure in the different countries. Great Britain, being an economy that is dominated by SMEs in its industrial structure, reaches a share of more than 50 percent SME patents. SMEs also are comparably patent active in the US and Switzerland, however not reaching a share of more than 50 percent. The opposite is true for Japan, where the industry structure is dominated by large firms. Only about ten percent of Japanese patents from the industry are filed by SMEs. In sum, the results support H1a, stating that SMEs patent less internationally than large enterprises, with Great Britain as an exception. Yet, since the shares of transnational SME patents are also dependent on the industry structure of the filing country, only the following multivariate analyses allows us to investigate H1a in further detail.

Figure 1 Shares of transnational SME patents by applicant country (industry only), 2006-2008

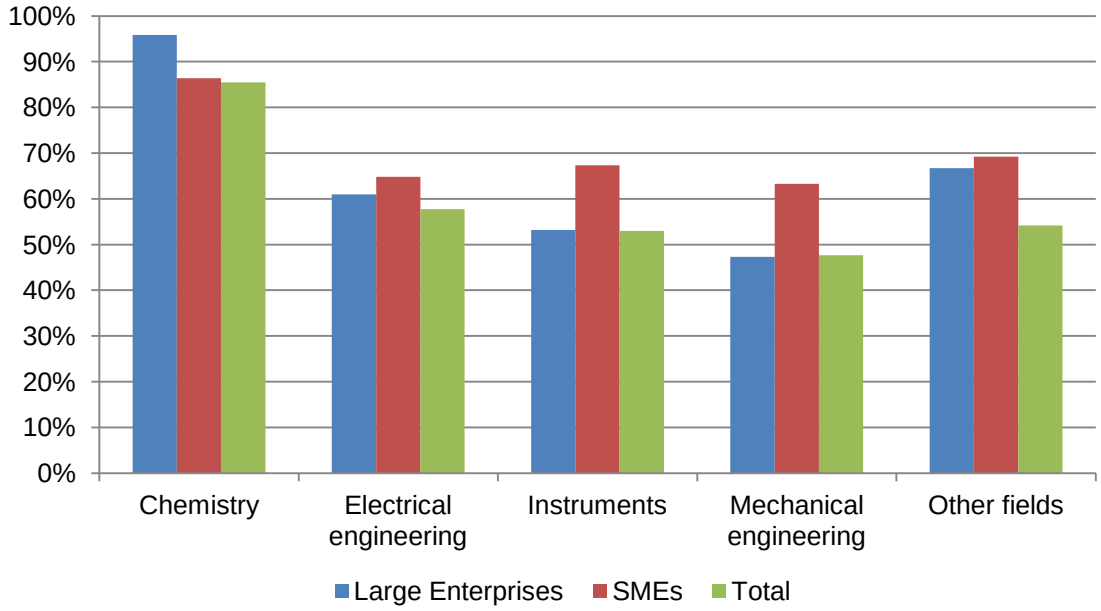


Source: EPO – PATSTAT, own calculations

In Figure 2, EPO applications from German applicants, differentiated by size, in relation to patent applications at the German Patent and Trademark Office (GPO) are plotted. We can see that the share of EPO applications on applications at the national office is higher than the respective share for MNEs in all technology fields, except for chemistry. This effect is especially pronounced in the field of mechanical engineering and instruments. In electrical engineering and the residual category of "other fields" the difference is smaller. However, it can be stated that German SMEs, although having lower shares of transnational patents in general, outperform large firms in terms of international pa-

tent activity as soon as they are patent active at an international level. This indicates a higher internationalization of SMEs, at least in relative terms. This finding is also in line with empirical results reported in the literature (Chetty/Stangl 2010; Kinkel et al. 2008; Leiponen/Byma 2009; Olejnik/Swoboda 2012). Once a company makes the decision to use patents at all, it generally starts using them continuously. In addition, there are companies which are active internationally and those which are not. Once a company is active internationally, it generally does so with a large share of its portfolio. In combination, this indicates a kind of threshold effect for international SME patenting. This threshold seems to be higher for SMEs, yet once a certain level of internationalization is reached, the lion's share of the patent portfolio is internationalized.

