Empirical Analyses of Company Patenting Behavior –

Essays on the Role of Strategic Patenting, Standardization, Technology Exchange and Product Piracy

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Structure

Contents

Overview

This thesis consists of five essays on the management and economics of patents. I empirically analyze strategic patenting behavior and specifically the role of three important economic phenomena which influence the corporate use of patents: technology standards and the process of standardization, technology exchange and patent licensing, and incidences of unauthorized reproduction of companies' proprietary technology (product piracy).

Part I: Strategic Patenting, Technical Standards and Technology Exchange

The first paper, **"Patent Claim Amendments as the Result of Strategic Patenting and as a Driver for Patent Value"**, studies the effect of strategic patenting motives such as the protection motive, the blocking motive and the technology exchange motive on the characteristics of a company's patent portfolio. Strategic patenting has been identified as one of the most important drivers for the increasing use of patents, especially among large corporations in the 1990's (see for example Cohen et al. 2000, Hall and Ziedonis 2001). In this paper we go beyond analyzing the effect of strategic motives on the number of patent applications and study how different motives i) are connected to certain parameters of the application process and ii) how these parameters relate to the outcomes – forward citations as a proxy for patent value – of the patenting process.

First, we look at the frequency of change requests ("amendments") to the originally filed claims. We expect a positive relation between patenting for exchange reasons and the incidence of amendments, since these allow the applicant to shift the exact scope of a patent application to fit the potential demand in the market for technology. Furthermore, a higher number of amendments proxies an above average effort in the application process. We expect this to be the case especially among companies using the patent system for its original protection purpose and thus anticipate a positive relationship of the use of amendments with this motive.

Subsequently, we address the relationship of amendments and forward citations. As amendments allow the applicant to incorporate knowledge gained after the original filing into the claims, amendments can result in patents of higher quality as measured by forward citations. Additionally, strategic patenting behavior is expected to result in higher citations not only indirectly through amendments, but also directly, since different patenting motives mirror different underlying invention characteristics.

We rely on survey data from 441 German companies as well as matched data on their respective patent portfolio including new EPO information on the application process. Using multivariate tobit models as well as two-staged least squares models, we find that firm's patenting motives are reflected in the patent portfolio in different aspects: First, the technology exchange motive is related to a higher number of amendments, whereas for the blocking and protection motives we do not find significant effects. This finding suggests that claim amendments are an instrument which is highly relevant when the applicant wants to provide for external technological needs or developments. This is shown in chapter 2 for the standard setting context and is also found to be important for the generic technology exchange motive. Second, amendments are associated with higher levels of citations, which suggests that they might be an instrument to address concerns about patent quality or patent value. However, amendments are also an important factor responsible for the uncertainty in the patent system. As discussed in more detail in chapter 2, claim amendments can be detrimental since higher degrees of legal and technological uncertainty can potentially hamper investments in research and development and new technological developments. Consequently, the resulting trade-off associated with claim amendments between a potentially positive impact on patent value and a potentially negative impact of certainty in the economy needs to be taken into account. This paper contributes to the literature of economics and management of IPR by highlighting a specific element – claim amendments – of the patenting procedure which can be exploited strategically by applicants. As amendments can have both positive and detrimental consequences these results have to be taken into account by policy makers and patent offices in order to ensure the efficiency of patenting policies.

Chapter 2, entitled **"Keep 'Em In, Make 'Em Fit - An Analysis of Filing Behavior for Essential Patents in Standards"**, analyzes a related, but more specific aspect which influences the way companies apply for patents. We analyze interactions between the development of industry standards in the telecommunication sector and the patenting behavior of firms. Intellectual property rights (IPR), especially patents, play an increasingly important role for standard-setting organizations (SSOs) and the number of patent disclosures to SSOs has been steadily growing since the 1990's (Rysman and Simcoe 2008). Accordingly, the strategic implications for firms active in standardization have dramatically changed. At the same time, important issues are to be explored for academia: the relationship of IP and the efficiency of standards development, IP in standards and market structure, anti-trust issues and many more. Against this background, chapter 2 analyzes patenting and standardization at the firm level and addresses the implications for patent filing strategies in several ways.

First, we discuss the application process of patents potentially relevant for a standard ("essential patents"). We argue that in the standards context applicants have an incentive to draft filings with a specifically broad scope. The rational for this application behavior is making the patent overlap with technology covered by the standard. If companies realize this goal, they increase their market power considerably and the incentives for this strategy are consequently very high.

Second, we analyze the dynamic development of the patent claims. We argue that a shifting of claims to make them fit to particular standards specifications is important in the standardization context. However, high numbers of corresponding amendments result in additional work load and pendency times at patent offices and higher levels of uncertainty in the marketplace. Both results are likely to have detrimental effects on innovative behavior and therefore warrant a detailed analysis.

Furthermore, we argue that it is important for a company involved in standard setting to keep its application pending for a longer period than expected for comparable applications. The reason is that, once a patent is granted, the flexibility of amending the claims is lost and the applicants cannot react to developments in the standard setting process. Our hypothesis is that this behavior is more prevalent for essential patents compared to a control group and that essential patents are therefore pending longer than comparable patents not relevant for a standard.

We test these propositions empirically by comparing 291 patents disclosed as essential for standards developed at European Telecommunications Standards Institute

(ETSI), a major SSO responsible for widely used standards like GSM or UMTS. The information on "essentiality" is matched to a database of all patent applications in the relevant classes of the International Patent Classification (IPC), containing information on procedural EPO data such as the number of amendments, claims, citations and relevant dates like application and grant/refusal date. The construction of the control sample is done by a one-to-one matching approach, where the matches each have the same IPC subclass, the same filing month, and the same applicant. The methodology includes paired t-tests for the claims, amendments and other parameters as well as non-parametric and semi-parametric survival models to analyze the pendency times.

Results strongly corroborate the hypotheses by showing significantly higher outcomes in the "essential" patents group compared to the control group for the number of claims, amendments, and other parameters of interest such as opposition rates, forward citations as well as for the share of divisionals. Survival time analyses show that the characteristics which are found to be prevalent among essential patents are responsible for longer pendency times. We conclude that the relevance for a standard increases the incentives of strategic applicant behavior with the objective of slowing down the application process.

The findings reveal important insights on the interactions between the economic institutions of the patent and the standardization system. They highlight aspects in which a stronger cooperation between both institutions should be established in order to prevent creating incentives for applicants which could harm the technological development and which could endanger the common goal of promoting economic growth and welfare.

In chapter 1 the technology exchange motive was identified as an important aspect of corporate patent filing behavior. The paper **"Patent Cross-Licensing, the Influence of IP Interdependency and the Moderating Effect of Firm Size"** analyzes the relevance of technology exchange for different companies in greater detail and investigates driving factors of companies' motivation to engage in cross-licensing transactions. In recent years, the academic literature on licensing has grown rapidly (e.g. Anand and Khanna 2000, Arora et al. 2001, Arora and Fosfuri 2002, Arora and Ceccagnoli 2006, Arora 1997, Fosfuri 2004, Kim 2004). However, the focus has been mostly on the incentives for licensing out technology and on the implications for innovation incentives or market structure. Studies addressing cross-licensing, that is a mutual technology exchange between firms, are relatively scarce (Fershtman and Kamien 1992, Grindley and Teece 1997) and often limited to large firms only (Anand and Khanna 2000, Nagaoka and Kwon 2006). The main reason seems to be that cross-licensing is widely known to be an important issue in large multinationals (Grindley and Teece 1997). However, as the underlying causal mechanisms of cross-licensing – the growing number of patents, the increasing fragmentation of the IP landscape, potential hold-up problems and the need to rely on complementary proprietary technology (IP dependency) – are becoming increasingly relevant for all companies in certain sectors, research-intensive small and medium enterprises (SMEs) are forced to deal with this issue as well.

In this paper, I elaborate on two factors which have been discussed in previous studies as relevant for the use of cross-licensing: the importance of cross-licensing for firms in different size classes and the effect of IPR dependency. Specifically, I analyze an interaction effect between those two factors. If IPR dependency is high, any firm will *ceteris paribus* pose a higher importance to cross-licensing compared to firms of the same size with a low degree of IPR dependency. I argue, however, that this effect could be smaller with increasing firm size, because capacities for an alternative technological strategy (workaround) become available. Additionally, the chances to actually achieve the workaround rise. A further argument for a different effect of IPR dependency in different size classes is that *explicit* cross-licensing agreements (compared to an implicit litigation standstill agreement) can be of higher importance for smaller firms. Among large corporations in complex industries the high interwovenness itself serves the same purpose as the explicit exchange of patents. If every actor in the marketplace is aware of mutual patent infringement, everyone is barred from taking legal action and the purpose of a cross-licensing agreement is implicitly reached. This, however, is more applicable for large corporations whereas smaller firms might not be willing to take the legal risk and would therefore have stronger incentives to explicitly engage in cross-licensing.

The findings are generally in line with the theoretical argumentation. I show that the factors IP dependency and firm size should not be analyzed separately. The effect of IP dependency found in this analysis is high for smaller firms and subsequently decreasing with firm size. I argue that this can be ascribed to the lack of means to achieve a workaround of the technology and the experience of out-licensing smaller firms tend to gather in order to efficiently exploit their IP externally. Larger firms, however, have better odds to avoid an (explicit) arrangement of cross-licensing and, in addition, have better chances to have an alternative technology in their portfolio.

The main contribution of the paper is an extension of the analysis of factors on firms and industry level which have been identified in the literature as important for cross-licensing to a broad sample of firms in various size classes and sectors. This paper thus avoids the limitations of the majority of previous research on cross-licensing which focuses on specific (complex) industries or certain size classes only (Grindley and Teece 1997, Hall and Ziedonis 2001, Anand and Khanna 2000, Nagaoka and Kwon 2006). An additional novel point is the analysis of the interrelationship between firm size and IPR dependency. The paper thus adds some new insights to the discussion of cross-licensing and technology exchange in general.

Part II: Patenting and Product Piracy

The phenomena of product piracy and counterfeiting have received increasing attention in the public debate. A widely known OECD report (OECD 2007) states that the volume of international trade in tangible counterfeit goods "could have been up to US-$ 200 billion in 2005". Recent updates of this report (OECD 2009) indicate that this trend is going to prevail in the coming years. However, there is very scarce scientific literature on the economic implications. The reasons for this include the lack of reliable data on a clandestine activity such as illegal copying. The two papers in the part "Patenting and Product Piracy" of this thesis try to fill part of this research lacuna.

The paper **"Risk Factors and Mechanisms of Product Piracy"** examines the relationship of a firm's strategic framework and its business environment with the probability of becoming the target of unauthorized imitation. Using original survey data among around 200 German firms we present extensive bivariate descriptive evidence and conduct multivariate approaches in order to shed some light on this issue. We use different definitions and empiric operationalizations to approach the phenomenon of "product piracy". The first refers to incidences of unauthorized reproduction of product features, regardless whether the features were actually legally protected or not. The second referred to actual infringement in the legal sense. Furthermore, we distinguish between the copying of technological elements of a product and the imitation of brand names and labels. We empirically examine the role of firm's intellectual property protection strategy (use of brands, patents or informal protection methods), its general strategic business positioning (e.g. international sales activity or production facilities) and factors exogenous to the individual firm such as industry characteristics. Furthermore, we discuss mechanisms of piracy, analyze how business operations induce "enabling" and "signaling" effects and how these influence the likelihood of being illegally imitated. Enabling effects refer to implications of specific company behavior which can provide potential illegal imitators with technological information about the copied product. An example is the disclosure of information in patent documents or the diffusion of information via a "defensive publication" strategy. Signaling effects refer to actions by the original producers which indicate the discovery of new technological elements (e.g., signaled by new patent application) or the introduction of a new product or product line (e.g., signaled by a new trademark registration).

We find that a firm's general strategy alignment seems to matter more than the use of formal IP rights in avoiding unauthorized reproduction or infringement incidences with respect to technical elements. Especially strategic behavior which bears the risk of potential information leakage (defensive publication, participation in standard setting activities, R&D activities out the home market) increases the likelihood of (illegal) imitation. Companies should be aware of the consequences their strategic decisions can have for their intellectual property and carefully design a holistic protection approach to minimize potential damages. The results highlight the need for a certain harmonization between brand and patent strategies and the need for a tight coordination between different (formal or informal) IP protection instruments.

The contribution of this paper is one of the first systematic analyses of the risk factors for "product piracy" in the economic literature. Although there are some limitations of our approach such as the measurement problems for product piracy and the use of self-reported data by survey participants, the results provide some insights which can help to get a better understanding of this important topic.

The last paper of this thesis, entitled **"An Empirical Analysis of the Effect of Product Piracy on Corporate IP Strategy"**, builds on the previous chapter and takes a dynamic perspective on the same topic. I analyze how cases of unauthorized reproduction ("product piracy") of a company's technological elements influence the subsequent intellectual property protection strategy of around 200 German manufacturing companies. In specific, I examine whether product piracy induces a stronger use formal IP strategies such as patents or whether a shift to informal protection mechanisms occurs. Using a propensity score matching approach, I compare companies with similar company characteristics in terms of their prior IP strategy, business activities, industry affiliation and other characteristics.

I find that incidences of unauthorized reproduction do not provoke firms to resort to informal protection methods, but induce an even stronger use of formal protection rights. Based on company responses, firms with a reproduction incidence report significantly higher values on questions regarding the relevance of future use of formal protection instruments such as patents. On the other hand, informal protection such as secrecy is not seen as more relevant in the “treatment” group compared to the control group.

An implication of these results is that companies which are constrained in their choice of the usage of formal protection such as patents could be disadvantaged by the rising level of IP infringements. Specifically small firms are often not willing or capable of using patents to protect their IP. If, as a result of rising levels of unauthorized reproduction, the need to obtain more patents is intensified, this disadvantage could grow. The gap in patent use between SMEs and large firms might thus be widening, which can put in danger the innovative activity by smaller firms, entrepreneurs, or start-ups.

Submission and Publication Record

The paper “Patent Claim Amendments as the Result of Strategic Patenting and as a Driver for Patent Value” (chapter 1), co-authored with Knut Blind, was accepted for presentation at the DRUID Society Summer Conference 2010 (Imperial College Business School, London) and the 13th Conference of the International Schumpeter Society (Aalborg University). After some revisions it was then submitted to Research Policy.

The paper “Keep ’Em In, Make ’Em Fit - An Analysis of Filing Behavior for Essential Patents in Standards” (chapter 2) is co-authored with Knut Blind and Nikolaus Thumm. It was prepared while I was visiting researcher at the European Patent Office in Munich. Previous versions of the paper were accepted for presentation at the conference “Patent statistics for decision makers” in Vienna (coorganized by the European Patent Office and the Organisation for Economic Co-operation and Development) and at the summer school “Economics and Management of Intellectual Property Rights” (Department of Management, University of Bologna). It is currently under review at Research Policy.

A previous version of the paper "Patent Cross-Licensing, the Influence of IP Interdependency and the Moderating Effect of Firm Size" (chapter 3) was presented at DRUID-DIME Academy Winter 2009 PhD Conference in Aalborg, Denmark. A substantially revised version was accepted for presentation at the Spring Meeting of Young Economists (Marmara University, Istanbul) and the European Meeting of Applied Evolutionary Economics, organized by the Max Planck Institute of Economics in Jena. It was then submitted to the Journal of Technology Transfer and was accepted for publication after the first round of revisions.

The paper "Risk Factors and Mechanisms of Product Piracy" (chapter 4, co-authored with Knut Blind and Alexander Cuntz) was presented at the European Conference on Corporate R&D (CONCORD 2010), organized by the Institute for Prospective Technological Studies (IPTS), Seville and the European Commission (Joint Research Centre and DG Research) and at the "Knowledge in Organizations Conference" at Monte Verita (EPF Lausanne and ETH Zurich). It is currently in the second round of revisions at Research Policy.

The paper "An Empirical Analysis of the Effect of Product Piracy on Corporate IP Strategy" (chapter 5) was presented at internal seminars at the Chair for Innovation Economics. It was then submitted to Industrial and Corporate Change.

Bibliography

Anand, B. and T. Khanna (2000), The structure of licensing contracts, Journal of Industrial Economics, 48(1): 103–135.

Arora, A. (1997), Patents, licensing, and market structure in the chemical industry, Research Policy, 26(4-5): 391–403.

Arora, A. and M. Ceccagnoli (2006), Patent protection, complementary assets, and firms' incentives for technology licensing, Management Science, 52(2): 293–308.

Arora, A. and A. Fosfuri (2002), Licensing the market for technology, Journal of Economic Behavior and Organization, 52: 277–295.

Arora, A., A. Fosfuri, and A. Gambardella (2001), Markets for Technology. The Economics of Innovation and Corporate Strategy, MIT Press, Cambrige, MA.

Cohen, W., R. Nelson, and J. Walsh (2000), Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not), NBER Working Paper 7552.

Fershtman, C. and M. Kamien (1992), Cross Licensing of Complementary Technologies, International Journal of Industrial Organization, 10(3): 329–348.

Fosfuri, A. (2004), Determinants of international activity: evidence from the chemical processing industry, Research Policy, 33(10): 1599–1614.

Grindley, P. and D. Teece (1997), Managing intellectual capital: Licensing and cross-licensing in semiconductors and electronics, California Management Review, 39(2): 8 – 41.

Hall, B. and R. Ziedonis (2001), The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995, Rand Journal of Economics, 32(1): 101–128.

Kim, Y. (2004), Market structure and technology licensing: evidence from US manufacturing, Applied Economics Letters, 11(10): 631–637.

Nagaoka, S. and H. Kwon (2006), The incidence of cross-licensing: A theory and new evidence on the firm and contract level determinants, Research Policy, 35(9): 1347–1361.

OECD (2007), The Economic Impact of Counterfeiting and Piracy, Organisation for Economic Co-operation and Development, Paris.

OECD (2009), Magnitude of counterfeiting and piracy of tangible products – November 2009 update, Organisation for Economic Co-operation and Development, Paris.

Rysman, M. and T. Simcoe (2008), Patents and the Performance of Voluntary Standard-Setting Organizations, Management Science, 54(11): 1920–1934.

Part I

Strategic Patenting, Technical Standards and Technology Exchange

Chapter 1

Patent Claim Amendments as the Result of Strategic Patenting and as a Driver for Patent Value

Abstract We study the effect of strategic patenting motives on the characteristics of a company's patent portfolios. First, we analyze the frequency of change requests ("amendments") to the originally filed claims. We theorize that firms that patent for technology exchange have an incentive to shift the exact scope of a patent application to fit potential demand in the market for technology. Furthermore, a higher number of amendments proxies an above average effort in the application process and could therefore also be relevant for companies using the patent system for its original protection purpose. Subsequently, we address the relationship of amendments and forward citations. As amendments allow the applicant to incorporate knowledge gained after the original filing into the claims, amendments can result in patents of higher quality. We rely on survey data from 441 German companies and matched data on their respective patent portfolio including new EPO information on the application process. Using multivariate tobit models as well as two-staged least squares models, we find that, first, the technology exchange motive is related to a higher number of amendments, implying a strategic use of this instrument. Second, amendments are also associated with higher levels of citations, which suggests that they might be an instrument to raise patent quality or value. Since amendments are also partly responsible for the uncertainty in the patent system, the resulting trade-off "patent quality versus technological" certainty needs to be taken into account.

1.1 Introduction

In the literature on the economics and management of intellectual property rights, strategic patenting is seen as one of the main drivers of the increased use of patents by companies during the last decades (see for example Cohen et al. 2000, Hall and Ziedonis 2001, Blind et al. 2006). The quantitative effect of this development – i.e. the mere rise in the number of patent applications and patent grants – has posed important challenges for the patent system: a significant backlog at patent offices worldwide, a scattered IP landscape (referred to as patent thickets, see for example Shapiro 2001, Harhoff et al. 2008), hold-up problems, an increased technological and legal uncertainty (especially for small and medium-sized companies) and, as a consequence, alleged negative consequences for the technological and economic evolution. Besides the problems of the mere quantity aspect of the "patent inflation" or "patent bubble", some observers have argued that the rise in patent applications and grants has been accompanied by changes in patent characteristics, especially in patent quality. Relevant studies include the one by van Pottelsberghe de la Potterie and van Zeebroeck (2008), who show that the average value of patents filed at the European Patent Office (EPO) has been decreasing since the mid-eighties and de Rassenfosse et al. (2009), who find evidence in company survey data that this fall in quality might be due to a strategic trade-off for companies balancing quality versus quantity.

To our knowledge, very few authors have empirically addressed the interrelationship between strategic patenting and the change in patent characteristics beyond the effect of strategic patenting on the size of a company's patent portfolio.[1] Among those are Blind et al. (2009), who study this subject directly and attempt to empirically explain portfolio characteristics using information on patenting strategies.

This paper focuses on a part of the remaining "black box" of how specific patenting motives translate into real applicant behavior which, in turn, causes changes in patent portfolio characteristics. In this sense, we expand the empirical literature by zooming into the relationship between patenting motives and patent citations and by analyzing the intermediary phenomenon of patent claim amendments. For this purpose, we draw on novel information on the interactions of applicants with the patent office during the patenting process.

In a first step, we analyze how often applicants amend the originally filed claims of their patent applications. We expect that companies which primarily use patents to

[1] An exception is the mentioned study by de Rassenfosse et al. (2009).

protect their inventions, will exhibit an above-average effort in achieving the patent scope needed for effective appropriation and thus we assume a higher incidence of amendments for these firms. The extent to which this above-average effort will be effective and efficient is also determined by the organizational capacities of the individual firms (Reitzig and Puranam 2009), but amending an application will in any case generate uncertainty for competitors. Therefore amendments can theoretically be of value for companies using patents for blocking purposes, since they can fine-tune blocking claims after the original filing. The competing view is that blocking strategies often rely on a large number of different applications which would reduce the average number of amendments observed in the patent portfolio. According to the empirical literature, relying on quantity rather than quality in patents for blocking purposes seems to be more prevalent (Noel and Schankerman 2006). We thus expect blocking strategies to be connected with less amendments. When patents are seen as facilitators of technology trade, amendments have an additional private benefit. They allow the applicant to shift the exact scope of a patent application to fit the potential demand in the market for technology. Thus, companies which highlight the exchange motive in their patenting decision are expected to use this instrument more frequently.

In a second step, we revisit the relationship between patenting motives and forward citations (Blind et al. 2009) and enhance it with data on patenting behavior. By doing so, we strive to disentangle the direct effects of patenting motives on patent outcomes and the indirect effect mediated by amendments.

While the use of amendments can be beneficial for the individual company, it implies negative external effects for the patent system and the economy as a whole by generating higher degrees of uncertainty. Therefore, an analysis of claims amendments is valuable in order to understand the strategic use of this instrument, its effects on patent value and the implied costs.

1.2 Motives to Patent

The literature on company patenting behavior and the strategic use of patents has by now grown quite large (e.g. Cohen et al. 2000, 2002, Hall and Ziedonis 2001, Blind et al. 2006, Graham et al. 2009, Peeters and van Pottelsberghe de la Potterie 2006, van Zeebroeck et al. 2009). Since information on strategic aspects can only be collected by adopting a survey or case study approach, several groups of researchers have used this method, starting with the Yale and the Carnegie Mellon Survey (Levin et al. 1987, Cohen et al. 2000). The findings of several other relevant surveys are summarized in Blind et al. (2006). In the same paper, the authors additionally collected primary data which will also be the basis of the empirical analysis in this present paper. They used respondents' answers about the importance of 15 different possible patenting motives and conducted a factor analysis to cluster these motives into five groups: the protection motive, the blocking motive, the exchange motive, the incentive motive and the reputation motive.[2]

A finding common to all studies is that the protection motive plays the most prominent role, although informal protection strategies such as secrecy and lead time advantages are more important than patenting for appropriability in some circumstances (Cohen et al. 2000). However, strategic motives have become more important over the last years and especially for large corporations which make up the vast majority of patent applications (Blind et al. 2006). Hall and Ziedonis (2001) and others have coined the term "patent paradox" to describe the concurrent decline in importance of patents for appropriability reasons and the rise in application numbers. Again, the explanation for this paradox is found in the strategic reasons to patent.

The influence of the strategic incentives on the patent portfolios has, to our knowledge, mostly been studied concentrating on the effect of boosting the patent portfolio. Two exceptions are de Rassenfosse et al. (2009) and Blind et al. (2009). The former authors use survey data to analyze patenting motives and their impact on the value of patents in a company's portfolio.[3] Although they state that the motive of preserving the freedom to operate affects patent quality negatively, their main argumentation concentrates on the trade-off between quantity and quality. Blind et al. (2009) study this subject more directly and attempt to empirically explain portfolio characteristics using information on patenting strategies. They find that companies using patents for protection reasons receive a higher number of forward citations, while blocking leads to fewer citations. Additionally they look at opposition data and show that offensive blocking leads to a higher incidence of oppositions while the exchange motive is negatively correlated with the opposition incidence.

The following section will revisit and extend their analysis and discuss the theoretical implications of strategic patenting on citations and amendments.

[2]The blocking motive can be split up in defensive and defensive blocking, i.e. blocking other companies from patenting within the technological core competencies of the firm or actively trying to prevent other companies to pursue their patenting strategy.

[3]Value is proxied here as the average number of countries in which the patent was filed.

1.3 Patent Portfolio Characteristics and the Influence of Patenting Motives - Hypotheses

In assessing the characteristics of patent portfolios, the use of indicators like forward and backward citations, opposition incidence, renewal decisions, family size, claims, and many more have proven to be a useful, yet noisy measure (Harhoff et al. 1999). Forward citations are one of the most widely used indicators for the value of patents. In our analysis, we will rely on this established measure[4] and, in addition, consider a novel indicator for strategic patenting behavior, patent amendments. Consequently, in the following section, we will first describe applicant behavior as observed by the number of amendments and will discuss how it mirrors the company's patenting motives. Afterwards, we will turn to the value component and derive our hypotheses regarding i) the influence of amendments on citation frequency and ii) – in addition to the indirect effects via amendments – the direct effect of different patenting motives on citations.

1.3.1 The Influence of Patenting Motives on the Use of Amendments

Amendments to filed patent applications are usually changes or restrictions requested by patent examiners if they come to the conclusion that a patent cannot be granted based on the claims in the present form. Rule 137 of the European Patent Convention provides that after receiving the European search report, "the applicant may, of his own volition, amend the description, claims and drawings". After receiving the first communication from the Examining Division, the applicant may, of his own volition, amend once, every further amendment needs the consent of the Examining Division.[5] However, practice (before April 2010, see footnote 5) at the EPO seems to be rather generous in allowing applicants to make amendments and one can expect that patent attorneys will find ways to have files amended more often, e.g. by deliberately keeping

[4]Here, the term "value" can be both understood as technological and economic value of a patent. Forward citations might mirror primarily technological value. However, the literature has pointed out a significant correlation between forward citations, the technological value and the economic value. Accordingly, they can be regarded as a suitable proxy for this study.

[5]This refers to Rule 137 in its version valid until spring 2010. In March 2009, the Administrative Council of the EPO decided on changes in the Implementing Regulations to the European Patent Convention. As of April 1, 2010, amendments can only be made after receipt of the search report. Any amendments made to the description, claims and drawings must be identified and the basis in the application as filed must be provided. Since the patent data used in this paper are from before April 2010, this policy change does not affect our analysis.

the set of claims deficient. Requested and voluntary amendments can have different implications. Our argumentation concentrates on the possibility of applicants to shape the patent to their interest. This is clearly given for voluntary amendments. But even in the case of requested changes, applicants can – in addition to addressing the examiner request – shape the application to their interest. For this reason, we will in the following assume that both types of amendments can be valuable to the applicant, although possibly to a different degree.

There are two main reasons why amendments are of value for the applicant. The first is directly connected with changes in the exact patent scope. Often applicants rush to file an application in order to obtain an early priority date and to prevent from being "patented out" by competitors. In the following weeks, months and years research and development on the patented subject matter does not stop. Accordingly, there is additional information available to the patentee, such as findings on applications of the technology, competitor activities or related research conducted by potential licensees. This additional information can lead to the need to adapt the originally filed claims and would thus lead to requests for amendments. A second aspect is a more strategic one. Key to this argument is the fact that applicants not only profit from granted patents, but also from pending applications. Since competitors can never be sure of the outcome of the examination and granting process, the pending file generates uncertainty (for evidence on this topic see for example Henkel and Jell 2009). An additional amendment thus raises the uncertainty through i) the change in the exact formulation of the claims and ii) the additional pendency time needed by the patent office to process the request.

We hypothesize that a firm's patenting motives influence the use of amendments. First, companies which use a patent primarily for protection want to safeguard technological features which they expect will play a crucial role in the company's own future technological path. They will thus put a high effort in having exactly these features covered by the patent claims. This can imply an extra investment in the interactions with the patent examiner, resulting in a higher frequency of "negotiations" (i.e., amendments) with the patent office. Furthermore, there is another argument supporting the hypothesis of a higher incidence of amendments connected with the protection motive. Since the claimed invention is extremely important from the company's point of view, the firm will press to file an early application. As pointed out before, an early application also implies high technological uncertainty and a higher probability of detecting additional insights about the claimed invention. This is specifically probable for companies filing patents for protection since they are the ones which invest heavily in R&D on this specific topic and do not only patent to block competitors in a field they do not necessarily regard as crucial for their own technological progress. These subsequent research findings can lead to a need to amend the application after the actual filing date. For these reasons we hypothesize:

> *Hypothesis A-1: Companies with more pronounced protection motives will, on average, use amendments more frequently.*

A blocking strategy can be achieved by different means. One is to generate uncertainty among competitors which is expected to prevent them from entering specific technological fields. Another would be to target certain patents and block them from covering certain subject matter. In theory, both measures could be achieved by amendments. Uncertainty is generated by the *ex post* change in the claims and for targeting specific technology fields, the instrument of amendments allows applicants to fine-tune their blocking patent. Therefore, amendments are expected to be more frequently observed among companies which use patents as a blocking device. However, there is empirical evidence that blocking happens more over quantity than quality. Noel and Schankerman (2006), for example, find that greater patenting activity by a firm reduces a rival's patenting activity, R&D and market value. In line with these findings, one would assume that exact claims targeting is not a dominant strategy. This seems even more plausible when taking into account that there is substantial information asymmetry between the company and the rival to be blocked, especially in offensive blocking. The blocking company has less information about the exact technological features of the "target". Targeting special features by amending applications will, thus, not be feasible for information reasons. To block different competitor patents, the company will, therefore, have to file many different applications. This reduces the *average* incidence of amendments.[6] We therefore conclude:

> *Hypothesis A-2: Companies with more pronounced blocking motives will, on average, use amendments less frequently.*

Companies active in technology exchange have an additional aspect to bear in mind: the demand on the market for technologies. This could mean, in addition to the rationales elaborated under the protection motive, an incentive to incorporate aspects

[6] In addition, a single application can only be amended within the originally filed scope of the claims. This means that there are also legal constraints to blocking competitors by building on amendments. This stresses the importance of filing many different blocking patents.

in a patent which will make it more appealing for potential licensees. Thus, if the applicant becomes aware of technological needs on the demand side, he will try to amend the application according to this need. In comparison to the protection motive, where we argued that additional information collected on the technology supply side causes amendments, the exchange motive leads to the integration of additional information released or generated on the demand side, causing an even higher likelihood of amendments. There are other specific examples of incentives to make a patent fit certain technological characteristics. In chapter 2 of this thesis we analyze patents which are relevant to technological standards. Companies want some of their proprietary technology to be included in the standard, since this considerably increases their market and bargaining power. On the other hand, they also try to keep some patents out of the standard to avoid being restricted in their pricing strategies for licensing fees. We detect a statistically significant higher incidence of amendments in these patents which lead us to the conclusion that this kind of technology exchange plays a role in explaining amendments. These findings also support our argument here that additional insights from the market for technologies generate a need for amendments. In the standard setting example, this additional know-how would be drawn from the work in the standard-setting process. All in all, the discussion leads to hypothesis A-3:

> *Hypothesis A-3: Companies with more pronounced exchange motives will, on average, use amendments more frequently.*

1.3.2 The Influence of Amendments and Patenting Motives on Citation Frequency

Forward citations to a specific patent show how often subsequent patent applications build on this particular invention. The more often this happens, the more important a patent is for future technological developments. Furthermore, this technological importance has been found to correlate with the social and also the private financial value of a patent (Trajtenberg 1990, Harhoff et al. 2003). In this paper, we keep in mind this value interpretation of patent citations, but complement it with the knowledge spill-over view (Jaffe et al. 1993). Just like a high number of forward citations can proxy a high economic value of a patent for the patent holder, value is also generated for society by disseminating know-how, i.e. knowledge spill-overs.[7] As

[7] Information disclosure in patents is, after all, one of the *raisons d'être* for the patent system.

mentioned before, if a patent is cited often, the knowledge embodied in the patent is relevant for subsequent technological developments (Jaffe et al. 2005).[8] It follows that strategies which explicitly aim for the produced patents to be connected with other patentable inventions (e.g. for patent exchange or for blocking reasons and more explicitly via the use of amendments) affect citation frequency. What exactly does this mean for the impact of amendments and different patenting strategies discussed in section 1.2?

Amendments

Some arguments stated above are also relevant when discussing the effect of amendments on citation frequency. We have argued that applications for highly important patents are likely to be filed at the earliest time possible. This can make subsequent changes to the application necessary. As a consequence, amendments are likely to coincide with higher forward citations. Furthermore, the argumentation regarding a possible "fine-tuning" of claims, be it for blocking reasons or for the purpose of reacting to the demand on the technology market, implies that amendments, which are the strategic instrument used to change claims, should be associated with higher citations if this fine-tuning generates patents of higher value.

One could argue that amendments in the patenting process play a similar role just as revisions in the peer review process in the scientific community. An amended patent application would, in this analogy, be the revised version of a scientific paper which is presumably of higher quality than the original draft. Of course, one can also argue that excellent articles (highly inventive patent applications) will be accepted (granted) without the need for further revisions (amendments). In this sense, a higher number of amendments would be associated with a lower value of a patent, since more "revisions" are needed before the application can be granted. To disprove this objection, we stress the following aspects. First, our argumentation focuses on voluntary amendments rather than amendment requests by the examiner. This means that the applicant always has an incentive to improve the application, irrespective of the initial patent quality.[9] Here, the analogy to the paper review process fails, since the change requests ("revise and resubmit") do not come from the

[8] In assessing the validity of this view, one should bear in mind that most citations at the European Patent Office are not added by the applicant himself, but by the examiner. It is, therefore, not ensured that the applicant has actually read all cited patents. Nevertheless, it is assumed that the applicant is aware of the knowledge embodied in the cited patent.

[9] This argument implies that the progression of the function quality-amendments is identical for different quality starting levels.

authors themselves, but from the reviewers or editors. Second, even if the relationship between quality and amendments was different for high quality patents, we can neglect the problem in our specific analysis. It is known that the quality distribution of patents is highly skewed to the right. Since we analyze entire patent portfolios, the influence of a few high quality patents is moderated by the vast majority of average, i.e. low value patents.

Taking these aspects into account, we therefore argue that amendments are associated with higher numbers of citations and thus hypothesize:

> *Hypothesis B-1: Companies using amendments more frequently will, on average, generate patents with higher number of citations.*

Patenting Motives

Blind et al. (2009) argue that companies which patent for protection purposes generate more important patents. Their strategy aims to protect the firm's core assets. Viewing citations as an indicator for the importance or the value, one would thus expect these documents to also have a higher citation frequency. Viewing citations as a diffusion parameter does not change the result of this argumentation, since a company focusing on the protection motive is assumed to patent more important inventions which, as a consequence of their importance, diffuse more widely and are thus cited more.

Blind et al. (2009) further argue that blocking competitors could be achieved with patents of rather mediocre quality. A blocking strategy is often operationalized by boosting up the mere number of applications which can imply a fall in average patent quality. Noel and Schankerman (2006) suggest that the effect of greater patenting activity reduces a rival's patenting activity. One can, therefore, argue that the rise in applications connected with blocking intentions on average leads to lower citations. When we keep in the mind the diffusion-related interpretation of citations, the expectations of the effect of a blocking strategy become less clear-cut. Successful blocking means filing a patent with an earlier priority date than the patent to be blocked and tries to generate prior art, preventing competitors from having their application granted. Blocking actually attracts other citations, namely of those patents it is trying to block. Successful blocking can, therefore, also be expected to result in higher number of citations. Of course, we would not be able to identify such a relationship in the portfolio of a company which is not successful with their blocking strategy. Furthermore, analyzing the citations of granted patents could be misleading. A blocking strategy does not necessarily mean that a company is seeking to have a patent granted. It is sufficient to file an early application and to keep this application pending for a long time (Henkel and Jell 2009). Once the technological development has advanced, the company can withdraw the application, save examination and grant fees and still manage to block the competitor. In summary, we can conclude that there are two competing views on the effects of blocking on the number of citations.

