Formal vs. informal protection instruments and the strategic use of patents in an Expected-Utility framework

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Abstract

The present article examines the question whether or not different types of firms tend to protect their innovations with varying mechanisms. Against the background of the Expected-Utility Theory (EU-Theory), firms are differentiated by their size, technological field and their degree of internationalization. According to the EU-Theory modelling, it is hypothesized that large, high-tech and strongly internationalized firms show a stronger tendency to use formal instruments, e.g. patents, to protect their innovations, whereas small and medium-sized (SME), low-tech and weakly internationalized companies follow the strategy of protecting their innovations with informal instruments, e.g. secrecy, to maximize their expected utility.

A twofold approach is followed to analyze the theoretical model. For the empirical testing a large-scale survey – about 540 records – of patenting companies in Germany is used. Differences in attitudes towards protection mechanisms and differences in the actual IPR-management behavior between firms are analyzed.

The results show that the attitudes towards protecting innovative achievements only differ slightly by firm type. Large differences can be revealed on the behavioral level which, together with other findings, leads to the conclusion that mostly SMEs are forced to use certain protection mechanisms to keep pace with large companies and technological precursors in fast growing markets.

Keywords: Intellectual property, patents, secrecy, expected utility, rational choice

1   Introduction

The question of how to protect intellectual property has always played a crucial role for companies in securing their returns from technological innovations. During the 1990s the number of patent applications almost doubled in all OECD countries. Patent statistical analyses of the European and international applications reveal that especially since the mid 1990s a massive increase of patent applications, the so-called patent surge, could be observed, which cannot be explained solely through a corresponding rise in R&D activities, since the R&D expenditures increased only modestly in this period.

Consequently, the patent intensity, defined as the number of patent applications per unit of R&D expenditure, showed a significant increase (Blind et al. 2004). Partly, this can be explained through an expansion of the firms' activities in foreign markets. This development is additionally accompanied by a concentration of patent applications to large firms, which therefore account decisively for the gap between patent applications and R&D activities (Blind et al. 2003). There are several possible explanations for the phenomenon of the patent surge: An increase in R&D efficiency, i.e. improvements in the research process itself (Janz et al. 2001), a shift to more applied research activities that raises the yield of patentable discoveries (Kortum/Lerner 1999), or the rise of new and strongly growing technology fields like biotechnology or software (Blind et al. 2005; Kortum/Lerner 1999; Thumm 2003). Finally, it is argued that patent strategies of innovative companies became broader and more complex, thus resulting in an expansion of patent applications. This reasoning can be confirmed by a number of previous studies (Arundel et al. 1995; Cohen et al. 2002; Schalk et al. 1999). The patent system, whose original purpose was to provide a temporally limited protection for technological knowledge, is more intensively used by companies for various other so-called strategic motives, e.g. trying to block competitors or to generate licensing revenues (Blind et al. 2009). If this is true, the patent surge is fundamentally affected by large patent applicants that use patents strategically in technology competition.

Against this background, the present article tries to explain how different kinds of firms act to protect their innovations optimally from competitors and maximize their returns on R&D activities. Through the increased strategic utilization of patents, the general conditions for the different actors have changed radically. On the basis of the Expected-Utility Theory (EU-Theory), the rational action strategies of different kinds of companies under the newly evolved conditions will be modeled, where the distinction between companies of different size, research intensity and degree of internationalization lies in the focus of the analysis. The data also allow for a distinction between the attitudes of firms towards protection mechanisms and their actual behaviour in protect-

ing their intellectual assets. Due to the high uncertainty the actors are confronted with during the innovation process, they have to develop differentiated protection strategies.

Two sources of data were used to empirically test the assumptions of the model. First these are data on patent applications from national patent offices, the European Patent Office (EPO) and international patent filings via PCT, that were extracted from the QUESTEL-Orbit[1] und PATSTAT[2] databases. The second source are data from a survey conducted by the Fraunhofer Institute for Systems and Innovation Research (FhG-ISI) in the year 2002 that consists of a sample of 540 German manufacturing firms, which applied for at least three patents at the EPO in the year 1999.

The remainder of this paper is organized as follows. Section 2 introduces the different possibilities to protect innovations and explains how patents can be used as strategic protection mechanisms. Section 3 deals with the EU Theory modeling of the actions of companies with certain characteristics and hypotheses about their behavior are derived. Section 4 shows the results of the patent statistical analyses differed by firm type. Section 5 first gives an overview of the methodology and descriptive results are presented. Afterwards the assumptions of the theoretical model are tested via multivariate regression models. Section 6 concludes.

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[1]   QUESTEL-Orbit is a commercial database for patent analyses. http://www.questel.com/

[2]   PATSTAT is a database of the EPO which covers the patent data of about 70 national and international patent offices.

2   Ways of Protecting Intellectual Property

The expectation that new or improved products or processes will increase profits leads firms to innovate. The successful completion of the innovation process alone, however, is not a sufficient condition to obtain the expected benefits from innovation. A firm has also be able to appropriate these benefits, i.e. to prevent its competitors to imitate, which can be achieved via various intellectual property rights and other strategies (Hanel 2002).

Several possibilities exist to exclude third parties from the exploitation of one's own innovative endeavors (Rammer 2002), which are commonly grouped into two broad categories. The first are the so-called formal protection mechanisms, e.g. patents, trademarks, industry designs, utility models and copyright, which grant innovators an exclusive - but usually timely limited - right, to use their results from innovation activities (Rammer 2002). These formal protection mechanisms can be seen as incentives for innovators to invest in and generate new knowledge, new technology and foster their diffusion because their enforcement is guaranteed by the state (Rammer 2007). In order to obtain this legal protection, all the information covered by the respective formal instrument have to be disclosed at the latest 18 months after application. Patents are probably the most popular and most utilized formal protection instruments. It can be stated that patents still are mainly used to serve as protection from imitation to secure markets, which can be seen as the traditional motive of patenting (Blind et al. 2003). However, additional strategic groups of motives which are only indirectly connected to the active protection of the results of R&D have gained increased importance.

The second category of mechanisms to detain third parties from imitating, are the so-called informal protection instruments, which cover different actions firms can undertake to protect their innovations and maximize their expected returns. In contrast to formal instruments they are not guaranteed by the state (Rammer 2002). The most common informal mechanism is secrecy, e.g. keeping the technological knowledge on which the innovation is based confidential as long as it is ready to be commercialized. A second mechanism that is referred to as head-start, is trying to commercialize an innovation as fast as possible to benefit from so-called first-mover advantages. A less common form is the complex design of a product that impedes competitors from engaging in reverse engineering or invent-around strategies (Rammer 2007). Studies in the United States and Germany show that by the end of the 1980s informal protection instruments gained increased importance in securing innovative returns in comparison to formal mechanisms (Cohen et al. 2000; Levin et al. 1987).