Figure 2 EPO applications of German applicants in relation to applications at the German Patent and Trademark Office (GPO), 2006-2008

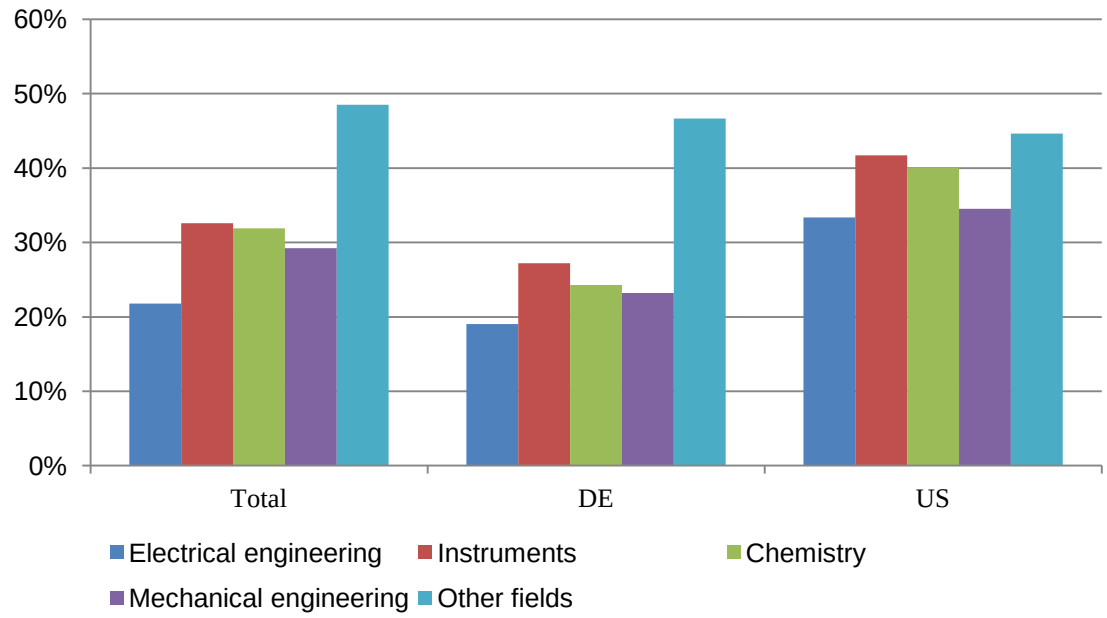


Source: EPO – PATSTAT, own calculations

Taking a closer look at the field differences, Figure 3 shows the share of transnational SME patents compared to the share of transnational patents by large firms by field for Germany and the US. Overall, we find that SMEs are least active in the field of electrical engineering, only reaching a share of about 20 percent. In the fields of chemistry, instruments and mechanical engineering, the share of SME patents is rather equal, with the shares reaching between 25 and 30 percent on average. In the residual category of "other fields" SMEs reach the highest shares in comparison. A similar picture can be drawn for Germany, although the shares of SME patents are slightly smaller over all technological fields. In the US, the shares of SME patents in electrical engi-

neering, instruments, chemistry and mechanical engineering are higher than in the case of the overall patent applications and thus also higher than in Germany. Yet, also in the US, the shares of SME patents are highest in the "other fields" category. In sum, we can state that SMEs in general are less active in high-technology fields like electrical engineering than their large counterparts and more active in the "other fields" category.

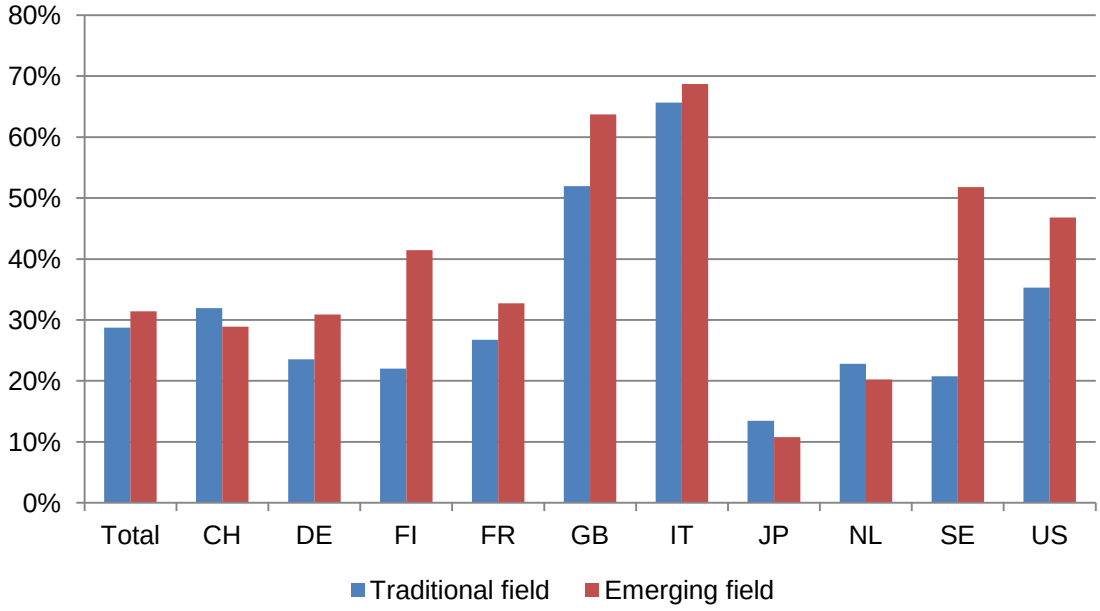
Figure 3 Transnational SME patents by field, total, Germany and the USA