Blind et al. (2009) furthermore analyze the exchange motive and argue that companies have the incentive to boost up their portfolio to secure a high bargaining power in future licensing negotiations. This applies, above all, to technological environments with high (cross-)licensing activities. This concentration on the number of patents could lead to lower average citations. However, it is also possible that companies which patent for technology exchange reasons want to foster their technological image and therefore generate more high quality patents. This is specifically relevant for smaller firms active in out-licensing technology as opposed to large multinationals which merely secure their freedom to operate by cross-licensing entire patent portfolios. The former group of companies primarily consists of small, specialized, research oriented firms. As they lack complementary assets, they usually do not focus on the production of the final product and are therefore dependent on out-licensing their patents. This view would imply a higher average value and quality of patents. Returning to the view of citations as a diffusion measure, they could here be seen as the result of a company's external technology commercialization strategy. If this strategy is successful, other inventions will build on the original patent and thus (presumably) cite it. A third argument stresses that external commercialization tends to be more important when it is embedded in the overall technological trajectory. If this embeddedness is high, it will also result in higher citations. This higher citation frequency would thus not be caused by the exchange motive. It is endogenous to a scattered IP landscape which both leads to stressing the exchange motive in patenting and to higher citations.[10] We can thus sum up that we expect the exchange motive to be positively associated with citations.

[10] In the regression models, we control for industry characteristics attempting to rule out this endogeneity issue.

1.4 Empirical Part

1.4.1 Data

There are two sources for the data used in this paper. We rely on a paper-and-pencil survey conducted in 2002 among all German companies which applied for at least three patents in 1999 – more than 1500 in total (for more details see Blind et al. 2006). The response rate was around 33%.[11] These companies account for more than 40% of all German applications at the European Patent Office in 1999. The survey thus covers a high share of very large, actively patenting companies, with an average of 6,664 and a median of 550 employees. All companies were then identified in the patent data and internal procedural data of the European Patent Office, which not only contains the standard variables on citations and so forth, but also information on the interaction between the applicant and patent office, namely the amendments. The data matching was achieved by a manual string search comparing applicant information in the EPO data with the one from the survey. The results of the search then underwent a thorough manual plausibility check. After removing observations with insufficient company information, we end up with a sample of 441 companies for which we have combined information on motives and EPO data.

	Size Class (Number of employees)				
Industry	up to 100	101 to 1000	1001 to 5000	more than 500	Total
Drugs Health	6	10	3	5	24
Chemicals	18	24	10	10	62
Electronics	23	33	28	11	95
Mechanical	32	93	57	36	218
Other	10	24	6	2	42
Total	89	184	104	64	441

Table 1.1. Sector and size distribution of the sample (absolute number of observations)

[11] The large majority (more than 85%) of the respondents are involved in the strategic issues of patenting (CEO, patent department) and not in the purely technical aspects (R&D manager, engineers). This supports the validity of the answers. Only 13% of the respondents represent the R&D department.

Dependent Variables

We use company patenting strategies to explain two different aspects. The first is the number of amendments, extracted from internal EPO databases and the second is the number of citations received within three years extracted from the OECD citations database. For data availability reasons regarding the amendment data, we can only rely on applications with filing dates between 1998 and 2002. We identified all applications filed in these years which have subsequently been granted. We then extracted the average number of amendments for these patents.[12] On average, the mean number of amendments in the company portfolio is sightly lower than 1 (.89). The median is approximately the same, which implies a rather symmetric distribution of this variable.

Furthermore, we run regressions explaining the average number of forward citations in a company's patent portfolio. To avoid a bias resulting from the different "times at risk" – i.e. the fact that applications filed at an earlier point in time have a longer time during which they can be cited – we restrict the citations to the ones received within the first three years after publication. The distribution of the citations is skewed - most companies receive very few citations or no citations at all. This observation has implications for the choice of the regression method (see section 1.4.2).

Independent Variables

The construction of the motive variables is based on nine different patenting motives covered in the company survey. Respondents were asked to rate the motives on a five-point scale from 1, for not important, to 5, for very important. In order to condense the information, the motives were grouped into three categories based on their similarity and their statistical correlation (protection, blocking, exchange; see table 1.6 in the appendix and Blind et al. 2009). The protection motive includes "protection from imitation" as well as "securing market shares" on national, European and non-European markets. It is calculated as the average assessment of all answers in this group. The blocking motive is measured as the average of "offensive blocking" (defined as preventing competitors from the application of technological developments and taken directly from assessments of the questionnaires) and "defensive blocking" (securing freedom to operate to develop one's own technology without

[12] Our database does not allow us to distinguish between voluntary and requested amendments. An analysis of the voluntary amendments only would have raised the quality of this study. However, as discussed in section 1.3.1, the joint analysis of voluntary and requested amendments can be justified and need not be problematic.

Variable	Mean	Std. Dev.	Min.	Max.
Average forward citations*	0.682	0.661	0	5
Average number of amendments*	0.896	0.541	0	3.571
Protection motive	3.95	0.815	1	5
Blocking motive	3.946	0.779	1	5
Exchange motive	2.474	1.057	1	5
Portfolio size*	41.571	147.034	1	1668
Average share of X references in all refs.	0.223	0.171	0	1

* for grants with application year from 1998 to 2002

Table 1.2. Variables: descriptive statistics

actively using the obtained patents commercially). The third block of motives — the exchange motives — is defined as the average assessment of the motives "income from licensing", "use for cross-licensing" and "improvement of company position in cooperations".

In addition to our key variables, a number of controls for company age, portfolio size and industry affiliation are included. We also control for the incidence of X references in the amendment regressions. These are categories of references in the EPO search report indicating that the search has revealed prior art documents which prevent the application from being granted for reasons of non-inventiveness (Harhoff et al. 2007). They are included as explanatory variables since an X reference will inevitably lead to an amendment to address the objections of the patent examiner.

1.4.2 Regression Results

In this section, we present the results of regressions explaining the average number of amendments and the average number of forward citations of all patents in a company's portfolio applied for between 1998 and 2002. As econometric model, we use tobit regressions since a large share of observations did not receive citations or was not amended at all. This is especially true for the citation variable, where around 17% of the portfolios are not cited at all.

Amendments

We first look at the models explaining the average number of amendments in a company's patent portfolio. Table 1.3 shows four models, in the first three the motives are included separately and the fourth contains all motives simultaneously.

Dependent variable: Amendments	(1)	(2)	(3)	(4)
Protection motive	0.0233			0.00907
	(0.0343)			(0.0378)
Blocking motive		1.021		0.0106
		(0.0302)		(0.0332)
Exchange motive			0.0632**	0.0615**
			(0.0289)	(0.0296)
Average share of X references in all refs.	0.960***	2.630***	0.908***	0.903***
	(0.230)	(0.612)	(0.231)	(0.229)
Portfolio size (grants)	0.0251	1.026	0.0136	0.0124
	(0.0186)	(0.0192)	(0.0206)	(0.0202)
Age dummy (0-5 years) (d)	0.216*	1.246*	0.191	0.189
	(0.129)	(0.162)	(0.129)	(0.128)
Age dummy (6-10 years) (d)	-0.0243	0.974	-0.0445	-0.0461
	(0.112)	(0.109)	(0.109)	(0.109)
Age dummy (11-20 years) (d)	0.258**	1.294**	0.233**	0.233**
	(0.111)	(0.144)	(0.113)	(0.113)
Industry dummy: pharma/health (d)	0.167*	1.182*	0.162*	0.163*
	(0.0861)	(0.101)	(0.0863)	(0.0869)
Industry dummy: chemicals (d)	0.186**	1.207**	0.146	0.144
	(0.0876)	(0.107)	(0.0904)	(0.0902)
Industry dummy: electronics (d)	-0.0216	0.980	-0.0433	-0.0403
	(0.0613)	(0.0604)	(0.0621)	(0.0633)
Industry dummy: other (d)	-0.0506	0.952	-0.0465	-0.0457
	(0.0769)	(0.0736)	(0.0787)	(0.0786)
N	441	441	441	441
ll	-359.7	-359.8	-357.0	-356.9

Reference categories for age dummies: older than 20 years; for industry dummies: mechanical engineering; Marginal effects; Standard errors in parentheses – (d) for discrete change of dummy variable from 0 to 1
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.3. Tobit regressions of amendments on patenting motives (marginal effects)

We have argued that amendments are expected to be more frequent when the applicant focuses on the protection motive and the exchange motive, but we did not expect this effect for the blocking motive. The results in table 1.3 only confirm a positive influence of the exchange motive. The coefficient is positive and significant on the 5% level both in the model with the exchange variable only and in the specification with all three motives.[13] In contrast, the variables for the protection and blocking motive are not significant.

A further observation is that the variable for the average share of X citations among all citations in the company's portfolio obtains highly significant coefficients in all specifications. We see a positive effect for this variable, which is not surprising. An X citation means that the search officer has found prior art and this prevents the claims as filed from being patentable. Thus the applicant is forced to rethink them and eventually change, i.e. amend them.

[13] In additional regressions, we split up the exchange motive into the original questionnaire items. We found positive impacts for two of the three components: the licensing income motive and the cross-licensing motive, but not for the importance of patents in cooperations. This supports our notion that amendments serve to fine tune patents to certain demand characteristics in the technology market.

The effect of the exchange motive on the average number of amendments seems to be robust and positive.[14] We can therefore confirm hypothesis A-3. However, the evidence is not clear for the protection and the blocking motive. We do not find significant coefficients which would allow us to confirm or reject hypothesis A-1 and A-2.

Citations

We now turn to analyzing the influence of amendments and patenting motives on the average forward citations to a patent portfolio.

If amendments are associated with higher citations, one has to incorporate this variable as explanatory variable in the regression models. For lack of data, this was not done in previous research causing an omitted variable bias in the regressions. Consequently, in table 1.4 we include amendments in addition to the motives. We get highly significant results for the amendments variable. This observation – in addition to our theoretical reasoning – is reassuring that the amendment variable should be included in the specification.[15] The amendments have a positive influence on the average citation frequency in the portfolio as the marginal effects in all columns indicate. Our expectations about the protection motive cannot be confirmed and neither do we obtain significant coefficients which would allow conclusions about the direction of the blocking motive.[16] However, we see that the significant effect for the exchange motive is robust to the introduction of the amendment variable.[17] A statistically significant and positive effect is observed in columns (4) and (5). We can therefore for the moment conclude that there seems to be a relationship between the motive to patent for exchange reasons and citation frequency.

From these findings, we conclude that our argumentation about a "claims-shifting" motivation of firms which patent for exchange purposes seems to be consistent with the empirical analysis presented. The exchange motive has both a direct effect on

[14]In other auxiliary regressions – available on request – this finding was confirmed.

[15]The potential econometric issue of the protection motives having themselves an influence on the amendment variable is addressed below in Subsection 1.4.2. Concerns that the inclusion of the amendments variable could bias the coefficients for the motives seem to be of minor relevant, since regressions with the motive variables only yield similar results.

[16]These findings contrast with the ones in Blind et al. (2009), which find positive effects on the citations for the protection motive and negative effects for the exchange motive.

[17]This also applies to a separate model specification where we used the original questionnaires items that are combined in the motive variable. All three items (licensing for income reasons, cross-licensing and patenting to improve the company position in cooperations) keep significant coefficients.

Dependent variable: Citations	(1)	(2)	(3)	(4)	(5)
Protection motive		0.0153			0.000125
		(0.0380)			(0.0388)
Blocking motive			1.018		0.0111
			(0.0373)		(0.0364)
Exchange motive				0.0648**	0.0640**
				(0.0291)	(0.0301)
Average number of amendments for granted filings 98-02	0.148**	0.146**	1.158**	0.129**	0.128**
	(0.0649)	(0.0656)	(0.0751)	(0.0650)	(0.0653)
Portfolio size (grants)	0.129***	0.128***	1.136***	0.115***	0.114***
	(0.0188)	(0.0188)	(0.0217)	(0.0208)	(0.0209)
Age dummy (0-5 years) (d)	0.254*	0.250*	1.287*	0.220	0.219
	(0.144)	(0.143)	(0.183)	(0.142)	(0.141)
Age dummy (6-10 years) (d)	0.423**	0.422**	1.522**	0.396**	0.394**
	(0.184)	(0.185)	(0.284)	(0.179)	(0.181)
Age dummy (11-20 years) (d)	-0.0174	-0.0174	0.983	-0.0390	-0.0387
	(0.114)	(0.114)	(0.112)	(0.111)	(0.111)
Industry dummy: pharma/health (d)	0.277*	0.277*	1.320*	0.273*	0.274*
	(0.158)	(0.158)	(0.209)	(0.156)	(0.155)
Industry dummy: chemicals (d)	0.403***	0.400***	1.493***	0.356***	0.355***
	(0.104)	(0.104)	(0.156)	(0.106)	(0.106)
Industry dummy: electronics (d)	0.00642	0.00804	1.009	-0.0138	-0.0118
	(0.0647)	(0.0649)	(0.0654)	(0.0648)	(0.0653)
Industry dummy: other (d)	0.0477	0.0480	1.050	0.0507	0.0516
	(0.0919)	(0.0920)	(0.0966)	(0.0902)	(0.0904)
Observations	441	441	441	441	441
ll	-445.9	-445.8	-445.8	-443.4	-443.3

Marginal effects; Standard errors in parentheses
(d) for discrete change of dummy variable from 0 to 1
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.4. Tobit regressions of citations on amendments and patenting motives (marginal effects)

the citations and an indirect one via the amendments; the amendments themselves also seem to coincide with more forward citations. A causal interpretation seems intuitive if amendments are seen as “revisions” of a previously poor patent application. Through the incorporation of information which emerges after the first filing, the patent is improved and thus more qualified for subsequent inventions to build on it.

We close this section with a few remarks on some of the control variables. We find significant effects for the portfolio size as well as for some industry and firm age dummies. The effect of the portfolio size is positive and consistently so over all specifications. This finding can be interpreted as an indication of economies of scale or learning curves in the production of patents (Blind et al. 2009). As for industry differences, companies in our sample that belong in the pharmaceutical and chemical industries receive, on average, more citations than those in the reference category (mechanical engineering). The effect is not significant for electrical engineering and the residual category “other industries”. These findings largely correspond with the ones in Blind et al. (2009) and other research.

Two-Stage Regression

In this section, we present additional regressions in order to address a potential econometric issue. In table 1.4, we include both the patenting motives and amendments as explanatory variables. However, as the previous section has shown, the patenting motives also affect the amendments themselves. This causal structure would result in a kind of simultaneous equation system of the following form:

$$\begin{aligned} Citations = \beta_0 + \beta_1 ProtectionMotive + \beta_2 BlockingMotive + \\ \beta_3 ExchangeMotive + \beta_4 Amendments + X\beta + e \end{aligned} \tag{1.1}$$

$$\begin{aligned} Amendments = \pi_0 + \pi_1 ProtectionMotive + \pi_2 BlockingMotive + \\ \pi_3 ExchangeMotive + X\pi + u \end{aligned} \tag{1.2}$$

In this situation, the amendments serve as a control variable in Equation 1.1 to estimate the effect of patenting motives and also are the outcome of the motives in Equation 1.2. In this case, the amendments are an endogenous control variable. To deal with this situation, we use a *two-stage model*: In the first stage, we use the motive variables as well as the control variables as regressors on the amendments. The second stage regresses the motive variables as well as the predicted values for the amendments from stage one on the citations. We take this additional step primarily to assess the influence of the motives, not the amendments, because in the regressions in table 1.4 the amendments are an outcome of the motives. For the coefficient of the amendment variable, this problem does not exist, because the motives are obviously not an outcome of the amendments. However, as a by-product, we can also assess the endogeneity issue, which would exist if the underlying expected value of an invention would cause both more citations and the decision to file amendments.

In the first stage, we need an instrument which is not part of the second stage regressions, but correlated with the amendments. Here we use the average share of X citations in the patent portfolio. This variable is especially suited, since we know from table 1.3 that it has a significant influence on the number of amendments.[18]

[18] The instrument would not be suitable if it is itself correlated with the citations. As X references indicate lack of novelty they could be negatively associated with the patent value. We argue that this is not the case, because the appearance of X references is to a large extent induced by the drafting of the application by the patent attorney (e.g., by claiming a too broad scope) and not necessarily systematically associated withe the patent value.

Dependent variable: Citations	(1)	(2)	(3)	(4)
Protection motive	0.00981			-0.00126
	(0.0408)			(0.0401)
Blocking motive		1.008		0.00337
		(0.0402)		(0.0381)
Exchange motive			0.0704*	0.0703*
			(0.0384)	(0.0390)
Average number of amendments for granted filings 98-02	0.315	1.375*	0.246	0.246
	(0.195)	(0.264)	(0.210)	(0.212)
Portfolio size (grants)	0.0955***	1.100***	0.0825***	0.0823***
	(0.0191)	(0.0216)	(0.0216)	(0.0216)
Age dummy (0-5 years)	0.211	1.236	0.195	0.195
	(0.153)	(0.189)	(0.150)	(0.150)
Age dummy (6-10 years)	0.456**	1.576**	0.432**	0.432**
	(0.184)	(0.294)	(0.179)	(0.181)
Age dummy (11-20 years)	-0.0296	0.970	-0.0391	-0.0391
	(0.116)	(0.113)	(0.113)	(0.112)
Industry dummy: pharma/health	0.245	1.278	0.252	0.252
	(0.164)	(0.210)	(0.165)	(0.163)
Industry dummy: chemicals	0.407***	1.503***	0.374***	0.374***
	(0.109)	(0.165)	(0.109)	(0.109)
Industry dummy: electronics	0.0101	1.011	-0.0138	-0.0134
	(0.0671)	(0.0677)	(0.0681)	(0.0682)
Industry dummy: other	0.0361	1.037	0.0372	0.0374
	(0.0987)	(0.103)	(0.0954)	(0.0958)
Observations	441	441	441	441
R^2	0.172	0.171	0.194	0.194

Marginal effects; Standard errors in parentheses - (d) for discrete change of dummy variable from 0 to 1
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Instrumented: Average number of amendments
Instruments: Average share of X References, motive variables, portfolio size, age and industry dummies

Table 1.5. Two-stage regressions of citations on patenting motives and amendments

We tested for endogeneity of the amendments variable and used a Hausman-Test to check whether differences between the "normal" and the two-stage estimates are large enough to suggest that the OLS estimates are not consistent. Both results indicate that the two-stage method seems appropriate. Table 1.5 presents the results of the second stage. We can see that the effect of the exchange motive on citations also persists in this model, while the other two motive variables do not obtain significant coefficients as before. We take this as an additional indicator towards a causal effect of the technology exchange motive on citation frequency. Furthermore, we see that the coefficients for the amendment variable maintain their positive sign. Due to the higher standard errors that result from the two-stage method, they are beyond the significance threshold of 10% for three of the four specifications. Nevertheless, taking into account our previous results from table 1.4, we think that a correlation between amendments and citations can be assumed. For this interpretation of the amendments variable, table 1.4 delivers the relevant coefficients, since the two-stage regression approach was primarily necessary in order to ensure the causal interpretation of the motive variables.[19]

1.5 Conclusions

In this paper, we have studied the relationship of patenting motives, instruments of strategic patenting (claim amendments) and the characteristics of firms' patent portfolios. Relying on survey data among 441 German patent-active companies combined with information on their patent portfolios and interactions with the patent office, we are able to empirically substantiate several hypotheses. We find that companies, which regard patenting for technology exchange reasons as relevant, amend their originally filed claims more often. Second, we show that amendments are associated with higher numbers of forward citations. We interpret this finding as evidence for the argument that there can be a rise in value of patents which are "revised" after the first application, since information which was not available at the time of filing can now be incorporated. Third, besides the indirect effect via amendments, we find a direct positive effect of the technology exchange motive on subsequent citations to the portfolio.

In combination, these findings have some interesting implications. From an economist's point of view, the exchange motive can be regarded as a highly desirable use of the patent system, especially in comparison with the blocking motive. Technology exchange promotes a collaborative research environment, facilitates technology diffusion and can eliminate hold-up problems in situations of fragmented IP ownership. However, we have shown that it seems to coincide with a higher frequency of amendments which increases technological uncertainty in the market. It also causes greater information asymmetry in the exact scope of a patent between applicants and third parties. Uncertainty about the scope of competitors' patents, in turn, can slow down economic dynamics and result in hold-up problems. On the other hand, amendments could facilitate technology exchange by *reducing* uncertainty about the value of a patent for potential licensees. Uncertainty about the outcome of a patenting process or the patent claims could be mitigated if the applicant takes into account the potential licensee's technological need. As uncertainty is one of the main factors limiting the growth for markets for technology (Arora and Gambardella 2010), amendments

[19] If endogeneity of the amendment variable is assumed, causal interpretation regarding the effect of the amendments with respect to the citations is difficult in the light of their weak significance in table 1.5.

could thus help to moderate these transaction costs. This ambiguity of the implications of amendments are even more articulate when we take into account that amendments themselves are also associated directly with higher levels of citations.

We therefore face a dilemma, since desirable patenting motives imply higher uncertainty. In the light of these results, the EPO decision (see footnote 5) to limit the possibilities for amendments and to require the applicant to identify the changes in claims is reasonable in terms of eliminating undesirable uncertainty in the patent system, but might come at the cost of lowering the value of some patents. It may also pose problems for technology providers in technology markets, because they are restricted in shaping their patents to match the preferences of companies looking for certain technology.

Further research on this trade-off seems promising for both scientific reasons and policy implications.

Bibliography

Arora, A. and A. Gambardella (2010), Ideas for rent: an overview of markets for technology, Industrial and Corporate Change, 19(3): 775–803.

Blind, K., K. Cremers, and E. Müller (2009), The influence of strategic patenting on companies' patent portfolios, Research Policy, 38(2): 428–436.

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

Cohen, W., A. Goto, A. Nagata, R. Nelson, and J. Walsh (2002), R&D spillovers, patents and the incentives to innovate in Japan and the United States, Research Policy, 31: 1349–1367.

Cohen, W., R. Nelson, and J. Walsh (2000), Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not), NBER Working Paper 7552.

de Rassenfosse, G., D. Guellec, and B. van Pottelsberghe de la Potterie (2009), Quality versus quantity: strategic interactions and the patent inflation, Working Paper.

Graham, S., J. H. Merges, S. P. Robert P., and T. M. Sichelman (2009), High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey, CELS 2009 4th Annual Conference on Empirical Legal Studies Paper.

Hall, B. and R. Ziedonis (2001), The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995, Rand Journal of Economics, 32(1): 101–128.

Harhoff, D., K. Hoisl, and C. Webb (2007), European Patent Citations – How to Count and How to Interpret Them, Unpublished Discussion Paper, University of Munich.

Harhoff, D., F. Narin, F. M. Scherer, and K. Vopel (1999), Citation frequency and the value of patented inventions, Review of Economics and Statistics, 81(3): 511–515.

Harhoff, D., F. M. Scherer, and K. Vopel (2003), Citations, family size, opposition and the value of patent rights, Research Policy, 32(8): 1343–1363.

Harhoff, D., S. Wagner, and S. von Graevenitz (2008), Incidence and Growth of Patent Thickets - The Impact of Technological Opportunities and Complexity, CEPR Discussion Paper 6900.

Henkel, J. and F. Jell (2009), Alternative Motives to File for Patents: Profiting from Pendency and Publication, Munich University of Technology - Faculty of Economics and Business Administration Working Paper Series, http://ssrn.com/abstract=1271242.

Jaffe, A. B., M. Trajtenberg, and M. S. Fogarty (2005), The Meaning of Patent Citations: Report on the NBER/Case-Western Reserve Survey of Patentees, in: A. B. Jaffe, M. Trajtenberg, and P. M. Romer, eds., Patents, citations, and innovations: a window on the knowledge economy, The MIT Press.

Jaffe, A. B., M. Trajtenberg, and R. Henderson (1993), Geographic localization of knowledge spillovers as evidenced by patent citations, Quarterly Journal of Economics, 108(3): 577–598.

Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. G. Winter (1987), Appropriating the returns from industrial-research and development, Brooking Papers on Economic Acttivities, 783–831.

Noel, M. D. and M. A. Schankerman (2006), Strategic Patenting and Software Innovation, LSE STICERD Research Paper No. EI43.

Peeters, C. and B. van Pottelsberghe de la Potterie (2006), Innovation strategy and the patenting behavior of firms, Journal of Evolutionary Economics, 16(1-2): 109–135.

Reitzig, M. and P. Puranam (2009), Value appropriation as an organizational capability: the case of ip protection through patents, Strategic Management Journal, 30(7): 765–789.

Shapiro, C. (2001), Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting, in: A. Jaffe, J. Lerner, and S. Stern, eds., Innovation Policy and the Economy I, 119–150, The MIT Press, Cambrigde, Massachussetts.

Trajtenberg, M. (1990), A penny for your quotes - patent citations and the value of innovations, Rand Journal of Economics, 21(1): 172–187.

van Pottelsberghe de la Potterie, B. and N. van Zeebroeck (2008), A brief history of space and time: The scope-year index as a patent value indicator based on families and renewals, Scientometrics, 75(2): 319–338.

van Zeebroeck, N., B. van Pottelsberghe de la Potterie, and D. Guellec (2009), Claiming more: the Increased Voluminosity of Patent Applications and its Determinants, Research Policy, 38(6): 1006–1020.

Appendix

Variables	1	2	3	4	5	6	7	8	9
1 Imitation protection	1.000								
2 Securing market share (national)	0.394	1.000							
	(0.000)								
3 Securing market share (Europe)	0.341	0.655	1.000						
	(0.000)	(0.000)							
4 Securing market share (excl. Europe)	0.200	0.344	0.674	1.000					
	(0.000)	(0.000)	(0.000)						
5 Offensive blocking	0.384	0.294	0.296	0.244	1.000				
	(0.000)	(0.000)	(0.000)	(0.000)					
6 Defensive blocking	0.195	0.214	0.250	0.271	0.209	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
7 Generating income from licensing	0.069	0.138	0.182	0.239	0.077	0.046	1.000		
	(0.153)	(0.004)	(0.000)	(0.000)	(0.109)	(0.343)			
8 Use for cross-licensing	-0.015	0.014	0.088	0.189	-0.002	0.195	0.452	1.000	
	(0.754)	(0.775)	(0.075)	(0.000)	(0.969)	(0.000)	(0.000)		
9 Cooperation	0.054	0.188	0.211	0.240	0.038	0.197	0.494	0.488	1.000
	(0.270)	(0.000)	(0.000)	(0.000)	(0.442)	(0.000)	(0.000)	(0.000)	

Table 1.6. Correlation matrix: patenting motives

Chapter 2

Keep 'Em In, Make 'Em Fit - An Analysis of Filing Behavior for Essential Patents in Standards

Abstract This article addresses companies' filing behavior for patents which are part of technology standards ("essential patents"). We analyze why and how standardization induces applicants to exploit the flexibility within the patent application process. First, we discuss applicants' incentives to achieve conformity of patent applications with the standards under development. Subsequently, we show how companies try to achieve this fit. Additionally, we argue that applicants benefit from delaying the grant decision and thus keep applications pending to gain flexibility in amending the claims. For empiric validation, we use new procedural patent data from the European patent application process. We adopt a one-to-one matching approach, pairing essential patents in telecommunication with control patents on the matching criteria of application time, IPC subclass and applicant name. Additionally, we compare these essentials with patents of companies that do not hold standard-relevant patents. We find higher number of patent claims and amendments to these claims for the essential patents as well as differences in a number of other parameters. Using survival analysis, we show that essential patents have significantly longer pendency times, with lower hazard rates caused by the higher number of amendments, claims, share of X references and other factors. We discuss implications and address the detrimental effects caused by the these filing strategies. Possible solutions such as better coordination efforts between standardization and patenting organizations are devised.

2.1 Introduction

Strategic patenting has received a fair amount of attention among researchers in the field of strategic and intellectual property management and industrial economics (e.g. Arundel and Patel 2003, Blind et al. 2006, Cohen et al. 2002). This paper concentrates on a subprocess of strategic patenting, the application process. We study the incentives of patent applicants and the instruments they use to shape this subprocess and examine the characteristics of a possible process outcome, i.e. the granted patent, with respect to two dimensions: the "scope of protection" and "time to grant" of the application. Both dimensions are important strategic elements for patent applicants. The patent scope has frequently been analyzed in the literature (e.g. Hall et al. 2005, Lanjouw and Schankerman 2004, Lerner 1994), as it heavily determines a firms market power in a specific technological field. Far less attention has been paid to the importance of time in the process of patenting and its competitive elements. Creating time lags between patent application and patent grant is a major factor when the objective of a patent application is to create uncertainty among other market participants about the real scope of protection and about the value of the technology in the application. In times of increasing backlogs at patent offices with a world-wide stock of pending applications far over two million, the strategic value of pending rights can be enormous.

Concerning patent scope, it is clear that a genuine interest of patent applicants - but by far not the only one[1] - is to have a granted patent with claims covering the maximum scope of protection and thus being of maximum value. A broad scope guarantees a high freedom to operate and makes it more difficult for competitors to work around the invention. However, in order to prevent too broad patents, patent examiners often demand to cut back the initially filed claims. Thus applicants (or their legal representatives) will design and amend the claims carefully to ensure protection of the most relevant components. This paper analyses one of the aspects which applicants take into account when filing or subsequently amending their claims: industry standards. Among them, one of the most important examples are compatibility standards in telecommunication. Firms participating in standard-setting organizations (SSOs) often aim to have their own patents included in the list of a standard's essential patents.[2] If this goal is met, the IPR holder can expect a substantial leverage of

[1] See for example Henkel and Jell (2009) for alternative motives to patent.

[2] According to the directives the European Telecommunication Standards Institute (ETSI), "essential" as applied to intellectual property rights (IPR) means that it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of the art generally available at the time of standardization, to make, sell, lease, otherwise dispose of, repair,

the patent's value, either in the form of an increased market and bargaining power in negotiations with competitors or in the form of royalty payments since firms willing or having to implement the standard have to license the relevant IP. The goal of applicants is thus not necessarily always to obtain the broadest protection possible, but to achieve an exact fit with the expected standard. How can applicants achieve this conformity? As pendency times are getting longer in patent offices around the world (WIPO 2009) and as the development of standards can be a matter of years, companies make use of the possibility to change their initially filed claims. This is perfectly legitimate if the examiner opposes certain claims or requires the applicant to adapt the application to make it patentable. On the other hand – and this could be the case with patents relevant for standards – applicants can try to strategically shift the exact protection of the patent, if they become aware of decisions in the standards committee which could lead to certain technological specifications. An example is the famous Rambus vs. Infineon case, in which the trial record of the US Court of Appeals for the Federal Circuit showed that Rambus explicitely changed the patent claims in order to cover SDRAM technology under standardization at the JEDEC standard-setting body (Chiao et al. 2007).

Furthermore – and this leads to the time dimension which has so far received sparse attention in the literature[3] – applicants have an incentive to keep the application pending in order to adapt the claims or cut them back to the ones necessary for the patent to be essential. In the context of standards, this incentive, however, might change depending on the progression of the standards development. At the beginning of the process, with high uncertainty about the future standard specifications, it is crucial to keep the application pending to preserve room for maneuver. However, once a standard has been defined, it is of utmost importance to have an essential patent fixed so that a share of the standard's licensing fees can be claimed.

The aim of this paper is to illustrate that the participation in standardization activities can have a strong influence on the patenting and application behavior both concerning the scope of protection and the time to grant. In the following we will analyze three groups of aspects and the according hypotheses:

First, we will address the application process of essential patents. We hypothesize that, in business environments where standards are important, applicants have an increased incentive to draft filings with high numbers of claims (proxying a broad

use or operate equipment or methods which comply with a standard without infringing that IPR. (Annex 6 of the ETSI Rules of Procedure, Article 15.6)

[3] An exception is Harhoff and Wagner (2009) and van Zeebroeck (2008), but both address the strategic implications only marginally.

scope of protection). The intention is to make the patent scope contain technological specifications covered by the standard.

Second, we will analyze the development of the patent claims arguing that amending claims to make them fit to particular standards specifications is important.

Third, we argue that it is important for a company involved in standard setting to keep its application pending as long as the standard is being developed. Once a patent is granted the flexibility of amending the claims is lost.[4] We argue that essential patents are therefore pending longer than comparable patents not relevant for a standard. This is especially true for applications filed before the specifications of a standard are fixed as the incentives to delay the process decrease and are eventually replaced by motivation to have the patent granted fast. We also analyze whether the higher need for flexibility is reflected in a more extensive use of divisional applications.

We test our propositions empirically by comparing a number of patents disclosed as essential for standards developed at the European Telecommunications Standards Institute (ETSI), a major SSO responsible for the initial standardization activities of widely used standards such as GSM or UMTS. In a first step, we match the information on "essentiality" to a new database of patent applications containing information on procedural EPO data, especially on the number of amendments and relevant dates such as application and grant/refusal dates etc. We use two different control groups. One is constructed by a one-to-one matching approach with each match belonging to the same IPC subclass, the same filing month, and the same applicant. A wider control group includes only granted applications in the same IPC subclass and filing years of firms that do not hold essential patents.

Results strongly corroborate our hypotheses showing significantly higher outcomes in the "essential" patents group compared to the control groups for the number of claims, amendments and the extent to which divisional applications are used. Survival time analysis shows that these factors which are found to be prevalent among essential patents are responsible for longer pendency times. Furthermore, filings after the freezing date of the relevant standard show significantly lower number of amendments and shorter pendency times, reflecting a lower need to delay and amend the application once the information about the future standard is available. Our results reveal a number of interesting aspects on how standardization affects patent

[4] Companies trying to delay the application process will thus have to keep the application deliberately deficient causing a higher number of communications being sent by the search examiner, will use the "right to oral proceedings" strategically to keep the process lasting or react only just before the expiration of a legal term. Guellec and van Pottelsberghe de la Potterie (2007) list more possible strategies under the heading "Slow track filing strategy" and "Deliberate abuse of the system".

applicant behavior and the patent system as a whole. These interactions should be taken seriously because the described behavior increases uncertainty in the patent system resulting in possible disincentives for investment in research and development.

2.2 Related Literature

As standardization is a relatively young field of research, we will briefly review some important and recent contributions and describe how our work is related to them. The theoretical literature on standards was pioneered by Farrell and Saloner (1988) who model the bargaining process within SSOs as a war of attrition between participants. They conclude that finding consensus in an SSO takes longer than a solution via the market mechanism (standards war). This finding plays a role in our analysis since a long standards development process will lead to more strategic patenting as a reaction to new developments during this time. Later important theoretical work on standards was done by Lerner and Tirole (2006) who concentrate on the SSOs' IPR policies and emphasize the possibility of IPR holders to choose an SSO most suitable to their interests. Empirical support for this model is shown in Chiao et al. (2007) where the connection between an SSO's orientation towards technology sponsors and their disclosure requirements is shown by analyzing a large number of SSOs. A further connected strand of literature is the work on strategic patenting and the motives to file patents (Blind et al. 2006, Cohen et al. 2000, Hall and Ziedonis 2001). Blind et al. (2006) explicitly include "influence on standardization" as a particular motive to patent, but find it to be of relatively low importance compared to both the traditional protection motives and other strategic motives. Recent papers have turned to the level of the single patent in order to investigate peculiarities of essential patents. Rysman and Simcoe (2008) show that essential patents in four major SSOs are cited around twice as often as the control sample and that they receive citations over a longer period of time. They observe a strong increase after disclosure to the SSO. Bekkers and West (2009) analyze essentials in the development in GSM and UMTS and point out the high increase in the number of potentially essential patents. Furthermore, patents essential to the UMTS standard are held by a smaller proportion of companies than those essential to the GSM standard.[5]

[5]Different work by Bekkers et al. (2002) also covers the ETSI essentials and shows that the market dominance of firms in the telecommunication industry is strongly associated with the possession of essential IPR.