However, the existence of the patent system leads to possibilities to exploit patents for strategic purposes (Blind et al. 2009). According to Arundel and Patel (2003) all motives that go beyond the protection of one's own inventions to appropriate benefits on relevant markets based on this inventions are defined as "strategic". The consequence is that the decision to patent has partly uncoupled the technological needs of protection from competitors in the traditional sense or at least the strategic behavior of other market participants is anticipated and patents serve as new sources of revenue (Blind et al. 2003).

The most common strategic motive is blocking competitors, which can be differentiated in two versions (Blind et al. 2009; Blind et al. 2003). The first is the so-called defensive blockade, where firms use patents to avoid their own technological elbow room being diminished by patents of others. The second version is the offensive blockade, that exists when firms only patent to prevent competitors using technological inventions in the same or adjacent areas of application that are close to one's own inventions but not identical. So-called patent thickets are built up and firms patent "more broadly" than necessary.

In addition, there is a large bandwidth of further strategic motives (Blind et al. 2009; Blind et al. 2003; Cohen et al. 2000). For example, firms may choose to generate licensing revenues or trade with other firms (cross-licensing) or use patents as bargaining chips in negotiations with other companies to gain access to new technologies, which is especially prominent in sectors like ICT (Hall/Ziedonis 2001). Furthermore, patents can be used for international market extension, standardization or to increase the firm's reputation or technological image. Another motive can be seen in the use of patents as a measure of internal performance of a firm's R&D personnel that can also be used for motivational purposes. Especially for SMEs (small and medium-sized enterprises), easier access to the capital market can also be regarded as a strategic motive for patenting. Generally, companies' patent portfolios can be seen as a hurdle to deter new potential competitors from entering the market or to establish themselves in a certain sector.

3   Rational Choice and the Expected-Utility Modeling

The decisions of firms to use formal or informal mechanisms are modeled on the basis of the EU Theory. According to the EU Theory, an action is seen as a selection between alternatives. In line with the Rational Choice Theory an actor chooses the alternative where the expected-utility is highest, i.e. the optimal alternative (Eisenführ/Weber 1999). To calculate the optimal alternative from the view of a rational actor, all possible outcomes for each alternative are multiplied by their respective probabilities. Their sum reflects the corresponding expected-utilities for each alternative, on which a decision is made. So the basic equation for the evaluation of different alternatives is: $EU_i = \sum p_{ij} U_j$ (Esser 1999).

Figure 1:   Decision Tree for the alternatives of using formal or informal instruments to protect intellectual property
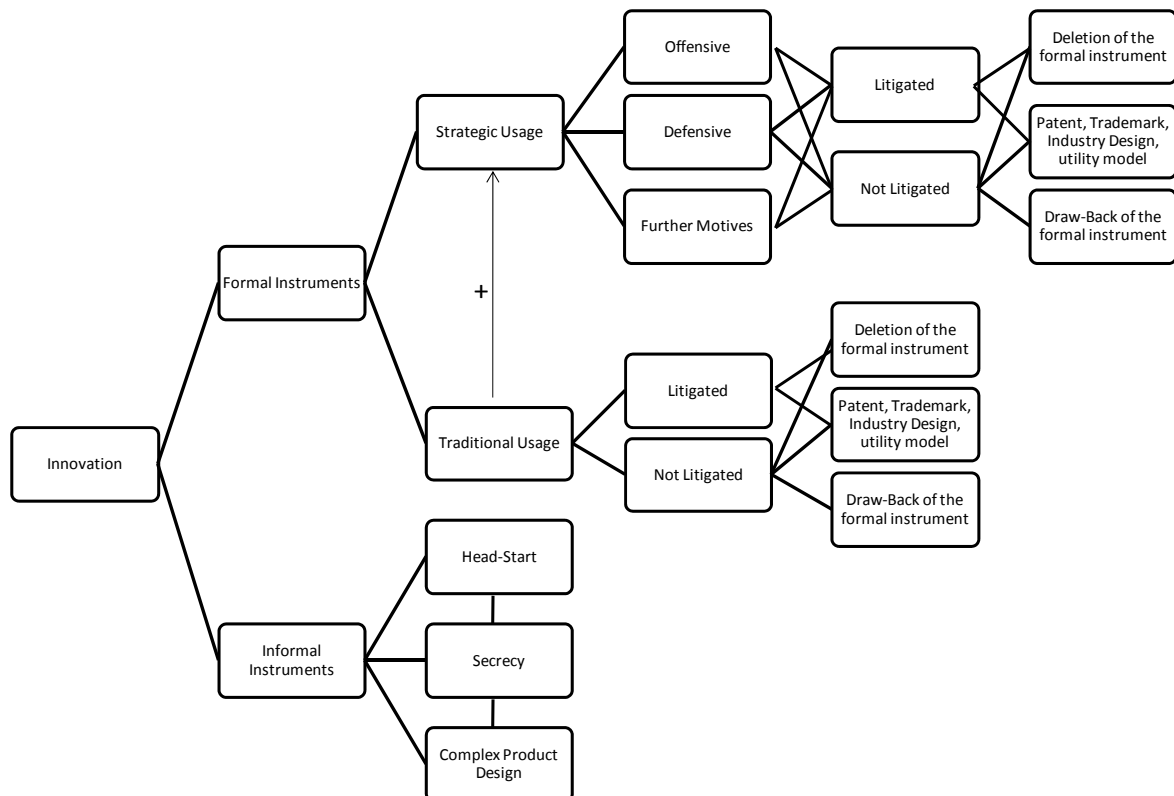
Source: own compilation

The choice of an adequate instrument to protect an invention is often accompanied by a great deal of uncertainty. Over time and during the innovation process the information base steadily changes, which makes a permanent re-evaluation by the company management indispensable (Harhoff/Reitzig 2001). In addition, it has to be taken into account that a single economic decision-maker cannot see all business opportunities that

result from technological possibilities and manage them in a way that maximizes prof-
its. He thus operates under a scheme of bounded rationality and acts not always max-
imizing but "satisficing" (Verspagen 2005).

A first step towards examining the optimal alternative for different ideal types of firms is
to illustrate the central tendencies visually by using a so-called decision tree (Figure 1).
The analysis concentrates on the first decision that has to be made, namely deciding
between formal or informal instruments to protect one's innovations. For simplicity it is
assumed that the two alternatives are mutually exclusive, although this assumption
would not hold in the real world because, as we will see below, often a combination of
formal and informal protection mechanisms is used, e.g. trying to keep an invention
secret in the first place and filing for a patent afterwards.[3] The variables used for mod-
eling the optimal decision of a company with a special characteristic are displayed in
Table 1.