Source: EPO – PATSTAT, own calculations

In order to gain some more insight on our third hypothesis, which stated that SMEs are more active in emerging technology fields, Figure 4 shows the share of SME patents across countries, differentiated by traditional versus emerging fields. The emerging fields category is an aggregate of the four fields that are analyze in more detail in the multivariate analyses, namely optics, renewable energies, nanotechnology and biotechnology. All other technological fields are categorized as "traditional" here. Already at this stage, it becomes obvious that SMEs are more active in emerging fields in almost all analyzed countries, providing a first support for H3. This is especially true for the Scandinavian countries Sweden and Finland, but also for the US, Great Britain, France and Germany. The only countries where MNEs are more active in "traditional" fields are Japan, Switzerland and the Netherlands, which can be seen as exceptions here. However, the multivariate models provided in Section 4.2, which will allow a more differentiated and detailed analysis of the data, will shed some more lights on the activity of SMEs in emerging technology fields.

Figure 4 Share of SME patents in traditional and emerging technology fields, 2006-2008



Source: EPO – PATSTAT, own calculations

4.2 Multivariate Results

Taking our analyses from Section 4.1 one step ahead, this section presents the results of our multivariate analyses (Table 2). It shows the effects of the dichotomous firm-size variable on the different outcome variables, like granted patents, family size or the number of forward and backward citations, all calculated in single regression models with firm size as an explanatory variable as well as control variables for the country of the applicant and technological field of the patent application.[7] Therefore, on the left-hand side of the table, the response variables can be found. The presented coefficient is the coefficient of the dichotomous firm size variable on the respective outcome variable. The effects of the country and technology field dummies, which are also a part of each of the regressions, are not shown explicitly because they do not form the core of this analysis. Since large firms are coded 1, positive values of the coefficients mean that the probability to be in the respective outcome category is higher for large firms, whereas negative values mean the probability is higher for SMEs.

7 The technology field dummies in these regressions are aggregated values, differentiating leading-edge, high-level and low-technology fields. Further details on the field composition can be found in Legler and Frietsch (2007).

Starting with the family size variable, we find a significantly positive effect, indicating that large firms have larger family sizes on average than small firms. This supports our H1b that SMEs patent less broadly, i.e. target fewer patent offices with their patent filings on average, than MNEs.

In H2 we stated that the inventor teams of SMEs are smaller on average than the inventor teams of MNEs. The significantly positive coefficient of the firm size variable in our models supports this hypothesis. This also replicates the results from the study of Fernández-Ribas (2010). Yet, argumented from a creativity perspective, a smaller inventor team reflects a smaller set of skills that lies beyond an invention (Guellec/van Pottelsberghe de la Potterie 2000; Van Zeebroeck et al. 2009), which should thus result in (technologically) less valuable inventions (Schmoch et al. 1988). Seen from this perspective, increasing the size of research teams could be an innovation strategy that is easier to realize for large firms, due to their larger resource base.

Table 2 Results of the regression models

Dependent Variable	**Coef.**		**S.E.**	**Obs.**	**R^2**	**Regression Type**
Granted (Dummy)	0.114	***	0.009	345914	0.014	Logit
Withdrawn (Dummy)	-0.242	***	0.010	345914	0.011	Logit
Refused (Dummy)	0.670	***	0.041	345914	0.039	Logit
Withdrawn or Refused (Dummy)	-0.189	***	0.009	345914	0.013	Logit
Opposed (Dummy)	0.045		0.035	345914	0.036	Logit
Average Family Size$^{\alpha}$	0.116	***	0.002	1127038	0.010$^{\alpha}$	Zero Trunc. Neg. Bin.
# NPL citations$^{\beta}$	0.038	***	0.010	1199711	0.029$^{\alpha}$	Neg. Bin.
# BW citations$^{\beta}$	0.015	***	0.003	1199711	0.006$^{\alpha}$	Neg. Bin.
# FW citations$^{\beta}$	0.197	***	0.006	1199711	0.008$^{\alpha}$	Neg. Bin.
# XY citations$^{\beta}$	0.178	***	0.007	1199711	0.011$^{\alpha}$	Neg. Bin.
# AXY citations$^{\beta}$	0.180	***	0.006	1199711	0.009$^{\alpha}$	Neg. Bin.
# Inventors$^{\beta}$	0.141	***	0.001	1199711	0.009$^{\alpha}$	Neg. Bin.
Country-Dummies	YES					
Field-Dummies	YES					