2.3 Hypotheses

We have already mentioned that the potential inclusion of IPR in standards can induce incentives for over-patenting or opportunistic patenting. Furthermore, companies will try to shape the application process itself to their interest. This refers to aspects of the initial drafting of the patent application and especially to the way patent claims are used.[6] A strategy for filing essential patents is most likely to initially focus on a broad scope that eventually covers the scope of the future standard. If necessary or required by the examiner, the claims can subsequently still be cut back to the ones that are eventually relevant. While this strategy is observable in many industries, we argue that it is especially important in the standard setting context, because the inclusion in the essential patents list leverages patent value and market power. In addition, we argue that this attempt to create a broad scope by filing high numbers of claims will also be reflected in more X or Y documents. These documents are references added by the patent examiner or search officer. If X or Y documents are found, "a claimed invention cannot be considered novel or cannot be considered to involve an inventive step" (EPO 2009). X documents indicate "particularly relevant documents when taken alone", Y references refer to relevant documents "when combined with one or more other documents of the same category".[7] If there are more claims in a single patent application, it is more likely that at least one X or Y document is detected. Additionally, claims of essential patents might be drafted (too) broadly in order to cover a technology of a relevant standard. We argue that the detection of X or Y documents – as an effect of the higher number of claims and a broader scope – is more likely among the essential patents than in the control group.

> *Hypothesis 1: Standards-relevant patents have more claims than patents in the control group.*

[6]The number of claims in incoming applications at the EPO have increased significantly from around 12 in 1990 to more than 20 in 2004 (van Zeebroeck et al. 2009). Additionally, it seems to be a common strategy to file a high number of claims and let the examiner figure out the exact invention, thus shifting additional work to the search or examining division and at the same time generating uncertainty among competitors (see Guellec and van Pottelsberghe de la Potterie 2007, p. 165). Another purpose of filing large number of claims might also be to obtain a broader grant than justified.

[7]Strictly speaking, the breadth of the claims determines the likelihood of finding an X or Y document. In the literature the number of claims is often taken as a proxy for the breadth of a patent, because it raises the probability of an infringement and is connected with patent value (Lanjouw and Schankerman 1999). We follow this approach, but are well aware of the limitations of this proxy, interpreting the corresponding results with caution.

Hypothesis 2: The share of X or Y references is higher among standards-relevant patents than among patents in the control group.

Amendments of claims are usually changes or restrictions induced by the examiner indicating that the claims as they stand are not patentable. Rule 137 of the European Patent Convention sets out the legal basis for amendments: after receipt of the European search report, the applicant may, of his own volition, amend the description, claims and drawings. After receiving the first communication from the Examining Division, the applicant may, of his own volition, amend once, every further amendment needs the consent of the Examining Division.[8] However, conversations with examiners and other EPO representatives suggest that current practice at the EPO seems to be rather generous in allowing applicants to make amendments and one can expect that patent attorneys will find a way to have the file amended more often. Examples include deliberately keeping the set of claims deficient, causing additional requests for amendments from the examiner, or adding a set of claims introducing new subject matter, which is, in principle, ruled out by Article 123 EPC. The use of these strategies is caused by the strong incentive for applicants involved in standard setting to change the exact wording of their application. They have a much better chance to have their patent included in the list of essential patents if the technical content of patent and standard match completely. Every change in the wording of a standards document would thus make an additional amendment necessary.

We have to mention that the expected higher number of amendments might also be caused by applicants actually trying to avoid making the patent essential to the standard. We have so far argued that the inclusion into a standard highly leverages the value of the patent and increases the applicant's expected royalty revenues. As a number of SSOs (among them ETSI) require participants to license their IP on FRAND ("Fair, Reasonable, And Non Discriminatory") terms, patent holders can actually have an incentive to avoid their IP being included in the standard. Consequently, they are not restricted by the FRAND terms. If they hold a patent that is not officially "essential", but in practice hard to circumvent, their expected royalty revenue can be even higher. We thus have to bear in mind that applicants can act into two different directions: towards a better fit to the standard and (slightly) away from the standard. Thus, differences between the number of amendments of essential patents and the control group could be diminished, because a small num-

[8] In March 2009 the Administrative Council of the EPO issued new official terms for the Implementing Regulations to the European Patent Convention. As of April 1 2010 amendments can only be made after receipt of the search report, any amendments made to the description, claims and drawings must be identified and basis in the application as filed must be provided.

ber of patents falls into the control group because it was amended “away from the standard”. Nevertheless, only a very small subsample of the control patents is likely to belong to those applicants who explicitly try that their patent is excluded from the essential patents list. The hypotheses to be tested in the empirical part are the twofold:

> *Hypothesis 3a: The number of amendments to the initially filed claims is higher for standards-relevant patents than for patents in the control group.*

> *Hypothesis 3b: The share of multiply amended applications is higher among standards-relevant patents than among patents in the control group.*

In order to be able to make amendments, an application has to be kept pending as long as possible; once the patent is granted, the scope and the exact wording of the application are fixed. There are numerous ways to prolong the pendency time of an application, even to a larger extent than the time span already caused by the backlog in patent offices worldwide. This includes choosing the filing route (e.g. Euro-direct versus Euro-PCT), which is a first potential strategy to gain time. The filing route is a rather straightforward way to delay the patenting process and the additional time serves to prolong the period of time from the priority date to the final decision. More subtle ways include application drafting practices and the way interactions with the patent office are handled. Patent examiners at the EPO pointed out in personal conversations with the authors that a common strategy to delay the procedure is to wait with certain actions (e.g. claims restrictions) until they can no longer be avoided or until the examiner summons to oral proceedings. Probably the most effective way to take advantage of an early priority date and to postpone the date of a final decision is the filing of divisional applications.[9] Two types of divisional applications can be distinguished: mandatory and voluntary divisionals. Divisionals can be demanded by the EPO because the original application does not meet the requirement of “unity of invention”(Article 82 EPC). As applicants in a standards-relevant industry might have an incentive to initially file large numbers of claims, the principle of unity of invention could be violated more frequently thus making a split into two or more divisional applications necessary.[10] In this case,

[9]The EPO has experienced a sharp increase in divisional applications in recent years with an average rise of 12% per annum from 2002 to 2008. In 2008, the share of divisionals among all applications entering the European procedure was around 5% whereas from 1998 to 2001 it was around 2.7%.

[10]The validity of this argument again depends on whether the number of claims is accepted as an indicator of the breadth or scope of an application.

a high incidence of divisionals would be an indicator of excessively broad parent applications. However, applicants can also voluntarily split up applications into two or more divisionals.[11] The percentage of divisional filings and the degree to which these are voluntary differs considerably among technologies. Both numbers are among the highest in telecommunication. One possible reason for this is the importance of standard setting in this industry. Applicants can increase the number of patents regarded as essential for a standard by filing divisional. This can improve their negotiating position on the standard's essential IP and their potential market power or licensing income increases. Additionally, creating uncertainty plays a role since potential licensees will be left with doubts about how much IP has to be licensed in order to being able to implement a standard. We derive the two following hypotheses:

> *Hypothesis 4: The pendency time is longer for standards-relevant patents than for patents in the control group.*

> *Hypothesis 5: The share of divisional applications is higher among standards-relevant patents than among patents in the control group.*

The timeline in Figure 2.1 illustrates a hypothetical situation of concurrent patenting and standardization activities.[12] One can see how the ongoing standard development during time t=1 to t=6 creates the need to keep the application pending, since a grant in period t=5 would mean losing the possibility of adapting the application to the future standard. A subsequent attempt to amend the file and delay the intention to grant moves the point in time where the claims are fixed to after the "freezing point" of the standard.

2.4 Empirical Part

2.4.1 Description of Data and Matching Methodology

The following section describes the data used for the subsequent empirical analysis. We use patent process data not used before in the scientific empirical literature,

[11] In his decision in March 2009, the Admistrative Council of the EPO imposed a time limit of 24 months after the Examining Division's first communication after which divisionals can no longer be filed. This applies to divisionals filed after April 1 2010.

[12] The figure shows only one possible situation of the chronological overlap between patenting and standardization. It goes without saying that other temporal situations (indicated with dashed brackets) are possible.

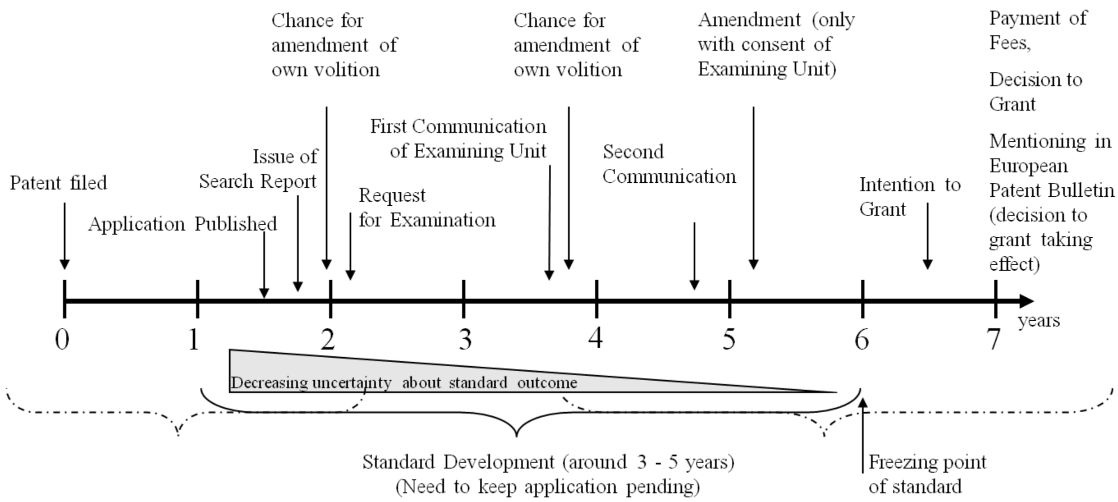

Figure 2.1. Example of timeline with overlapping examination and standardization periods

namely the information on how often a single patent application was amended before a decision about grant or refusal was made. Our unit of observation is the individual patent application in sections G (physics) and H (electricity)[13] of the International Patent Classification (IPC), for which a decision "granted/refused/(deemed) withdrawn" has been reached and which were pending at the European Patent Office between 1998 and 2001. We have information on the application procedure for every application including the filing date, the filing route, the number of claims, the number of amendments made to the application and the pendency time (calculated as the filing date until the date of intention to grant or refuse the patent or the date at which the application is deemed withdrawn). This gives us a rich source of data on the life cycle of every single application. We match the OECD citations database (Webb et al. 2005) to this dataset to obtain information on the different types of backwards (patent literature, non-patent literature) and forward citations. Next we collected information on a patent's potential relevance to a standard by analyzing ETSI's database of essential patents (http://webapp.etsi.org/IPR). Not all declarations to the SSO can be used because our dataset on procedural data contains EP filings only.[14] Furthermore, constraints on the information on amendments forced us

[13]These sections are relevant, since we analyze standards in telecommunication for which relevant patents belong to these two sections.

[14]At the date of retrieval (February 2009), there were around 1500 declarations related to EP patents. However, the data quality of a large number of these declarations is not sufficient, because there was no reference to a specific (EP) patent or there were duplicate entries with a single patent being declared essential several times.

to only consider filings from 1998 to 2001. The total number of identified granted essential patents used is 326.[15]

We identified a "statistical twin" for each essential application based on three criteria and employed a three-step matching procedure. First, we identified all non-essentials in the same 4-digit IPC subclass, filed in the same month by the same applicant. Second, we randomly selected one of these as control patent. This procedure yielded 227 matches. If we were not able to identify a suitable match, the time criterion was broadened to the same application year, yielding 54 "statistical twins". In the third step, ten essentials were matched to a control patent with same IPC subclass, same filing year, but different applicant. No suitable match could be identified for the rest of the essential patents and they were thus dropped from the analysis. The final number for our analysis is 291 essential patents. The aim of the matching procedure is to rule out a bias in the construction of the control sample and to control for differences between technology classes, timing issues and heterogeneity of filing strategies between applicants. We therefore compare only the matches using a paired (repeated measures) t-test. As described, our construction of the first control sample relies on a narrow matching approach only comparing patents that have been filed by the same applicant. While this approach is appealing because it shows how filing behavior differs within companies, we additionally consider a wider control group consisting of 69,195 patents that do not belong to the companies which disclosed IP in the essential patents database.[16] This control group can reveal how the essentials differ compared to a broader average of applications in the relevant technology fields, which may also belong to applicants who were not successful in including their patents into the list of essential patents or those who did not intend to do so.

Finally we justify why the essential patents database can be considered suitable for our purposes. Possibly, not all patents declared as essential, which are therefore part of our sample, will ultimately be seen as essential by the SSO's working committee and will be included in the final specification of the standard. Some evidence suggests that a real essentiality might in fact not be given for a high number patents listed on an SSO's IP disclosure sheet.[17] For our purposes, however, it is irrelevant whether the patent is, in fact, technically needed for standard implementation. We merely exploit the declaration of potential essentiality and thus have an indicator of the motivation for the observed behavior in the application process. However, patents that are in

[15] About half of the essentials are connected to the UMTS project, followed by declarations concerning the GSM project accounting for 30% of the essential declarations.

[16] The criteria filing year and IPC subclass are maintained.

[17] Goodman and Myers (2005) claim that only 21% of declared patents in 3GPP and 3GPP2 are actually essential.

fact essential are in some cases not submitted to the SSOs or are only submitted in late stages of the standards development process (patent ambushing). This would mean that our control group would potentially also contain essential patents thus biasing the comparison. However, since we only focus on patents filed from 1998 to 2001 for a standard that was developed at that time, we think that if a firm indeed held an essential patent, it would most likely have declared it to the SSO by the time of data collection for this study in early 2009. Failing to submit relevant IP seems unlikely since the firm would lose its strategic advantages. Thus, the number of standards-relevant patents in the control group not declared as essential patents should at worst be very small and therefore does not challenge the measurement approach of our empirical analyses.

2.4.2 Descriptive Analysis: Claims, X/Y Documents, Amendments and Divisionals

First we analyze how the number of claims in an application differs between the groups by analyzing this parameter in essential patent applications and in the control groups. Our comparison shows that there is a pronounced difference: while patents in the treatment group (i.e. the essential patents group) have on average more than 20 claims, the mean in the matched control group amounts to only 17 to 18 claims (Figure 2.2) and to 16 in the wider control group. The difference between treatment and control groups is statistically significant on the 1% level. We interpret this as an indication that applicants of standard-relevant patents draft broader applications covering a wide range of potential outcomes of the standard being developed. If this is true, applicants possibly also run a larger risk of claiming non-novel applications which would be identified by a higher share of applications with X or Y documents being added by the search officer. The share of applications that do not meet the requirement of novelty or inventive step seems indeed to be different in the two groups. The percentage is 0.56 for the control group and 0.67 for the treatment group. A two-sample test of proportions reports a significant difference on the five percent level. Comparing the actual number of X documents, there is a slightly higher number in the treatment group, but the difference is not significant. Combining the two observations of systematically higher numbers of claims in the essential patents group with higher rates of X and Y documents found by the examiner is consistent

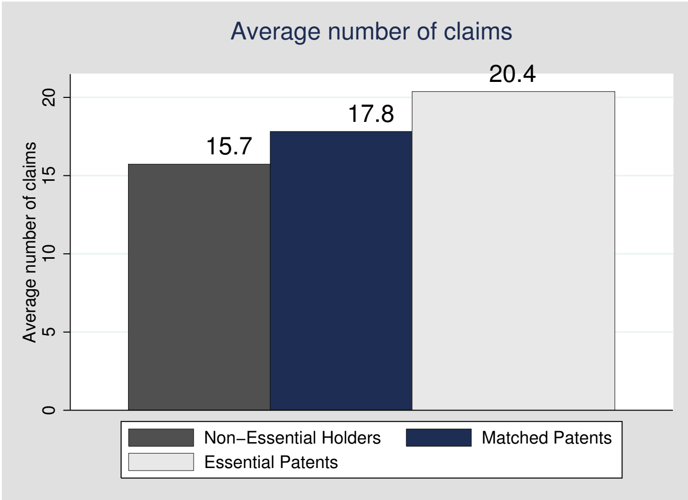

Figure 2.2. Average number of claims in treatment and control group

with the assumption that applicants draft the “essential” applications relatively broad in order to cover certain standard-relevant subject matter.[18]

After having analyzed the static view of claims and citations, in a next step we turn to the dynamics of the claims and analyze how often applicants change the set of claims, possibly in order to achieve a better fit with the expected standard. As Figure 2.3 clearly shows, the average number of amendments is higher in the treatment group (on average 1.5 amendments compared to 1.2); similarly the share of applications which are amended more than two times almost doubles in the group of essential patents. This supports our view that (multiple) amendments can be seen a strategic tool which is important for adapting the own patent application to an evolving standard.

A further strategic instrument to keep the examination process of patentable subject matter pending and at the same time increase the mere number of patents which could be relevant to a standard is the filing of divisional applications. Comparing the share of divisional applications among essential patents with the share among patents of firms not holding essentials in the same IPC subclass, we see a share of

[18] Another theoretical argument on citations measures can be assessed in this context: potentially essential patents are highly embedded in the standard-setting process and could be expected to make more references to technical documents outside the patent literature. These can be measured by the share of non-patent references in the search report. We detect, however, no significant differences in overall non-patent literature references or in references to non-patent literature that are considered as an X document. The most likely explanation is that the integration in scientific work outside the patent literature is technology-specific (and high in ICT compared with other IPC classes) and not explicitly related to standardization. We thus do not detect differences between our treatment and control group.

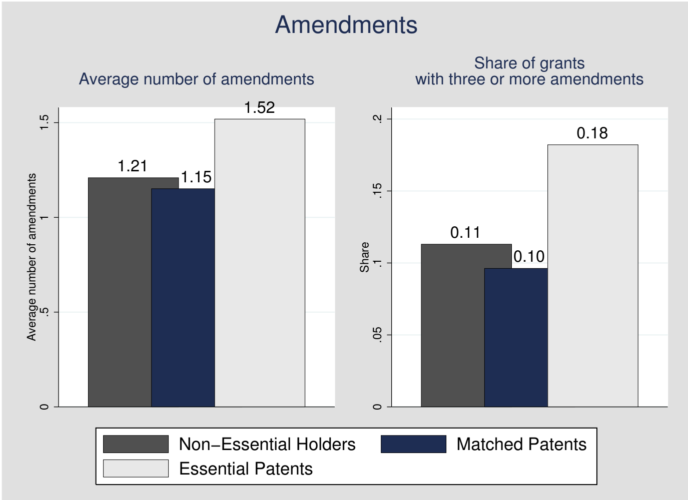

Figure 2.3. Average number of amendments / share of grants with three or more amendments in treatment and control group

divisionals which is around 1.7 times larger. Using our matched sample approach, the difference becomes statistically insignificant. Therefore, there is somewhat ambiguous evidence on the relationship of the rate of divisionals with the relevance to standard setting. Conversations with patent professionals, however, suggest that the filing of divisionals is indeed likely to be the outcome of strategic patenting behavior, even though we cannot statistically prove this notion here. As the relation to a standard makes an articulate patent strategy more important, it is reasonable to assume that our results reflect an intentional strategy, causing detrimental effects such as an increased workload for the patent offices and legal uncertainty among competitors and potential users of the future standard.[19]

We briefly discuss some characteristics of essential patents which are worth mentioning even though they are not in our primary focus. These are characteristics outside the scope of the applicant's own strategic behavior and thus rather depend on actions by other agents in the applicant's business context. However, as they underline the high commercial relevance of standards and the included IP, they are worth a short digression. An indicator of the fierce competition for standards-relevant patents can be seen in the incidence of opposition filings.[20] We thus compare the share of granted patents for which an opposition has been filed during the opposition period, exclud-

[19] Unfortunately, we cannot distinguish between mandatory and voluntary divisionals. Thus it is also possible that the high number of claims shown above translates into a higher probability of "non-unity" under Art 82 EPC and thus into a higher share of mandatory divisionals.

[20] An opposition can be filed by any third party within nine months of the publication of the grant of the European patent and one could expect a higher use of oppositions within patents of (potentially) high value, like essential patents in our case.

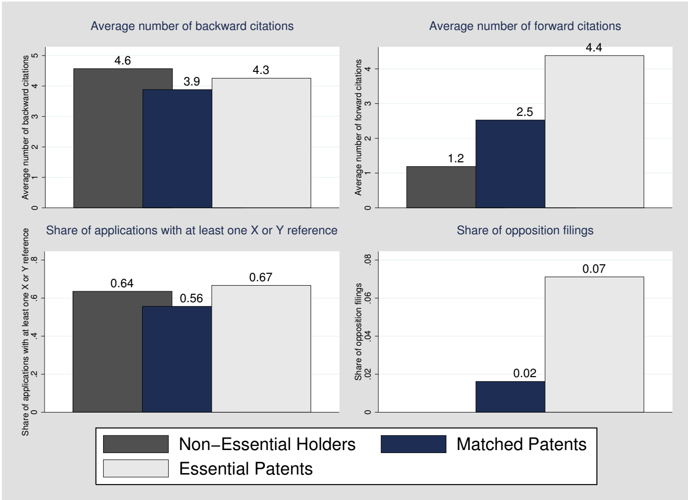

Figure 2.4. Average number of backward and forward citations, share of applications with at least one X or Y citation as well as opposition rates in treatment and control group
Note: Opposition information was not available for the non-essential holders

ing all cases in which this period has not expired. The paired t-test results for the remaining 230 essential and control patents[21] shows a highly significant difference with the opposition rate in the treatment and control group at around 7% and 1-2% respectively.[22] These results clearly reconfirm the importance of essential patents and show the competitiveness of the environment for patents in standards. Opposition incidence rates can also be interpreted as value indicators for patents and we analyze another value indicator: forward citations. We observe that essentials receive significantly more citations than both control groups. They are cited almost two times more often than the matched patents, on average 4.3 times (as of July 2005) and the difference is even more pronounced when compared with the patents of companies not having essentials. This observation also true for the citations received in the first three years after publication of the application (2.2 versus 1.2 forward citations).[23] Figure 2.4 gives a final overview of the forward and backward citations, the share of documents having at least one X or Y reference and of the opposition rates in the treatment and control group.

[21] Opposition information was collected manually. For practical considerations it was only searched for the treatment group and the matched patents, but not for the 69,195 patents of the non-essential holders.

[22] 13 opposed patents in the treatment group were maintained after the procedure, only one patent was revoked and 4 were amended.

[23] A comparable finding is reported by Rysman and Simcoe (2008) who look at the forward citations of US patents disclosed at four SSOs.

2.4.3 Multivariate Regression Results: Pendency Time

So far our hypotheses related to the number of claims, amendments and divisionals were confirmed by the univariate statistics presented above. We found higher values for all of these parameters among the essential patents. Next, we will turn to the effects of these observations. Since each amendment leads to additional work for the examining unit and each divisional application prolongs the decision from the legal filing date to the final decision, this is very likely to affect the pendency time of patents. This section examines the differences in pendency time among essential patents and the control group and determines the influencing factors by using multivariate methods.

We start with a nonparametric survival analysis and estimate the Kaplan-Meier survival function.[24] Figure 2.5 shows the survival functions for essential and non-essential patents. Results do not clearly reveal differences in pendency times as the survival curves are located close to each other. Additionally, a Wilcoxon (Breslow) test for equality of survivor functions suggests that there is no significant difference. A closer look at sample subsets shows interesting results. Within the group of files that are granted relatively fast (within 5 years), the pendency times for the essentials are longer. The result is significant on the 5% level ($\chi^2(1) = 4.64; Pr > \chi^2 = 0.0312$). However, among the files with longer pendency times, the essentials are on average finalized earlier than the control group (weakly significant: $\chi^2(1) = 2.29; Pr > \chi^2 = 0.1300$). We interpret this finding as a hint that there is a substantial benefit by delaying the patenting process only up to a certain point. It is rational for an applicant of standard-relevant patents to keep the application pending only in the early stages of a standard development. Once the standard gets closer to being finalized, it is important to have the patent granted as soon as possible in order have it accepted as an essential patent and to be able to claim licensing income based on the granted patent. The link between the standard development process and the pendency time will also be revisited in section 2.4.4

To further elaborate on the determining factors of pendency times, we estimate two different (semi-) parametric survival models to assess the influence of several factors that have been shown to be prevalent among the essential patents group (the number of amendments and claims as well as the share of divisionals) while at the same time controlling for other factors that have been shown to influence the pendency

[24]We exclude divisionals to rule out a bias in the calculated pendency times since the starting point for the pendency time of divisionals is the legal filing date of the parent application.

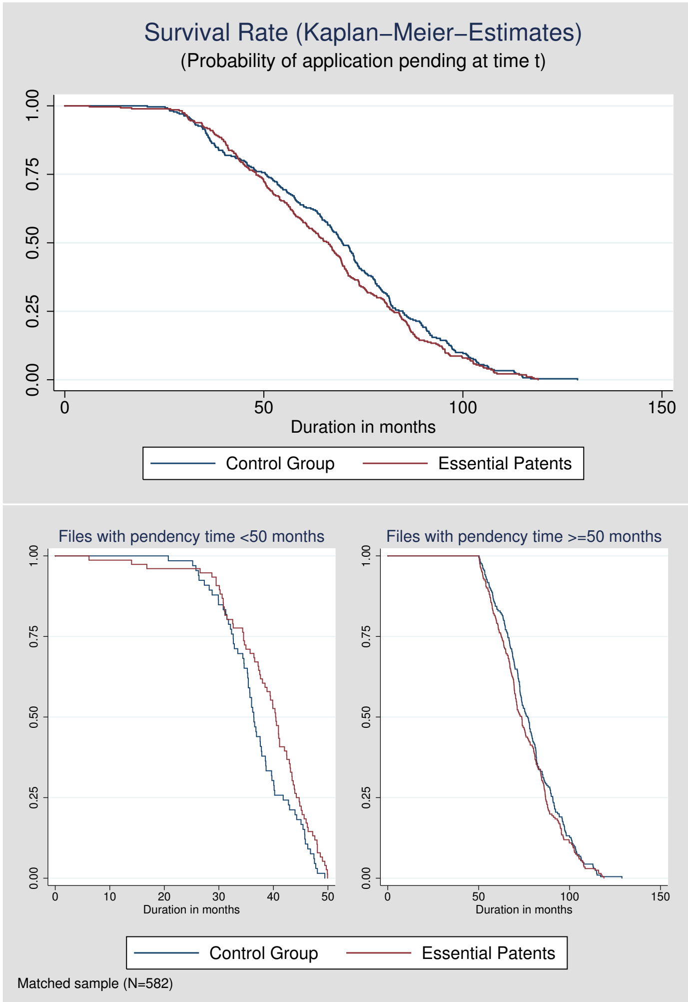

Figure 2.5. Kaplan-Meier survival functions of essential patents and matched control patents

time.[25] The influential factors to be measured can be clustered into three groups: i) the interactions with the EPO and the patenting behavior (number of amendments, filing of divisionals, using the PCT route instead of Euro-Direct applications, and filing high number of claims), ii) measures of technological complexity (number of references to patent literature as well as to non-patent literature and the share of X references), and iii) value measures (the number of citations received). In addition, time dummies for the filing year are included to control for the different levels of backlog at a given time. Table 2.1 lists the results of a Cox Proportional Hazard Model as well as an accelerated failure time model with log-logistic specification. All variables for which significant coefficients were obtained turn out to have a prolonging influence on pendency time. As both models yield consistent results, the following discussion will concentrate on the accelerated failure time model. Column (2) in table 2.1 reports exponentiated coefficients which can be interpreted as the factor by which the pendency time is multiplied as a result of increasing the corresponding variable by one unit. When an application is a divisional (and thus has the legal filing date of the parent application) and when the PCT route is chosen, the pendency time significantly increases by a factor of 1.39 and 1.06.[26] Furthermore, every amendment increases the pendency time by about 8%. Considering the relatively high share of patents with at least 3 amendments in the essential patents group, this can be seen as a serious deferral factor. With regard to the citation measures, one can see that complexity measured by the number of references and especially the share of X references increases the pendency time by 2.3% and 11.7% respectively. The patent value (measured as forward citations) does not have a significant coefficient. This contrasts the results of Harhoff and Wagner (2009) who find shorter pendency times for grants with higher value indicators. The reason for this difference is probably due to our focus on essential patents, which – as shown and argued above – differ considerably from the average grant in terms of both forward citations and in terms of the incentives to speed up or delay the grant process.

2.4.4 Robustness Checks

In the following section we present additional estimations in order to confirm the robustness of our estimations and to strengthen the link of the detected behavior with the participation in standardization. First we investigate the possibility that

[25] See Harhoff and Wagner (2009) or van Zeebroeck (2008)

[26] The latter variable is not significant on the 10% level, just missing this threshold having a t-value of 1.60.

	(1) Cox-PH Model	(2) AFT-Model
Number of Amendments	-0.247***	1.084***
	(0.0437)	(0.0141)
Divisional Patent	-0.951***	1.387***
	(0.201)	(0.0909)
PCT Route	-0.0742	1.063
	(0.109)	(0.0407)
Number of Claims	-0.000916	1.001
	(0.00358)	(0.00121)
Number of Patent Refs.	-0.0812***	1.023***
	(0.0249)	(0.00834)
Number of Non-Patent Refs.	-0.0436	0.997
	(0.0450)	(0.0156)
Share of X Refs.	-0.276*	1.117**
	(0.145)	(0.0545)
Number of Forward Citations	0.00663	0.998
	(0.00770)	(0.00245)
filed in 1999	0.490***	0.854***
	(0.113)	(0.0308)
filed in 2000	0.813***	0.743***
	(0.131)	(0.0323)
filed in 2001	1.064***	0.736***
	(0.158)	(0.0376)
Observations	582	582
Exits	582	582
Log Likelihood	-3054.3	-207.6
LR $\chi^2(11)$	147.1	136.0

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.1. Estimation results from Cox Proportional Hazards Model and Accelerated Failure Time model (with log-logistic specification)

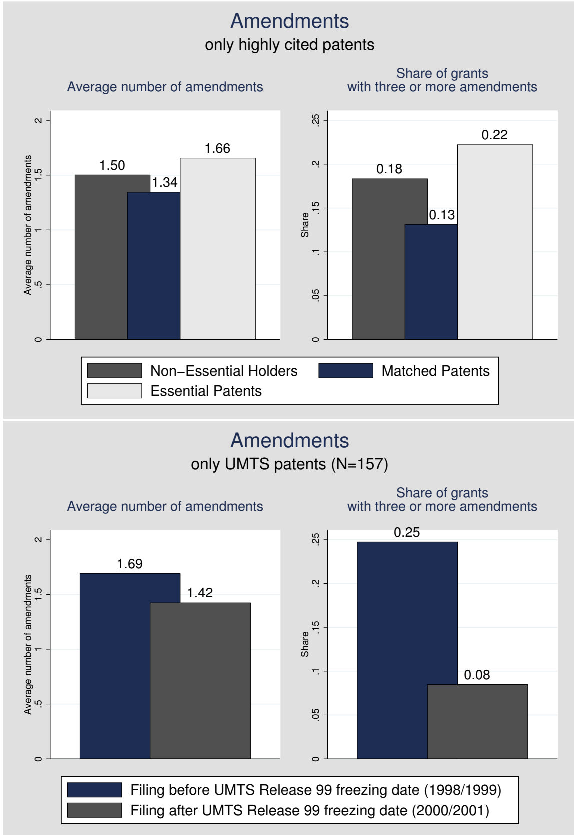

Figure 2.6. Comparison of the average number of amendments among highly cited patents only and UMTS patents (filed pre/post Release 99 "freezing date")

amendments are more common among more valuable (measured as highly cited) patents and are therefore not necessarily connected to their standard essentiality. We check this issue by restricting our sample to highly cited patents only. As a cutoff point, we choose the average number of forward citations in the matched treatment group, which is 4.38. The significant difference in amendments between the groups does not change: we obtain 1.8 amendments per application for the treatment group, only 1.3 amendments for the matched control group and an average of 1.5 for the non-essentials holders (see figure 2.6). The difference between treatment and two control groups is significant on a 5% level and 10% level respectively. We thus conclude that our observation is not an artifact caused by comparing more valuable patents with less valuable ones but that the difference in amendments is attributable to the context of strategic behavior related to standardization processes.

Next we examine the hypothesis that amendments are particularly important when there is high uncertainty about the emerging standard and that this uncertainty declines substantially once the standard has been approved. The information on how to draft the patent document is better after this "freezing point" and therefore a lower number of amendments for later filings can be expected. Due to data restrictions for the number of amendments in this study, we only examine applications from 1998 to 2001. We use the UMTS standard as an example to investigate the development of amendments for filings early in this period with later ones. An important milestone for the UMTS standard was the "Release 99", defining the core elements of the standard at the end of 1999 (see for example Bekkers and West (2009)). We therefore compare the number of amendments made to essential patents filed in 1998 and 1999 with the ones filed when the specifications for "Release 99" were fixed. We see that the share of patents amended at least three times is more than 20% in the "pre-freezing point" filings whereas it is only 8.5% of UMTS patents filed in 2000 or 2001. The actual number of amendments amounts to 1.7 in filings in 1999 and 2000 and 1.4 in the later group. Consistent with the argumentation that later patent applications do not have to be amended as much as earlier applications, we argue that the incentive to keep the application pending declines for later UMTS applications. Since all filings in our analysis have already been granted, we do not have to be concerned about right truncation and can start by comparing the mean pendency times between the early and late filings. As the backlog of applications at the European Patent Office has been growing during 1998 to 2001, one might expect that pendency times for later filings are longer. However, we see a pendency time of around 70 months for filings in 1998 and 1999 and only 57 months for filings in the following years. This is possibly the case because more deferral takes place when there is high uncertainty about the future standard compared to when the content of the standard is clear. This can also be seen by looking at the coefficients of the dummy variable "Application filed in 1998 or 1999" in table 2.2 which suggests that for this sample, applications filed in these years have a longer pendency time than the ones filed in the two following years.

2.5 Conclusions

In this paper we have empirically analyzed the incentive effects for patent applicants participating in standard-setting organizations to strategically shape the application process of potentially "essential patents". While every patent applicant will naturally try to achieve the broadest claims and the strongest protection, this motivation is magnified in the standard setting context. Several legal options allowing the applicant to influence and delay the application process seem to be used to a much higher extent for essential patents. First, essential patents contain significantly more claims,

	(1) Cox-PH Model	(2) AFT-Model
Application filed in 1998 or 1999	-0.651***	1.308***
(i.e. prior to Release 99 freezing date)	(0.194)	(0.0818)
Number of Amendments	-0.327***	1.125***
	(0.0790)	(0.0282)
Divisional Patent	-0.441	1.367**
	(0.402)	(0.178)
PCT Route	-0.249	1.180**
	(0.240)	(0.0947)
Number of Claims	0.00406	1.001
	(0.00621)	(0.00208)
Number of Patent Refs.	-0.0601	1.010
	(0.0499)	(0.0158)
Number of Non-Patent Refs.	0.0634	0.952
	(0.100)	(0.0322)
Share of X Refs.	-0.545*	1.174*
	(0.297)	(0.113)
Number of Forward Citations	0.0306	0.993
	(0.0213)	(0.00613)
Observations	156	156
Exits	156	156
Log Likelihood	-614.0	-53.39
LR $\chi^2(9)$	42.69	53.74

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.2. Estimation results for survival analysis of UMTS relevant applications with dummy variable indicating a filing date prior to Release 99 “freezing date”

potentially in an attempt to cover subject matter under standardization. Second, we showed that the claims of essentials are amended around 25% more often than patents not relevant for the standardization context. We interpret this as an attempt to adapt the filing to the standard's (expected) specifications. Third, the time until a final decision about the application is reached is significantly longer for essentials. A reason could be the need for applicants to keep the filings open until there is a higher certainty about the outcome of the standardization process. Furthermore, we have shown that the chronological concurrence between the development of the standard and the patenting process is not coincidental: If an application is filed in the early stages of the standardization process, the incentives to retard the grant are high since there is a high degree of uncertainty about the specifications of the future standard. These incentives change after the standard specifications are frozen and the willingness to close the application process is now given to a larger extent.