Table 1:   Variables of the model with short explanations

Variable	Explanation
U_{trad}	Traditional utility emerging through protection from imitation
U_{strat}	Additional strategic benefits that can be obtained by using formal instruments
C_{app}	Costs for the patent application, translation, information search and market entrance
C_{lit}	Costs emerging when a patent is litigated
C_{des}	Costs for the "destruction" of a formal instrument through patent litigation
C_{dis}	Costs emerging when the informal mechanism, e.g. secrecy, fails
p_{strat}	Probability that a formal instrument can be used strategically
p_{lit}	Probability for patent litigation
p_{des}	Probability for the "destruction" of a formal instrument through successful litigation of a competitor
p_{dis}	Probability for an informal mechanism to fail, e.g. being "discovered"

Source: own compilation

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3   Several possibilities exist to combine protection mechanisms in an effective way. For ex-
     ample Arora et al. (1997) stated that in the chemical industry it was typical to protect indi-
     vidual compounds of dyestuffs by patents, whereas the composition of the dyestuff was
     kept secret.

The variables can be categorized into the three groups: benefits (or utilities), costs and probabilities that vary according to the different firm characteristics. On the basis of these variables the following Expected-Utility weights (EU-weights) for the choice between formal or informal protection mechanisms can be calculated:

$$EU(A_f) = (U_{trad} + p_{strat}U_{strat}) - (C_{app} + p_{lit}C_{lit} + (p_{lit|des}p_{des})C_{des}$$
$$EU(A_i) = U_{trad} - (p_{dis}C_{dis})$$

The next three sections deal with the various assumptions that can be made for the different types of firms on the basis of those variables.

3.1   Differences in size

Basically, large companies tend to control more resources and virtually possess more market power to enforce their rights than smaller firms. Several assumptions can be derived from this fact.

Referring to the utilities, it can be assumed that the traditional and strategic utility which can be attained via formal instruments should be equal for large and for small firms. The first discrepancy can be found in the probability to use a formal instrument strategically. Most of the strategic motives are potentially more beneficial for large enterprises. Blocking competitors, for example, is not possible until a firm has some patents at its disposal and has the (financial) capabilities to patent broadly (Blind et al. 2003). The use of patents for cross-licensing negotiations or trade with other firms also tends to be more beneficial for larger companies, as a larger patent portfolio goes along with such "player-strategies" (Cohen et al. 2000; Hall/Ziedonis 2001). Additionally, using patents as an internal performance indicator can also be seen as being far more beneficial with increasing firm size, mainly because larger firms are assumed to have more R&D personnel and more often possess a special in-house patent department that can be evaluated. But there are two exceptions. First, there is the possibility to increase the reputation or the technological image of a firm, by holding a stock of (at best valuable) patents, which can be seen as beneficial for small and for large enterprises. Cohen et al. (2000) suggest that small firms, especially in technology industries, are even more likely to report this motive. Second, patents are able to ease the access to the capital market as they can be used in order to acquire financing or alliance partners. Overall, a tendency for large firms to use strategic patenting more often can be revealed, but the effects on SMEs cannot be denied.

Moreover, the probability for patent litigation differs by firm size. Large firms are – relatively seen – less often the target of patent litigation than SMEs (Bessen/Meurer 2005; Cremers 2004). Reasons could be the higher threat potential of large enterprises that is

additionally increased through the existence of a large patent portfolio and in-house patent departments, which leads to a larger experience or routine in patenting (as proposed by Arundel et al. 1997) and in the enforcement of their rights. This also leads to a decrease in the probability of a patent being destroyed during litigation for larger companies.

The second group of differences between small and large firms is due to the costs (virtually or anticipated) linked with patenting. First, the application for a patent and the associated search for information are significant cost factors, especially because the costs to apply for patents in foreign countries are very high (Hanel 2006). Furthermore, large firms often have in-house patent departments, consisting of experienced patent attorneys and specialized R&D personnel. Hereby, the fixed costs for the application process, especially the costs for information search, can be decreased with the extension of patent applications and therefore scale effects can be realized (Hall/Ziedonis 2001). In addition, Cohen et al. (2000) conclude that that the high costs of patent litigation dissuade small firms from patenting, which stems from the assumption that large firms are better able to spread the fixed costs of applying and defending patents over greater levels of output. Finally, there are costs for entering specific markets. Large firms usually already are established in relevant markets and mostly possess large patent portfolios that can be used to hinder small firms establishing themselves in a certain sector.

For the use of informal instruments it can be assumed that there is virtually no significant difference between large and small firms, because the benefits and costs should not differ. For example, the costs of being discovered have to be carried by both types of firms and the probability of being discovered or being outpaced by a competitor cannot be assumed to vary according to firm size.

3.2   Differences in research intensity

The central difference between firms of the research-intensive sectors and companies with lower research intensity lies in the fact that the financial input in R&D largely increases with an extension in research intensity.

Against this background it can be assumed that the traditional protection motive is the focus in more research-intensive sectors, whereas this motive plays a less significant role in firms where research intensity is lower. Also the strategic benefits from formal instruments should be higher compared to low-tech sectors. With rising research intensity, the probability of generating inventions that do not necessarily lead to direct profits but can be used for strategic aims, e.g. blocking of competitors, increases. These as-

sumptions seem in part contrary to some results found in earlier studies, which state that the differences in patenting behavior in different sectors stem mainly from the distinction between discrete and complex product industries and do not mirror differences in research intensity (Blind et al. 2009; Cohen et al. 2000; Cohen et al. 2002). Complex product industries, e.g. the electro-technical and automotive industry, where the number of patents per innovation is large, are assumed to show increased strategic use of patents, than discrete product industries, like the chemical sector, where the number of patents per market-exploitable innovation is considerably smaller. Another argument comes from Arundel and Kabla (1998) who state that patents are of greatest value in those sectors where the cost of copying an innovation is considerably less than the initial cost of invention.

The size of the financial input in R&D is also the determining criterion for the difference in costs between the sectors. It can be assumed that the costs for the destruction of a patent are much higher in research-intensive industries than in less research-intensive sectors, since, relatively seen, the loss of financial resources is higher. However, these can be regarded as sunk or irreversible costs, which cannot be influenced and therefore should have no direct effect on the selection of the optimal alternative. The probabilities for patent litigation, however, should be higher in research-intensive industries. It can be assumed that in sectors with high research intensity more patents with substantial economic benefits (so called "valuable patents") are generated (Allison et al. 2004).

For the alternative of using an informal instrument the costs of being discovered or outpaced are also higher for more research-intensive firms, which again is associated with higher financial input into R&D. The probability for this outcome can be seen as equal between firms of different research intensity.

3.3   Differences in the degree of internationalization

Several situations describing assumptions can be derived for companies with different degrees of internationalization. The main difference between high and low internationalized firms is the number of markets they operate in. As pointed out by Arundel et al. (1995), the importance of patents increases with the relevance of global markets.