Significance level: ***<0.01, **<0.05, *<0.1, robust standard errors. $^{\alpha}$ McFadden's R^2

Source: EPO - PATSTAT, own calculations

Turning to the legal status variables, it can be observed that, contrary to our expectations, patents of large firms have a higher chance to be granted than patents filed by SMEs. However, this effect could be mediated by the fact that MNEs file more Euro-PCT applications in total, which are ceteris paribus granted more often by the EPO (Van Zeebroeck 2009a). In addition, the effect could also be associated with the fact that large firms have more bargaining power and experience in negotiations with the

patent office and therefore have a higher chance to get their patents granted than small firms. Nevertheless, we have to reject our hypothesis of a higher grant rate for patents filed by SMEs (H4a). Similarly, we find a higher withdrawal rate for small firms, indicated by the negative coefficient, but a lower refusal rate. In the case of the refusals the interpretation is quite straightforward. Patents filed by MNEs meet the regular conditions for being granted less frequently than patents filed by SMEs. In the case of withdrawals the story becomes a bit more complicated. On the one hand, a withdrawal can simply indicate an anticipated refusal. If that would be the case, SMEs could simply withdraw their patents before refusal more often than large firms do, which could explain the difference in the sign of the coefficients. On the other hand, withdrawn patents can also have had a strategic (e.g. blocking value) during their lifetime, and can therefore at least in part be seen as strategic patent applications. We thus constructed the indicator for withdrawals or refusals in combination to analyze this in more detail. The coefficient is significantly negative, showing that the event of a withdrawal or a refusal is more common for patents filed by SMEs. Assuming that strategic patenting is more common large firms, this effect could also reflect a different kind of patent portfolio management of SMEs in comparison to large firms. However, these explanations remain speculative because, at least with our current data, we are not able to provide evidence for one or the other of these assumptions.

When looking at the citation variables, we find that the number of backward citations on average is significantly higher for MNE patents, pointing at the fact that patent applications by large firms are broader in scope (Harhoff et al. 2003). However, it could also be interpreted in the sense that MNEs are building on a larger stock of existing knowledge, implying a lower originality of their inventions or even a larger number of inventions that are more incremental in nature (Fernández-Ribas 2010; Rosenkopf/ Nerkar 2001). Turning the argument the other way round and taking a closer look at the forward citations, it can be shown that patents filed by MNEs are cited more often, in general and also when looking at the effects of X and Y and A, X and Y citations only. This can be interpreted insofar as MNEs file more valuable patents than SMEs, at least in terms of citations those patents receive and we thus have to reject H4b. This stands in contrast to the results of Mogee (2005), who found that small-business patents are represented more highly among the most highly cited patents. Yet, she also found this difference to be significant only in the fields of communications, computers and “miscellaneous electrical”. The result in our sample that MNE patents are cited more often is supported by the relatively high significant correlation of the number of forward and backward citations (0.254***). A patent making a larger number of references to previous patents is also cited more often.

In addition, the number of NPL-citations is larger for MNEs than SMEs and thus we have to reject H4d. This implies a closer linkage to science or basic research by large firms. As we have seen in the theoretical section, this might mostly have to do with the resource base of larger firms, which allows them to build on scientific knowledge especially in order to gain access to non-core technologies (Santoro/Chakrabarti 2002).

Concerning the opposition rates, we find no significant difference between small and large firms. It seems that firm size does not matter when it comes to opposing the patents of competitors in the field, implying that small as well as large companies on average become targeted equally often by an opposition appeal. This results stands in contrast to the results of Bessen and Meurer (2005) and Cremers (2004). However, they first of all analyzed patent litigation, not opposition, which is a specialty of the EPO system. Second, and even more important, the analyses of Bessen and Meurer (2005) covered the US system, where patent litigation is a much more common event than in Europe and structures might differ significantly.