It is important to bear in mind that this exercise is not an end in itself, but ultimately about potential negative welfare effects caused by the generation of uncertainty in the market. This includes impacts on the level of research and development conducted in an economy, which has shown to be more sensitive to high levels of uncertainty than non-R&D investment (Goel and Ram 2001). Although there are only few empirical studies studying the effect of uncertainty on R&D spending (Minton and Schrand 1999, Goel and Ram 2001, Czarnitzki and Toole 2007), it is clear that a firm facing a competitor's patent application, which is pending artificially long, will have to take into account the risk of being eventually confronted with a valid blocking patent. It is probable that a deterrent effect is higher for smaller firms. Larger firms can accept higher uncertainty, because their portfolio is more diversified and a potential patent litigation suit does not necessarily compromise their entire business model and financial resources. But even for large multinationals IPR disputes mean immense risks, as frequent litigation and infringement cases between big players, especially in the telecommunication industry, show. Another issue is the competition effect: If applicants manage to include (too) many patents in the essential patents lists merely by the strategic patenting behavior revealed above, they obtain a disproportionate degree of market power. Barriers to entry are created and collusion among big industry players is a danger. Again, frequent antitrust cases connected with IPR in standards indicate that this problem is highly relevant. The most prominent case is the series of lawsuits and regulating authorities' investigations connected with the alleged "patent ambushing" of Rambus Inc. in JEDEC standard setting for DRAM memory storage technology.

Some aspects for improvement to mitigate the problems demonstrated by our analysis should be pointed out. The first is related to the interdependence of patenting and standardization processes. There is clearly a need for closer cooperation between patent offices and standard-setting organizations. Art. 115 of the European Patent Convention allows third parties to communicate documents relevant to the examination of a pending application. This rule could be exploited to improve information sharing between SSOs and patent offices: If examiners had better access to documents discussed in SSOs' working committees, it would be easier to identify "claims shifting" as the reason for an amendment.[27] This can deliver good arguments to the examiner to refuse questionable requests for amendments. The same goal can be reached by "early warning systems" for suspicious cases or by special training sessions for examiners. Both patent offices and standardization organizations could benefit from such coordination. One of the SSOs' main concerns is patent ambushing, i.e. companies not disclosing relevant patents until very late in the standardization process. If there was a way for patent offices to identify standards-relevant applications and if they indicated these applications to SSOs, this threat would be moderated substantially. A practical step would be a better integration of patent offices' and SSOs' databases (e.g. an automatic updating of SSO databases with information from patent offices).[28] Another solution could be the communication of "track changes" in the examination process by the patent offices to SSOs or other relevant authorities. Coordination efforts would also improve the situation of "weak" pending patents, i.e. applications declared essential, but – because of the claimed subject matter – with rather low chances of being granted. Again, if questionable applications could be indicated to SSOs, information asymmetries between IP holders and SSOs could be more leveled out.

With respect to the functioning of the patent system itself, an adaptation of patenting rules should be considered in order to limit the extent of this abuse of the patent system. A first step has been taken by the European Patent Office by limiting the possibilities to file divisional applications which largely contribute to longer pendency times and to uncertainty in the system. A restriction to the use of amendments seems to be adequate (at least in some cases) to reduce the room to maneuver within the application process and to reduce overly long times pendency times. The final objective should be an acceleration of the patenting process by preventing problematic applicant behavior and by improving the performance and efficiency of patent offices.

[27] Possibly even a participation of patent office representatives in SSO committees would be desirable.

[28] EPO efforts to "shine a light" on the patenting process in order to reduce uncertainty for applicants are based on the same idea.

This could reduce the uncertainty to a minimum and at the same time promote the innovation enhancing features of the patent system.

Bibliography

Arundel, A. and P. Patel (2003), Strategic Patenting - Background Report for the Trend Chart Policy Benchmarking Workshop, Technical report, New Trends in IPR Policy.

Bekkers, R., B. Verspagen, and J. Smits (2002), Intellectual property rights and standardization: the case of GSM, Telecommunications Policy, 26(3-4): 171–188.

Bekkers, R. and J. West (2009), The limits to IPR standardization policies as evidenced by strategic patenting in UMTS, Telecommunications Policy, 33(1-2): 80–97.

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

Chiao, B., J. Lerner, and J. Tirole (2007), The rules of standard-setting organizations: an empirical analysis, Rand Journal of Economics, 38(4): 905–930.

Cohen, W., A. Goto, A. Nagata, R. Nelson, and J. Walsh (2002), R&D spillovers, patents and the incentives to innovate in Japan and the United States, Research Policy, 31: 1349–1367.

Cohen, W., R. Nelson, and J. Walsh (2000), Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not), NBER Working Paper 7552.

Czarnitzki, D. and A. A. Toole (2007), Business R&D and the interplay of R&D subsidies and product market uncertainty, Review of Industrial Organization, 31(3): 169–181.

EPO (2009), Guidelines for Examination in the European Patent Office, European Patent Office, Munich.

Farrell, J. and G. Saloner (1988), Coordination through committees and markets, Rand Journal of Economics, 19(2): 235–252.

Goel, R. K. and R. Ram (2001), Irreversibility of R&D investment and the adverse effect of uncertainty: Evidence from the OECD countries, Economic Letters, 71(2): 287–291.

Goodman, D. J. and R. A. Myers (2005), 3G cellular standards and patents, 2005 International Conference On Wireless Networks, Communications And Mobile Computing, Vols 1 And 2, 415–420.

Guellec, D. and B. van Pottelsberghe de la Potterie (2007), The Economics of the European Patent System - IP Policy for Innovation and Competition, Oxford University Press.

Hall, B., A. Jaffe, and M. Trajtenberg (2005), Market value and patent citations, Rand Journal of Economics, 36(1): 16–38.

Hall, B. and R. Ziedonis (2001), The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995, Rand Journal of Economics, 32(1): 101–128.

Harhoff, D. and S. Wagner (2009), The Duration of Patent Examination at the European Patent Office, Management Science, 55(12): 1969–1984.

Henkel, J. and F. Jell (2009), Alternative Motives to File for Patents: Profiting from Pendency and Publication, Munich University of Technology - Faculty of Economics and Business Administration Working Paper Series, http://ssrn.com/abstract=1271242.

Lanjouw, J. and M. Schankerman (1999), The Quality of Ideas: Measuring Innovation with Multiple Indicators, NBER Working Paper 7345.

Lanjouw, J. O. and M. Schankerman (2004), Patent quality and research productivity: Measuring innovation with multiple indicators, Economic Journal, 114(495): 441–465.

Lerner, J. (1994), The Importance of Patent Scope: An Empirical Analysis, The RAND Journal of Economics, 25(2): 319–333.

Lerner, J. and J. Tirole (2006), A model of forum shopping, American Economic Review, 96(4): 1091–1113.

Minton, B. A. and C. Schrand (1999), The impact of cash flow volatility on discretionary investment and the costs of debt and equity financing, Journal of Financial Economics, 54(3): 423–460.

Rysman, M. and T. Simcoe (2008), Patents and the Performance of Voluntary Standard-Setting Organizations, Management Science, 54(11): 1920–1934.

van Zeebroeck, N. (2008), Long live patents: the increasing life expectancy of patent applications and its determinants., CEB Working Paper, 09/005.

van Zeebroeck, N., B. van Pottelsberghe de la Potterie, and D. Guellec (2009), Claiming more: the Increased Voluminosity of Patent Applications and its Determinants, Research Policy, 38(6): 1006–1020.

Webb, C., H. Dernis, D. Harhoff, and K. Hoisl (2005), Analysing European and International Patent Citations: A Set of EPO Patent Database Building Blocks, STI WORKING PAPER 2005/9 Statistical Analysis of Science, Technology and Industry.

WIPO (2009), World Intellectual Property Indicators 2009, World Intellectual Property Organization, Geneva.

Chapter 3

Patent Cross-Licensing, the Influence of IP Interdependency and the Moderating Effect of Firm Size

Abstract This paper analyzes technological interdependencies as the key factor for companies' motivation to engage in cross-licensing transactions. It provides evidence on how the incentive effects for mutual technology transfers vary by firm size and by the degree to which a firm has to rely on its competitors' intellectual property (IP dependency). Even though IP dependency exists also among smaller firms, cross-licensing has previously only been analyzed for large firms. This paper fills this gap in the empiric literature using original survey data among German manufacturing companies. Findings suggest that the influence of firm size and IP dependency on the use of cross-licensing can not be regarded separately. While the effect of IP dependency on the relevance of cross-licensing itself obviously has a clear positive effect this seems to be true to a higher extent for small firms and decrease for larger companies. A possible reason for the interaction effect between these two factors is that larger firms have better odds of achieving a technological workaround which can serve as an alternative to in- or cross-licensing. Furthermore, small high tech firms might need to explicitly use cross-licensing to secure the freedom to operate while a large firm's patent portfolio itself can serve as an implicit insurance by posing a threat which prevents other technology holders to file patent infringement cases.

3.1 Introduction

The boom in patent applications worldwide over the last two decades is a well documented and extensively analyzed fact among management scholars and industrial economists. The number of triadic patent families, for example, has more than doubled since the mid-1980s with a strong increase of 5.8% per year in the mid-90s and a slightly lower pace since the beginning of the millenium (see for example OECD (2008)). The increase is even more pronounced when looking at the number of PCT applications, which in 2008 was approximately 163,600, up from around 100,000 in 2000 (WIPO 2009). The reasons for this surge are manifold: an increase in inventive efforts, research and development (R&D) efficiency and the speed of technological change (Kortum and Lerner 1999), policy changes and court decisions in favor of patent holders (e.g. Hall 2007), an expansion of patents to new fields of technology (Kortum and Lerner 1999), and changes in patenting strategies. These strategies include, among others, a more prominent use of patents as a means to block competitors, to boost the own technological image, to influence standard-setting processes, and to build up patent portfolios in order to improve the firm's position in licensing negotiations. This last point of patent licensing, which has become increasingly important in recent years, will be analyzed in this paper.

In specific I will focus on the exchange of patent rights via cross-licensing. This type of technology transfer is mainly relevant in "complex" industries, i.e. sectors characterized by products consisting of large numbers of separately patentable elements and a high fragmentation of relevant intellectual property rights. The need to have access to competitors' intellectual property rights (IP dependency) is high in these industries and firms thus tend to regard cross-licensing as an important instrument. Cross-licensing strategies can be operationalized in a number of different ways: broad exchanges of entire patent portfolios (the norm in the microprocessor industry (Shapiro 2001)) or agreements on a few patents only, agreements on already granted patents or on all future grants within a fixed term, geographical restrictions, side payments from both parties etc. In this analysis I will employ a broad definition: every transaction implying a swap of technical industrial property rights which is not carried out for the primary purpose of generating licensing revenues falls within this definition of cross-licensing.[1]

[1] As technology exchange among smaller firms will certainly differ from the trade of whole patent portfolios practiced in larger firms (Grindley and Teece 1997), the understanding of cross-licensing in this paper thus contains both bargaining whole portfolios as well as individual (or bundles of a limited number of) patent rights, with the latter being a more likely way to handle cross-licensing in small or medium-sized firms.

With respect to the question of which firms are actually involved, empirical studies in the field of cross-licensing exhibit a strong focus on analyzing large firms' behavior. The main reason seems to be that cross-licensing is widely known to be an important issue in large multinationals (Grindley and Teece 1997). Obviously, the practical relevance of cross-licensing rises with the availability of (mainly human) resources in order to realize such complex transactions. This ability depends on previous experience with (out-) licensing as well as the capacities to have IP-licensing experts work on the subject. The former surely exists in large corporations but can also be existent in smaller firms as they often use (out-)licensing as a means to exploit their technology beyond their own limited production facilities. Furthermore, with a growing number of patents and an increasing fragmentation of the IP landscape, research-intensive small and medium enterprises (SMEs) are forced to deal with this issue.

In this paper I argue that there is an interaction effect between size and IPR dependency: If IPR dependency is high, any firm will pose a higher importance to cross-licensing compared to firms of the same size with a low degree of IPR dependency. With increasing firm size, this could be less the case, because capacities for an alternative technological strategy – a workaround, i.e. a technological solution not infringing the blocking patent – become available. Additionally, the chances to actually achieve the workaround rise due to larger numbers of researchers working on a topic and possible economics of scale and scope. It is clear that it becomes increasingly difficult to work around a given technology as the technological development enters later stages. In advanced stages there might exist a technically feasible workaround, but it could be *de facto* excluded due to prohibitive sunk costs or to the unwillingness to leave the once chosen technological path. A further argument for a different effect of IPR dependency is that an explicit cross-licensing agreement (compared to an implicit litigation standstill agreement) can be more important for smaller firms. Among large corporations in complex industries the high interwovenness itself serves the same purpose as the explicit exchange of patents. If every agent in the marketplace is aware of mutual patent infringement, everyone is barred from taking legal action and the purpose of a cross-licensing agreement is implicitly reached. This, however, is more applicable for large corporations whereas smaller firms might not be willing to take the legal risk and would therefore explicitly engage in cross-licensing.

The main contribution of this analysis is an extension of the analysis of factors on firms and industry level that have been identified in the literature as important for cross-licensing to a sample of firms of all size categories. A focus will be on the interrelationship between firm size and IPR dependency. The employed data contains a broad range of industries in manufacturing and therefore avoids the limitations of the majority of previous research on cross-licensing which focuses on specific (complex) industries or size classes only (Grindley and Teece 1997, Hall and Ziedonis 2001, Anand and Khanna 2000, Nagaoka and Kwon 2006).

In the following section, I will elaborate in more detail on the theoretical reasoning why cross-licensing can be of relevance for small firms and give a short overview on the existent literature. In section 3.3, I derive the hypotheses and section 3.4 presents the data, methods and results of the empirical work. The findings are discussed in detail in section 3.5, before the work is rounded off by concluding remarks concerning implications and limitations of the study.

3.2 Background and Relevant Literature

In order to keep up with the technological development, firms increasingly stop limiting themselves to only using technology developed in-house, but open up to sources from outside their own research lab (open innovation (Chesbrough 2003b)). Firms, however, do not only consider licensing in technology from other companies, but are increasingly open to exploit their own IP externally (Chesbrough 2003a). One possible goal is the generation of revenue through patent royalties. As IP management has stepped out from under the shadow of physical or financial asset management, the importance of firms exploiting (unused) patents through out-licensing has been described as selling the so far undiscovered precious "Rembrandts in the Attic" (Rivette and Kline 2000).

Even if one does not thoroughly share the enthusiasm triggered by prominent examples like IBM's licensing revenues for unused patents of over $ 1 billion in 1999 (Rivette and Kline 2000), the need to trade patent rights not for money, but for other patents has become a major issue in certain industries. These industries can be characterized as "complex" industries. Following the definition of Cohen et al. (2000) and other authors, a new commercializable product or process in complex industries is characterized by numerous separately patentable elements. In "discrete" industries, on the other hand, a one-to-one relationship between product and patent exists – or at least the product is comprised of relatively few separately patentable parts. The likelihood for a single company to possess all relevant patent rights is much lower in a complex industry than in a discrete.[2]

Evidence indeed shows that cross-licensing is of high importance for specific industries and firms (see for example Grindley and Teece (1997)). These firms do not necessarily need to be the large multinationals. A recent OECD survey on the amount of and the motivation for licensing (Guellec and Zuniga 2008) asked managers of Japanese and European firms split into size classes "more than 250" / "less than 250 employees" to report the share of licensing transactions in 2003 to 2006 that was done for cross-licensing reasons. The results suggest that in Japan cross-licensing is relevant to a similar extent for firms in both size classes, the actual figures amounted to 19% and 16% respectively. For European firms the authors found larger differences (28% and 12% respectively) between firm sizes. A further analysis of mutual technology exchange among smaller firms seems therefore useful for a deeper understanding of cross-licensing incentives.

The fact that some SMEs dispose of substantial experience with respect to licensing transactions, primarily in out-licensing technology, increases the practical feasibility of cross-licensing for them. Out-licensing can be important for small firms to exploit technology for the efficient use of which they lack complementary or down-stream assets such as production facilities or marketing capacity (see for example Arora and Ceccagnoli (2006) or Gambardella et al. (2007)). Additionally, SMEs face a better trade-off between the profit dissipation and revenue effect discussed in Arora and Fosfuri (2002) and accordingly have higher incentives for out-licensing than larger players in the market. Thus they are much more likely to license out patents than large firms (Gambardella et al. 2007, Fosfuri 2006) and therefore have a potential ability for managing cross-licensing as well. Indeed, some authors have found that previous experience in licensing matters is one crucial point in explaining the observation of licensing activity (Kim 2004, Kim and Vonortas 2006). Smaller firms might then use their experience and know-how gained in out-licensing for engaging also in cross-licensing.

To illustrate the potential relevance of cross-licensing for smaller firms, two short examples can be brought up here: In August 1998, QuickLogic, a California based, semiconductor company with around 130 employees and sales of $ 31.9 million in

[2] As a consequence, the strategic incentives for patenting differ between industries. Cohen et al. (2000) find that the exchange motive plays a more pronounced role in complex industries. Other authors like Blind et al. (2006) object that the differences between these two groups of industries increasingly blur and do not find strong support for differing importance of the exchange motive among German companies.

2008, agreed with Actel (584 employees and \$ 218.4 million revenue in 2008) to mutually grant each other a "nonexclusive, royalty-free, worldwide license" to use all patents that the two parties "now own or may hereafter during the term of this Agreement own". A second example is an agreement between the two US automotive and transport equipment manufacturers Amerigon Incorporated and BSST with 70 and 21 employees respectively. They agree that each firm become the licensee "of certain U.S. applications for patents which disclose technology developed by [the other firm]" and are therefore able to use the technology of both firms.[3] These examples illustrate that licensing can indeed be of importance for relatively small companies.

One reason for the scarcity especially of empirical research on smaller firms' cross-licensing behavior, despite the relevance just outlined, is data availability: Company databases often do not dispose of detailed information on smaller firms, because disclosure requirements are less rigid for them. Sources of information used by researchers about licensing deals in the US are the annual reports (10-k's) filed with the Security and Exchange Commission. As this is only required for publicly traded firms, smaller firms are often omitted from analysis. For Germany, where the companies analyzed in this paper come from, publication requirements of data connected to licensing transactions are even less strict, limiting the basis for empirical research. One of the few studies on cross-licensing was carried out by Grindley and Teece (1997) who present case study evidence from large U.S. companies in the semiconductor and electronics industry and discuss how those companies deal with increasing dependence on other companies' patents by cross-licensing whole portfolios of current and future patents rights. Shapiro (2001) includes the use of patent pools and discusses the importance of licensing in the context of standard setting and patent thickets. Hall and Ziedonis (2001) conducted interviews and analyzed the patent behavior of 95 semiconductor firms. They show evidence of patent portfolio races of firms in order to secure bargaining power in (cross-)licensing transactions. Further research focusing explicitly on cross-licensing was done by Nagaoka and Kwon (2006) for Japanese firms. They present a stochastic model suggesting that a higher symmetry between firms tends to raise the probability of cross-licensing. They subsequently analyze data at contract and industry level and show that licensing is more probable among larger firms and for patent licensing compared to know-how licensing. A last widely cited study by Anand and Khanna (2000) provides large-scale econometric

[3]Information on the mentioned cross-licensing agreements comes from the website www.techagreements.com, a database of reference agreements of various kinds (last accessed in February 2009).

evidence on contract characteristics including the frequency of cross-licensing. The largest incidence of licensing in general is reported in the chemical industry, cross-licensing shows to be prevalent in computer and electronics. They also show that a significant fraction of cross-licensing is the result of litigation settlements.

The following section will present the hypotheses concerning firm size and technological interdependence on the importance of cross-licensing as well as the interaction effects of these two aspects. In the next step, additional influencing factors on the propensity to cross-license are discussed, before an empiric test will be carried out in the subsequent section.

3.3 Hypotheses

In general, larger technology-oriented firms *ceteris paribus* dispose of a broader technological portfolio than smaller, possibly more specialized firms. This rather obvious fact leads to a first argument in support of the proposition that larger firms have to rely more often on an exchange of patent rights. Due to capacity reasons, the number of R&D projects in the pipeline at large companies is higher than in SMEs. This leads to a higher probability that at least for one of the projects IP needed to proceed with the research or to market the results is already held by other companies. As a consequence, (in-) licensing is a phenomenon observed more commonly among larger companies. At the same time, a larger patent portfolio increases the probability that technology, which is important for the entire industry, is held by the company itself. This would make the firm more relevant as a “technology supplier” for competitors. Therefore not only in-licensing becomes more important, but also the mutual technology exchange: cross-licensing. Using contract level data, Nagaoka and Kwon (2006) show empirically that cross-licensing is indeed more prevalent among large firms as licensor and licensee.

In favor of the positive relationship firm size/cross-licensing is furthermore the notion that the administrative costs of arranging complex IPR exchange mechanisms can only be borne when there are enough resources available. This refers to both the existence of an IPR department and a sufficient number of IPR managers as well as the relevant competences of the staff. In many smaller firms, the responsibility for IPR issues lies with only one person. This person is in many cases also the General Manager of the company, which means that the allocation of time to IPR issues is small. This fact complicates the practical relevance of cross-licensing to a certain extent and limits its implementation in SMEs. Of course they have the possibility to resort to external IP specialists for support in their licensing efforts. This way their organizational or competence constraints could be overcome. However, outsourcing of such complex transactions bears considerable, possibly prohibitive, transaction costs (Reitzig and Puranam 2009). Furthermore, (smaller) companies are often found to be very reluctant to grant external parties access to their technological "crown jewels" and to create new entrants – potential competitors – on a specific product market (Arora et al. 2001).

One other point should be mentioned here: Nagaoka and Kwon (2006) show that the incidence of cross-licensing is higher when codified knowledge, such as a patent, is involved compared with the transfer of know-how only. It is well known that the propensity to use the patent system increases with firm size (e.g. Hall and Ziedonis 2001, Arundel 2001, Kingston 2000, Lanjouw and Schankerman 2004). The reason is to be found in the costs involved with patenting technology, which are characterized by sunk costs as well as decreasing marginal costs. As a consequence, large firms are more involved in the patent system and thus meet a critical prerequisite of licensing to a higher extent. The arguments above add up to the derivation of

Hypothesis 1: The importance of cross-licensing rises with company size.

It is clear that companies would not engage in cross-licensing transactions if they did not need to do so because of problems with their "freedom to operate", i.e. the barriers built up by competitors' property rights which the firm's own new product potentially infringes.[4] This problem of the individual firm's innovative effort being restricted by a high number of competing patents is specifically observed in certain industries such as semiconductors or telecommunication (Shapiro 2001). There are several explanations for this problem: One addresses the nature of the technology in the industry and whether one technology heavily relies on previous R&D results. This concept is referred to in the literature as "sequential" or "cumulative" innovations (Hall and Ziedonis 2001, Bessen and Maskin 2008, Green and Scotchmer 1995). These authors bring up the argument that in industries like software, computers and semiconductors innovation strongly builds on the imitation of previous technology. Product or process innovations are merely (minor or major) improvements of this

[4]If cross-licensing was entirely voluntary one would expect a higher overall licensing activity in companies which regard cross-licensing as important for them. Drawing on the survey data used below one cannot observe a strong connection between the share of patents within the company patent portfolio which are actually licensed with the importance of cross-licensing. This confirms that cross-licensing is important for specific IP only, i.e. only patents which have blocking features and does not increase the propensity to license *per se*.

existing technology.[5] In such a setting, intellectual property rights like patents can inhibit the innovative activity of firms. As a result they are forced to share patents via institutions like patent pools or cross-licensing agreements.

A connected, but slightly different concept is the technological complexity of an industry (Cohen et al. 2002). As mentioned before, an industry is a "complex" one, if a high number of different patents, potentially held by different companies, is needed to commercialize a given product. This fact, again, leads to a necessity of an interchange of patent rights. The issues of "sequentiality" and "complexity'" are quite similar and they both lead to the proposition that firms which have to rely more heavily on competitors' IP (possibly because they operate in certain industries namely electrical engineering, computers, semiconductors) will pose a higher importance on cross-licensing. In other words:

> *Hypothesis 2: The importance of cross-licensing rises with the dependency of other IP holders.*

The two hypotheses stated above are quite straightforward. In the following I argue that firm size and IPR dependency must not be considered independently from each other. On the contrary, I hypothesize that the influence of IP dependency on the propensity to cross-license changes with firm size. My reasoning draws on three factors that influence the likelihood of a company engaging in cross-licensing when its dependency on competitors' IP is high: previous experience in licensing issues, the feasibility of an alternative "workaround strategy" and strategic considerations of relative market (or rather bargaining) power.

On average, small firms show a much higher propensity to license out than larger firms (Arora et al. 2001), they therefore tend to have previous experience and licensing-specific know-how. If they are in a situation with a high technological interrelationship and functioning markets for technology, they are therefore potentially able to manage cross-licensing transactions as well as large companies with an own IP department (and/or even licensing department). However, concerning the trade off between licensing and working around a blocking patent, the odds of managing a

[5] "Incremental" innovation is similar, but not identical to "sequential" innovation: An incremental innovation is *per definitionem* a minor improvement over the existing technology as opposed to a radical innovation which clearly breaks away from the current state of the art. Sequential innovation only implies that the new concept builds on existing know-how, but does not refer to the inventive step *per se*, which can be both small or high. An example for an innovation which is both radical and sequential is the step in the operating systems from DOS to Windows: the innovation of a graphical user interface instead of a command line is clearly both radical and sequential (as Windows builds on DOS).

workaround (i.e. finding a technological solution circumventing a blocking patent) are considerably better for large companies and their technological portfolio might even contain possible technologies to be used instead of the one held by the competitor.[6] The trade-off licensing versus working around might therefore shift towards the latter strategy. This effect would moderate the influence of IP dependency downwards as firm size increases.

The third argument relates to legal aspects of technological interdependency. It goes without saying that infringement cases play a crucial role in IP issues and cross-licensing is connected to that. Accordingly, both the importance of cross-licensing for a company and the importance of in-licensing to avoid litigation cases are highly correlated in the survey data used below. However, for a large company, an alternative to cross-licensing can just be deliberately accepting the risk of potentially infringing a competitor's patent. If this option is chosen, two scenarios are possible as a result: First, the competitor does not realize the potential patent infringement (e.g. due to a dense patent thicket) and the infringer gets away with it. In the second scenario the patent infraction is detected.[7] Possibly a long litigation process will start now, but the patent holder might also refrain from prosecuting the infringer. There might be several reasons for this behavior: First, the patent holder will try to avoid the tremendous legal fees and the high degree of uncertainty associated with a patent infringement suit. His decision on risking a suit will be based on the prospects of winning it, but are also influenced by the rival's size because a large corporation has more possibilities to dedicate judicial manpower and financial means to the case than an SME. A large company's reaction to being accused of infringing a competitor's patent will in many cases result in a judicial counterstrike. As complex industries exhibit a high degree of overlapping technologies there are many products within the plaintiff's product portfolio which might potentially be infringing one of the defendant's patent. Therefore the company might decide to refrain from any legal action against the infringer to avoid an accusation against itself. This argumentation applies more to the situation of large companies than to SMEs, because small firms cannot bear a comparable risk of being taken to court and furthermore cannot credibly threat with a countercharge. They will thus try to avoid this risk beforehand

[6]This is true even though with high levels of IP interdependency a firm will not be able and willing to work around every time it is faced with a blocking patent. This is after all why broad cross-licensing deals are agreed on in the first place.

[7]This scenario is maybe more probable: firms are increasingly monitoring the market for infringement cases since they are both more alerted by illegal copying activities especially in countries and additionally exploiting the value of their IP portfolios more aggressively (Rivette and Kline 2000).

and one way to do so is licensing relevant patents. All in all, the argumentation adds up to

> *Hypothesis 3: IP dependency raises the importance of cross-licensing to a larger extent in smaller firms than in larger ones.*

There are other factors which can potentially influence the importance of licensing in general and cross-licensing in particular. Even though they are not in the focus of this analysis, I shortly discuss some of them since they will also be considered in the design of the econometric models in section 3.4.

A major influencing factor of companies' licensing decisions is competition both in the product and the technology market (Arora et al. 2001). With higher competition among companies on the market for technologies, more companies are involved in the patent race. This raises the likelihood of the relevant patents being distributed among a number of different firms. This, in turn, can have a positive influence on the importance of exchanging patents via cross-licensing.

A further point refers to the organization of R&D. Companies do only part of their research in-house. There are a number of ways firms collaborate: joint ventures, contract R&D, research collaborations with specialized R&D providers or universities, spin-outs etc. If cooperation focuses on research and development, all partners want to reap the fruit of this labor. This situation can result in agreeing to grant all partners the rights to use the developed technology – and potentially to use related patents as well. Additionally, an involvement in cooperations might serve as an indicator of the firm's general openness. We therefore expect that firms which cooperate more frequently, also show a higher predisposition to engage in cross-licensing activities.

A further possible influence is the legal status of a firm, i.e. whether it is an independent entity or part of a (national or international) group of firms. Statistics like the Technological Balance of Payments indicate that a significant portion of licensing takes place between members of a group of firms. One of the primary reasons seems to be dislocating profits in order to optimize the tax burden. Patents are held by one single entity within the group, which licenses out the relevant rights to the firms. In cross-licensing agreements, however, there is normally no payment involved, therefore optimizing the tax burden is not relevant here. Still it could be argued that the members of a group – similar to the R&D cooperation argument – mutually give each other access to their relevant IP and realize this via cross-licensing. On the other hand, one can argue that R&D activities within groups are organized in such a way that the need for cross-licensing does not come up in the first place. Instead, research tasks with high inter-dependency would be concentrated within one specialized firm (Nagaoka and Kwon 2006, von Hippel 1990). In this case no influence on cross-licensing activities would be expected.

One last potentially influential factor is the R&D intensity of a firm or industry, usually defined as the ratio of yearly R&D expenses and sales of a company. Again, two competing views regarding the influence on the importance of cross-licensing are possible. First, R&D intensive firms might be involved to a larger extent in cutting edge research and thus come up with more radical innovations. They are therefore less dependent on existing, already patented technologies than less R&D intensive firms which generate a smaller number and/or rather incremental innovations. The alternative view is connected with the argumentation regarding firm size. More R&D intensive firms have a stronger involvement in a higher number of technological fields and thus possibly need to rely more on other companies' technology. Referring to Cohen and Levinthal (1989) this would constitute one of the "faces of R&D": the generation of new information through R&D. The second "face" would address the fact that R&D intensive firms have a much higher capability to exploit information (e.g. patented technology) from outside. As a consequence, the absorptive capacity of a firm rises and companies are more apt to cope with the technology they can access via cross-licensing.

3.4 Survey Results

3.4.1 Data and Descriptive Statistics

The data for the subsequent analysis was collected as a survey among German manufacturing firms. About 2700 firms were asked to fill out a paper-and-pencil questionnaire, with the additional possibility to access the same set of questions online. A pretest was conducted before the actual field work in order to clear out possible difficulties. The sample is deliberately focused on patent-active firms, which is especially suitable for this study as it concentrates on the licensing of patents. German firms which have applied for more than 10 patents in 2002-2004 were identified, considered were applications at the German Patent Office (DPMA), the European Patent Office (EPO) and via the PCT. In addition, a randomly drawn sample of companies which have been identified as being R&D-active through the Hoppenstedt

Industry	Size Class up to 249 employees	250 to 999 employees	1000 or more employees	Total
Chemicals and Pharma	4	5	10	19
Plastics	5	4	3	12
Mechanical Engineering	15	26	32	73
Metal Processing	10	6	13	29
Electrical Engineering	28	10	22	60
Consumer Goods	2	8	7	17
Other manufacturing	3	2	4	9
Total	67	61	91	219

Table 3.1. Sector and size distribution of the sample (absolute number of observations)

company database was contacted. The same database was used to identify a relevant contact person, which was defined as the head of R&D, the head of the IPR/law department or – especially for the smaller companies – the firms' General Manager. Despite the direct addressing and two reminder letters, a response rate of only 10% was obtained. A number of firms were contacted by phone to get further information about the reasons for non-participation. Results suggested that in some firms there is an increasing reluctance of participating in voluntary surveys irrespective of the concrete subject. The information collected by phone also suggested that a non-response bias (e.g. towards more patent-active or licensing-active firms) seems not to be a major problem. Table 3.1 gives an overview of the size and industry distribution of the final sample. Due to non response and deliberately restricting the sample to manufacturing firms there are 219 companies available for the multivariate analysis further down.

The questionnaire addressed several IPR issues ranging from the use of instruments for intellectual property protection to licensing aspects and problems with IPR infringement. For this paper, the involvement in licensing activities and especially the assessment of different licensing motives will be the main focus. The importance of a number of motives was assessed on a five point ordinal scale ranging from one ("low importance") to five ("high importance"). Only the lowest and the highest value were anchored with verbal labels. If the response levels are assumed to be equidistant, the scale can be interpreted as interval scale and average values can be interpreted. Figure 3.1 shows the mean values attributed to some of the motives, in order of overall importance.

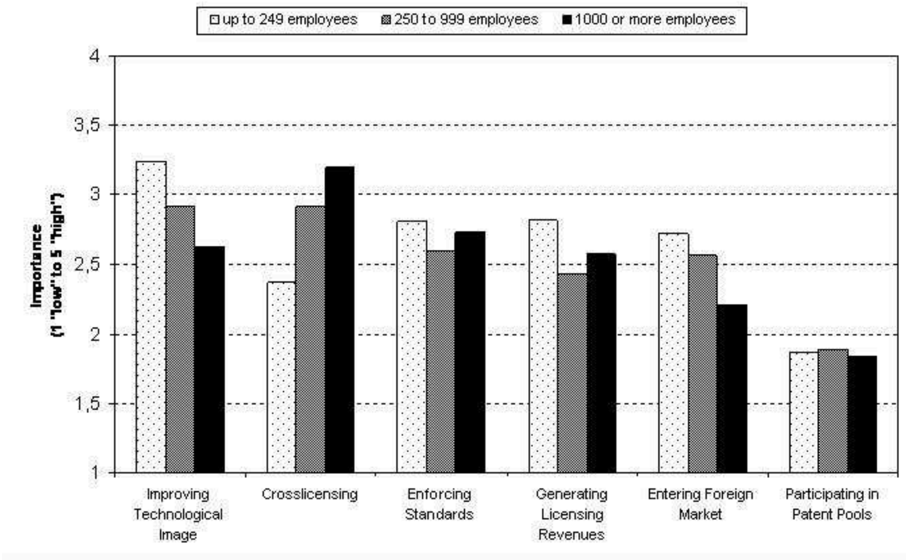

Figure 3.1. Importance of different licensing motives (mean values by firm size)

3.4.2 Variable Construction and Econometric Model

The dependent variable in the model is the individual firm's assessment of the importance of cross-licensing. As said above, the item was measured on a five point ordinal scale. The most appropriate approach in this case is an ordinal regression. Here a General Ordered Logit Model is applied to avoid the parallel regression assumption (Greene and Hensher 2008, Long and Freese 2001). Due to data restrictions there are no sufficient numbers of observations for some categories of the dependent variable. I therefore recoded it into an aggregated variable with three levels, indicating low, medium or high importance of cross-licensing.

The independent variables are defined as follows: Firm size is measured by the number of employees of a firm. As figure 3.1 shows, the importance of cross-licensing seems to rise with company size, but we can not assume a completely linear relationship. The difference in the assessment between the small and medium firms seems to be more pronounced than between medium and large firms. I therefore use a log-transformed version of the original employment variable. I interpret this variable as a proxy for a larger technological portfolio that raises the likelihood of having at least one R&D project that has to rely on other companies' IP. I expect – as described above – a positive sign of the coefficient. However, the higher values for cross-licensing among larger firms might in fact not be due to the firms' size, but a rather to a higher interdependency on competitors' IP. Figure 3.1 might therefore be delusive and the interaction effect discussed below has to be taken into account. For measuring dependence of other companies' technologies, the self assessment of firms is used. The questionnaire included an item referring to the importance of competitors' technologies for the firm, measured on a five point scale from one ("low importance") to five ("high importance"). The technological interdependence caused by differences between industries is caught by introducing industry dummies for Chemicals/Pharma, Plastics, Mechanical Engineering, Metal Processing, Electrical Engineering, Consumer Goods, and "Other manufacturers", which mainly covers production of construction as well as packaging materials. For the estimations, Electrical Engineering will be the base category. As previous research suggests that cross-licensing has a particular importance here, the coefficients of the other industry dummies are expected to have a negative sign. For reasons shown below, a greater aggregation into "complex industries" and "discrete industries" is needed. Following a widely accepted distinction (see for example Cohen et al. 2000, Kusunoki et al. 1998, Hall 2005) the former include Mechanical Engineering and Electrical Engineering. Whether a firm belongs to a complex industry is indicated by a dummy variable, which is expected to have a positive coefficient.[8]

The argumentation above regarding the interaction between firm size and IPR dependency will be addressed with a multiplicative interaction term of firm size and IPR dependency. As argued above, I test whether small firms with high technological dependence tend to regard cross-licensing as more important than medium-sized and large firms and I therefore expect a negative sign for the interaction term.