The main benefit of using formal instruments for more internationalized firms lies in the possibility to reach legal protection to generate returns on innovations in several markets, i.e. the traditional motive for patenting lies in the focus. For example, Arundel and Kabla (1998) could show that firms who sell products in the US or Japan are more likely to patent a higher percentage of their product innovations than firms that do not sell

products in one of those two markets. This is especially important as the intensity of competition rises with the entry to each new market (Blind et al. 2006). A contradictory argument is that the concern about disclosing information about an innovation rises with each new country a patent (or other formal instrument) is filed. Operating in additional markets increases the probability that an innovation is imitated through invent-around or reverse-engineering, which can be seen as an argument rather not to file formal instruments in foreign countries.

The increased competition intensity also affects the strategic patenting motives, above all the importance of offensive and especially defensive blockade as the threat of being sued rises. This is even amplified by the increased costs for infringement suits in other countries.

Furthermore, patents and other formal instruments are only valid for the country in which they were filed. So the costs for applications, associated with information search, and the maintenance fees for granted patents rise with every additional market that is being secured. The increased costs for litigation also have to be taken into account as every additional jurisdiction in which a patent is filed is positively correlated with the occurrence of an infringement suit (Cremers 2004). Generally, domestic firms even enjoy a so-called "home field advantage" in lawsuits, which also affects the probability that a patent is being destroyed (Moore 2003).[4] Another hindering effect was reported by Takenaka (1994), who suggests that many overseas firms believe that (especially the US) patent system has become less friendly to foreign patentees.

For the alternative of using informal instruments, the increased number of competitors is also important. The probability of being discovered or outpaced sharply increases. For this reason also the costs of being discovered rise, as with a higher degree of internationalization generating returns on an innovation is made impossible in several markets. This would not automatically be the case for the destruction of a formal instrument, since a successfully litigated patent is locked exclusively for the markets in which a suit was filed.

3.4   Hypotheses to be tested

According to the different frame conditions for the different ideal-typical kinds of firms, hypotheses could be derived that affect the EU weights in a special way (Tab. 3-2). Due to economic modeling, these assumptions are certainly not exhaustive, but summarize the main differences between the chosen types of firms.

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4   The analysis of Moore (2003) covers only American courts.

According to the EU theory, the alternative with the highest EU weight in comparison to all other alternatives is chosen in order to maximize utility. Based on these weights, the following hypotheses can be derived:

H1:   The probability of using a formal instrument to protect results from innovative endeavors as compared to using an informal protection mechanism increases with firm size.

H2:   In sectors where research intensity is high, the probability of using a formal instrument as compared to using an informal protection mechanism is higher than in sectors where research intensity is low.

H3:   The higher the degree of internationalization of a firm, the greater the probability of using a formal instrument as compared to using an informal protection mechanism.

Table 2:   Trends of expected benefits and costs of formal and informal protection mechanisms for firms of different sizes, research intensity and degree of internationalization

Variable of the model	Variation by firm characteristics					
	Large	Small	Research intensity high	Research intensity low	Degree of internationalization high	Degree of internationalization low
U_{trad}	0	0	+	-	+/-	+/-
U_{strat}	0	0	+/-	+/-	+	-
C_{app}	-	+	0	0	+	-
C_{lit}	0	0	0	0	+	-
C_{des}	0	0	0	0	0	0
C_{dis}	0	0	+	-	+	-
p_{strat}	+	-	+	-	+	-
p_{lit}	-	+	+	-	+	-
p_{des}	-	+	0	0	+	-
p_{dis}	0	0	0	0	+	-
$EU(A_f)$	+	-	+	-	+	-
$EU(A_i)$	-	+	-	+	-	+

with   0   as equal value (compared to the different firm characteristics)
       +   as higher value (compared to the different firm characteristics)
   -   as lower value (compared to the different firm characteristics)
Source: own compilation

4 Global Patenting Structures

For the structural analysis of the changes in patenting activities of different kinds of companies since the 1990s, application data of transnational patent applications[5] from PATSTAT was used.

Figure 2:   Number of transnational patent applications of German enterprises diffe-
rentiated by size, 1990-2005 (absolute numbers)
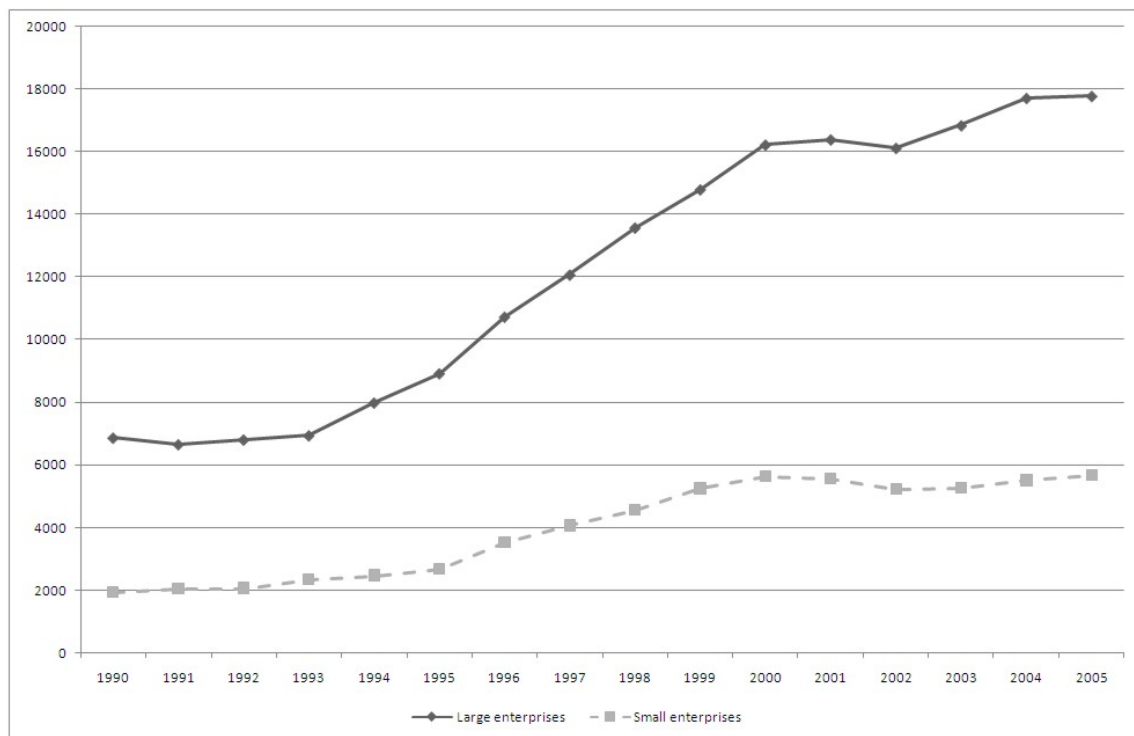
Source: PATSTAT, own calculations