In sum, we have to reject the hypothesis of a higher technological quality of SME patents, at least in our sample (H4a-H4d). Rather we find support for the argument that SME patents might be more original in their nature, however, not being more technologically valuable. Additionally, we find no support for H3, stating that opposition should target SMEs more often than MNEs.

Table 3 Results of the logistic regression models on technology fields

Dependent Variable	**Coef.**		**S.E.**	**Obs.**	**R^2**	**Regression Type**
High-Tech	0.402	***	0.005	1199711	0.012	Logit
Emerging Field	-0.187	***	0.006	1199711	0.014	Logit
Optics	0.109	***	0.007	1199711	0.026	Logit
Nanotechnology	-0.132	***	0.023	1199711	0.008	Logit
Renewable Energies	-0.267	***	0.021	1199711	0.016	Logit
Biotechnology	-0.600	***	0.009	1199711	0.027	Logit
Country-Dummies				YES		

Significance level: ***<0.01, **<0.05, *<0.1, robust standard errors

Source: EPO - PATSTAT, own calculations

Table 4 presents the results of the logistic regression models on the technology field differences in patenting between small and large firms. The table needs to be read in a similar way as Table 2. The response variables are depicted on the left-hand side of the table. The presented coefficient is the coefficient of the applicant type variable on the respective outcome variable. First of all, we can see that large firms, ceteris paribus, are more active in high-technology fields, like electrical engineering. However, in

conformity with our expectations, SMEs are more active in emerging technology fields (overall) than their large counterparts. A look at the single emerging fields reveals, that this effect is most strongly pronounced in biotechnology, followed by renewable energies and nanotechnology. Interestingly, in the field of optics the effect is inversed, showing that large firms are more active than SMEs in this particular field. Thus, besides the field of optics, the results are in support of our H5. However, optics can be seen as the most mature field among the emerging technologies, which could explain this exceptional effect.

5 Conclusion and Implications

In this paper, patterns in the patenting activities of SMEs in comparison to the patenting activities of large firms were analyzed. More specifically, we explored in which respects the patent strategies between small and large firms differ – in terms of internationalization, sector of activity and technological value of patents. Especially against the background that SMEs are facing a more and more severe technological competition at the national and international level and in the light of the discussion on strategic patenting (compare for example Blind et al. 2006; Blind et al. 2009) these questions become a major challenge for the patent system, thus being an important policy issue.

Our results show that SMEs patent less at the international level than their larger counterparts. In addition, they also patent less broadly than MNEs, i.e. SME patents target fewer patent offices with their patent applications on average. However, once SMEs are active on the international level, they are even able to outperform MNEs in terms of internationalization. In addition, it could be found that the inventor teams of SMEs are smaller on average than the inventor teams of MNEs.

Concerning the discussion of patent value, however, contrary to our hypotheses, SMEs can be shown to have lower grant rates and higher withdrawal rates than large firms, whereas the patents from MNEs are refused more often than SME patents. This can be interpreted insofar as MNEs file more valuable patents than SMEs, at least in terms of citations those patents receive. The result could yet be mitigated by the fact that patents filed by MNEs are broader in scope, building on a larger knowledge stock and therefore being more general. In addition, the number of NPL-citations is larger for MNEs than SMEs. This implies a closer linkage to science or basic research by large firms at first sigh. However, this might mostly have to do with the resource base of larger firms (Bekkers/Bodas Freitas 2008; Bodas Freitas et al. 2010). Yet, at least in terms of citations made to non-patent literature, MNEs seem to be benefitting more from university collaborations than SMEs do.

Regarding the opposition rates, we find no significant difference between small and large firms. It seems that firm size does not matter when it comes to opposing the patents of competitors in the field, implying that small as well as large companies on average become targeted equally often by an opposition appeal.

It can further be shown empirically that SMEs are more active in emerging technology fields than in established fields. This could be confirmed for nanotechnology, biotechnology and renewable energies. Yet, this does not apply to optical technologies, which can be seen as the most mature field among our group of emerging technologies.

The implications of the results on the differences in SME and MNE patenting for innovation policy are manifold. SMEs are not only essential but even a pushing factor for the structural rejuvenation of innovation systems. Thus, they should be supported in their R&D and patenting efforts because there are reasons that deter SMEs from patenting. In comparison to large firms, SMEs mostly have fewer resources at their disposal and therefore are constrained by their smaller resource base (Hoisl 2010). Thus, besides informational deficits regarding patent systems in general, the costs and efforts for filing patents are too high (Arundel 2001). In addition, the costs for enforcing patents (Cohen et al. 2000) and the lack of a sufficiently large patent portfolio, which allows settling disputes via cross-licensing or trade with other firms (Lanjouw/Schankerman 2001), deter SMEs from patenting, especially in foreign jurisdictions.