The remaining variables (Competition Intensity, Cooperation Intensity, Group Affiliation and R&D Intensity) are defined as follows. For the first one, competition intensity, firms' self assessment on a five point scale is used. I assume that competition in the product market correlates positively with competition in the technology market. This is reasonable since the firms in the sample are all involved in research and development and ultimately compete for patents in their specific technological environment. Therefore a positive sign of the coefficient is expected. Firms were asked whether they are engaged in R&D cooperations of several kinds: with suppliers, customers, or competitors in the same industry, private R&D service providers, or public research institutes. The reasoning above, where cross-licensing was regarded as a means to let all partners in the cooperation benefit from the research results,

[8] As I control for industry differences (by industry dummies or the variable complexity), the variable "IP Dependency" should capture primarily firm specific effects rather than industry effects. The correlation between the variables "IP dependency" and "Complex Industry" was checked to avoid multicollinearity problems. Several measures (e.g. variance inflation indices) suggest that multicollinearity is not a major concern here.

Variable	Mean	Std. Dev.	Min.	Max.
Firm Size (ln(Employees))	6.393	2.104	1.386	11.622
Competition Intensity	4.288	0.781	2	5
Cooperation Intensity	0.493	0.501	0	1
IPR Dependency	2.845	1.29	1	5
Group Affiliation	0.584	0.494	0	1
R&D Intensity	0.11	0.146	0	0.833

Table 3.2. Descriptive statistics of the explanatory variables (N=219)

holds only true for vertical cooperation with suppliers or customers and horizontal cooperations (with competitors in the industry). In the other two forms (cooperation with R&D service providers and public research institutes) the firm takes more the role of an ordering party which assigns certain R&D tasks to the contractor. Cross-licensing agreements are rather unlikely to originate from these forms of cooperation. Cooperation intensity is thus defined as a dummy variable with 1 indicating a "frequent" or "very frequent" cooperation in any of the other three alternatives. With regard to the legal status of the firm the variable group takes the value 1 if a firm is affiliated to a national or international group. This information was obtained from the firms via the questionnaire. It is included to control for potential organizational capacities arising from a small firm being part of a larger group of companies. The last variable in the model is R&D intensity. Firms were asked both for their sales figures and R&D expenditure. Both statements were apparently (and as expected) regarded as sensitive data, with corresponding high non-response rates of 30 to 40%. I therefore proxy the R&D intensity with the ratio of employees in R&D divided by the overall number of employees. Both figures were asked in the questionnaire. Again, the discussion above yielded arguments for both a possible negative as well as a positive impact on the importance of cross-licensing.

Table 3.2 gives an overview of all variables for the model and corresponding descriptives.

3.4.3 Regression Results

The results of the ordered logit model are presented in table 3.3. Four specifications are reported. In the first two, the seven industry dummies are included with Electrical Engineering being the reference category. In Model 2 the interaction term is integrated as one of the model parameters. In Model 3 and 4 the industries are aggregated in only two categories with the dummy variable "Complex Industry" indicating whether a firm belongs to a complex (Mechanical and Electrical Engineering) or a discrete industry (Chemical/Pharmaceuticals, Plastics, Metal Processing, Consumer Goods and other manufacturing). Again, Model 3 (Model 4) is reported without (with) the interaction term. The specifications' explanatory power ranges between 0.18 and 0.22 (Aldrich-Nelson-Pseudo-R2 with Veall-Zimmermann-Correction). The model fits can be considered as acceptable.[9]

I use a General Ordered Logit model with three outcome values of the dependent variable.[10] As a result of the ordered logit approach, two different coefficient panels are obtained. The first one refers to the probability of a firm stating medium or high importance for cross-licensing (compared to reporting low importance) and the second one shows the coefficients for a firm giving a high importance (compared to giving a low or medium value). In the subsequent section I will report only the the first panel, discussing which factors influence a "medium or high" relevance of cross-licensing compared to a low one.[11] I will first concentrate on Model 1 and 3. They show that firm sizes as well as IPR dependency have the expected positive influence on the importance of cross-licensing. As the main focus of this paper is on the interaction of these two factors, their interpretation has to focus on Model 2 and 4, discussed in detail further down.

With respect to other factors in Model 1 and 3, R&D intensity raises the relevance of cross-licensing. This backs the hypothesis that firms that are more active in research more often have to deal with other firms' IP in order to proceed. Additionally, they are more able to integrate external technology into own production processes (absorptive capacity). The influence of competition intensity, cooperation intensity and group affiliation is uncertain. The significance of the corresponding coefficients is at best weak and inconsistent between specifications. The industry dummies in general do not obtain coefficients significantly different from zero. The small number of observations per industry category is likely to be responsible for this observation. The relevance of industry characteristics becomes more obvious with industries concentrated in the two technological categories, according to their technology complexity.

[9]The McFadden-(Pseudo-)-R^2 ranges from .12 to .14. In the literature it is assumed that this measure severely underestimates the "true" R^2 in ordinal logit models. The Pseudo-R^2 reported above are considered to be more informative (see Veall and Zimmermann 1992).

[10]As robustness checks I tested a number of other specifications and econometric models. Coefficient signs for the principal variables turned out stable between the models, although at times breaking out of conventional significance level

[11]See the Appendix for the results for the second panel. Comparing the two tables, several coefficients lose their significance, indicating that the main influence of the parameters is connected with attributing medium or high importance to cross-licensing compared to low importance. The influence of several factors of the first panel on giving the highest value (compared to values 1 and 2) cannot be confirmed.

Dep. Var: Importance of Cross-Licensing	(1)	(2)	(3)	(4)
Firm Size (ln(Employees))	0.294**	0.327*	0.263**	0.288^{+}
	(3.29)	(1.73)	(3.01)	(1.55)
IPR Dependency	0.476***	0.551^{+}	0.475***	0.534
	(3.75)	(1.47)	(3.86)	(1.42)
Interaction (Employees x IPR Dependency)		-0.0125		-0.00787
		(-0.22)		(-0.14)
Competition Intensity	-0.304^{+}	-0.302^{+}	-0.222	-0.229
	(-1.56)	(-1.55)	(-1.18)	(-1.22)
Cooperation Intensity	0.229	0.230	0.281	0.303
	(0.73)	(0.73)	(0.91)	(0.97)
Group Affiliation	0.454	0.441	0.435	0.457
	(1.34)	(1.28)	(1.35)	(1.39)
R&D Intensity	3.168**	3.165**	3.148**	3.130**
	(2.58)	(2.58)	(2.77)	(2.74)
Chemicals and Pharma	-0.617	-0.625		
	(-1.17)	(-1.18)		
Plastics	-0.834	-0.831		
	(-1.16)	(-1.17)		
Mechanical Engineering	-0.0633	-0.0604		
	(-0.16)	(-0.15)		
Metal Processing	-0.516	-0.512		
	(-0.98)	(-0.98)		
Consumer Goods	-0.0834	-0.0929		
	(-0.14)	(-0.15)		
Other manufacturing	-1.062	-1.064		
	(-1.11)	(-1.11)		
Complex Industry			0.583*	0.607*
			(1.86)	(1.92)
Constant	-1.946*	-2.149*	-2.730**	-2.914*
	(-2.21)	(-1.65)	(-3.17)	(-2.20)
Observations	219	219	219	219
Pseudo R^2 †	0.207	0.207	0.184	0.186

t statistics in parentheses; † Aldrich-Nelson with Veal-Zimmermann correction
$^{+}$ $p < 0.15$, * $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$

Table 3.3. Estimation results (coefficients of first panel of ordered logit)

The variable turns out to be significant, which shows that technological characteristics significantly influence the relevance of cross-licensing.

The interpretation of the influence of firm size and IP dependency as well as their interaction will be addressed in detail in the following paragraph. The first panel of Model 2 and Model 4 shows a negative sign for the interaction term's coefficient.[12] One might be tempted to interpret this as the negative interaction effect under scrutiny here. However, when calculating the marginal effect based on the interaction term's coefficient only, the result cannot be regarded as the correct whole interaction effect (Ai and Norton 2003, Brambor et al. 2006). The "true" interaction effect is the cross derivative of the function

$$\begin{aligned} E(y>1) = &\Delta(\beta_{firm\_size} x_{firm\_size} + \beta_{ipr\_dep} x_{ipr\_dep} + \\ &\beta_{firm\_size*ipr\_dep} x_{firm\_size*ipr\_dep} + X\beta) \end{aligned} \tag{3.1}$$

with respect to the two constitutive terms x_{firm_size} and x_{ipr_dep} (all other variables captured by $X\beta$). In formal terms this is $\frac{\partial E(y>1)}{\partial x_{firm_size} \partial x_{ipr\_dep}}$ and does not correspond to the marginal effect based on $\beta_{firm\_size*ipr\_dep}$, which is $\frac{\partial E(y>1)}{\partial x_{firm\_size} x_{ipr\_dep}}$. Furthermore, the coefficients (and corresponding marginal effects) of the constitutive terms as they are reported in table 3.3 (Firm Size and IPR Dependency) can only be interpreted as the effect of one variable under the condition that the other constitutive term takes the value zero. The influence of IP dependency on the importance of cross-licensing for a firm with zero employees is a parameter without relevance. For better interpretation, the marginal effects for the variable IP dependency are therefore calculated for a firm in one specific industry (Electrical Engineering) with average characteristics in all control variables, but varying firm sizes. In formal terms this corresponds to the derivative on equation (1) with respect to x_{ipr_dep}

$$\begin{aligned} \frac{\partial E(y>1)}{\partial x_{ipr\_dep}} = &\Lambda'(\beta_{firm\_size} x_{firm\_size} + \beta_{ipr\_dep} x_{ipr\_dep} + \\ &\beta_{firm\_size*ipr\_dep} x_{firm\_size} x_{ipr\_dep} + X\beta) * \\ &(\beta_{ipr\_dep} + \beta_{firm\_size*ipr\_dep} x_{firm\_size}) \end{aligned} \tag{3.2}$$

with x_{ipr_dep} and all other controls in $X\beta$ being set to the average value of the corresponding variable across the sample. The marginal effect therefore only depends on the value for $x_{employees}$.

[12] The insignificance of the interaction terms coefficient does not imply that it should not be included in the specification. There might nevertheless exist a conditional relationship between the two variables.

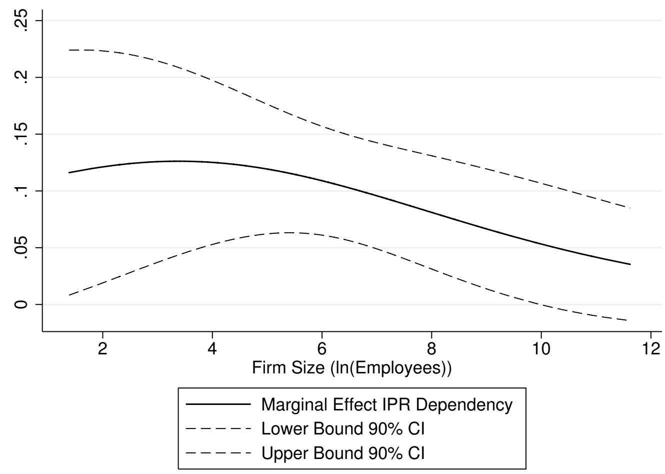

Figure 3.2. Marginal effect of IPR dependency on the importance of cross-licensing for firms with average sample characteristics and changing number of employees

In figure 3.1 and table 3.4, I split the firm in three size categories: "up to 249 employees", "250 to 999 employees" and "100 or more employees". Calculating the marginal effect (and standard errors) for three firms with the average firm size within each size class returns values of .12 (.043), .11 (.033) and .08 (.037) for small, medium and large firms, respectively.[13] This can be seen as a first hint to confirm Hypothesis 3, showing that indeed the effect of IP dependency changes for firms of different sizes: a higher degree of IP dependency leads smaller firms to attribute higher importance to exchanging patents via cross-licensing, while this effect seems to be less relevant for firms of larger sizes.

In order to present further evidence on the marginal effects' relative sizes for different firms, figure 3.2 graphs the marginal effects of IP dependency with respect to firms' size.[14] One can clearly see a declining interaction effect, the marginal effect first stays relatively even and begins to fall at a value of around 4, corresponding to a firm size of less than 100 employees (ln(100)=4,6). The graph suggests that for larger firms, the effect of IPR dependency gets continuously lower. I interpret this development as the effect of better possibilities to gain a workaround instead of cross-licensing. From figure 3.2 it becomes also clear that the computed confidence intervals are rather wide, meaning that despite the clear trend in the marginal effect for the different firm sizes one has to be careful about the statistical significance of the difference between them. As a robustness check I therefore calculate a model with dummy variables for the size

[13]The first two values are significant on an 1% level, the third on an 5% significance level.

[14]This way of presenting marginal effects in models with interaction effects corresponds to the approach described in Brambor et al. (2006).

classes instead of the continuous variable “Firm Size”. The size classes correspond to the categorization above into firms with less than 250 employees (size_class1), more than 250 but less than 1000 employees (size_class2) and companies with 1000 or more employees (size_class3). Table 3.4 shows the results corresponding to the four previous specifications. Size dummies in Model 1 have significantly positive values supporting the impact of firm size. When entering the interaction terms (both dummies are interacted with the variable IPR Dependency) variable size_class3 loses significance and only the interaction term for size_class2 turns out significant. As stated above, considering only coefficients’ signs and significance levels in logit models with interaction terms can lead to wrong conclusions. I therefore re-estimated the marginal effect of IPR dependency on the importance of cross-licensing for a medium sized firm (size_class2=1) and compared it with a company in the reference category “small firm”. The latter is estimated to 0.2180 (s.e.= 0.0626, p< 0.01), whereas the former one is not significantly different from zero (-.0136, s.e.= 0.0430). The same value for large firm (size_class3=1) amounts to .1418 (s.e.= .0427, p<0.01). We can thus conclude that the effect for small firms seems to be more important than for the medium firms and is in fact significantly higher as the 90% confidence intervals do not overlap ([0.1150;0.3211] for the small firms and [-.0844; .0570] for the medium sized firms). Surprisingly, comparing the group of large firms with the reference group of small firms the difference in the effect of IPR between the groups is not sufficiently large to allow a clear conclusion of group differences in a statistical sense. Moreover, the calculation of the interaction effect itself (size_class2xipr_dep, size_class3xipr_dep) yields a significantly negative value for the medium firms, but a non-significant one for large firms backing the results above. Some caution regarding the implications of IPR dependency in large firms is therefore appropriate. A reason for the findings could be that the notion of better possibilities to work around needed IP does not apply to the largest firms, because they have the means to manage cross-licensing deals and do not bother with trying to achieve a workaround every time they are blocked by a competitor’s IP.

As a last remark, I address the potential endogeneity problem of R&D intensity. It can be argued that not only R&D intensity influences the likelihood of cross-licensing but that vice versa firms engaged in cross-licensing activities have an incentive to boost up their R&D expenditures in order to be able to compete on the market for technologies or even to reduce their effort since the can get access to technology via licensing agreements. These two notions would make the variable R&D intensity endogenous. To avoid econometric problems I tried to instrument this variable with the corresponding values on the two-digit NACE industry level as well with an in-

Dep. Var: Importance of Cross-Licensing	(1)	(2)	(3)	(4)
Size Class 2 (250 to 999 employees)	0.775*	3.237**	0.691*	2.651**
	(1.91)	(3.23)	(1.73)	(2.71)
Size Class 3 (1000 or more employees)	1.004**	1.291	0.979**	1.120
	(2.70)	(1.22)	(2.63)	(1.09)
IPR Dependency	0.507***	0.877***	0.507***	0.803**
	(3.80)	(3.48)	(3.98)	(3.26)
Interaction (Size Class 2 x IPR Dependency)		-0.939**		-0.771*
		(-2.93)		(-2.49)
Interaction (Size Class 3 x IPR Dependency)		-0.0916		-0.0465
		(-0.27)		(-0.14)
Competition Intensity	-0.220	-0.275	-0.177	-0.235
	(-1.13)	(-1.34)	(-0.94)	(-1.21)
Cooperation Intensity	0.321	0.332	0.364	0.384
	(1.02)	(1.00)	(1.18)	(1.20)
Group Affiliation	0.588*	0.550+	0.555*	0.589*
	(1.85)	(1.58)	(1.81)	(1.81)
R&D Intensity	2.719*	2.944*	2.750**	3.030**
	(2.38)	(2.28)	(2.63)	(2.62)
Chemicals and Pharma	-0.535	-0.501		
	(-0.96)	(-0.89)		
Plastics	-0.704	-1.251*		
	(-1.00)	(-1.76)		
Mechanical Engineering	-0.0765	-0.0284		
	(-0.19)	(-0.07)		
Metal Processing	-0.525	-0.619		
	(-1.02)	(-1.08)		
Consumer Goods	-0.132	-0.412		
	(-0.21)	(-0.72)		
Other manufacturing	-0.956	-1.154+		
	(-1.10)	(-1.50)		
Complex Industry			0.599*	0.701*
			(1.91)	(2.12)
Constant	-1.238	-1.985*	-2.013*	-2.681*
	(-1.36)	(-1.87)	(-2.30)	(-2.50)
Observations	219	219	219	219
Pseudo R^2 †	0.193	0.242	0.178	0.213

t statistics in parentheses; † Aldrich-Nelson with Veal-Zimmermann correction
$^+$ $p < 0.15$, * $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$

Table 3.4. Estimation results (alternative specification/robustness check with size dummies; coefficients)

teraction of this value and firm size to account for size differences within the sample (Grimpe and Hussinger 2009). Using these instruments, a River & Voung test and the Wald-statistic did not hint to the presence of endogeneity. However, the used instruments itself turned out to be rather weak, limiting the test validity, I therefore cannot reliably rule out a coefficient bias due to endogeneity problems.

3.5 Summary and Implications

In this paper I have analyzed how the importance of cross-licensing changes with firm size as well as with the degree to which the firm has to rely on competitors' IP. I have shown that – even though each of them has an effect of its own – the two variables should not be analyzed separately as there is an interaction effect between them. The effect of IP dependency found in this analysis is high for smaller firms and subsequently decreasing with firm size. I argue that this can be ascribed to the lack of means to achieve solutions to work around a blocking technology to and the experience of out-licensing that smaller firms tend to gather in order to exploit their IP efficiently. Larger firms, however, have better odds to avoid an (explicit) arrangement of cross-licensing and, in addition, have better chances to have an alternative technology in their portfolio.

How can these findings be consolidated with the observed high relevance of cross-licensing among large multinationals in certain industries like electronics and semiconductors? Even if the effect of IPR dependency seems to be getting lower in larger companies, the positive size effect might be dominant for them. The fact that they have specialized IP staff that can deal more easily with complex transactions than the average General Manager of a smaller firm makes cross-licensing agreements more realistic. Additionally, larger firms do not engage in exchanging particular patents, but trade entire patent portfolios or sign contracts mutually waiving all possible future infringement charges. For smaller firms, trading an individual patent (or a small set of patents) might be more relevant. If firms referred to cross-licensing as an arrangement of trading only particular patents it would be just reasonable to explain the higher impact of IPR dependency for smaller firms: it has an impact for them in terms of a connected higher importance of trading certain rights. For larger firms this is less the case because they deal with IP dependency via patent pools or implicit standstill agreements.

Cross-licensing as an institution to solve the underlying problem of patent thickets brings a number of problems and potentially harmful incentives with it. In order to be in a good position in cross-licensing bargaining, firms will adapt their patenting activities in different ways.[15] One option is applying for more patents and seeking protection for smaller inventions. Another strategy is to seek broader patents by a suitable design of the patent claims.[16] Consequently, patent thickets become even tighter and firms potentially achieve to secure unreasonably broad protection which could be a barrier for subsequent research. These problems could be mitigated by rigorous patent examiners and/or stricter rules concerning application procedure at patenting offices. With rising patent applications and a higher work load for patent offices, however, requirements regarding the inventive step are in danger of getting lower (for the USPTO see Hunt (1999) or Hall et al. (2005)). This could result in a kind of vicious circle, as the resulting surge in patents increases IP fragmentation, which in turn raises the need to exchange patent rights.

There are also implications which concern certain firms only. As a consequence of tighter patent thickets and the subsequent higher importance of cross-licensing, smaller firms could potentially be disadvantaged as they often have a weaker bargaining position compared to large multinational firms. Since we have seen that smaller firms in situations of technological interdependency attribute a high importance to cross-licensing too, this might be critical to the important role SMEs play for the technological progress. Institutions like patent pools, where a number of companies bundle the relevant patents for a specific technology, could help small and medium firms to get access to relevant IP without the organizational overhead of multiple cross-licenses. However, if IP dependency in smaller firms is only about a limited number of relevant patents held by a competitor, the cost of joining a patent pool might outweigh the benefits of accessing only a few crucial patents. In order to reduce the need to cross-licensing in the first place, the controversial US Supreme Courts ruling *KSR vs. Teleflex*, which tightened the definition of non-obviousness, or the European Patent Office patent quality initiative "Raising the Bar", which is part strategic renewal process at the EPO (see the EPO's Annual Report 2007) could potentially be steps into the right direction, as they increase the hurdles to obtain patents and thus slow down the concentration of patent thickets.

[15] Supporting evidence for the connection of cross-licensing and the preceding patenting behavior can be seen in the high positive correlation of the variables on the importance of cross-licensing in the survey data with the reported importance of technology exchange being a significant motive to file patents beforehand.

[16] A third possibility is delaying the time to grant in order to keep the flexibility to adapt specific claims (see Chapters 2 and 1 of this dissertation).

Another point should be addressed here. With high IP fragmentation, companies have to invest more time and effort in monitoring the IP landscape. This has to be done in two directions: Checking competitors' products for possible infringement of own patents and screening a high number of others' patents in order to avoid unintentional infringement by own products. This means that highly qualified staff has to invest a considerable amount of time in patent monitoring, which ultimately translates into higher (opportunity) costs for the companies. Of course, it has to be the natural behavior of an innovative firm to review the existing state of the art. The effort to accomplish this task in an efficient manner, however, increases significantly as patent numbers go up. Especially the problem of an unintended infringement of another firm's patent can have severe financial consequences as the business model of "patent trolls" gets more attractive (Fischer and Henkel 2009). Firms face the possibility of exorbitant financial claims and longsome lawsuits with firms who acquire relevant patent rights for the only goal of suing companies infringing – knowingly or not – a particular patent. The impact of this kind of firms on innovative effort is only beginning to become clear as more and more "patent trolls" are developing their business models.

This study was a first attempt to identify the role cross-licensing plays for small firms in situations of high technological interdependency. Limitations include the sample size of just over 200 companies. Further research, with larger samples or for other countries, could help to confirm or challenge the findings of this paper. However, data collection would probably require large effort, as secondary data for licensing in small firms is rarely available and data has to be collected as primary data. Alternatively, a case study approach among SMEs might prove useful in order to shed more light on cross-licensing among smaller firms.

Bibliography

Ai, C. R. and E. C. Norton (2003), Interaction terms in logit and probit models, Economics Letters, 80(1): 123–129.

Anand, B. and T. Khanna (2000), The structure of licensing contracts, Journal of Industrial Economics, 48(1): 103–135.

Arora, A. and M. Ceccagnoli (2006), Patent protection, complementary assets, and firms' incentives for technology licensing, Management Science, 52(2): 293–308.

Arora, A. and A. Fosfuri (2002), Licensing the market for technology, Journal of Economic Behavior and Organization, 52: 277–295.

Arora, A., A. Fosfuri, and A. Gambardella (2001), Markets for Technology. The Economics of Innovation and Corporate Strategy, MIT Press, Cambrige, MA.

Arundel, A. (2001), The relative effectiveness of patents and secrecy for appropriation, Research Policy, 30(4): 611–624.

Bessen, J. and E. Maskin (2008), Sequential Innovation, Patents, and Imitation, Rand Journal of Economics.

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

Brambor, T., W. R. Clark, and M. Golder (2006), Understanding interaction models: Improving empirical analyses, Political Analysis, 14(1): 63–82.

Chesbrough, H. (2003a), The era of open innovation, Mit Sloan Management Review, 44(3): 35–41.

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

Cohen, W., A. Goto, A. Nagata, R. Nelson, and J. Walsh (2002), R&D spillovers, patents and the incentives to innovate in Japan and the United States, Research Policy, 31: 1349–1367.

Cohen, W. and D. Levinthal (1989), Innovation and Learning - the 2 Faces of R-And-D, Economic Journal, 99(397): 569–596.

Cohen, W., R. Nelson, and J. Walsh (2000), Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not), NBER Working Paper 7552.

Fischer, T. and J. Henkel (2009), Patent Trolls on Markets for Technology - An Empirical Analysis of Trolls' Patent Acquisitions, Working Paper - Available at SSRN: http://ssrn.com/abstract=1523102.

Fosfuri, A. (2006), The licensing dilemma: Understanding the determinants of the rate of technology licensing, Strategic Management Journal, 27: 1141 – 1158.

Gambardella, A., P. Giuri, and L. Alessandra (2007), The market for patents in Europe, Research Policy, 36: 1163–1183.

Green, J. R. and S. Scotchmer (1995), On the division of profit in sequential innovation, Rand J. Econ., 26(1): 20–33.

Greene, W. H. and D. A. Hensher (2008), Modeling Ordered Choices: A Primer and Recent Developments (June 15, 2008), Available at SSRN: http://ssrn.com/abstract=1213093.

Grimpe, C. and K. Hussinger (2009), Inventions under Siege? The Impact of Technology Competition on Licensing, ZEW Discusscion Paper No. 09-39.

Grindley, P. and D. Teece (1997), Managing intellectual capital: Licensing and cross-licensing in semiconductors and electronics, California Management Review, 39(2): 8 – 41.

Guellec, D. and P. Zuniga (2008), Who licenses out and why - Lessons from a survey of European and Japanese Firms, Paper presented at the 4th Annual Conference of the EPIP Association.

Hall, B. (2005), Exploring the Patent Explosion, Journal of Technology Transfer, 30: 35–48.

Hall, B. (2007), Patents and patent policy, Oxford Review of Economic Policy, 23(4): 568–587.

Hall, B., A. Jaffe, and M. Trajtenberg (2005), Market value and patent citations, Rand Journal of Economics, 36(1): 16–38.

Hall, B. and R. Ziedonis (2001), The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995, Rand Journal of Economics, 32(1): 101–128.

Hunt, R. M. (1999), Nonobviousness and the Incentive to Innovate: An Economic Analysis of Intellectual Property Reform, Federal Reserve Bank Working Paper, 99(3).

Kim, Y. (2004), Market structure and technology licensing: evidence from US manufacturing, Applied Economics Letters, 11(10): 631–637.

Kim, Y. and N. S. Vonortas (2006), Determinants of Technology Licensing - The Case of Licensors, Managerial and Decision Economics, 27: 235–249.

Kingston, W. (2000), Enforcing small firms' patent rights, European Commission, DG Enterprise.

Kortum, S. and J. Lerner (1999), What is behind the recent surge in patenting, Research Policy, 28(1): 1–22.

Kusunoki, K., I. Nonaka, and A. Nagata (1998), Organizational capabilities in product development of Japanese firms: A conceptual framework and empirical findings, Organization Science, 9(6): 699–718.

Lanjouw, J. O. and M. Schankerman (2004), Protecting intellectual property rights: Are small firms handicapped?, Journal of Law and Economics, 47(1): 45–74.

Long, J. S. and J. Freese (2001), Regression Models For Categorical Dependent Variables Using Stata, Stata Press.

Nagaoka, S. and H. Kwon (2006), The incidence of cross-licensing: A theory and new evidence on the firm and contract level determinants, Research Policy, 35(9): 1347–1361.

OECD (2008), Compendium of Patent Statistics, Organisation for Economic Cooperation and Development, Paris.

Reitzig, M. and P. Puranam (2009), Value appropriation as an organizational capability: the case of ip protection through patents, Strategic Management Journal, 30(7): 765–789.

Rivette, K. and D. Kline (2000), Rembrandts in the Attic: Unlocking the Hidden Value of Patents, Harvard Business School Press, Boston.

Shapiro, C. (2001), Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting, in: A. Jaffe, J. Lerner, and S. Stern, eds., Innovation Policy and the Economy I, 119–150, The MIT Press, Cambrigde, Massachussetts.

Veall, M. R. and K. F. Zimmermann (1992), Pseudo-R2s in the ordinal probit model, Journal of Mathematical Sociology, 16(4): 333–342.

von Hippel, E. (1990), Task Partitioning - An Innovation Process Variable, Research Policy, 19(5): 407–418.

WIPO (2009), World Intellectual Property Indicators 2009, World Intellectual Property Organization, Geneva.

Appendix

Dep. Var: Importance of Cross-Licensing	(1)	(2)	(3)	(4)
Firm Size (ln(Employees))	0.122	0.132	0.146^{+}	0.283
	(1.27)	(0.55)	(1.60)	(1.35)
IPR Dependency	0.368**	0.393	0.378**	0.656^{+}
	(2.97)	(0.87)	(3.16)	(1.61)
Interaction (Employees x IPR Dependency)		-0.00412		-0.0447
		(-0.06)		(-0.72)
Competition Intensity	0.250	0.251	0.203	0.231
	(1.15)	(1.14)	(1.02)	(1.14)
Cooperation Intensity	0.198	0.202	0.269	0.263
	(0.61)	(0.62)	(0.83)	(0.82)
Group Affiliation	0.564*	0.566^{+}	0.573*	0.516^{+}
	(1.66)	(1.60)	(1.74)	(1.50)
R&D Intensity	2.182^{+}	2.182^{+}	2.292*	2.286*
	(1.49)	(1.49)	(1.80)	(1.80)
Chemicals and Pharma	-0.293	-0.296		
	(-0.49)	(-0.49)		
Plastics	-0.315	-0.316		
	(-0.42)	(-0.43)		
Mechanical Engineering	-0.345	-0.344		
	(-0.88)	(-0.87)		
Metal Processing	-1.514*	-1.520*		
	(-2.38)	(-2.29)		
Consumer Goods	-0.00552	-0.00963		
	(-0.01)	(-0.02)		
Other manufacturing	-0.925	-0.927		
	(-1.05)	(-1.05)		
Complex Industry			0.663*	0.643*
			(1.99)	(1.92)
Constant	-3.836***	-3.903*	-4.709***	-5.622***
	(-3.51)	(-2.11)	(-4.54)	(-3.39)
Observations	219	219	219	219
Pseudo R^2 †	0.207	0.207	0.184	0.186

t statistics in parentheses; † Aldrich-Nelson with Veal-Zimmermann correction
$^{+}$ $p < 0.15$, * $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$

Table 3.5. Estimation results (coefficients of second panel of ordered logit)

Part II

Patenting and Product Piracy

Chapter 4

Risk Factors and Mechanisms of Product Piracy

Abstract This paper examines the relationship of a firm's strategic framework and its business environment with the probability of becoming the target of unauthorized reproduction of its product elements or names. Using survey data, we empirically examine the role of firm's intellectual property protection strategy, its general strategic business alignment and factors exogenous to the individual firm. Furthermore, we discuss mechanisms of imitation and analyze how business operations induce "enabling" and "signaling" effects and how these relate to the likelihood of being imitated. We find that a firm's general strategy positioning seems to matter more than the use of formal IP rights in avoiding unauthorized reproduction or infringement incidences. Especially strategic behavior which poses the risk of potential information leakage (defensive publication, participation in standardization activities, R&D activities out the home market) increases the likelihood of (illegal) imitation. We derive management implications for designing successful protection strategies.

4.1 Introduction

Precious coins in ancient Rome, Chinese porcelain in medieval times, mp3 files with the latest U2 album or high-tech car parts in the 21st century: Copying competitors' goods is by no means an exclusively modern phenomenon but it has received increasing public attention (and subsequently attention among policy makers) in recent years. Globalisation, highly dispersed value creation chains and distribution of goods in international markets are all partly responsible for a growing emergence of counterfeiting and product piracy. Part of the phenomenon is also related to the rise of emerging economies such as India and China, which are often blamed as the primary producers of goods infringing the intellectual property rights (IPR) of other (Western) companies. The OECD (2007) estimates a volume of up to US-$ 200 billion in international trade in tangible counterfeit goods.[1] In terms of the share of firms affected by counterfeiting, data for German companies suggest that around two-thirds of German manufacturing companies have experienced illicit activities connected to their intellectual property (e.g. a survey by the German Engineering Association (VDMA 2007), a similar survey on behalf of the German association of Chambers of Industry and Commerce (APM 2008)[2] and a report by the University of Dublin on behalf of the European Commission (Kingston 2000)).

All empirical studies in this field of research have one serious problem in common. The very nature of counterfeiting activities makes it hard to obtain reliable data. To overcome this problem, the OECD (2007) chose the approach of analyzing seizure rates at customs, thus catching only international flows of pirated goods. The main problem with this approach is that certain substantial assumptions have to be made for example concerning the percentage of illegally copied goods being detected. An alternative methodological approach is to analyze survey data collected among companies. A comparison of the two approaches once more highlights the measurement problems in this area. While customs seizure data suggest that most cases are connected with trademark infringement – which can be identified more easily by customs authorities – firm responses in surveys such as the one used in this paper also show a high relevance of unauthorized imitation of patents and technological components in general, which are, at best, difficult to spot by customs officers.

This paper chooses the survey approach as it has the advantage that firm and industry characteristics can be analyzed with respect to their impact on the probability of being affected by piracy. A first glance at the firm-level data collected for this research shows that there are certain factors which seem to be related with the incidence of counterfeiting. First of all, there are strong differences between industries. Mechanical engineering companies, for example, are more affected than the plastics

[1] At the same time the OECD acknowledges that it is very difficult to acquire sufficiently accurate data on a (more or less) secret and potentially undetected activity such as counterfeiting (see further down).

[2] These two surveys were carried out by industry groups, whose goals and interests have to be taken into account when interpreting their figures and whose results have thus to be used with caution (see also the discussion in section 4.2).

processing industry. Industry characteristics thus seem to play a role. The severity of the problem also seems to vary within industries with medium-sized and big corporations being more affected than small firms. However, it is interesting to have a closer look at these firm-level characteristics. Are multinationals more affected because they sell or produce their products in markets outside of their home market, for example in emerging countries where IPR regimes are less developed? What role do IP strategies play? Does a firm with a pronounced patenting (and enforcement) strategy deter piracy because of potential litigation procedures or does this strategy promote patent documents to be used as technological templates to copy know-how? What is the impact of the signaling effect of a patent application or brand to the market? The questions are manifold and are summarized in the following research questions: What factors are related with the probability of being affected by unauthorized reproduction ("product piracy")? Which of these factors can be influenced by a single firm (firm-strategic factors), and which are exogenous to the individual firm (*inter alia* industry characteristics and technological aspects)? What is the role of intellectual property rights?

The structure of the paper is as follows. The next section reviews literature related to this new field of research, section 4.3 addresses the theoretical framework by discussing potentially relevant risk factors. Section 4.4 deals with the empirical part. Section 4.5 discusses management and policy implications and concludes.

4.2 Review of Relevant Literature

For an overview on the extent and the impact of counterfeiting and product piracy, the most frequently cited sources are industry reports (e.g. BSA 2008), government reports (Kingston 2000, finding that 67 % of European SMEs think that own patented inventions have been copied) and a highly cited series of studies by the OECD (OECD 1998, 2007). In terms of scientific standards, these studies (esp. the various industry reports) have severe drawbacks since they lack a transparent methodological setting as well as a comprehensive theoretical framework. Furthermore, especially in the case of industry reports, the views of the authors cannot always be considered completely neutral.