The International Patent Classification (IPC, 4-digit) was used to classify patent appli-
cations by industries. The goods that are produced in these industries can be differen-
tiated by research intensity according to an already introduced list, the so called
NIW/ISI list, by Legler and Frietsch (2007). Electrical engineering (incl. instruments,
optics), chemistry (incl. pharmaceuticals, biotechnology and rubber and plastics) and
mechanical engineering can therefore be classified as high-technology, whereas con-
struction (building, mining, wood, paper, stone and earth) and consumer goods (food,
textiles, furniture) are classified as low-tech. The metal industries (production and work-
ing) can be regarded as medium research-intensive. Although Kirner et al. (2009) have

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5   Transnational patent applications are the sum of European and International (PCT) patent
applications, excluding double counts.

been able to show that a classification based on low-, medium and high-tech sectors only partly reflects the actual R&D intensity of the firms belonging to these sectors, the list by Legler and Frietsch serves as a good proxy to reflect the research intensity on a sectoral level. The chosen industry classes by IPC are in line with the NACE classification for industries that is used for the analyses of the survey (see below).

Regarding the differences by industry (Figure 3), the largest upward trend during the 1990s can be observed for the electronic industry, which shows the largest number of patent applications from 1996 onwards. It is followed by the chemical industry and mechanical engineering. The lowest numbers of patent applications can be found in the so-called low-tech sectors, i.e. the metal industries, consumer goods and construction, which do not differ strongly in their patenting behavior. The larger growth rates in the high-tech sectors indicate an increased use of patents as strategic means.

Figure 3:   Number of transnational patent applications of German enterprises differentiated by industry, 1990-2005 (absolute numbers)
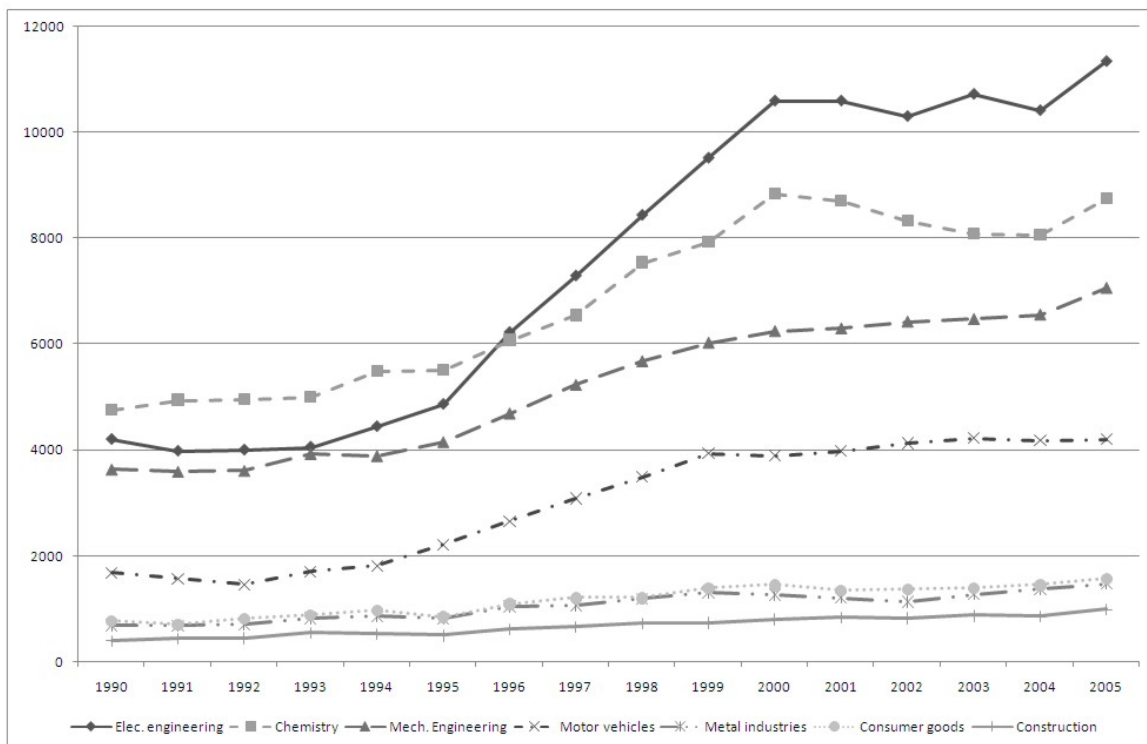

Source: PATSTAT, own calculations

The difference in the patenting behavior between firms with different degrees of internationalization cannot be captured directly with patent data. The share of transnational patent applications on national applications by industry serves as a proxy. According to this indicator, the degree of internationalization increases continuously from 1990 until

2002, with chemistry and electrical engineering being the most internationalized sectors. From the year 2002 onwards, the share of transnational on national patent applications increases more dramatically which counts most for the chemical industry.

Figure 4:   Share of transnational on national patent applications (German Patent Office) by industry, 1990-2004 (in %)
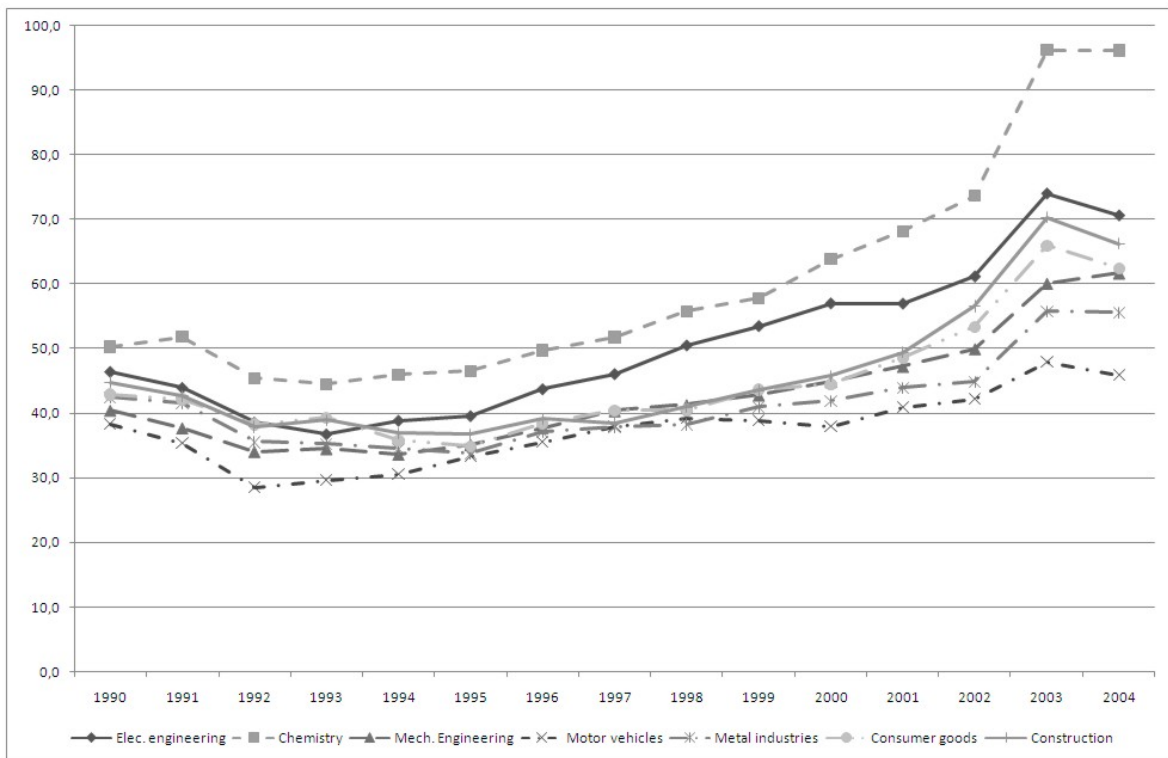
Source: PATSTAT, own calculations