Yet, the European Commission as well as the German Patent and Trademark Office (GPO) have reacted to that situation with several information platforms or helpdesks as well as a reduction of patent filing costs for SMEs. However, these informational and filing costs are relatively low compared to the costs for patent lawyers and information search as well as maintaining and enforcing patents in later stages of the patent process. SMEs offer great potential for further internationalization of the innovation systems. Those which are already active in the national patenting system should be motivated and supported to internationalize. From a patent offices' perspective, SMEs are an unexplored, promising (in terms of growth), and different (to MNEs) group of customers, which might be worth canvassing.

6 References

Albert, M.B./Avery, D./Narin, F./McAllister, P. (1991): Direct validation of citation counts as indicators of industrially important patents, *Research Policy,* 20, 251-259.

Arundel, A. (2001): The Relative Effectiveness of Patents and Secrecy for Appropriation, *Research Policy,* 30, 611-624.

Arundel, A./Demandt, I./Steinmueller, E./Malo, S. (1997): *New Developments in Patenting and Dutch SMEs*, Merit Research Memorandum. Maastricht: MERIT.

Arundel, A./Patel, P. (2003): *Strategic patenting*, Background report for the Trend Chart Policy Benchmarking Workshop "New Trends in IPR Policy".

Audretsch, D.B. (2001): *The Dynamic Role of Small Firms: Evidence from the U.S.* Washington, D.C.: The International Bank for Reconstruction and Development/The World Bank.

Bekkers, R./Bodas Freitas, I.M. (2008): Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?, *Research Policy,* 37, 1837-1853.

Bessen, J./Meurer, M.J. (2005): *The Patent Litigation Explosion* (= Working Paper). Boston University School of Law.

Blind, K./Cremers, K./Mueller, E. (2009): The Influence of Strategic Patenting on Companies' Patent Portfolios, *Research Policy,* 38, 428-436.

Blind, K./Edler, J./Frietsch, R./Schmoch, U. (2006): Motives to patent: Empirical evidence from Germany, *Research Policy,* 35, 655-672.

Bodas Freitas, I.M./Geuna, A./Rossi, F. (2010): *University-Industry Interactions: The unresolved puzzle* (= Working Paper No. 09/2010). Torino: Università di Torino, Department of Economics "S. Cognetti de Martiis" LEI & BRICK - Laboratorio di economia dell'innovazione "Franco Momigliano", Bureau of Research in Innovation, Complexity and Knowledge, Collegio Carlo Alberto.

Breitzman, A./Hicks, D. (2008): *An Analysis of Small Business Patents by Industry and Firm Size* (= Small Business Research Summary No. 335). SBA, Office of Advocacy.

Chesbrough, H.W. (2003): *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press.

Chetty, S.K./Stangl, L.M. (2010): Internationalization and innovation in a network relationship context, *European Journal of Marketing,* 44, 1725-1743.

Cohen, W.M./Nelson, R./Walsh, J. (2000): *Protecting their Intellectual Assets - Approbiability Condition and why U.S. Manufacturing Firms Patent or not* (= Working Paper No. 7552). Cambridge: NBER.

Cremers, K. (2004): *Determinants of Patent Litigation in Germany* (= Discussion Paper No. 04-72). Mannheim: Zentrum für Europäische Wirtschaftsforschung (ZEW).

de Rassenfosse, G. (2010): *How SMEs Exploit their Intellectual Property Assets: Evidence from Survey Data* (= Working Paper No. 8/10). Intellectual Property Research Institute of Australia, The University of Melbourne.

Deng, Z./Lev, B./Narin, F. (1999): Science and technology as predictors of stock performance, *Financial Analysts Journal,* 55, 20-32.

Edler, J./Blind, K./Frietsch, R./Schmoch, U. (2003): Motive der Patentierung. Gutachten im Auftrag des BMBF. Karlsruhe: Fraunhofer ISI (ed.) (unpublished work).

European Patent Office (2012): *Guidelines for Examination at the European Patent Office* . Munich: European Patent Office.

Fernández-Ribas, A. (2010): International Patent Strategies of Small and Large Firms: An Empirical Study of Nanotechnology, *Review of Policy Research,* 27, 457-473.

Frietsch, R. (2007): *Patente in Europa und der Triade - Strukturen und deren Veränderung* (= Studien zum deutschen Innovationssystem No. 9-2007). Berlin: Bundesministerium für Bildung und Forschung.