In the theoretical scientific literature on the effects of counterfeiting, Grossman and Shapiro (1988a) provide an theoretical analysis using a two-country model with imperfect information and brand-name reputations. They show harmful implications for the home-country (original producers) and report that overall welfare does not necessarily decline with the possibility of counterfeiting.[3] These potentially positive effects of counterfeiting have also been called the “piracy paradox”. In a recent paper, Raustiala and Sprigman (2009) claim that in some industries such as fashion and music, piracy could promote innovation because imitation turns a formerly innovative design into a non-exclusive feature and demand for differentiated consumer goods then leads to even more innovative activity. The last argument holds particularly true for low investment industries. However, even in industries with substantial R&D expenditures, illegal imitation can have positive effects for the originator due to a faster diffusion of the imitated product. This is especially relevant when network effects are important (Conner and Rumelt 1991, Givon et al. 1995), where the imitators thus create barriers to entry for competitors (Givon et al. 1995) and help the originator establish own technology as an industry standard with switching costs further cementing the originator’s competitive position (Katz and Shapiro 1994). The concept of signaling has been discussed in the context of product piracy assuming that imitation signals the original product’s high quality (Castro et al. 2008). This helps to overcome market information asymmetries and influences buying decisions. Cordell et al. (1996) empirically study the determinants of buying decisions and willingness to pay for pirated goods and discuss the expected performance of the imitation relative to the original good, moral attitude and “investment-at-risk” of the purchased product.

The scientific literature on the risk factors of being attacked by product pirates – the focus of this paper – is by far smaller than studies on the counterfeiting demand side or on the impacts of product piracy, especially when the focus is not on brands or on digital piracy such as software but on imitation of technological aspects. Harvey and Ronkainen (1985) describe how pirates can obtain information, referring especially to the risk of information leakage from within the company.[4] Mansfield (1985) provides evidence on the speed of diffusion of internal know-how. He finds that information about development decisions is generally known by competitors within about 12 to 18 months and information on the detailed nature and operation of a new product or process generally leaks out within about a year. Inferences on the factors influencing the piracy rate can also be drawn from research on managerial implications of counterfeiting. Several authors (e.g. Olsen and Granzin 1992) highlight the need for

[3] Another important theoretical contribution by the same authors (Grossman and Shapiro 1988b) points out how the status and the quality characteristics of brand-name products are unbundled by counterfeiting.

[4] This process can also be seen as a special case of unwanted knowledge spill-over thus connecting to the large amount of empirical research on this topic (e.g. Jaffe 1986).

tight cooperation in sales channels to address the piracy risk for suppliers in product distribution in insecure markets. In a recent study among Australian inventors – maybe the one with an approach closest to ours – Weatherall and Webster (2009) survey inventors about their infringement cases. They report a 28 % rate and also find correlations between infringement rates and *ex post* estimates of patent value, export activities, and whether the patent covers a radical or incremental innovation.

Other relevant studies center on the appropriability of technical innovations which generally show a low effectiveness of patents and a high importance of lead time advantage (Blind and Thumm 2004, Blind et al. 2006, Harabi 1995) and on the relative importance of secrecy and patenting (Arundel 2001, Denicolo and Franzoni 2004).

All in all, literature on firm characteristics which influence product piracy incidence rates is virtually inexistent to our knowledge. The following analysis can therefore be a starting point to obtain valuable insights on a topic highly relevant for management professionals and policy makers alike.

4.3 Drivers of Unauthorized Reproduction and IP Infringement

The terms "counterfeiting" or "product piracy" (as defined by the OECD or the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS)) refer to the infringement of trademarks and copyrights, patents and design rights, as well as to a number of related rights (OECD 2007). In our analysis, we categorize these phenomena along two different criteria. First, we differentiate whether technological (potentially patentable) elements of a firm's product are copied by other players in the marketplace or whether product names or labels are copied. Second, we take into account whether the imitation refers to features of the product which are legally protected by a patent or a trademark. Regardless of whether there is a formal IP right on the product feature of the imitated element, we refer to copying as "unauthorized reproduction" of a technological element or a name/logo of the product. Unauthorized reproduction can be the result of a failed trade secret strategy and would in this case be seen as a legitimate imitation of successful products or the diffusion of know-how in the marketplace. Cases of actual IP violation in the legal sense will be referred to as patent or trademark infringement in the following analysis. IP infringement is thus a subset of unauthorized reproduction. It should be noted that the economic implications between cases of legitimate unauthorized imitation and patent/trademark infringement do not necessarily differ. In both situations, the imitated company is affected with respect to individual revenues (on sales output and price competition[5]) and brand value (as the product quality of a counterfeited good is usually lower than the original product[6]), incurs costs for unjustified product liability claims caused by the lower quality of fake goods, and has additional expenditures to address the threat of counterfeiting. The only difference between imitation of formally protected goods and the copying of elements, for which formal IP has not been registered, is the potential risk for the pirate of being litigated for infringing the relevant right. Assuming a sufficiently high likelihood of successful prosecution, formal protection would thus have a negative impact on the probability of becoming a victim of product pirates.

The following three subsections describe several factors that can potentially have an influence on unauthorized reproduction and infringement cases. We structure our analysis by first looking at instruments of a company's IP strategy. We then consider factors found at a more general firm strategic level and conclude with those that can generally not be controlled by the firm itself, since they are largely exogenous to the individual company.

4.3.1 IP strategy

The most important formal instruments in protecting a firm's intellectual property are patents and trademarks. These instruments cover very different aspects of a product and the implications for our analysis differ considerably. We will thus first address the situation for patents before turning to brands.

Firms bear certain costs in order to "buy" the option of suing illegal imitators for patent infringement. In the case of patents, these costs – apart from monetary aspects – include the disclosure of a detailed description of the claimed inventive steps. These patent documents – although rather cryptic to read for non-patent lawyers – should in theory be understandable for a "person skilled in the art" (Article 56 of the European Patent Convention) and cases have been reported in which patents are used as "libraries of technological information" (Keupp et al. 2009). A European Patent

[5]Recent work by Qian (2008) and Belleflamme and Picard (2007) emphasize the price dispersion effect of piracy entry, potentially enhancing long-run quality performance of genuine producers in the market.

[6]See discussion by Bosworth (2006) on differences in quality of genuine and pirated goods, probability of perception by consumers and deception success.

Office survey among both users and non-users of patents shows that more than 80 % of firms regard patent information as important or very important for their business. More specifically around 40 % to 50 % consider the technical information in patents as very important and especially in early phases of the product cycle, i.e. investigating and developing new product opportunities (EPO 2003). This suggests that patent information disclosure may help potential (illegal) imitators to copy a successful product. We refer to this notion as the "enabling effect" of a patent document. This effect can be relevant for both types of imitation of technical components: IP infringement could theoretically arise since the protected know-how is disclosed, but imitation of unprotected components can also be affected. One reason is that the patented information is complementary to unpatented technology and thus the patent document assists in copying the unprotected part. Another reason is that technology is patented in one country or geographical region, but due to cost considerations not always in all other relevant legislations. Thus, using the information of a European patent to produce goods in the Asian region is not considered IP infringement in our definition.[7]

Before a product is copied, a promising "target" has to be identified by the imitators. Again, the patent system can be useful for the imitator because patent applicants send a signal to society (and to their competitors) that a new process or product has been discovered[8], which can be used by everybody in the public domain after the patent has expired. This fact is inherent to the patent system and together with flaws such as long pendency times, high costs and other uncertainty factors, lead companies to refrain from using official ways to protect their intellectual property. They want to avoid the signaling effect of a new patent application and to prohibit competitors from learning about their new research. An alternative strategy would be a strict reliance on informal protection models like lead time advantage and secrecy on multiple levels: strict confidentiality policy with employees, suppliers, or cooperating firms. As argued above, a signaling effect could be relevant for both unauthorized reproduction and IP infringement.

Our argumentation above can be summed up as follows: Firms using patents to protect their IP cause a signaling effect (with respect to a new invention) and an enabling effect (through information disclosure). They thus run the risk of disclosing information to potential imitators which could increase the probability unauthorized

[7]This is specifically relevant for small or medium-sized companies which often do not patent worldwide due to cost reasons or due to a lack of know-how in IP management.

[8]There are numerous service providers and websites monitoring new patent or trademark applications and subsequent potential industry trends based on them (one example is *ipnewsflash.com* or The Trademark Blog on *schwimmerlegal.com* and (in German) *markenblog.de*)

reproduction or patent infringement. This risk is mitigated by the potential enforcement of the patent before a court. Firms that rely stronger on trade secrecy to protect their IP cause neither a signaling nor an enabling effect. As a result of waiving the use of patents, they also have a lower risk of IP infringement. However, as trade secret strategies can fail and do not entail a litigation option, the expected effects of a trade secret strategy on unauthorized reproduction of technical elements are ambiguous.

Obviously, a trade secret strategy is only relevant for the protection of technological elements of a firm and not adequate for product names and labels. A brand value entirely depends on its level of diffusion in the market and the brand awareness associated with it. A second difference is that the registration of a trademark does not lead to the disclosure of relevant know-how. The "enabling effect" of a patent document does not exist here. However, the signal to the market is analogous to the patent application example. In both cases, the signal can assist imitators in identifying a product worth counterfeiting, i.e. free-riding opportunities on expected innovation rents and advertisement efforts of original producers and the emergence of a new product life cycle. The trademark can signal to the public that there is a brand premium to be earned, which is, after all, the basic concept of a branding strategy: a brand reputation inducing a favorable product quality leads to a higher willingness-to-pay and allows higher prices. Thus, a heavy use of trademarks can be understood as a signal to imitators that there are relatively high profit margins, which could be an incentive to enter the market. Again, this risk is lowered by the enforceability of a registered trademark.

The differentiation between unauthorized reproduction and trademark infringement is more difficult for product names/logos than for technical elements. This is due to the lack of a trade secret strategy in this case, but also because a trademark – compared to a patent – is relatively easily obtainable, also for smaller firms and for foreign markets. One can thus assume that there is a high overlap between these two sorts of imitation.

Various other measures can be taken to protect intellectual property. Firms are increasingly creating preventive technological barriers in their products to make reverse engineering by pirates more difficult. The rationale lies in raising the costs for potential pirates and making their cost-benefit ratio less attractive.[9] A relatively

[9]It should be noted that additional costs of this strategy, e.g. by using encrypted software product components or by explicitly de-standardizing mechanical product components away from industry standards occur for the original manufacturer as well. These might be prohibitively high, so that the strategy might not be chosen by every firm.

new strategy is the implementation of management tools such as offering additional services for original goods. This bundling may help to protect products and enable (long-term) enforcement of related intellectual assets. This way, specialized know-how of the originator's staff serves as a selling argument for the original product. Another measure is the regular inspection of customers' facilities which may support detection of (unintended) counterfeit purchases. None of these protection mechanisms cause a signaling or an enabling effect. A possible effect of an explicit strategy focusing on technological or management tools on the rate of both unauthorized reproduction and IP infringement is thus expected to be negative. Although the discussed measures primarily concern technological aspects, they can also impact copying of names and logos. Therefore, these measures are expected to affect the imitation of technical aspects as well as the copying of product names or labels.

A further strategy to secure a firm's freedom to operate in a certain technological area is to deliberately refrain from keeping the latest research results secret. This strategy is known as defensive publication and aims at raising the "state of the art" in a specific field. As a consequence, competitors are prevented from patenting the same invention, as a patent will only be granted for new, previously unknown applications.[10] The down-side of this strategy is that relevant knowledge is disclosed (with the connected enabling effect) without the potential legal enforcement option.[11] Even though defensive publishing will never be a firm's sole IP strategy (a patent application will, of course, be filed for an important technological break-through), it increases the know-how of competitors and potential pirates about a company's technological developments. Defensive publishing not only signals a relatively "open" company culture, but can also enable unauthorized reproduction or patent infringement. Obviously, defensive publication is not relevant in the trademark case.

The instruments above are the traditional methods of how firms try to protect their IP. This does not necessarily mean that they are the most efficient or effective, but are analyzed here since they are widely used. Besides these specific IP protection instruments, it is also important to consider more general factors of the overall business strategy. The following subsection addresses them.

[10]This is especially true for the European Patent Office (see Article 52 (1) EPC). In the US, the legal situation is different as the patent can be granted even though the invention was patented or described during the previous year (see 35 U.S.C. § 102).

[11]A considerable part of defensive publishing is also done via the patent system itself. (Henkel and Pangerl 2008) In this case, this last argument is not valid, as the patent application creating the state of the art might eventually turn into a valid grant.

4.3.2 General Strategy

An important driving factor of the probability of counterfeiting is related to the degree of a firm's involvement in operations out of the home market. We do not claim that copying of technological elements or logos only exists outside a firm's home market, which is Germany in our empirical study. However, every engagement in a foreign market, especially when technology work is involved, may lead to a loss of control and may pose operational risks (Granstrand et al. 1992). The reason for this is that, despite conducting market research, management is unlikely to know the foreign market as well as it knows its home market. This knowledge gap can stem from differences in legal (IP) regimes and can also include challenges with recruiting reliable and trustworthy staff (for evidence on this topic in China, see Gassmann and Han 2004). Therefore, we claim that engagement in a foreign market raises the odds of being counterfeited. We furthermore assume that this probability increases the more sensitive knowledge is transferred from the home to the foreign market or the more the commitment in the foreign market increases (Johanson and Vahlne 1977). Only selling goods overseas does not bring the same risks as establishing production facilities. The relevance of this problem is even greater when research and development is conducted in a foreign country, e.g. by staff fluctuation[12]. This risk of foreign activities is relevant for both types of technology copying, but also affects copying of trademarks, since the use of proprietary names or logos by other companies more difficult to monitor in foreign markets than in the home market. Furthermore, low levels of public enforcement , for example in emerging economies like China, tend to attract large numbers of counterfeiters (Gassmann and Han 2004), and effective legal regimes are only beginning to evolve.

Technical information is not only disclosed in patent documents. Another way of know-how diffusion occurs via standardization activities. Companies, especially large multinationals in industries such as electrical engineering or telecommunications, have a strong incentive to participate in (formal or informal) standard-setting organizations because they may influence the orientation of the future technological path. Furthermore, having their own IP included in a standard opens up royalty streams from competitors willing or forced to implement the standard. The downside for the individual firm lies – analogous to the patent case – in the disclosure of technological information. Not only does the standard itself contain such information, but all patents considered to be relevant have to be communicated as well. Both a signaling

[12] Agarwal et al. (2009) show how knowledge spillovers caused by inventor mobility can be reduced by building up a tough patent enforcement reputation.

and enabling effect are relevant here. Apart from having knowledge codified in the standard documents, the standardization process itself can lead to sensitive knowledge being discussed during technical committee or working group meetings (Blind and Thumm 2004, Blind et al. 2006). Company representatives and standard-setting organizations are, of course, aware of these problems and strive to keep certain information confidential. It is, nevertheless, reasonable to assume a potential information outflow with an effect on unauthorized reproduction of technological elements or patent infringement.

Similar to the diffusion of know-how outside the home market, knowledge can be at risk in inter-firm cooperations. If a firm cooperates with suppliers, competitors or customers, the partners hope to benefit from joint research activities, but these could also lead to increased knowledge leakage. This is one of the reasons why firms often object to opening up their research labs and is an important barrier for the "open innovation" model (Chesbrough 2003). Companies have to balance this risk of giving away too much knowledge with the benefits, which can be substantial as well (Grant 1996). We argue that firms which heavily cooperate – be it with universities, customers, suppliers or competitors – run the risk of a higher knowledge outflow and thus face a higher rate of unauthorized reproduction and/or infringement cases of technical elements, but also of the names and labels associated with these products. There is an alternative reasoning regarding the effect of cooperative company behavior, focusing on the connection between research cooperations and firm innovativeness (Becker and Dietz 2004). If cooperative activities are seen as a signal that the originator's firm is highly innovative, the effect on the rate of imitation cases might also be expected to be negative.

A similar signaling effect could be expected for the degree to which a firm engages in own (intramural) research and development in relation to its overall business alignment, i.e. R&D intensity. We assume that illegal imitators do no conduct state of the art research themselves. Therefore their absorptive capacity is limited and they do not have the potential to reverse engineer high-end products on the market. A more relevant strategy for them would be to concentrate on low or medium tech products with a relatively steep learning curve. These products can be rapidly imitated and produced without too many sunk costs. Illegal imitators always need to calculate the risk of being detected and consequently production facilities being shut down. It is, therefore, important to enter the market quickly, which makes it unlikely for illegal imitators to focus on technology of a high-tech company.[13] A reputation of producing high-tech products might therefore be favorable with respect to a firm's danger of unauthorized reproduction as this can, *per se*, generate barriers to the exact imitation of technological elements. An implicit barrier to entry connected with a higher R&D intensity is also the length of the product life cycles which can be assumed to be shorter for products with a higher R&D intensity. The shorter the life cycle is, the less time imitators have to appropriate their own "imitation rents" and might therefore be discouraged to copy the product in the first place.

A reputation of producing high tech products obviously does not discourage illegal imitation of names and labels. Fake brand products are often found to be of inferior quality or incorporate different technology, but nevertheless carry the product name or logo of the high-tech product. Since the demand for certain high-tech products is relatively inelastic, they could be a rewarding target for imitation. One could, therefore, expect that innovativeness, measured by the R&D intensity, can increase the frequency of both unauthorized reproduction and trademark infringement.

4.3.3 Exogenous Factors

The last group of factors are potential drivers which are not controlled by the firm itself, but are based on the business environment of the firm.

First, the competitive environment plays a role. If profit margins are low as a result of competitive pressure, the financial incentives for new entrants are also low. Therefore unauthorized reproduction or IP infringement by newcomers in a specific market is expected to decrease in this situation.[14] This changes if we look at incumbents in a market. If they realize that a competitor is successful with a product protected by relevant IP, they might be "forced" to imitate the successful product, legally or not, in order to survive in the market. In this sense, "unauthorized imitation" by firms already active in the market can rise with the level of competitive pressure. Additionally, competition in the product market can coincide with higher competition in the technology market. A single firm's chances to be the first to make an invention and the first to file the connected patents decrease in constellations of strong compe-

[13] Some evidence in EU customs seizure data indicates that pirates increasingly violate patent rights (Blind et al. 2009). This could imply a "piracy shift" to medium- and high-tech sectors – even though the majority of seized counterfeits concerns trademark infringements.

[14] On the other hand, one can argue that a higher level of competition signals an attractive market with respect to the detection probability of illegal imitation. A high number of market players and a potentially broader variety of products may, in this sense, increase the probability of not being detected and prosecuted by authorities or competitors, or detected as "fake" by customers.

tition. If the firm is then "patented out of the market" it might deliberately choose to continue product development even if an infringement suit is to be expected.

A similar situation occurs when technological interdependence among firms is high.[15] When a competitor holds a patent which potentially blocks the firm's own technological or commercial path – be it due to higher competition or to technological interdependence – a work around must be attempted. This strategy might, however, not be completely successful and the relevant IP is still infringed.[16] The existence of patent thickets – situations where IP ownership is highly dispersed among a large number of IP holders – can even increase the chances of unintentional infringement.[17] This is a separate form of "product piracy" but still relates to our rather broad understanding of unauthorized reproduction. We subsequently propose that a higher interdependence in a firm's technological setting will coincide with higher rates of imitation. Other exogenous firm characteristics can be seen in firm size and industry affiliation. Descriptive univariate analyses (see section 4.4) show a positive connection between firm size and the incidence of piracy as well as differences among industries. This could be due to product characteristics, to properties of manufacturing processes in those industries or could be attributable to the firm-level factors discussed in this section. Multivariate regression in the empirical part will show whether the observation of industry differences will also endure a more rigorous analytic approach.

4.4 Empirical Part

In the following section, we present our sample and some descriptive results, before turning to our findings regarding the first question of risk factors for product piracy. We will also discuss whether the most significant factors are firm-strategic or exogenous to firm behavior allowing conclusions on the extent a firm can actually influence its exposure to pirates.

[15]This is often the case in "complex" industries (e.g. semiconductors or information technology), where a single product consists of a significant number of separately patentable elements.

[16]There are, of course, many cases in which original and copying firms have substantial differences in their evaluation of this matter, ending before court.

[17]Situations of high technological interdependence lead to arrangements such as cross-licensing of whole patent portfolios or (implicit or explicit) agreements between firms to fully refrain from litigation relating to their patent rights.

4.4.1 Data and Survey Description

We collected a unique data set by surveying patent active companies in Germany. All German companies with more than 10 patent applications between 2002 and 2004 were identified on the basis of applications at the German Patent Office (DPMA), the European Patent Office (EPO) and under PCT. In addition, a set of R&D active companies was randomly drawn from a commercial company database (Hoppenstedt database). The same database was used to identify a relevant contact person, who was defined as the head of R&D, the head of the IPR/law department or – especially for the smaller companies – the firm's General Manager/member of the executive board.[18] A pretest was conducted to eliminate possible difficulties. Finally, around 3,000 companies received a paper questionnaire with the additional possibility of accessing the questionnaire on the web.[19] Despite adressing personalized cover letters to relevant employees in each company and sending reminder letters, we had a high unit and item non-response (especially for the counterfeiting questions) resulting in a response rate of less than 10%. This fact is likely due to the high level of detail with numerous IP and counterfeiting related questions.

We conducted a number of tests to check the reliability of our data. We had information on sales and firm size for part of the sample, allowing a comparison of respondents and non-respondents. Results showed a slight tendency for larger firms, both in terms of sales and number of employees, to participate. The mean of both figures was larger in the respondent group. However, a Wilcoxon-Mann-Whitney test on differences between the groups did not yield significant results and also the median for both groups was similar. A unit non-response bias towards larger companies thus seems not to be a major problem. We also had the concern that companies heavily affected by infringement cases or firms for which IP is more important had a higher likelihood to participate in the survey, since they have a stronger interest on the topic. Since we do not have data for non-respondents on their exposure to unauthorized imitation or infringement, we cannot control for this directly. Instead we conducted a non-response analysis comparing early and late respondents, with the latter defined as those having answered after the reminder letter. This implies the assumption that late respondents are more similar to non-respondents than early respondents. A comparison would thus lead to hints on self-selection into the sam-

[18] Around 45% of the respondents fell into the second group, one third into the third group. Around 10% identified themselves as head of the R%D department, while the rest had positions such as assistant to the General Manager, head of innovation management or similar positions.

[19] Only a small fraction of around 10% used the online tool. We tested for differences between online and offline respondents on some key variables and did not detect significant differences.

ple. If self-selection was a problem, we would expect early respondents to report a higher exposure to “piracy” or attach a higher importance to patents than the late respondents. We thus compared the two groups with respect to the importance of patents and brands they report for their company, the frequency of unauthorized reproduction of their products, actual patent and trademark infringement and the sales shortfall they experienced as a result of these problems (see a more detailed description of the variables below). We did not detect significant differences for the IP importance and the sales shortfall, but found slightly higher results for the “piracy indicators” among the late respondents. However, these results are only significant for unauthorized reproduction of names and labels. This suggests that a potential upward bias on this variable through unit non-response can be neglected. Since the slight downward bias detected is not statistically significant, we assume that non-response bias is small at most. This assumption is also supported by a number of telephone interviews we conducted on key questions among non-respondents.

The following section gives a more detailed description of the questionnaire items used to derive the indicators of imitation incidences. There were two questions on this topic. The first referred to the incidence of unauthorized reproduction of product features, regardless whether the features were legally protected or not. Thus, this may include infringement of legally protected intellectual property as well as a failed trade secret strategy. The second referred to actual infringement in the legal sense. This distinction was used in order to allow conclusions about alleged infringement cases on subject matter that was actually not properly protected.[20]

The exact wording of the first question was: “How frequently did your company experience unauthorized reproduction (“product piracy”) of features of its products in 2007?”[21]. Survey participants were asked to respond separately for i) technical components of the product and ii) product names/logos in order to distinguish between the two different phenomena of imitation referred to later as “patent infringement” and “trademark infringement”. We used a 5-point Likert scale with the anchors labeled as “very infrequently” and “very often”. There were separate items referring to incidences of unauthorized reproduction within and outside the European Union. There was also an additional answering option for “never”. The ultimately used binary variable takes the value “one” for a company reporting at least “very infre-

[20]Expert interviews before the survey design indicated that this happens relatively frequently among small companies with a lack of knowledge in IP management and sporadic export activities into countries with a high piracy emergence such as China.

[21]Original questions in German, translation by the authors.

quent" incidences of unauthorized imitation inside or outside the EU. It is set to "zero" otherwise.

The second question referred to actual infringement of intellectual property in a legal sense. The wording of this question was: "How frequently did your company experience infringement of intellectual property although the product feature was protected by a valid formal industrial property right in the relevant country?"[22] The answering options were identical to the ones described before.

A crucial feature of our data is that the unit of observation is at company level and not at product level. It can be argued that the latter might be more suitable as "product piracy" often refers to an imitation of specific products rather than whole product portfolios. This might be specifically problematic for imitation of technical components, but to a lesser extent for the trademark infringement case. The reason for this is that infringing an (umbrella) brand or abusing the reputation of a well-known company name has an impact on the company as a whole, while copying of a single technological feature could leave other product lines unaffected. However, because of the nature of our data, we cannot analyze differences at product level. We thus have to assume a certain extent of homogeneity of products in the company portfolio to justify our analysis at company level.

Table 4.1 gives an overview on the distribution of the sample over firm size and industries. Both small and medium-sized firms as well as large corporations are represented. The industries with the most observations are Mechanical and Electrical Engineering. Table 4.1 additionally allows a closer look at the extent to which companies are actually affected by unauthorized reproduction of their products. The share of companies reporting at least one case of imitation of technological components is stunningly high: around 75 % of all surveyed companies. Small firms with fewer than 250 employees report significantly lower rates than their larger counterparts. This first look at size effects thus suggests that larger firms run a higher risk of being affected. This holds true for both types of unauthorized imitation (of technological components and of brand names and labels). With respect to industry affiliation, firms in Metal Processing report the highest piracy rates for technological goods, whereas Chemicals/Pharmaceuticals and Consumer Goods have the highest rates for the imitation of brand names. Firms in the Plastics industry seem to be among the least affected.

[22]The question of the validity of an industrial property right can, of course, be problematic. We here have to rely on the opinion of respondents and do not have information on whether the concerned IP right would be upheld in a patent reexamination or a trademark validity trial.

		Number of observations over firm size in employees)				Unauthorized reproduction	
		< 249	250 ≤ 999	≥ 1000	Total	Technical Elements	Names and Labels
Industry	Chemicals and Pharmaceuticals	5	4	10	19	78.95 %	73.68 %
	Plastics	4	3	3	10	60.00 %	30.00 %
	Mechanical engineering	15	24	31	70	77.14 %	54.29 %
	Metal processing	6	6	13	25	96.00 %	60.00 %
	Electrical engineering	26	8	22	56	66.07 %	48.21 %
	Consumer goods	5	8	6	19	73.68 %	73.68 %
	Other manufacturing	3	2	4	9	66.67 %	44.44 %
	Total	68	58	91	217	75.00 %	54.81 %
Unauthorized reproduction							
	Technical Elements	62.50 %	85.45 %	77.53 %	75.00 %		
	Names and Labels	34.38 %	65.45 %	62.92 %	54.81 %		

Table 4.1. Number of observations by firm size and industry affiliation as well as mean incidence of unauthorized imitation (share of firms reporting at least one incidence of unauthorized imitation in 2007; first value refers to technical components, the second to product names/labels)

We will briefly describe the measurement approach concerning the risk factors discussed in section 4.3. The questionnaire items for the IP strategic factors are quite straightforward. Participants were asked to indicate the importance of different industrial property rights (especially patents and trademarks) for their company on a five-point scale. An identical question addressed several informal methods to protect intellectual property such as using defensive publication, emphasizing a trade secret and employing technological means to impede reverse engineering. We conducted a factor analysis to condense the nine informal protection methods into three groups of informal strategies according to the factor loadings of the variables. As a result, we kept defensive publication as a single variable, used the arithmetic mean of four items related to confidentiality to construct the variable “Importance of trade secrets”[23] and joined the four remaining items to the variable “Importance of other informal protection methods” (including “implementing technological protective features”, “implementing management tools to prevent illegal copying”, “emphasizing fast time to market” and “creating exclusive customer relationships”).

We used a simple transformation to back-calculate the importance of patents and other IP strategies, because we asked about the importance of protection strategies at the time of answering the survey (2008) and the items on imitation issues referred to the year 2007. In this back-calculation, we exploited the fact that we had information on how the importance had been changing over the last five years. The result is

[23]This included “emphasizing confidentiality of production processes”, “confidentiality provisions with suppliers”, “confidentiality provisions with employees” and “long term staff retention”.

an estimation of the importance of all factors how it “used to be” in 2003. This back-calculation tries to rule out that the experience of “unauthorized imitation’ in 2007 has affected the answers on the importance of formal and informal protection methods. It thus gives us an “observation” of how important they were before an infringement case in 2007.

The construction of the variables in the group “General business strategy”, is mostly straightforward. The four variables foreign sales activities, foreign manufacturing facilities, foreign R&D activities and participation in standardization are measured with a binary variable indicating whether these items were applicable to the respondent. Cooperation intensity is measured on a five-point scale and is the mean of company answers on the frequency of different types of cooperation with suppliers, customers, competitors and extramural private or public research institutions. R&D intensity is measured as the ratio of R&D employees to the total number of staff.

In the last group, firm-exogenous factors, we use two more self reported indicators: the competition intensity in the firms relevant product markets and the perceived dependency of the firm on technology and intellectual property held by competitors. This last factor intends to mirror a technological complexity in the sense that patent thickets and complementary patents are problematic in the industry. A high IP dependency would increase patent infringement cases for technological peculiarities.

Table 4.2 shows summary statistics for all variables.

	Variable	Mean	Std. Dev.	Min.	Max.
IP strategy	Importance of Patents	3.404	1.104	1	5
	Importance of Brands	3.087	1.176	1	5
	Importance of Trade Secrets	3.398	0.892	1	5
	Importance of other informal protection	3.064	0.847	1	5
	Importance of Defensive Publication	2.591	1.147	1	5
General business strategy	Foreign Sales	0.957	0.204	0	1
	Foreign Manufacturing	0.716	0.452	0	1
	Foreign R&D	0.625	0.485	0	1
	Participation in Formal Standardization	0.63	0.484	0	1
	Cooperation Intensity	0.606	0.49	0	1
	R&D Intensity	0.107	0.134	0	0.786
Exogenous factors	ln(employees)	6.448	2.143	1.099	11.622
	Competition Intensity	4.288	0.782	2	5
	IPR dependency	2.803	1.272	1	5

Table 4.2. Summary statistics of regressors (N=208)

4.4.2 Bivariate Analysis

In this section, we present a number of descriptive analyses, charts and bivariate correlation tables to take a first step in assessing the relationship of the factors discussed in section 4.3 with the incidence of unauthorized reproduction and patent/trademark infringement.

We have distinguished between "unauthorized imitation", which does not necessarily imply a legal offense, and actual patent or trademark infringement throughout section 4.3. Table 4.3 shows the percentage of companies reporting one or more incidence of both types of imitation. More than 80% indicated that they had had experience with unauthorized imitation of technical elements in 2007. However, this drops to around 70% in incidences where the product feature was protected by a patent right. We also see that more than 85% of the firms, which had problems with unauthorized reproduction, were affected by patent infringement. This suggests that formal protection had been sought for most cases of unauthorized reproduction. A smaller share of the companies in our sample report incidences of the copying of names and labels or trademark infringement (64% unauthorized reproduction vs. 53% trademark infringement). This difference could be caused by our sampling frame which focuses on patenting companies.

	Patent Infringement								
Unauthorized Reproduction	**No**			**Yes**			**Total**		
(technical elements)	No.	Col %	Row %	No.	Col %	Row %	No.	Col %	Row %
No	29	60.4%	100.0%	0	0.0%	0.0%	29	18.5%	100.0%
Yes	19	39.6%	14.8%	109	100.0%	85.2%	128	81.5%	100.0%
Total	48	100.0%	30.6%	109	100.0%	69.4%	157	100.0%	100.0%

	Trademark Infringement								
Unauthorized Reproduction	**No**			**Yes**			**Total**		
(product names/labels)	No.	Col %	Row %	No.	Col %	Row %	No.	Col %	Row %
No	57	77.0%	100.0%	0	0.0%	0.0%	57	36.3%	100.0%
Yes	17	23.0%	17.0%	83	100.0%	83.0%	100	63.7%	100.0%
Total	74	100.0%	47.1%	83	100.0%	52.9%	157	100.0%	100.0%

Table 4.3. Number of companies with at least one incidence of unauthorized reproduction of technical product elements//product names and labels as well as patent infringement/trademark infringement cases(only observations with valid answers on both types of imitation)

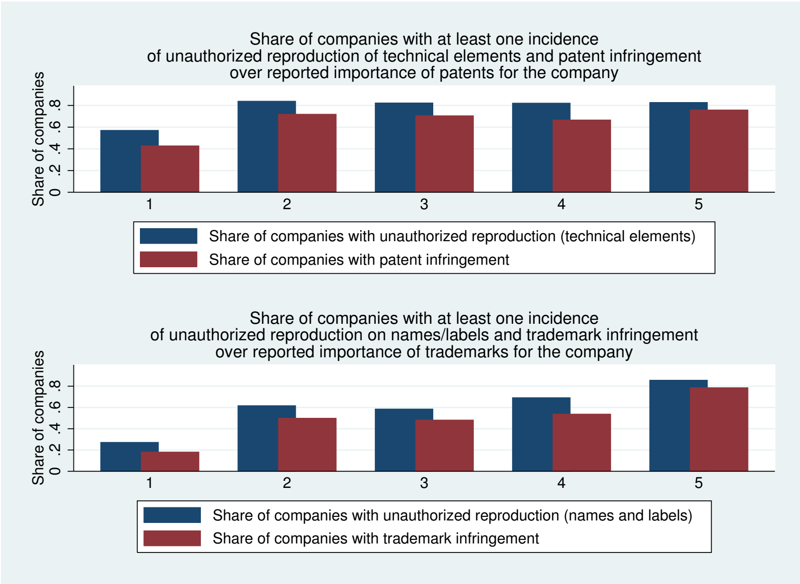

Figure 4.1. Share of companies with different types of imitation incidences over reported importance of patents and trademarks

IP Strategy

The following section analyzes how the factors grouped under the heading "IP strategic elements" relate to the incidence of unauthorized reproduction and patent/trademark incidences.

Figure 4.1 shows how the probability of a firm reporting at least one incidence of copying changes with the reported importance of patents and trademarks for the company. The upper panel of figure 4.1 shows only a very slight increase in the probability of unauthorized imitation of technical elements incidences with higher importance of patents. This also applies for actual patent infringements, for which the probability is consistently lower than for unauthorized reproduction: a weak tendency can be detected, but contingency tests (both χ^2 test and Fisher's exact test) do not suggest a statistically significant relationship. This changes for the relationship of the copying of names and labels and trademark infringement with the importance of brands. Here we find significant relations (see lower panel of figure 4.1 and table 4.8 in the appendix). A possible explanation for a positive correlation of imitation incidences with the importance of trademarks and patents could be seen as an indicator for the enabling and/or signaling effect discussed in section 4.3. We stress that this finding cannot, of course, be seen as strict proof of our enabling/signaling hypothesis, but does give an impression that the these empiric findings are, to some extent, consistent with the intuitions discussed in section 4.3.

With this precaution in mind, we now look at other elements of a firm's IP strategy: trade secret strategy, other informal protection methods and defensive publication. Since all three strategies are more relevant for technical elements than for the copying of product names or labels, we will concentrate on the unauthorized imitation of technical elements and patent infringement. Our data does not show significant relationships for unauthorized imitation incidences or for patent infringement for any of the three IP strategic factors (see figure 4.2 and table 4.9 in the appendix). However, a higher importance of trade secrets and the defensive publication seems to coincide with a higher imitation probability. This observation goes against the intuition discussed above for the trade secrets variable, where we argued that these do not cause enabling and signaling effects. The empirical findings would suggest instead that the more firms rely on trade secrets, the more they are also imitated. This could be due to the practical difficulties in keeping trade secrets from leaking (Mansfield 1985). For defensive publication, figure 4.2 (see appendix) would suggest that the information disclosed by the defensive publication strategy helps imitators in copying, despite a firm's obvious diligence in assessing what to publish and what not. Our interpretation of these relations is, however, somewhat speculative since a statistical significance is not given (see table 4.9 in the appendix).