5   Protection mechanisms and their importance: Results of the survey

The sample consists of 1,570 German manufacturing firms that applied for at least three patents at the EPO in the year 1999. The survey was conducted by the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer-ISI) in the year 2002. Due to a response rate of 33%, more than 500 completed questionnaires were obtained. The participating companies were responsible for more than 40% of all German patent applications at the EPO or via PCT procedures in the year 1999, thus a high share of large and actively patenting companies is covered. Besides the fact that the dataset only covers patenting companies, firms from sectors where patenting is important were more likely to participate in the survey.

The survey data were supplemented with published data from patent and company databases. From the patent databases data on patent applications at the EPO and via PCT procedures for the year 2001 were added. From the company database[6] information on sales, employees and sector were used to fill gaps in the questionnaires (Blind et al. 2003).

5.1   Descriptive Results

Two variables are used to account for the difference in the importance of protection mechanisms and the actual patenting behavior of firm. The patenting behavior of firms is represented in the sample through the number of patent applications for the year 2001.

Two indices were created to analyze the average importance of patents. The relevance of the respective protection mechanisms was measured on a 5-point Likert scale, where a value of 1 indicates low and a value of 5 high importance. To create the index for formal instruments the values for the importance of domestic and foreign patents, utility models, industry designs, trademarks and copyright were combined. In order to prevent a low sample size and to avoid that companies that did not assign a value to all items are given a lower score on the index, the sum of the importance values was divided by the number of actually given answers. This limits the following interpretation to actually given answers by the companies. For further analyses the variable was dichotomized, where all values below four were coded as 0 ("low importance") and values above or equal to four were coded as 1 ("high importance"). To construct the index for informal instruments the items secrecy, lead-time advantage, exclusive customer rela-

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6   Here the commercial database Hoppenstedt was used. http://www.hoppenstedt.de

tions, long-term assignment of personnel and design of sub-supplier contracts were used. In the questionnaire, complex product design was subsumed under the item "secrecy", so this informal instrument is implicitly represented in the index variable. The following calculations were performed in the same way as for formal instruments.

With the combination of those two measures differentiated conclusions can be drawn to what extent the behavior of firms corresponds to the EU theory model.

For the distinction of technology sectors, a taxonomy by Robson et al. (1988) was used (compare also Hanel 2002), who found that different groups of industries play different roles in the innovation process. A three-technology-sector taxonomy was introduced by the authors, based on observed patterns of innovation sources and use in manufacturing industries. The core sector (chemistry, electrical engineering, instruments and mechanical engineering) includes industries at the forefront of technological change whose product innovations are used in the secondary and "other" sector and in the rest of the economy. The secondary sector (metal industries, rubber and plastics, non-metallic minerals, transport equipment) is at the same time a user of product innovations from the core sector and a producer of innovation used in the "other" sector (building, wood, paper and consumer goods). This taxonomy provides a proxy for the research intensity of the technology sectors. The industries are classified according to the self-classification of the firms in the sample.

To differentiate between the degree of internationalization of companies, the share of foreign sales in total sales was calculated. Based on this share, two categories were constructed, where the upper third of all companies was classified as strongly internationalized and the lower two thirds as lowly internationalized. The frontier for this distinction, the 66 percent percentile, lies at a share of sales of about 64 percent. This frontier seems to be high at first sight, but can be explained by the fact that the sample consists largely of actively patenting companies of the manufacturing sector that generally show a relatively strong orientation to international markets.

Table 3 summarizes the average number of patent applications for the year 2001 and the average importance of protection mechanisms for the firms in the sample. The average number of patent applications increases nearly exponentially by firm size and also the degree of internationalization seems to have a high impact on patenting. But it should be taken into account that both firm characteristics are highly correlated. According to the sector classification, the secondary and core sector show comparable numbers of patent applications, whereas the "other" sector patents far less. The same trend can be revealed within industries, where by far the most patents come from the motor vehicles industry, followed by electrical engineering and chemistry. In the other

industries patenting seems far less prominent with average numbers below 10 for each.

Table 3:   Average number of patent applications and the importance of formal and informal protection mechanisms, differed by firm size, research intensity, industry and degree of internationalization

Firm characteristics	Sample size	Avg. No. of patent ap-plications	Importance of formal instruments		Importance of informal mechanisms	
			Mean	Std.Err.	Mean	Std.Err.
Size						
Small enterprises	174	3	0.17	0.03	0.44	0.04
Medium enterprises	205	7	0.14	0.02	0.40	0.03
Large enterprises	143	55	0.12	0.03	0.38	0.04
Research Intensity						
"Other" sector	38	7	0.18	0.06	0.50	0.08
Secondary sector	175	19	0.16	0.03	0.40	0.04
Core sector	319	20	0.13	0.02	0.40	0.03
Industry (NACE codes in brackets)						
Construction (10-14)	47	7	0.15	0.05	0.39	0.07
Consumer goods (15-19, 36)	20	6	0.20	0.09	0.45	0.11
Metal industries (27)	48	4	0.11	0.03	0.43	0.05
Motor vehicles (34)	68	41	0.19	0.06	0.40	0.07
Mechanical engineering (29)	118	9	0.14	0.03	0.36	0.04
Chemistry (24, 25)	118	17	0.12	0.04	0.48	0.06
Electrical engineering (30-33)	113	30	0.17	0.04	0.40	0.05
Degree of Internationali-zation						
Low	239	12	0.17	0.02	0.38	0.03
High	123	38	0.11	0.03	0.39	0.04

Source: PATSTAT, Survey Results

Size: Small enterprises: 0-249 employees, medium enterprises: 250-1999 employees, large enterprises: more than 2000 employees, Research Intensity: "Other sector: building, wood, paper and consumer goods, secondary sector: metal industries, rubber and plastics, non-metallic minerals, transport equipment, core sector: chemistry, electrical engineering, instruments and mechanical engineering, Internationalization: Low: Share of foreign sales on national sales less than 64%, High: Share of foreign sales on national sales more than 64%.