Frietsch, R./Jung, T. (2009): *Transnational Patents - Structures, Trends and Recent Developments* (= Studien zum deutschen Innovationssystem No. 7-2009). Berlin: Expertenkommission Forschung und Innovation (EFI).

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

Frietsch, R./Schmoch, U./van Looy, B./Walsh, J.P./Devroede, R./Du Plessis, M./Jung, T./Meng, Y./Neuhäusler, P./Peeters, B./Schubert, T. (2010): *The Value and Indicator Function of Patents* (= Studien zum deutschen Innovationssystem No. 15/2010). Berlin: Expertenkommission Forschung und Innovation (EFI).

Graham, S.G.H./Harhoff, D. (2005): *Can Post-Grant Reviews Improve Patent System Design? A Twin Study of US and European Patents* (= CEPR Discussion Paper No. 5680). London: Centre for Economic Policy Research.

Guellec, D./van Pottelsberghe de la Potterie, B. (2000): Applications, grants and the value of patents, *Economic Letters,* 69, 109-114.

Günterberg, B./Kayser, G. (2004): *SMEs in Germany - Facts and Figures 2004* (= IfM-Materialien No. 161). Bonn: Institut für Mittelstandsforschung (IfM).

Hanel, P. (2008): The Use of Intellectual Property Rights and Innovation by Manufacturing Firms in Canada, *Economics of Innovation and New Technology,* 17, 285-309.

Harhoff, D./Reitzig, M. (2004): Determinants of opposition against EPO patent grants - the case of biotechnology and pharmaceuticals, *International Journal of Industrial Organization,* 22, 443-480.

Harhoff, D./Scherer, F.M./Vopel, K. (2003): Citations, Family Size, Opposition and the Value of Patent Rights, *Research Policy,* 32, 1343-1363.

Harhoff, D./Wagner, S. (2009): The duration of Patent Examination at the European Patent Office, *Management Science,* 55, 1969-1984.

Hingley, P./Bas, S. (2009): Numbers and sizes of applicants at the European Patent Office, *World Patent Information,* 31, 285-298.

Hoisl, K. (2010): Die Bedeutung von Patenten für das Innovationsverhalten von KMU - Eine empirische Analyse, Forum "Junge Spitzenforscher und Mittelstand". Bonn.

Hsu, D.H./Ziedonis, R.H. (2008): Patents as quality signals for entrepreneurial ventures.

Kinkel, S./Kleine, O./Hild, R./Dorffmeister, L./Frietsch, R./Hinze, S./Jäger, A./Lay, G./Rothengatter, O. (2008): *Wertschöpfungs- und Innovationspotenziale deutscher Mittelständler - Strukturen, Treiber und Erfolgsfaktoren : Ergebnisse einer Studie für die Stiftung Industrieforschung und den Bundesverband der deutschen Industrie (BDI)*. Karlsruhe: Fraunhofer ISI.

Kleinknecht, A./Oostendorp, R. (2002): R&D and Export Performance: Taking Account of Simultaneity. In: Kleinknecht, A./Mohnen, P. (eds.): *Innovation and Firm Performance*. New York, 310-320.

Koehler, F. (2011): Patent cross-licensing, the influence of IP interdependency and the moderating effect of firm size, *Journal of Technology Transfer,* 36, 448-467.

Kortum, S./Lerner, J. (1999): What is behind the recent surge in patenting?, *Research Policy,* 28, 1-22.

Lanjouw, J.O./Schankerman, M. (2001): Characteristics of Patent Litigation: A Window on Competition, *Rand Journal of Economics,* 32, 129-151.

Lanjouw, J.O./Schankermann, M. (1998): *Stylized Facts of Patent Litigation: Value, Scope and Ownership* .

Legler, H./Frietsch, R. (2007): *Neuabgrenzung der Wissenswirtschaft - forschungsintensive Industrien und wissensintensive Dienstleistungen (NIW/ISI-Listen 2006)* (= Studien zum deutschen Innovationssystem No. 22-2007). Hannover, Karlsruhe: NIW, Fraunhofer ISI.

Legler, H./Krawczyk, O. (2006): The Global Distribution of R&D Activities. In: Schmoch, U./Rammer, C./Legler, H. (eds.): *National Systems of Innovation in Comparison. Structure and Performance Indicators for Knowledge Societies*. Dordrecht: Springer, 31-45.

Leiponen, A./Byma, J. (2009): If you cannot block, you better run: Small firms, cooperative innovation, and appropriation strategies, *Research Policy,* 38, 1478-1488.