General Strategy

In order to assess the relationship of the characteristics of a firm's general strategy with imitation, we present a number of contingency tables that illustrate our findings. Table 4.4 shows that all variables referring to business activities abroad have a significant positive relationship with both patent and trademark infringement. This clearly indicates that the loss of control over IP in foreign markets, insufficient IP protection regimes and the lack of IP enforcement effort in certain countries can endanger a company's intangible assets. We also see a clear correlation between the potential information outflow of knowledge in standardization with infringement incidences (see appendix). Surprisingly, besides patent infringement, trademark violation is also connected with standardization participation. This again shows that both IP types are highly complementary and that copying of technical elements also often coincides with the imitation of names and labels. Information leakage in cooperation – somewhat surprisingly – does not seem to be a major issue according to our data. The percentage of companies reporting a patent infringement case is even lower among firms who cooperate frequently, although the difference is not significant. A possible interpretation of this finding could be that cooperating firms are already skilled at protecting sensitive IP since they are more used to IP protection issues through the constant threat of knowledge outflow.

We have argued that a reputation of high R&D intensity can serve as a technological entry barrier and can discourage illegal imitators from copying. Table 4.5 shows that there is a negative influence on both copying phenomena which concern technology. However, we also find a negative coefficient for the imitation of names and labels and for trademark infringements. This finding would suggest that imitation phenomena largely concentrate on low to medium tech products, whereas high-tech products are relatively unaffected.

Exogenous Factors

The last group of factors comprises potential drivers of illegal imitation which are, to a large extent, exogenous to firms. In other words, firms will not be able to change these factors in the short and medium term in order to safeguard themselves against unauthorized imitation or infringement cases. These factors include the firm size category, the firm's industry affiliation and the characteristics of this industry or industry segment such as the competition intensity and the interdependence of firms with respect to intellectual property rights.

Table 4.1 has already shown several differences between industries and size classes. First, medium-sized and large firms seem to have more problems with unauthorized imitation than companies in the smallest size class. These differences are statistically significant according to Fisher's exact test. Second, the industries metal processing, chemicals and pharmaceuticals and mechanical engineering report the highest frequency of unauthorized imitation of technical elements. Chemicals and pharmaceuticals have the highest share of incidences for imitation of names and labels, but also companies in the consumer goods industry frequently reported trademark infringements. A contingency test reports a significant relationship between technical elements being copied and industry affiliation, but not for names and labels.

The last two factors under scrutiny are the level of competition and IPR dependency. Our conclusions about the theoretical effect of the level of competition in section 4.3 were ambiguous: high competition can mean low profit margins and thus low incentives for legal or illegal imitators to enter the market. On the other hand, competitive business environments can result in high competition on the technology side so that patent infringement increases or product names and labels are illegally used to earn at least a small premium on a product. This ambiguity is reflected in the empirical

Foreign Sales	Patent Infringement No Row %	No 95% CI	Yes Row %	Yes 95% CI	Total Row %
No (n=7)	71%	[32%,93%]	29%	[07%,68%]	100%
Yes (n=171)	29%	[22%,36%]	71%	[64%,78%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(1) =	8.0457				
Design-based F(1.00, 245.00) =	5.7980	Pr =	0.017		

Foreign Sales	Trademark Infringement No Row %	No 95% CI	Yes Row %	Yes 95% CI	Total Row %
No (n=7)	100%		0%		100%
Yes (n=171)	44%	[37%,52%]	56%	[48%,63%]	100%
Total (n=178)	47%	[39%,54%]	53%	[46%,61%]	100%
Pearson: Uncorrected chi2(1) =	10.9170				
Design-based F(1.00, 232.00) =	8.5941	Pr =	0.004		

Foreign Manufacturing	Patent Infringement No Row %	No 95% CI	Yes Row %	Yes 95% CI	Total Row %
No (n=45)	60%	[45%,73%]	40%	[27%,55%]	100%
Yes (n=133)	20%	[14%,28%]	80%	[72%,86%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(1) =	34.6536				
Design-based F(1.00, 245.00) =	24.9726	Pr =	0.000		

Foreign Manufacturing	Trademark Infringement No Row %	No 95% CI	Yes Row %	Yes 95% CI	Total Row %
No (n=45)	71%	[56%,82%]	29%	[18%,44%]	100%
Yes (n=133)	38%	[30%,47%]	62%	[53%,70%]	100%
Total (n=178)	47%	[39%,54%]	53%	[46%,61%]	100%
Pearson: Uncorrected chi2(1) =	18.9865				
Design-based F(1.00, 232.00) =	14.4425	Pr =	0.000		

Foreign R&D	Patent Infringement No Row %	No 95% CI	Yes Row %	Yes 95% CI	Total Row %
No (n=61)	43%	[31%,55%]	57%	[45%,69%]	100%
Yes (n=117)	24%	[17%,33%]	76%	[67%,83%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(1) =	9.1604				
Design-based F(1.00, 245.00) =	6.6013	Pr =	0.011		

Foreign R&D	Trademark Infringement No Row %	No 95% CI	Yes Row %	Yes 95% CI	Total Row %
No (n=61)	59%	[46%,71%]	41%	[29%,54%]	100%
Yes (n=117)	40%	[32%,49%]	60%	[51%,68%]	100%
Total (n=178)	47%	[39%,54%]	53%	[46%,61%]	100%
Pearson: Uncorrected chi2(1) =	7.4900				
Design-based F(1.00, 232.00) =	5.6974	Pr =	0.018		

Table 4.4. Contingency tables: foreign sales, manufacturing and R&D activities with patent and trademark infringements

	(1) Unauthorized Reproduction (technical elements)	(2) Patent Infringement	(3) Unauthorized Reproduction (names/labels)	(4) Trademark Infringement
R&D Intensity	-5.141***	-8.339***	-4.788***	-5.229***
	(-3.99)	(-4.68)	(-3.45)	(-3.33)
Observations	208	178	208	178

Marginal effects; t statistics in parentheses
(d) for discrete change of dummy variable from 0 to 1
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4.5. Simple logistic regression of the probability of unauthorized reproduction or patent/trademark infringement on company R&D intensity

findings, as we do not see a significant relationship between competition intensity and any type of imitation incidence (Table 4.11 in the appendix). Therefore, we cannot draw a conclusion with sufficient certainty. Our findings for IPR dependency are clearer and a statistically significant relationship is found for both unauthorized imitation of technical elements and patent infringement. This indicates – as expected – that situations of high interdependence ("patent thickets") provoke more IP disputes, both when the technology is patented and when it is only informally protected.

IPR Dependency	**Unauthorized Reproduction (technical elements)**				
	No		**Yes**		**Total**
	Row %	95% CI	Row %	95% CI	Row %
1 (n=40)	33%	[20%,48%]	68%	[52%,80%]	100%
2 (n=50)	22%	[13%,36%]	78%	[64%,87%]	100%
3 (n=51)	39%	[27%,53%]	61%	[47%,73%]	100%
4 (n=45)	13%	[06%,27%]	87%	[73%,94%]	100%
5 (n=22)	09%	[02%,30%]	91%	[70%,98%]	100%
Total (n=208)	25%	[20%,31%]	75%	[69%,80%]	100%
Pearson: Uncorrected chi2(4) =	17.7330				
Design-based F(4.00, 1116.00) =	3.2815	Pr =	0.011		

IPR Dependency	**Patent Infringement**				
	No		**Yes**		**Total**
	Row %	95% CI	Row %	95% CI	Row %
1 (n=35)	43%	[28%,60%]	57%	[40%,72%]	100%
2 (n=39)	23%	[12%,39%]	77%	[61%,88%]	100%
3 (n=44)	41%	[27%,56%]	59%	[44%,73%]	100%
4 (n=41)	20%	[10%,35%]	80%	[65%,90%]	100%
5 (n=19)	21%	[08%,45%]	79%	[55%,92%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(4) =	12.3105				
Design-based F(4.00, 976.00) =	2.2269	Pr =	0.064		

Table 4.6. Contingency tables: IPR dependency with unauthorized imitation and patent infringement

4.4.3 Regression Results

In this section, we will control whether our findings from section 4.4.2 hold up to a multivariate approach. We use the same set of variables as before, i.e. our dependent variables mirror whether there was an incidence of one of the four kinds of imitation for a specific company in 2007 or not.[24] Table 4.7 presents marginal effects of four probit models explaining the four outcome variables.

The lack of significance of the relationship between the importance of patents and incidences of copying also persists in the multivariate approach: we do not detect a connection between these factors. The second finding of table 4.8 also remains: the importance of trademarks in a firm's IP strategy has a positive connection with both illegal reproduction of names and labels and trademark infringement. We can, therefore, conclude that signaling could be relevant, even if we control for the industry characteristics. The threat of defensive publication by providing exploitable information to third parties seems to be relevant not only for imitation of technical elements, but also for the imitation of brands and trademarks. The variable is significant and has a positive effect. This suggests that the two kinds of copying are highly related, especially for our sample of technology-oriented firms.

Presence in foreign markets is confirmed to be an considerable risk in the group of general strategy factors. A high degree of internationalization (as measured by foreign R&D) seems to matter for both reproduction of technical elements and labels. Once copying refers specifically to patent and trademark infringements, the statistical significance of this variable is not given any more. This observation could mean that the use of formal IP in foreign market does, in fact, matter and that once patents and trademarks are properly handled, the additional risk of foreign R&D activities can be mitigated. Another variable covering aspects information outflow has a significant sign: the participation in standardization activities, which can be interpreted as an opportunity of potential information drain. The statistical significance found in section 4.4.2 is confirmed here. Again, a complementarity between the copying of technical elements and names and labels is given, since it also positively affects the infringement probability of trademarks for which obviously enabling does not matter directly.

R&D intensity was found to play a highly important role in the bivariate analyses and this result is also confirmed here. R&D intensity thus seems to be an implicit protection mechanism, arguably since illegal imitators are more inclined to copy products of low-to-medium tech companies instead of having to cope with highly complex technology. As a last observation, table 4.7 shows that – as expected – situations of overlapping IP rights, as captured by the variable "IPR dependency", cause a higher

[24]The number of observations differs from above where we analyzed only those companies with no item non-response on all variables. Since this constrains the number of cases in a way that makes multivariate analyses impossible, we now use all observations that have valid answers for all independent variables and either on unauthorized reproduction or patent infringement.

	(1) Unauthorized Reproduction (technical elements)	(2) Patent Infringement	(3) Unauthorized Reproduction (names/labels)	(4) Trademark Infringement
Importance of Patents	0.0217	0.00839	-0.0199	-0.0829*
	(0.78)	(0.23)	(-0.52)	(-1.86)
Importance of Brands	0.0245	0.0184	0.103***	0.152***
	(0.94)	(0.51)	(2.90)	(3.51)
Importance of Trade Secrets	-0.0314	-0.0526	-0.0794	-0.0490
	(-0.81)	(-1.02)	(-1.59)	(-0.82)
Importance of other informal protection	-0.0320	0.0298	-0.0345	-0.0956
	(-0.79)	(0.57)	(-0.64)	(-1.57)
Importance of Defensive Publication	0.0474*	0.0812**	0.0842**	0.0941**
	(1.80)	(2.23)	(2.31)	(2.22)
Foreign Manufacturing (d)	0.0833	0.0261	0.0107	0.0487
	(0.90)	(0.22)	(0.09)	(0.36)
Foreign R&D (d)	0.146*	0.0270	0.199**	0.00901
	(1.76)	(0.26)	(2.05)	(0.08)
Participation in Formal Standardization (d)	0.104	0.164*	0.136	0.161*
	(1.57)	(1.90)	(1.57)	(1.65)
Cooperation Intensity (d)	-0.119**	-0.0938	0.0278	-0.00773
	(-2.05)	(-1.15)	(0.33)	(-0.08)
R&D Intensity	-0.762***	-1.097***	-0.811**	-0.516
	(-3.02)	(-3.02)	(-2.01)	(-1.09)
ln(employees)	-0.0239	0.0227	0.0115	0.0623**
	(-1.33)	(0.91)	(0.47)	(2.16)
Competition Intensity	0.0513	0.0267	0.00528	0.0282
	(1.41)	(0.56)	(0.10)	(0.47)
IPR Dependency	0.0513**	0.0570*	0.0106	-0.0393
	(1.98)	(1.76)	(0.33)	(-1.10)
Plastics (d)	-0.332	-0.238	-0.485***	-0.433***
	(-1.44)	(-0.91)	(-4.43)	(-3.00)
Mechanical Engineering (d)	-0.0821	-0.151	-0.270*	-0.299*
	(-0.66)	(-0.91)	(-1.82)	(-1.75)
Metal Processing (d)	0.174**	0.104	-0.240	-0.233
	(2.48)	(0.65)	(-1.42)	(-1.19)
Electrical Engineering (d)	-0.122	-0.195	-0.279*	-0.330**
	(-0.90)	(-1.10)	(-1.89)	(-1.97)
Consumer Goods (d)	-0.121	-0.231	-0.110	-0.151
	(-0.70)	(-1.09)	(-0.57)	(-0.70)
Other manufacturing (d)	-0.352	0.0181	-0.403***	0.0402
	(-1.45)	(0.07)	(-2.67)	(0.14)
Observations	208	178	208	178

Marginal effects; t statistics in parentheses; (d) for discrete change of dummy variable from 0 to 1
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4.7. Probit models - marginal effects

probability of firms having to deal with illegal imitation of technological elements. In general, company size does not have a strong significant impact once controlling for other factors in three of the four models, table 4.7 shows an influence of firm size only for the trademark infringement.

4.5 Summary and Conclusion

We have examined the relevance of different factors of a firm's IP strategy, its general business strategy and its business environment for the incidence of unauthorized reproduction of a company's technical elements and names and labels, both with and without formal IP protection rights (patent or trademark). We find that a firm's general strategy alignment seems to matter more than the use of formal IP rights in avoiding unauthorized reproduction or infringement incidences with respect to technical elements. Especially strategic behavior which poses the risk of potential information leakage (defensive publication, participation in standardization activities, R&D activities out the home market) is connected with a higher likelihood of (illegal) imitation.

A number of managerial implications can be drawn from our analysis. Firms confronted with the threat of brand counterfeiting should be particularly aware of possible unwanted effects of their IP strategy. An example is the signaling effect of a brand registration to potential imitators, which could have the detrimental effect of causing illegal imitators' market entry. As mentioned before, there are many example for the practical relevance of this signaling effect such as various websites (e.g., ipnewsflash.com or trademarkblog.com) which monitor the trademark activities of firms and discuss upcoming new products these trademarks would be used for. In general, it should be stressed that any anti-piracy strategy has to be seen as interdependent with general strategic aspects for example when it comes to establishing R&D facilities abroad. Since an IP strategy detached from the general business framework can be expected to have only limited success (especially for imitation of technological elements), an integration of IP and overall business strategy is needed. This is particularly important for companies active in the international market since internationalization (especially of sensitive units such as research and development staff) is shown to be a significant driving factor of unauthorized imitation. Also, a signaling effect of a high research intensity can be exploited to discourage illegal imitator even by companies, which are not *per se* highly innovative. Technological means of protection, e.g. IT-security technologies, may offer an alternative way to successfully prevent product piracy.

This paper is the first attempt to empirically measure the relationship of different strategic characteristics of a company with the exposure to IP infringement issues. There are a number of limitations of our study. Firstly, we had to rely on survey responses from company representatives which allow a very detailed view, but mirror only subjective ratings of different phenomena. Furthermore, it is unclear to what extent companies are themselves aware of the "true" amount of infringement incidences. Also, a further analysis at the product level could be promising, since differences between products might exist, even within a particular firm. On the methodological side, further research needs to take into account endogeneity or reverse causation issues in the multivariate regressions, e.g. by examining the use of appropriate instrumental variables. At the present time, we are aware that a causal interpretation of some of our results is not possible and we tried to be cautious with this issue. The future use of panel data can help to address some of these concerns. Furthermore, research is needed to link information on the supply side (both originators and imitators) to demand characteristics. This combination could help to create a holistic analysis framework allowing insights on substitution rates between original and copied goods or consumer deception rates concerning the originality of products. These results might also indicate how illegal imitators will respond to the anti-piracy strategies suggested here and how this affects market dynamics. There are thus important paths to address in the future.

Bibliography

Agarwal, R., M. Ganco, and R. H. Ziedonis (2009), Reputations for toughness in patent enforcement: implications for knowledge spillovers via inventor mobility, Strategic Management Journal, 30(13): 1349–1374.

APM (2008), Studie des DIHK und des APM zu Produkt- und Markenpiraterie in Deutschland, Berlin.

Arundel, A. (2001), The relative effectiveness of patents and secrecy for appropriation, Research Policy, 30(4): 611–624.

Becker, W. and J. Dietz (2004), R&D cooperation and innovation activities of firms - evidence for the German manufacturing industry, Research Policy, 33(2): 209–223.

Belleflamme, P. and P. M. Picard (2007), Piracy and competition, Journal of Economics and Management Strategy, 16(2): 351–383.

Blind, K., A. Cuntz, F. Köhler, and A. Radauer (2009), The economic significance of intangible capital and its protection in the German economy - a study focus on small and medium enterprises, German Federal Ministry of Economics and Technology, Berlin.

Blind, K., J. Edler, R. Frietsch, and U. Schmoch (2006), Motives to patent: Empirical evidence from Germany, Research Policy, 35(5): 655–672.

Blind, K. and N. Thumm (2004), Interrelation between patenting and standardisation strategies: empirical evidence and policy implications, Research Policy, 33(10): 1583–1598.

Bosworth, D. (2006), Counterfeiting and piracy: the state of the art, Working Paper.

BSA (2008), 5th Annual BSA and IDC Global Piracy Study, Washington, D.C.

Castro, J. O. D., D. B. Balkin, and D. A. Shepherd (2008), Can entrepreneurial firms benefit from product piracy?, Journal of Business Venturing, 23(1): 75–90.

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

Conner, K. R. and R. P. Rumelt (1991), Software piracy - an analysis of protection strategies, Management Science, 37(2): 125–139.

Cordell, V. V., N. Wongtada, and R. L. Kieschnick (1996), Counterfeit purchase intentions: Role of lawfulness attitudes and product traits as determinants, Journal of Business Research, 35(1): 41–53.

Denicolo, V. and L. A. Franzoni (2004), Patents, secrets, and the first-inventor defense, Journal of Economics and Management Strategy, 13(3): 517–538.

EPO (2003), Survey on the Need and Usage of Patent Information, European Patent Office, Munich.

Gassmann, O. and Z. Han (2004), Motivations and barriers of foreign R&D activities in China, R & D Management, 34(4): 423–437.

Givon, M., V. Mahajan, and E. Muller (1995), Software piracy - estimation of lost sales and the impact on software diffusion, Journal of Marketing, 59(1): 29–37.

Granstrand, O., L. Hakanson, and S. Sjolander, eds. (1992), Internationalization of R&D and Technology, New York, John Wiley and Sons.

Grant, R. M. (1996), Toward a knowledge-based theory of the firm, Strategic Management Journal, 17: 109–122.

Grossman, G. M. and C. Shapiro (1988a), Counterfeit-product trade, American Economic Review, 78(1): 59–75.

Grossman, G. M. and C. Shapiro (1988b), Foreign counterfeiting of status goods, Quarterly Journal of Economics, 103(1): 79–100.

Harabi, N. (1995), Appropriability of technical innovations - An empirical analysis, Research Policy, 24(6): 981–992.

Harvey, M. G. and I. A. Ronkainen (1985), International counterfeiters - marketing success without the cost and the risk, Columbia Journal of World Business, 20(3): 37–45.

Henkel, J. and S. Pangerl (2008), Defensive publishing - an empirical study, DRUID Working Paper No. 08-04.

Jaffe, A. B. (1986), Technological opportunity and spillovers of research-and-development - evidence from firms patents, profits, and market value, American Economic Review, 76(5): 984–1001.

Johanson, J. and J. E. Vahlne (1977), Internationalization process of firm - model of knowledge development and increasing foreign market commitments, Journal of International Business Studies, 8(1): 23–32.

Katz, M. L. and C. Shapiro (1994), Systems competition and network effects, Journal of Economic Perspectives, 8(2): 93–115.

Keupp, M. M., A. Beckenbauer, and O. Gassmann (2009), How managers protect intellectual property rights in China using de facto strategies, R & D Management, 39(2): 211–224.

Kingston, W. (2000), Enforcing small firms' patent rights, European Commission, DG Enterprise.

Mansfield, E. (1985), How rapidly does new industrial-technology leak out, Journal of Industrial Economics, 34(2): 217–223.

OECD (1998), The Economic Impact of Counterfeiting, Organisation for Economic Co-operation and Development, Paris.

OECD (2007), OECD Compendium of Patent Statistics, Organisation for Economic Co-operation and Development, Paris.

Olsen, J. E. and K. L. Granzin (1992), Gaining retailers assistance in fighting counterfeiting - conceptualization and empirical-test of a helping model, Journal of Retailing, 68(1): 90–109.

Qian, Y. (2008), Impacts of entry by counterfeiters, Quarterly Journal of Economics, 123(4): 1577–1609.

Raustiala, K. and C. Sprigman (2009), The piracy paradox revisited, Stanford Law Review, 61(5): 1201–1225.

VDMA (2007), Produkt- und Markenpiraterie in der Investitionsgüterindustrie, Frankfurt am Main.

Weatherall, K. and E. Webster (2009), Patent Infringement in Australia: Results from a survey, Intellectual Property Research Institute of Australia Working Paper Series, 10/09.

Appendix

Importance of patents	Unauthorized Reproduction (technical elements)				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=11)	45%	[20%,73%]	55%	[27%,80%]	100%
2 (n=30)	30%	[16%,48%]	70%	[52%,84%]	100%
3 (n=69)	25%	[16%,36%]	75%	[64%,84%]	100%
4 (n=60)	18%	[10%,30%]	82%	[70%,90%]	100%
5 (n=38)	26%	[15%,42%]	74%	[58%,85%]	100%
Total (n=208)	25%	[20%,31%]	75%	[69%,80%]	100%
Pearson: Uncorrected chi2(4) =	5.8317				
Design-based F(4.00, 1120.00) =	1.0753	Pr =	0.367		

Importance of patents	Patent Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=9)	56%	[25%,82%]	44%	[18%,75%]	100%
2 (n=27)	30%	[15%,49%]	70%	[51%,85%]	100%
3 (n=61)	30%	[19%,42%]	70%	[58%,81%]	100%
4 (n=49)	33%	[21%,47%]	67%	[53%,79%]	100%
5 (n=32)	22%	[11%,39%]	78%	[61%,89%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(4) =	5.4496				
Design-based F(4.00, 980.00) =	0.9818	Pr =	0.416		

Importance of trademarks	Unauthorized Reproduction (names/labels)				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=19)	68%	[45%,85%]	32%	[15%,55%]	100%
2 (n=45)	49%	[35%,63%]	51%	[37%,65%]	100%
3 (n=76)	47%	[36%,59%]	53%	[41%,64%]	100%
4 (n=35)	43%	[28%,60%]	57%	[40%,72%]	100%
5 (n=33)	24%	[13%,42%]	76%	[58%,87%]	100%
Total (n=208)	45%	[39%,52%]	55%	[48%,61%]	100%
Pearson: Uncorrected chi2(4) =	13.8256				
Design-based F(4.00, 1096.00) =	2.6048	Pr =	0.034		

Importance of trademarks	Trademark Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=14)	79%	[50%,93%]	21%	[07%,50%]	100%
2 (n=36)	50%	[34%,66%]	50%	[34%,66%]	100%
3 (n=65)	51%	[39%,63%]	49%	[37%,61%]	100%
4 (n=32)	44%	[28%,61%]	56%	[39%,72%]	100%
5 (n=31)	23%	[11%,41%]	77%	[59%,89%]	100%
Total (n=178)	47%	[39%,54%]	53%	[46%,61%]	100%
Pearson: Uncorrected chi2(4) =	17.8841				
Design-based F(4.00, 928.00) =	3.4010	Pr =	0.009		

Table 4.8. Contingency tables: importance of patents/brands and reported incidences of unauthorized reproduction (technical product elements/names and labels) and patent/trademark infringement

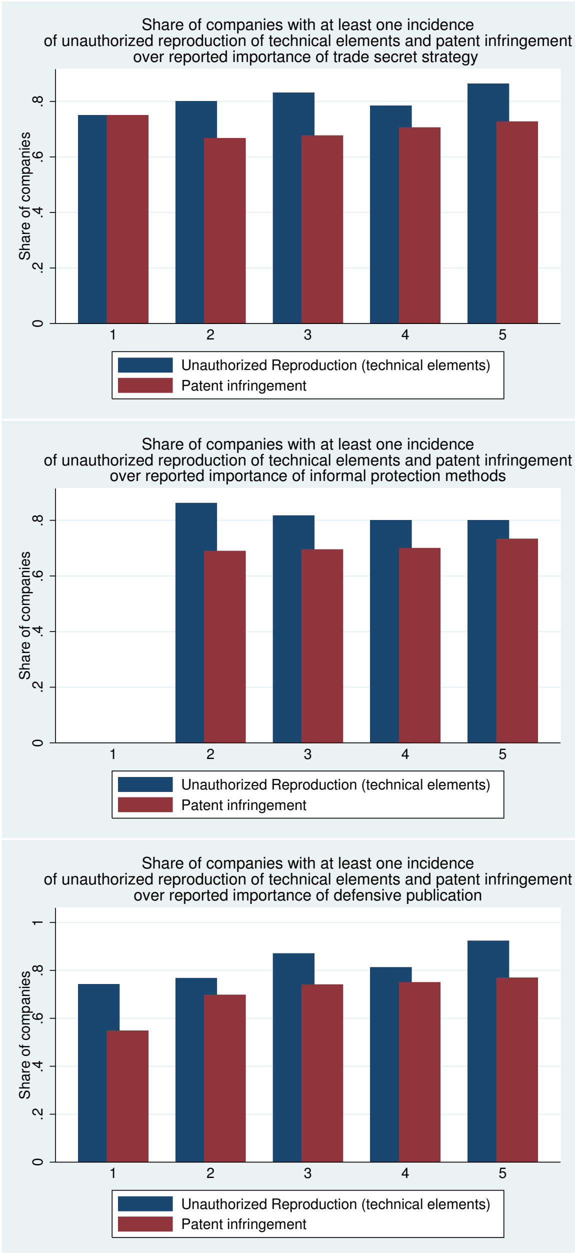

Figure 4.2. Share of companies with unauthorized reproduction of technical elements and patent infringement over the importance of different informal protection methods

Importance of Trade Secrects	Unauthorized Reproduction (technical elements)				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=4)	25%	[03%,76%]	75%	[24%,97%]	100%
2 (n=15)	20%	[07%,47%]	80%	[53%,93%]	100%
3 (n=65)	17%	[10%,28%]	83%	[72%,90%]	100%
4 (n=51)	22%	[12%,35%]	78%	[65%,88%]	100%
5 (n=22)	14%	[04%,35%]	86%	[65%,96%]	100%
Total (n=157)	18%	[13%,25%]	82%	[75%,87%]	100%
Pearson: Uncorrected chi2(4) =	1.6222				
Design-based F(4.00, 1120.00) =	0.2258	Pr =	0.924		

Importance of Trade Secrets	Patent Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=4)	25%	[03%,77%]	75%	[23%,97%]	100%
2 (n=15)	33%	[15%,60%]	67%	[40%,85%]	100%
3 (n=65)	32%	[22%,45%]	68%	[55%,78%]	100%
4 (n=51)	29%	[19%,43%]	71%	[57%,81%]	100%
5 (n=22)	27%	[13%,49%]	73%	[51%,87%]	100%
Total (n=157)	31%	[24%,38%]	69%	[62%,76%]	100%
Pearson: Uncorrected chi2(4) =	0.5481				
Design-based F(4.00, 980.00) =	0.0871	Pr =	0.986		

Importance of other informal protection methods	Unauthorized Reproduction (technical elements)				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=1)	100		0%		100%
2 (n=29)	14%	[05%,32%]	86%	[68%,95%]	100%
3 (n=82)	18%	[11%,28%]	82%	[72%,89%]	100%
4 (n=30)	20%	[09%,38%]	80%	[62%,91%]	100%
5 (n=15)	20%	[07%,47%]	80%	[53%,93%]	100%
Total (n=157)	18%	[13%,25%]	82%	[75%,87%]	100%
Pearson: Uncorrected chi2(4) =	8.7823				
Design-based F(4.00, 1119.99) =	1.2242	Pr =	0.299		

Importance of other informal protection methods	Patent Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=1)	100%		0%		100%
2 (n=29)	31%	[17%,50%]	69%	[50%,83%]	100%
3 (n=82)	30%	[21%,41%]	70%	[59%,79%]	100%
4 (n=30)	30%	[16%,48%]	70%	[52%,84%]	100%
5 (n=15)	27%	[10%,54%]	73%	[46%,90%]	100%
Total (n=157)	31%	[24%,38%]	69%	[62%,76%]	100%
Pearson: Uncorrected chi2(4) =	3.7394				
Design-based F(4.00, 979.99) =	0.5951	Pr =	0.666		

Importance of defensive publication	Unauthorized Reproduction (technical elements)				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=31)	26%	[13%,44%]	74%	[56%,87%]	100%
2 (n=43)	23%	[13%,38%]	77%	[62%,87%]	100%
3 (n=54)	13%	[06%,25%]	87%	[75%,94%]	100%
4 (n=16)	19%	[06%,45%]	81%	[55%,94%]	100%
5 (n=13)	08%	[01%,39%]	92%	[61%,99%]	100%
Total (n=157)	18%	[13%,25%]	82%	[75%,87%]	100%
Pearson: Uncorrected chi2(4) =	6.8961				
Design-based F(4.00, 1120.00) =	0.9598	Pr =	0.429		

Importance of defensive publication	Patent Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=31)	45%	[29%,63%]	55%	[37%,71%]	100%
2 (n=43)	30%	[18%,45%]	70%	[55%,82%]	100%
3 (n=54)	26%	[16%,39%]	74%	[61%,84%]	100%
4 (n=16)	25%	[10%,51%]	75%	[49%,90%]	100%
5 (n=13)	23%	[08%,52%]	77%	[48%,92%]	100%
Total (n=157)	31%	[24%,38%]	69%	[62%,76%]	100%
Pearson: Uncorrected chi2(4) =	6.6407				
Design-based F(4.00, 980.00) =	1.0552	Pr =	0.378		

Table 4.9. Importance of trade secrets, informal protection methods and defensive publication and reported incidences of unauthorized reproduction (technical product elements) and patent infringement

Participation in Formal Standardization	Patent Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
No (n=65)	48%	[36%,60%]	52%	[40%,64%]	100%
Yes (n=113)	20%	[14%,29%]	80%	[71%,86%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(1) =	19.6758				
Design-based F(1.00, 239.00) =	14.5320	Pr =	0.000		

Participation in Formal Standardization	Trademark Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
No (n=65)	60%	[48%,71%]	40%	[29%,52%]	100%
Yes (n=113)	39%	[30%,48%]	61%	[52%,70%]	100%
Total (n=178)	47%	[39%,54%]	53%	[46%,61%]	100%
Pearson: Uncorrected chi2(1) =	9.3802				
Design-based F(1.00, 226.00) =	7.3230	Pr =	0.007		

Cooperation Intensity	Patent Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
Low (n=65)	26%	[17%,38%]	74%	[62%,83%]	100%
High (n=113)	33%	[25%,42%]	67%	[58%,75%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(1) =	1.1431				
Design-based F(1.00, 239.00) =	0.8443	Pr =	0.359		

Cooperation Intensity	Trademark Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
Low (n=65)	48%	[36%,60%]	52%	[40%,64%]	100%
High (n=113)	46%	[37%,55%]	54%	[45%,63%]	100%
Total (n=178)	47%	[39%,54%]	53%	[46%,61%]	100%
Pearson: Uncorrected chi2(1) =	0.0593				
Design-based F(1.00, 226.00) =	0.0463	Pr =	0.830		

Table 4.10. Contingency tables: participation in standardization activities and cooperation intensity with patent and trademark infringements

Competition Intensity	Unauthorized Reproduction (technical elements)				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=0)	No observations *				
2 (n=6)	50%	[17%,83%]	50%	[17%,83%]	100%
3 (n=24)	38%	[21%,58%]	63%	[42%,79%]	100%
4 (n=82)	24%	[16%,35%]	76%	[65%,84%]	100%
5 (n=96)	21%	[14%,30%]	79%	[70%,86%]	100%
Total (n=208)	25%	[20%,31%]	75%	[69%,80%]	100%
*: chi2 calculated excluding values 1 for competition intensity (no observations)					
Pearson: Uncorrected chi2(3) =	4.9051	Pr =	0.179		

Competition Intensity	Patent Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=0)	No observations				
2 (n=6)	50%	[17%,83%]	50%	[17%,83%]	100%
3 (n=20)	40%	[21%,62%]	60%	[38%,79%]	100%
4 (n=71)	34%	[24%,46%]	66%	[54%,76%]	100%
5 (n=81)	23%	[15%,34%]	77%	[66%,85%]	100%
Total (n=178)	30%	[24%,38%]	70%	[62%,76%]	100%
Pearson: Uncorrected chi2(3) =	5.7562				
Design-based F(3.00, 729.00) =	1.3940	Pr =	0.243		

Competition Intensity	Unauthorized Reproduction (names/labels)				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=0)	No observations *				
2 (n=6)	50%	[17%,83%]	50%	[17%,83%]	100%
3 (n=24)	67%	[46%,82%]	33%	[18%,54%]	100%
4 (n=82)	39%	[29%,50%]	61%	[50%,71%]	100%
5 (n=96)	45%	[35%,55%]	55%	[45%,65%]	100%
Total (n=208)	45%	[39%,52%]	55%	[48%,61%]	100%
*: chi2 calculated excluding values 1 for competition intensity (no observations)					
Pearson: Uncorrected chi2(3) =	5.7900	Pr =	0.122		

Competition Intensity	Trademark Infringement				
	No		Yes		Total
	Row %	95% CI	Row %	95% CI	Row %
1 (n=0)	No observations				
2 (n=6)	67%	[27%,92%]	33%	[08%,73%]	100%
3 (n=20)	65%	[42%,82%]	35%	[18%,58%]	100%
4 (n=71)	44%	[33%,55%]	56%	[45%,67%]	100%
5 (n=81)	43%	[33%,54%]	57%	[46%,67%]	100%
Total (n=178)	47%	[39%,54%]	53%	[46%,61%]	100%
Pearson: Uncorrected chi2(3) =	5.6201				
Design-based F(3.00, 693.00) =	1.4311	Pr =	0.232		

Table 4.11. Contingency tables: competition intensity with unauthorized imitation and patent/trademark infringement

Chapter 5

An Empirical Analysis of the Effect of Product Piracy on Corporate IP Strategy

Abstract I analyze how cases of unauthorized reproduction of a company's technological elements ("product piracy") influence the subsequent intellectual property protection strategy of around 200 German manufacturing companies. In specific, I examine whether product piracy induces a stronger use of formal IP strategies such as patents or whether a shift to informal protection mechanisms occurs. Using a propensity score matching approach, I compare companies with similar company characteristics in terms of their prior IP strategy, business activities, industry affiliation and other characteristics. I find that imitation incidences induce a stronger use of formal protection rights, whereas for informal protection such as secrecy I detect no significant differences between the copied companies and the control group. These results contribute to the discussion on the effects of the increasingly relevant phenomenon of product piracy by analyzing possible effects on IP strategies of firms and the subsequent economic consequences.

5.1 Introduction

In recent years, discussions on imperfections in the patent system worldwide have been getting more frequent. Apart from problems with patent quality, intellectual property (IP) fragmentation, growing numbers of litigation cases, "patent trolls" or the patent flood in general (see e.g. Bessen and Meurer 2008), the attention towards infringement of patents and trademarks subsumed under the terms product piracy and counterfeiting is rising. An often cited OECD report suggests that international trade in tangible counterfeit and pirated goods could have accounted for up to US-$ 200 billion in 2005 and that there was a steadily growing trend for this figure in the period 2000 to 2007 (OECD 2007, 2009). Consequently, the EU and a number of other WTO members began working on a new international agreement in 2007 – the Anti-Counterfeiting Trade Agreement (ACTA) – and industry representatives make a tremendous effort in raising public awareness by promoting their own estimates of the impact of product piracy on innovative activities, sales, employment figures, or tax revenues. However, sound empirical research on the effects of product piracy and counterfeiting is scarce for obvious reasons: it is extremely difficult, if not impossible, to i) obtain suitable data on a clandestine activity such as counterfeiting and ii) calculate effects of piracy on the outcome of interest (sales, profits, innovative activity).