The measure for the importance of formal and informal protection mechanisms shows that over all types of firms informal mechanisms are seen as more important than formal protection mechanisms. Within the two categories, different kinds of firms show only slight differences in the importance of formal and informal mechanisms.

5.2   Multivariate Results

Two types of multivariate models are calculated. First, a multinomial-logit model to account for the differences in the importance dimensions of firms with different characteristics and secondly, a negative-binomal regression model on the number of patent applications by firm type is calculated. Both types of models use the same independent variables, except the importance measure variables which are additionally introduced as independent variables in the negative-binomial regression to see if the importance of one or the other protection mechanism significantly affects patenting behavior. To account for size effects in the importance of patenting and the actual patenting behavior, the number of employees is used (log-transformed). Accounting for the sector classification by research intensity a dummy variable for each sector (core, secondary and "other") is introduced, where the core sector serves as base category. To control for industry effects that are not accounted for by technology sector a set of industry dummy variables is used, which identifies seven industry groups according to the self-assessment of the firms in the sample. The electrical engineering industry serves as base category. The dichotomized variable that measures the degree of internationalization is also introduced into the model as a dummy variable. To control for increased monetary input into the innovation process, the sales of the firm and its R&D expenditures (both log-transformed, measured in euros) are introduced into the model. Additionally, the existence of a patent division and the importance of costs are accounted for by a dummy variable.

5.3   Multinomial-logit model on the importance of protection mechanisms

To account for the differences in importance for formal and informal instruments between firms, the two index variables were combined into one variable (Table 4), which represents the different importance dimensions of formal and informal protection mechanisms as well as their combination.

As the descriptive results already indicated, only few differences between different kinds of firms on the importance of formal or informal instruments can be observed. The multinomial-logit model reveals just a few significant and only very weak effects, which is why they are not further regarded in detail. Table 5 shows the marginal effects

calculated at the means of the independent variables, which show the effect of a one unit change in the respective explanatory variable on the importance of the respective instruments, keeping all other factors constant.

Table 4:   Distribution of the variable to measure the importance dimensions of the different protection instruments

	Informal mechanisms		
Formal instruments	Low	High	Total
Low	283	169	452
High	29	47	76
Total	312	126	528

Significant, but very small size effects only occur for the formal mechanisms dimension, where the importance of the formal instruments category decreases slightly by firm size. The most striking differences can be found between industries, where especially the pattern for the consumer goods industries seems to contradict the second hypothesis. Here, a very high relevance of the formal instruments category can be observed, whereas the other dimensions seem to be of very low importance. Another pattern can be found for the motor vehicles industry, where the category "protection not important" has a very low relevance and the importance of informal protection mechanisms scores very high. Informal protection mechanisms also seem to be very meaningful in chemistry, whereas solely using formal instruments is of less importance. The informal instruments category also seems to be of less relevance in the construction and metal industries. The remaining variables reveal no significant effects.

Summing up the descriptive and multivariate results a trend can be revealed. There seems to be no tendency that special kinds of firms show significantly different attitudes toward using informal or formal mechanisms. A reason could be that formal and informal instruments are often used in combination, so both types of protection mechanisms score high in importance, which seems to be rational reasoning, since all opportunities to act are initially left open. This pattern does not hold for the examined industries. Here a difference in attitudes towards special kinds of protection mechanisms can be revealed, which cannot solely be explained by differences in research intensity, as the broader classification reveals no significant effects.

Table 5:   Multinomial-logistic regression on the importance dimensions of formal and informal protection mechanisms by firm characteristics (marginal effects)

Index of *importance of protection mechanism*	Protection not important		Formal instruments			Informal instruments			Combination		
	dy/dx	S.E.	dy/dx		S.E.	dy/dx		S.E.	dy/dx		S.E.
Size (log number of employees)	0.0412	0.0355	-0.0004	***	0.0001	-0.0408		0.0353	0.0000		0.0053
Research Intensity³											
"Other" sector	-0.4227 *	0.2283	-0.0019		0.0012	0.2295		0.3583	0.1951		0.2605
Secondary sector	0.1054	0.1452	0.0002		0.0004	-0.1795		0.1328	0.0739		0.0703
Industry³³ (NACE codes in brackets)											
Construction (10-14)	0.1083	0.2639	0.0002		0.0007	-0.0872		0.2648	-0.0213	**	0.0094
Consumer goods (15-19, 36)	-0.5808 ***	0.0349	0.9999	***	0.0001	-0.3353	***	0.0335	-0.0838	***	0.0202
Metal industries (27)	-0.1902	0.2201	-0.0001		0.0003	0.2105		0.2209	-0.0201	**	0.0082
Motor vehicles (34)	-0.4078 **	0.1680	-0.0085	**	0.0038	0.4410	***	0.1686	-0.0247	***	0.0073
Mechanical engineering (29)	-0.0095	0.1008	0.0001		0.0004	0.0133		0.1014	-0.0039		0.0126
Chemistry (24, 25)	-0.1457	0.1021	0.0001		0.0003	0.1690	*	0.1023	-0.0233	*	0.0127
Degree of Internationalization	-0.0148	0.0716	0.0000		0.0003	0.0256		0.0711	-0.0108		0.0107
R&D expenditure (log)	-0.0108	0.0234	0.0000		0.0001	0.0102		0.0231	0.0006		0.0047
Sales (log)	-0.0183	0.0310	0.0002		0.0001	0.0199		0.0308	-0.0018		0.0038
Existence of patent division	0.0437	0.0781	0.0000		0.0003	-0.0386		0.0780	-0.0051		0.0126
Importance of costs	-0.0014	0.0680	0.0003		0.0003	0.0143		0.0677	-0.0132		0.0091

Reference Group: Model: Informal instruments, ³Core sector, ³³Electrical Engineering (30-33), N=275, Pseudo R^2=0.081, robust standard errors, for dummy variables dy/dx is for discrete change of dummy variable from 0 to 1

*   Significance level: $p<0.1$.

**   Significance level: $p<0.05$.

*** Significance level: $p<0.01$.

5.4   Negative-binomial regression model on actual patenting behavior

To see if there are differences between the attitudes of firms toward protection mechanisms and their actual patenting behavior, a negative-binomial regression model on the number of patent applications of the year 2001 is calculated.