Long, J.S. (1997): *Regression Models for Categorical and Limited Dependent Variables*. Advanced Quantitative Techniques in the Social Sciences Series 7, Thousand Oaks, London, New Delhi: SAGE Publications.

Long, J.S./Freese, J. (2003): *Regression Models for Categorical Dependent Variables using Stata*, Revised Edition. College Station, Texas: Stata Press.

Martinez, C. (2009): *Insight into different types of patent families* . Madrid: CSIC-Institute of Publuic Goods and Policies.

Martinez, C. (2010): Patent families: When do different definitions really matter?, *Scientometrics,* 86, 39-63.

Maskus, K.E./Penubarti, M. (1995): How trade-related are intellectual property rights?, *Journal of International Economics,* 39, 227-248.

Meyer-Krahmer, F./Dreher, C. (2004): Neuere Betrachtungen zur Technikzyklen und Implikationen für die Fraunhofer-Gesellschaft. In: Spath, D. (ed.): *Forschungs- und Technologiemanagement. Potenziale nutzen - Zukunft gestalten*. München: Hanser.

Mogee, M.E. (2005): *Foreign Patenting Behavior of Small and Large Firms: An Update*. Washington: SBA, Office of Advocacy.

Narin, F./Noma, E./Perry, R. (1987): Patents as indicators of corporate technological strength, *Research Policy,* 16, 143-155.

Neuhäusler, P. (2009): *Formal vs. informal protection instruments and the strategic use of patents in an Expected-Utility framework* (= Discussion Papers Innovation Systems and Policy Analysis No. 20). Karlsruhe: Fraunhofer ISI.

Neuhäusler, P. (2012): The use of patents and informal appropriation mechanisms - Differences between sectors and among companies, *Technovation,* 32, 681-693.

Olejnik, E./Swoboda, B. (2012): SMEs' internationalisation patterns: Descriptives, dynamics and determinants, *International Marketing Review,* 29, 466-495.

Rammer, C. (2003): *Patente und Marken als Schutzmechanismen für Innovationen* (= Studien zum deutschen Innovationssystem No. 11-2003). Mannheim: Zentrum für Europäische Wirtschaftsforschung (ZEW).

Rammer, C. (2009): *Innovationsverhalten der Unternehmen in Deutschland 2007 - Aktuelle Entwicklungen und die Rolle der Finanzierung* (= Studien zum deutschen Innovationssystem No. 4-2009). Berlin: Expertenkommission Forschung und Innovation (EFI).

Rosenkopf, L./Nerkar, A. (2001): Beyond Local Search: Boundary-Spanning, Exploration and Impact in the Optical Disc Industry, *Strategic Management Journal,* 22, 287-306.

Rothaermel, F.T./Agung, S.D./Jiang, L. (2007): University entrepreneurship: A taxonomy of the literature, *Industrial and Corporate Change,* 16, 691-791.

Santoro, M.D./Chakrabarti, A.K. (2002): Firm size and technology centrality in industry-university interactions, *Research Policy,* 31, 1163-1180.

Schmoch, U./Grupp, H./Mannsbart, W./Schwitalla, B. (1988): *Technikprognosen mit Patentindikatoren*. Köln: TÜV Rheinland.

Schmoch, U. (2007): Double-boom cycles and the Comeback of Science-push and Market-pull, *Research Policy,* 36, 1000-1015.

Trajtenberg, M. (1990): A penny for your quotes: patent citations and the value of innovation, *Rand Journal of Economics,* 21, 172-187.

Utterback, J.M./Abernathy, W.J. (1975): A dynamic model of process and product innovation, *Omega,* 3, 639-655.

van der Drift, J. (1989): Statistics of European patents on legal status and granting data, *World Patent Information,* 11, 243-249.

Van Zeebroeck, N. (2009a): *Filing strategies and the increasing durationof patent applications* (= CEB Working Paper No. 9/005). Brussels: Université Libre de Bruxelles - Solvay Brussels School of Economics and Management - Centre Emile Bernheim.

Van Zeebroeck, N. (2009b): *The puzzle of patent value indicators* (= CEB Working Paper No. 07/023).

Van Zeebroeck, N./van Pottelsberghe de la Potterie/Guellec, D. (2009): Claiming more: the Increased Voluminosity of Patent Applications and its Determinants, *Research Policy,* 38, 1006-1020.

Veer, T./Jell, F. (2012): Contributing to markets for technology? A comparison of patent filing motives of individual inventors, small companies and universities, *Technovation,* 32, 513-522.

Zucker, L.G./Darby, M.R./Armstrong, J.S. (2002): Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology, *Management Science,* 48, 138-153.