Table 6 shows the marginal effects calculated at the means of the independent variables. As can be seen from the table, there is a strong tendency for the number of patent applications to increase with firm size, keeping all other factors constant. The degree of internationalization also has a positive impact on the patenting behavior, although it is less pronounced than the size effect. Hence, the first and the third hypotheses can be seen as confirmed. Probably the most interesting result is that there are no significant industry effects on the number of patent applications. Although the most

striking differences in the attitudes towards protection mechanisms could be found be-
tween different industries, their patenting behavior does not differ significantly. Also the
broader sector classification does not show any significant effects, which contradicts
the second hypothesis.

Table 6:   Negative-binomial regression on the number of patent applications (mar-
            ginal effects)

Number of patent applications 2001	dy/dx		S.E.
Size (log number of employees)	2.354	***	0.456
Research Intensity³			
"Other" sector	-1.684		2.262
Secondary sector	-0.877		1.708
Industry³³ (NACE codes in brackets)			
Construction (10-14)	2.824		3.481
Consumer goods (15-19, 36)	0.828		4.033
Metal industries (27)	0.930		2.566
Motor vehicles (34)	1.654		2.752
Mechanical engineering (29)	0.071		1.071
Chemistry (24, 25)	0.186		1.127
Degree of Internationalization	1.515	*	0.881
R&D expenditure (log)	1.712	***	0.313
Sales (log)	-0.643	*	0.329
Existence of patent division	1.179		0.864
Importance of costs	1.652	**	0.838
Importance of formal instruments	0.132		1.211
Importance of informal mechanisms	-0.032		0.747

Reference Group: ³Core sector, ³³Electrical Engineering (30-33), N=259, Pseudo R²=0.235, for
dummy variables dy/dx is for discrete change of dummy variable from 0 to 1
*   Significance level: $p<0.1$.
**   Significance level: $p<0.05$.
*** Significance level: $p<0.01$.

As expected, a positive effect can be shown for the R&D expenditures on patent appli-
cations. Furthermore, application costs seem to matter as the importance of application
costs for national and international applications significantly affects patenting behavior.
Another interesting observation is that the sales of a firm negatively affect patenting. As
expected, the two importance measures for formal and informal instruments do not
reveal any significant effects.

6   Conclusions

The preceding analyses showed that patenting strategies of innovating firms became more and more complex and widespread, which resulted in an increase in patent applications during the 1990s. The results strongly indicate an increase in strategic patenting, leading to a decoupling of patent applications and R&D expenditures. Since the end of the 1990s it seems that the discrepancy between patent applications and R&D expenditures has settled down in a new equilibrium on a higher level.

To explain which kinds of firms are responsible for the patent surge, the theoretical part of this paper dealt with modeling the optimal firms' decisions on the basis of the Expected-Utility theory.

The following analyses, based on patent and survey data, showed that the different kinds of firms do differ in their actual patenting behavior. The total numbers of patent applications between 1990 and 2004 and the application data of the firms of the sample revealed that large enterprises apply for the majority of patents. Also the industries differ according to their patenting activity. While industries with lower research intensity apply for about 2,000 to 4,000 patents a year, more strongly research-intensive industries apply for about thrice as much. Furthermore, the survey data show that multinational enterprises apply for more patents a year than less internationalized firms.

However, additional descriptive analyses of the survey data revealed that informal protection mechanisms are seen as more important than formal instruments by all kinds of firms and the importance of formal and informal instruments differs only slightly by firm type.

Additional multivariate analyses were conducted to analyze this pattern. It can be shown that the differences between firms can only be observed in their actual patenting behavior. The multinomial-logit model revealed that the differences in the importance of protection mechanisms found in the descriptive analyses do not hold when controlling for other factors. Significant differences can only be found for the motor vehicles, chemistry and consumer goods industries that do differ in the attitudes towards protection mechanisms.

That patenting behavior actually differs by firm type can be revealed by analyzing patent applications. Keeping all other factors constant, especially firm size and degree of internationalization significantly influence the patenting behavior (hypotheses one and three), while research intensity and industry seem not to affect the decision to patent in a significant way (hypothesis two). This indicates that the patent strategies between industries have largely adapted. The small variations in attitudes toward protection me-

chanisms could be interpreted insofar as the combination of protection mechanisms seems to be the most widespread strategy to protect intellectual property. This adaptive strategy seems to fit most types of firms, since all opportunities to act are initially left open.

The results, however, lead to the question, what mediates the discrepancy between attitudes and actual behavior. The similar structures concerning the importance of protection mechanisms could be caused by convergence of the basic driving forces and strategies of firms to protect their intellectual property. This indicates a progressive adaptation process which is caused by increasing competition intensity and shorter innovation cycles. Inside this system, only those enterprises that adapt to technological precursors and generate returns with the help of strongly differentiated protection strategies stay capable of competing.

Although purely informal protection strategies come to the fore, the combination of protection mechanisms stays the prevalent strategy in protecting innovations. To secure a position in technology competition in the long run, one-dimensional protection mechanisms will not suffice, since they are highly sensitive to errors. This could also serve as an explanation for the small differences in patenting behavior between industry sectors.

However, rational decision-making is not masked out. Mainly large and strongly internationalized firms are able to use differentiated strategies, while SMEs and less internationalized firms more often have to adapt to sustain their position. Thus, the differences in the behavior of the firms persist. Additionally, large enterprises promote the application of formal instruments, as large firms often are strongly internationalized. This increases their strategic service capacity, since larger markets and additional competitors have to be taken into account. Moreover, internationalized firms are forced to legally safeguard their innovations more properly, which can most effectively be achieved by formal instruments.

Hence it can be derived that the different kinds of firms act largely rationally inside their given restrictions. Largely means that the differences in attitudes between firms are rather modest, which is mediated by the patent surge of the 1990s. Through the expansion of those patenting strategies, the starting conditions for the different firms change dramatically, which is why a fixed rational strategy or optimal decision is not applicable. In fact, the increase of strategic patent motives leads to the development of differentiated strategies to arrange the simultaneous application of formal and informal instruments and obtain benefits therefrom. Due to the high uncertainty the actors are confronted with, they can often act only with bounded rationality to find a satisfying alternative without having all possible information.

To sum up, inside the given conditions that are induced by large multinational enter-prises, firms can act rationally. If these conditions change, the strategies have to be adapted also if they are in contrast to the firms' rational decision-making procedures, to successfully generate returns from innovations and persist at the market.

To fully understand this pattern of attitudes to and usage of protection mechanisms, further research would be required. Especially, an indicator of the frequency of using informal instruments would be useful to find out if the hypothesized firm differences hold or draw a different picture. Moreover, it should be observed if the behavior and attitudes of firms remain stable or change over time to obtain more differentiated con-clusions about the observed patterns.

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