This paper is among the first to systematically analyze one specific detail of interest. I explore how companies react to incidences of unauthorized reproduction of their proprietary technology, specifically how they adapt their (IP) strategy after such an incidence. I concentrate on two broad groups of strategies concerning the appropriation of innovation rents: formal intellectual property rights such as patents or utility models and the use of informal or contractual protection mechanisms such as trade secrets or non-disclosure agreements. Using survey data among German manufacturing companies, I employ a matching approach to compare IP strategies of companies which are similar characteristics such as firm size, research intensity, past IP strategy and industry affiliation. The companies differ in one decisive aspect, namely whether they have reported cases of unauthorized reproduction of own technology (product piracy) for the reference year 2007 in the survey.

While it can be expected that all companies, especially if they are active in critical markets such as Asian economies, will react to changing appropriability conditions and weaknesses in the IP system, it seems worth analyzing whether the reaction of firms directly affected by product piracy differs from the effect on those affected only indirectly via a general, perceived deterioration of the IP situation. It will be furthermore interesting to explore whether incidences of unauthorized copying will push an imitated company into using patents even more strongly to secure their IP or if this will induce a shift towards informal protection mechanisms. There is anecdotal evidence for both cases. On the one hand, growing counterfeiting, product piracy and patent infringement cases, cause policy makers to encourage companies (especially SMEs) to use patents and trademarks more strongly and design support programs for that purpose. The growing number of patent litigation cases (Landes and Posner 2003) also suggests that patents are heavily used and defended, even in situations of uncertain effectiveness of patents. On the other hand, there is case study evidence on company IP strategies in countries with low enforcement regimes suggesting that companies refrain from using patents to avoid the information disclosure in patent documents and rather turn to informal, *de facto* protection strategies (Keupp et al. 2009). In any case, these reactions will not be uniform for all firms, but differ along industry and firm characteristics. In the following section, I will therefore review the existent literature concerning the relevance of different IP strategies for different companies. In the empirical part, I will attempt to match only those companies for comparison which are similar with respect to the factors determining IP strategies discussed in section 5.2. The matching methodology is discussed in section 5.3, section 5.4 presents the results. After some robustness checks of the analysis, I summarize and conclude in section 5.5.

5.2 Use of Formal and Informal Protection Mechanisms: Related Literature and Theoretical Background

A large strand of literature deals with the use of formal protection mechanisms (especially patents) and the relative importance of trade secrets, lead time advantages and other informal appropriation mechanisms. Many authors have found great differences both regarding the economic effects of patent *per se* and the degree to which they are used by firms and accordingly also the use of informal protection alternatives. These differences depend on a number of parameters. I will shortly review the most important aspects relevant for this paper, since they will have to be taken into account in the empirical setup in section 5.4.

First, one has to distinguish between large corporations and small and medium-sized companies (SMEs). Most studies suggest that the propensity to patent (usually defined as the number of patents per R&D dollar (e.g. Hall and Ziedonis 2001)) increases with firm size.[1] Arundel (2001) correspondingly found that smaller firms

[1] Audretsch (2002) states, however, that small firms have higher patenting rates when measured on a per-employee basis.

value secrecy more than large firms. Similar findings are also indicated by Thumm (2001) in a sector-specific analysis of the biotechnology industry. These findings are presumably due to the lack of financial and human resources in SMEs, which is needed to protect inventions with patents, but also to a certain lack of knowledge about the patent system.[2] Although the relative effectiveness of secrecy compared to patents is regarded as high by firms of all sizes (Cohen et al. 2000), it is often argued that the patent system favors large firms for various reasons (Kingston 2000): Among those reasons is the mentioned financial and organizational leeway needed to file large numbers of patents in different legislations. Large corporations use theses resources for strategic patenting and "crowd out" smaller players from the market (Lanjouw and Schankerman 2004). Additionally, SMEs often do not have the means to defend patents in cases of litigation and therefore do not file patents beforehand (Kingston 2000).

Second, there are large differences between industries in the effectiveness and the resulting use of patents and accordingly also in the use of the alternative, informal, appropriation mechanisms. Arundel and Kabla (1998) report that the average propensity to patent for product innovations in EU ranges from 8.1% in textiles to 79.2% in pharmaceuticals and for process innovations from 8.1% in textiles to 46.8% in precision instruments.[3] The reasons for these different patent propensities are – again – manifold. An important role plays the extent to which a patent can be invented around (Harabi 1995). Chemical and pharmaceutical patents, for example, cover a well-defined chemical composition: they are unusually strong, difficult to invent around, and there is substantial tacit knowledge involved which is not disclosed in the patent document (von Hippel 1988). The role of tacit knowledge refers to the degree to which technology can be codified in machines, technical reports, trade journals, or patent documents. Chemical and drug industries, for example, produce highly codified technology (Mandeville 1996). The importance of patents is thus higher in these industries. The extent to which a technology is codified, has also an effect on technology transfer. Patents provide an easy means for an innovator to license the technology, different licensing practices in industries can consequently result in different needs to obtain patents (Arora et al. 2001). Patenting for licensing reasons is one example for incentives to use the patenting system strategically, i.e.

[2] One other reason for the relative importance of secrecy is that smaller firms have better chances to keep confidential information secret, since there are fewer potential sources for information leakage (e.g., through disloyal employees).

[3] This figures also show the different relevance of patents and secrecy for process and product innovations within industries. For process innovations secrecy is almost always seen as the most effective mechanisms (Cohen et al. 2000).

for other reasons than protecting an invention. A further strategic incentive results from characteristics in the IP landscape: industries like semiconductors or telecommunication face a high fragmentation of IP rights, meaning that patents are held by many different players in the market. If there is furthermore high technological complexity – i.e. a large numbers of different patents are necessarily needed to produce a specific product (Cohen et al. 2000) – hold-up situations and mutual blocking can be a threat (Shapiro 2001, Grindley and Teece 1997). These hold-up situations can partially be solved by technology licensing, patent pools or similar institutions, but these organizations also cause incentives for companies to artificially boost up their patent portfolio with a large number of applications in order to secure their position in licensing negotiations (Hall and Ziedonis 2001). As a result, the propensity to patent is higher in "complex" industries (Cohen et al. 2000).

Differences in the use of patents can be observed on an even more aggregated level, the country level. This is due to different IP laws such as rules on the inventive step necessary for obtaining a patent, on the patentability of controversial subject matter (e.g. software or business methods) and many other factors. The cost of patenting obviously plays an important role. Obtaining patents is more expensive in Europe than in the United States (van Pottelsberghe de la Potterie and François 2006). Consequently, the propensity to patent in the US as reported by Cohen et al. (2000) is higher than the one in Europe (Arundel and Kabla 1998).[4]

It should be noted, that the differences in the use of patents between companies mirror also the reliance on informal protection methods, especially secrecy. For instance, in the survey by Cohen et al. (2000) those industries which indicate patents to be less important tend to attach a higher importance to secrecy, e.g. the food and textile industries or the machine tool industry.[5] This means that much of the previous discussion on differences in the use of patents between size classes, industries and countries also applies to disparities in the use of informal methods.

After the survey the usage of patents and informal protection mechanisms in general, I shortly review some of the few studies which analyze the effect of illegal reproduction incidences on the way companies try to appropriate innovation rents.

Most of the available research provides case study evidence. Keupp et al. (2009) describe strategies of 13 companies active in China which experienced IP infringement,

[4] For an analysis of the effect of different fees on patenting behavior see de Rassenfosse and van Pottelsberghe de la Potterie (2007) and Harhoff et al. (2009).

[5] However, the relationship between these two strategies need not necessarily be substitutive, since also other mechanisms (e.g. lead time, complementary services) exist.

both concerning technological elements and trademarks. They report that firms resort to using "*de facto* protection strategies" which comprise informal protection strategies such as technological specialization, secrecy, customer education and the exploitation of a China-specific phenomenon called *guanxi*. This means that companies exploit social norms which "prohibit" harming people with whom one has a social relationship. Thus, managers build trusting relationships to be able to "exploit guanxi to exert pressure on Chinese employees" (Keupp et al. 2009).

Qian (2008) conducted a very comprehensible study on entry effects of counterfeiters in the Chinese footwear market.[6] She finds that counterfeiter entry and sales induce originators to upgrade quality with more expensive materials and to differentiate their products from counterfeits. Counterfeiting additionally generates endogenous sunk costs including quality investments, self-enforcement efforts, the vertical integration of retail stores and other non-price signals. As a result of rising costs, she also reports significantly higher prices after counterfeit entry. She does not explicitly analyze effects of the IP strategy and does not regard a change in the use of patents at all, probably since patents are not the primary instrument for IP protection in the footwear industry. However, her findings can be interpreted as product piracy having a significant effect on informal ways to secure innovation rents. Those informal ways can also include a stronger business relationship with retailers. Olsen and Granzin (1992) provide some insights how manufacturers can successfully integrate retailers in fighting counterfeits.

The literature on patent litigation also produced some insights for the use of patents after alleged or real IP infringements. Although she does not focus on patenting strategies *per se*, Lanjouw (1998) shows that potential prosecution costs – and, more generally, concerns about the validity of patents – lower the value of patents and can thus lead to fewer patenting or at least induce a decision against renewals. However, the literature on patent thickets and strategic patenting indicates that the treat of litigation could increase the use of patents since they give the possibility for a judicial "counterstrike" against a plaintiff and increase the bargaining power in out-of-court settlements (Hall and Ziedonis 2001).

It should also be noted that there are some authors which put forward that illegal imitation – whether it actually occurred or is only a potential threat – does not necessarily only have negative effects. Raustiala and Sprigman (2009) argue that piracy

[6] Due to her empirical setting, Qian (2008) does not primarily focus on the imitation of technological elements. A comparison of her results and this present study has to take this difference into account.

can have positive effects in some industries. Their example refers to the fashion industry. They have two main arguments. One states that the process of diffusion trough counterfeiting leads to dissipation of social value of a good, which in turn creates more demand for the next generation of fashion designs (induced obsolescence). The other refers to the fact that copying also helps in generating fashion trends which help originators to establish their design (anchoring). The authors than state that these two phenomena help to explain that the fashion industry has a “stable political equilibrium of low IP protection”. If this is in fact the case, counterfeiting might thus interestingly provoke no changes in IP strategies in some industries at all. The empirical analysis of this paper will concentrate on manufacturing firms for which the validity of Raustiala and Sprigman (2009)’s argumentation is clearly limited. However, positive effects of counterfeiting and product piracy can also result from pirates creating network effects for original goods (Conner and Rumelt 1991), if it is assumed that buying counterfeits induces future legal purchases (Givon et al. 1995) or if imitation signals a particularly high quality of the original good (Castro et al. 2008).

5.3 Study Design and Methodology

The goal of this paper will be to evaluate how observed cases of unauthorized reproduction of a company’s technical elements (“product piracy”) influence a company’s IP strategy. I separately analyze a potential reaction in the use of formal protection methods such as patents and informal protection strategies such as emphasizing secrecy to protect intangible assets. I rely on survey data providing both information on the observed cases of unauthorized imitation and on the self-reported reaction caused by these cases. The questionnaire items referring to changes in IP strategies were answered by imitated companies and non-imitated companies. Thus, even if it is clear that a changing importance of IP, worse enforcement prospects of patents, or a generally higher frequency of “unauthorized reproduction” will trigger adaptations in every company’s IP strategy, through this analysis I can separate indirect effects from the ones emerging in directly affected firms (see figure 5.1). The comparison of the indirectly and directly affected firme with the ones only affected indirectly firms makes this analysis possible.

Since the existing literature on this topic is scarce, there is no sufficient empirical evidence to derive conclusive expectations regarding the changes in IP strategies *per se* which could lead to testable hypotheses. Therefore, the following analysis has a

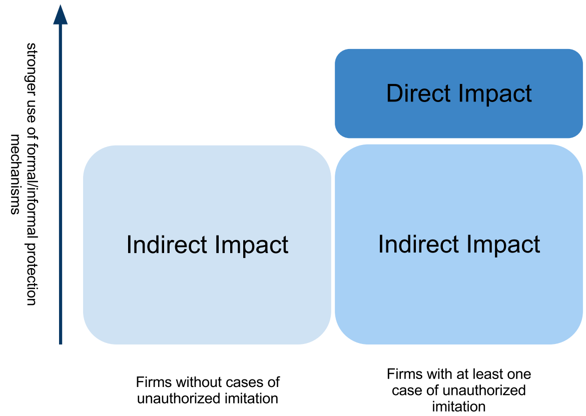

Figure 5.1. Direct versus indirect effects of unauthorized imitation

rather explorative character and will try to obtain first evidence in answering the following research question: Will cases of unauthorized reproduction lead a company to rely even more strongly on formal IP or will the firm refrain from this strategy since it has been proven partially unsuccessful in the past? Will we be able to identify any impact at all? What reaction can we expect for the informal protection methods? The literature reviewed in section 5.2 indicates a stronger reliance on informal methods of different kinds when companies are confronted with counterfeiting, but further research is needed.

It seems clear, however, that the "reaction functions" will not be uniform for all companies. As shown many times in the literature, the use of patents and informal protection methods differs between companies and the same will presumably apply to IP strategies induced by illegal imitation. To identify the effect of unauthorized imitation independently from company characteristics, it is therefore necessary to apply a suitable evaluation framework. This framework intends to rule out self selection effects, which could bias the results if one would do a simple comparison of the companies affected by direct unauthorized reproduction cases and the ones who are not directly affected. Such selection bias would, for instance, exist if the previous use of patents both influences the probability of unauthorized reproduction and the use of patents after the imitation incidence. An observed stronger use of patents would then possibly not be caused by the imitation incidence, but by the path dependency in IP strategies. It is therefore important to compare only those companies which are in fact comparable. In an ideal world, the researcher would have two observations of one company: the patenting behavior after an imitation incidence and the patenting behavior had the imitation not occurred. In real life, however, if there was indeed a case of unauthorized imitation for one specific company, the latter observation does not exist. This unobserved potential outcome is referred to as the *counterfactual outcome*. If it would exist, the expected average treatment effect on the treated (ATT; in this case the average change in IP strategies caused by the imitation incidence among the companies with an imitation incidence) can be formally described as

$$ATT = E(ATT \mid D = 1) = E[Y^1 \mid D = 1] - E[Y^0 \mid D = 1] \tag{5.1}$$

where Y^1 refers to the patenting behavior of a firm with an incidence of unauthorized reproduction, Y^0 the patenting behavior of a firm without such an incidence and D equals 1 if there was indeed a case of unauthorized reproduction, 0 otherwise[7]. The term $E[Y^0 \mid D = 1]$ refers to the counterfactual outcome in formal terms.

The evaluation literature has developed matching models to overcome the lacking observation for the counterfactual outcome (Rubin 1974). The basic idea is to find non-imitated (non-treated, i.e. control) companies, which are similar to the imitated (treated) companies in all relevant pretreatment characteristics X. If this is achieved, differences in the patenting behavior of this well selected and thus adequate control group and of the imitated companies can be attributed to the imitation incidence.

There are different ways to operationalize matching models (see for example Caliendo and Kopeinig 2008). The most straight-forward way is direct covariate matching, where only observations are compared which have the same values for the matching variables. However, conditioning on all relevant covariates is not feasible in the case of a high number of variables to be matched ("curse of dimensionality"). To solve this problem, Rosenbaum and Rubin (1983) suggest the use of balancing scores b(X), i.e. functions of the relevant observed covariates X such that the conditional distribution of X given b(X) is independent of the treatment, i.e. in our case the imitation incidence. They furthermore show that matching on this index results in consistent estimates of the treatment effect just as matching on all covariates would do. One possible index is the propensity score, i.e. the probability of being imitated given the observed company characteristics X. In this paper, I will use propensity score matching, since I am going to match observations on several characteristics and since the sample size is relatively small. Section 5.4.2 deals with the empirical setting of calculating the propensity score.

[7] The notation follows Rubin (1974).

Once a balancing score for each observation has been calculated, the exact method of matching has to be chosen. The methods differ in how many control observations are contrasted with one treated observation (one-to-one matching, one-to-many matching), how control observations are weighted, and in many other characteristics (Caliendo and Kopeinig 2008). For the present analysis, I will employ kernel matching, because I have a relatively small number of control cases. Kernel matching has the advantage that all control cases are used to construct the counterfactual, thus a lower variance is achieved because more information is used. A potential drawback is that possibly observations are used that are bad matches. It thus has to be made sure that the *common support assumption* is met, i.e. that the range of the propensity scores in treatment and control group overlaps sufficiently. I address this issue in section 5.4.3.

5.4 Empirical Test

This section will deal with the empirical setup concerning data generation, the estimation of the propensity score and the calculation of the matching estimates.

5.4.1 Data and Variables

The analysis relies on a survey among all German companies with more than 10 patent applications between 2002 and 2004. Considered were applications at the German Patent Office (DPMA), the European Patent Office (EPO) and under PCT. Additionally, a set of R&D active companies was randomly drawn from a commercial company database (Hoppenstedt database), which contained information on relevant contact persons. We specifically addressed the head of R&D, the head of the IPR/law department or – especially for the smaller companies – the firms' General Manager/member of the executive board.[8] Around 3,000 companies received a paper questionnaire and had access to an identical online version. We obtained a response rate of around 10%.[9]

In the following, I will describe in detail the main variables of interest, i.e. the questionnaire items used for constructing the dummy variable for a "product piracy"

[8]Around 45% of the respondents identified themselves as "Head of IPR/law departement", one third as General Manager. Around 10% worked as the head of the R%D department.

[9]for more detailed remarks on survey approach and non-response analyses, see Chapter 4 of this thesis.

incidence as well the two outcome variables "use of formal protection methods" and "use of informal protection strategies".

The treatment variable – i.e. the imitation incidence – is based on a question asking for incidences of unauthorized reproduction of product features in the particular company. The exact wording was: "How frequently did your company experience unauthorized reproduction ("product piracy") of features of its products in 2007?[10]" This question was asked separately for i) technical components of the product and ii) product names/logos. For this analysis, I will only use the information on imitation of technical components, since the focus is on patenting strategies versus informal strategies. The answers were obtained using a 5-point Likert scale with the anchors labeled as "very infrequently" and "very often". There was an additional answering options for "never" and the respondents were asked to respond separately for incidences of unauthorized reproduction within the European Union and outside of the EU. The main binary treatment variable takes the value "one" for a company reporting at least "very infrequent" incidences of unauthorized imitation inside or outside the EU. It is set to "zero" otherwise.

The two outcome variables refer to a questionnaire item asking the companies directly about the impact of unauthorized imitation cases on management decisions. The exact phrasing of the questions was: "What impact do cases of unauthorized reproduction/the infringement of intellectual property rights have on management decisions in your company?[11]" The answers used for this analysis refer to the items "stronger use of formal protection mechanisms such as patents and utility models" and a "stronger use of informal protection mechanisms such as secrecy". Respondents indicated on a 5-point Likert scale how relevant these two specific aspects were for their respective firm. This wording implies that also companies which are not directly affected can report an impact which would then be attributed to the general business environment or the IP situation in general. By comparing the responses for imitated and non-imitated firms and at the same time controlling for the balancing variables, conclusions about the impact of "product piracy" among *directly* affected firms can be drawn.

In addition to the treatment and outcome variables, the variables for the calculation of the balancing score are of importance for this analysis. These are the firm characteristics which should be as similar as possible among the "statistical twins" generated by the matching procedure. Most importantly, the IP strategy prior to the imitation

[10] Original questions in German, translation by the author.
[11] Original questions in German, translation by the author.

incidence has to be similar. Consequently, we use two variables for the use of formal protection methods (the importance of patents as well as brands) and three additional variables for different ways of informal protection strategies (variables “importance of defensive publication”, “importance of trade secrets”, and “importance of market-/product-based protection methods” including “emphasizing fast time to market”, “creating exclusive customer relationships”, “implementing technological protective features”, and “implementing management tools to prevent illegal copying”).[12]

Apart from the IP strategic variables, the companies will be matched on a number of other characteristics which have an influence on the treatment variables or outcome variables. These variables include the firm size (measured as the log-transformed number of employees) and interdependencies in the IP system (“patent thickets”, see section 5.2 above how IP fragmentation influences patenting behavior). Furthermore, we take into account, whether a firm is active outside its (German) home market, whether it participates in standard-setting organizations and whether the company cooperates with suppliers, customers, competitors and private or public research institutions. See table 5.1 for an overview on the construction of all variables.

5.4.2 Estimation of Propensity Score

The estimation of the propensity score should be based on those variables which are related to both the treatment and the outcome variables (Caliendo and Kopeinig 2008).[13] Guidance for choosing the relevant balancing variables should be based on both theoretic reasoning and empirical evidence. Since scientific research on product piracy is rather limited, I have to rely mainly on theoretical considerations as well as findings from chapter 4 of this thesis and further analyses of the survey data used here.

As the main block of balancing variables, I use information on the IP strategy of each company, i.e. the previous use of formal or informal ways to protect intellectual property. In particular, the importance of patents and brands as well as the three variables capturing informal protection behavior are relevant (see table 5.1). All of them are assumed to have a strong connection with the protection behavior after an

[12] This grouping resulted from a factor analysis with nine different variables referring to informal protection methods (see Appendix).

[13] There is, however, a recent methodological discussion about the appropriate variables to be included in the estimation of the propensity score(Austin et al. 2007, Brookhart et al. 2006). I take this issue into account in the final section of the discussion of the propensity score model on page 147.

Variable name	Level of measurement	Variable description
Importance of Patents	Dummy Variable	1: Importance of patents (measured on five-point Likert scale) for the company is “4-high” or “5-very high”; 0: otherwise
Importance of Trademarks	Dummy Variable	1 Importance of trademarks (measured on five-point Likert scale) for the company is “4-high” or “5-very high”; 0: otherwise
Importance of Trade Secrets	Interval variable	Average of questionnaire items (measured on five-point Likert scale) “Importance of confidentiality of production processes”, “Importance of confidentiality provisions with suppliers”, “Importance of confidentiality provisions with employees”and “Importance of long term staff retention”
Importance of Defensive Publication	Interval variable	Importance of defensive publication (measured on five-point Likert scale)
Importance of market-/product-based protection methods	Interval variable	Average of questionnaire items (measured on five-point Likert scale) “implementing technological protective features”, “implementing management tools to prevent illegal copying”, “emphasizing fast time to market” and “creating exclusive customer relationships”
Foreign Sales	Dummy Variable	1: Company has sales activities outside the home market; 0 otherwise
Foreign Manufacturing	Dummy Variable	1: Company has manufacturing facilities outside the home market; 0 otherwise
Foreign R&D	Dummy Variable	1: Company has research and development facilities outside the home market; 0 otherwise
Participation in Formal Standardization	Dummy Variable	1: Company is active in standardization activities; 0 otherwise
Cooperation Intensity	Dummy Variable	1: Importance of co-operation (measured on five-point Likert scale) “4-high” or “5-very high” for at least one of the categories “Cooperation with suppliers”, “Cooperation with customers”, “Cooperation with competitors”, “Cooperation with extramural R&D with private or public research institutions; 0: otherwise
R&D Intensity	Interval variable	Ratio of R&D employees to the total number of employees
Employees	Interval variable	Total number of employees (log-transformed)
Competition Intensity	Interval variable	Self-reported competition intensity (measured on five-point Likert scale) on the market(s) relevant for the firm
IPR Dependency	Interval variable	Self-reported dependency on technologies/IP of competitors for the company (measured on five-point Likert scale)
Industry	Dummy variables	for “Chemicals and Pharma”, “Plastics”, “Mechanical Engineering”,”Metal Processing”, “Electrical Engineering”, “Consumer Goods”, and “Other manufacturing”

Table 5.1. Variable overview

imitation incidence, because the copying is not going to change the company's IP strategy completely. The protection behavior is rather likely to be path-dependent to a certain degree and a firm which relied on patents before the imitation incidence has also a higher probability of doing so after the imitation incidence. Balancing on those variables is therefore important to be able to estimate the treatment effect. The use of the different IP instruments is also likely going to have a connection with the degree to which the company is (illegally) copied. This has partly been shown in chapter 4 and is also evident in the correlation matrix in table 5.6 (see appendix). The IP strategy variables mostly have a significant correlation with both outcome variables. The relationship with the treatment variable is also significant for the variables referring to formal protection and partly also for the ones concerning informal ways. Although a clear correlation cannot be seen for all variables, I include all of them in the propensity score estimations based on the theoretic considerations mentioned above.

Table 5.6 shows also that the variables for business activities in foreign markets as well as for participation in standardization are related with the outcome variable for the stronger use of formal protection mechanisms and, therefore, have to be included in the estimation of the propensity score. The correlation with the reproduction incidence is also highly significant. For the outcome variable "stronger use of informal protection methods" the pairwise correlations do not suggest significant relationships with sales, manufacturing, or R&D activities abroad. However, multiple regression models indicated that the sales activities have a significant relationship with the stronger use of informal protection methods (see table 5.7 in the appendix). It is therefore also included in the estimation of the propensity score for the informal strategies.

The remainder of the variables relate to the factors discussed in section 5.2: company size, industry affiliation and the IP landscape (especially patent thickets). The discussion above should have made clear how these factors influence the outcome variables of interest for this analysis. The matching thus has to take them into account, because also a significant relationship with the treatment variable is given (table 5.6 in the appendix).

It could be argued that one should additionally control for alternative reactions of the firms with respect to the imitation incidence such as a reduction in R&D spendings. The reasoning is that there could be an interaction effect between a future use of formal IP and alternative reactions such as a reduction of the R&D effort caused by

Dependent variable: Unauthorized imitation of technical elements	Propensity Score for formal protection		informal protection	
Importance of Patents	1.335***	(2.95)	0.948**	(2.26)
Importance of Brands	1.654***	(3.63)	1.615***	(3.79)
Importance of Trade Secrets	-0.569*	(-1.92)	-0.445	(-1.62)
Importance of Market-/Product-based Protection	0.106	(0.35)	0.0613	(0.21)
Importance of Defensive Publication	0.181	(0.93)	0.256	(1.32)
Foreign Sales			1.426*	(1.74)
Foreign Manufacturing	0.373	(0.67)		
Foreign R&D	1.396***	(2.69)		
Participation in Formal Standardization	0.528	(1.23)		
Employees	-0.0660	(-0.53)		
Cooperation Intensity			-0.698*	(-1.66)
IPR Dependency	0.336*	(1.96)	0.492***	(2.90)
Plastics	-1.890	(-1.53)	-1.216	(-1.16)
Mechanical Engineering	-0.634	(-0.62)	-0.612	(-0.74)
Metall Processing	-0.615	(-0.51)	-0.391	(-0.38)
Electrical Engineering	-1.996*	(-1.91)	-1.659**	(-1.98)
Consumer Goods	-1.303	(-1.15)	-0.887	(-0.91)
Other manufacturing	-2.150*	(-1.69)	-1.511	(-1.40)
Constant	0.310	(0.20)	-0.637	(-0.41)
Observations	213		210	
Prob > LR	0.0000		0.0000	
LR χ^2	66.23		50.88	
Pseudo R^2	0.291		0.225	

Marginal effects; t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.2. Estimation of the propensity scores (logit models)

"product piracy".[14] A reduction of R&D effort could imply that there is less need for IP protection and that this is the reason for an observed decline in the importance of formal protection. I do not include measures for these aspects into the propensity score model for two reasons: First, Caliendo and Kopeinig (2008) point out that only those variables should be included that are unaffected by the treatment variable. This is clearly not the case for these variables. Second, some authors (e.g. Augurzky and Kluve 2007, Bryson et al. 2002) advise explicitly against a over-parameterization of the propensity score model. Additionally, I do not find differences between treatment and control group for the relevant variables, i.e. these variables are balanced even without the inclusion into the specification of the propensity score. I therefore think that the decision of not including these variables is justified.

Table 5.2 shows the results of the logit models for the estimation of the propensity score. The goodness of fit for both models is satisfactory. Since the purpose of the models is primarily the prediction of the balancing metric, I will not discuss the coefficients in detail, but turn directly to an assessment of the common support condition.

[14] Other alternative reaction include a reduction of sales, production and R&D activities in critical markets or the reduction of technology licensing activities.

To ensure that the matching procedure creates suitable matches for the treated companies, it has to be guaranteed that the common support condition is met. This makes sure that "comparing the incomparable" is avoided. Caliendo and Kopeinig (2008) point out that the common support condition is particularly relevant for kernel matching and mention two different procedures to determine the common support: the minima-maxima rule and the trimming approach. I employ the first rule, which means that all observations for which the propensity score is smaller than the minimum and larger than the maximum in the opposite group are dropped from the sample. Figure 5.2 shows histograms of the calculated propensity scores for the treated and untreated companies. Following the minima-maxima rule, the observations within the interval – indicated by the dashed vertical lines – satisfy the common support condition. All other observations are dropped from the analysis. For the formal protection methods, this means that one company from the treatment group is dropped. 212 companies are left for the analysis, 165 in the treatment group and 47 in the control group. For the outcome variable informal protection methods, the common support condition requires a greater narrowing of the sample. 77 companies – 74 treated and 3 untreated – are dropped, which leaves 133 companies (88 in the treatment group and 45 in the control group).

5.4.3 Matching Quality

Before we turn to the results of the comparison between treatment and control group, I present some checks on how well the kernel matching has worked. The matching estimates are calculated with a Gaussian (normal) kernel matching approach. The bandwidth parameter is chosen according to the often used rule by Silverman (1986).[15]

Table 5.3 shows values for the variables in treatment and control group before the matching and – separated for the two outcome variables – after the matching. Since the actual aim is to eliminate differences between treatment and control group in the variables integrated in the propensity score estimation, the differences should not be significant after the matching. For the outcome variable "formal protection methods", table 5.3 shows that for 13 of the 16 variables, there is no statistically significant difference after the matching. Before the matching, this was only the case for 8

[15] The optimal bandwidth for the estimation of the ATT on formal protection methods is set to .067 and for informal protection methods to .0604. This results from the formula $h = 0.9 * A * n^{1.5}$, where n is the number of observations and $A = min(standard\ deviation\ of\ propensity\ score, interquartile\ range\ of\ propensity\ score/1.34.)$

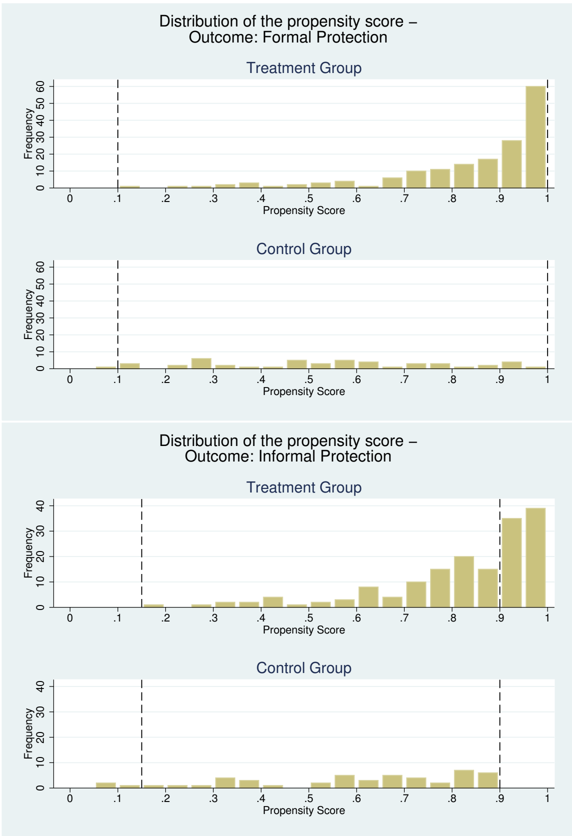

Figure 5.2. Common Support Condition

		Outcome: Formal Protection					Outcome: Informal Protection				
		Mean			% reduct.	t-test	Mean			% reduct.	t-test
Variable	Sample	Treated	Control	% bias	bias	p>t	Treated	Control	% bias	bias	p>t
Importance of Patents	Unmatched	.81818	.53191	63.7		0.000	.69318	.55556	28.5		0.118
	Matched	.81818	.78673	7.0	89.0	0.474	.69318	.69685	-0.8	97.3	0.958
Importance of Brands	Unmatched	.63636	.31915	66.5		0.000	.42045	.33333	17.9		0.334
	Matched	.63636	.57553	12.8	80.8	0.259	.42045	.40235	3.7	79.2	0.809
Importance of Trade Secrets	Unmatched	3.7258	3.8138	-10.7		0.521	3.7358	3.7889	-6.6		0.72
	Matched	3.7258	3.7393	-1.6	84.6	0.873	3.7358	3.7419	-0.7	88.6	0.96
Importance of market-/product-based protection methods	Unmatched	3.5424	3.484	7.7		0.635	3.4886	3.4444	5.9		0.747
	Matched	3.5424	3.4601	10.9	-41.0	0.299	3.4886	3.4986	-1.3	77.5	0.927
Importance of Defensive Publication	Unmatched	2.6788	2.4894	16.8		0.319	2.6023	2.4667	12.5		0.497
	Matched	2.6788	2.6549	2.1	87.4	0.836	2.6023	2.6728	-6.5	48.0	0.671
Foreign Manufacturing	Unmatched	.80606	.46809	74.5		0.000					
	Matched	.80606	.82596	-4.4	94.1	0.642					
Foreign R&D	Unmatched	.69697	.38298	65.9		0.000					
	Matched	.69697	.74382	-9.8	85.1	0.345					
Cooperation Intensity	Unmatched						.64773	.66667	-4.0		0.83
	Matched						.64773	.66598	-3.8	3.6	0.801
Foreign Sales	Unmatched						.95455	.93333	9.1		0.607
	Matched						.95455	.9696	-6.5	29.0	0.605
Participation in Formal Standardization	Unmatched	.68485	.46809	44.6		0.006					
	Matched	.68485	.5484	28.1	37.1	0.011					
Employees	Unmatched	6.8332	5.5215	58.8		0.000					
	Matched	6.8332	7.0285	-8.7	85.1	0.382					
IPR Dependency	Unmatched	3	2.4681	43.2		0.011	2.6591	2.4889	13.7		0.461
	Matched	3	2.9342	5.3	87.6	0.634	2.6591	2.6362	1.8	86.6	0.902
Plastics	Unmatched	.04848	.06383	-6.6		0.677	.07955	.06667	4.9		0.792
	Matched	.04848	.01506	14.4	-117.9	0.084	.07955	.0613	7.0	-41.7	0.639
Mechanical	Unmatched	.37576	.25532	26.0		0.128	.28409	.26667	3.9		0.834
	Matched	.37576	.30702	14.8	42.9	0.189	.28409	.29518	-2.5	36.4	0.872
Metal Processing	Unmatched	.13939	.06383	25.1		0.165	.06818	.06667	0.6		0.974
	Matched	.13939	.09943	13.3	47.1	0.264	.06818	.06988	-0.7	-12.1	0.965
Electrical	Unmatched	.2303	.38298	-33.3		0.036	.36364	.37778	-2.9		0.874
	Matched	.2303	.44213	-46.2	-38.7	0.000	.36364	.39226	-5.9	-102.4	0.698
Consumer Goods	Unmatched	.07879	.10638	-9.5		0.552	.10227	.08889	4.5		0.808
	Matched	.07879	.09101	-4.2	55.7	0.691	.10227	.09768	1.6	65.7	0.92
Other manufacturing	Unmatched	.03636	.06383	-12.5		0.412	.05682	.06667	-4.1		0.823
	Matched	.03636	.03734	-0.4	96.4	0.963	.05682	.04363	5.4	-33.9	0.692

Table 5.3. Group differences between imitated and non-imitated companies before and after the matching

variables. The matching has reduced the differences between the groups considerably. For two variables (standardization and one industry dummy) the matching has not been able to eliminate the differences and for one further industry dummy there are now differences after the matching which did not exist before.[16] Nevertheless, the quality of the matching can be regarded as high, this is also suggested by a significant reduction of the pseudo R^2 for the calculation of the propensity score after the matching (Sianesi 2004). For the second outcome, the informal protection, there were no significant differences before the matching in the first place. However, the matching achieved a significant reduction of the group differences.

5.4.4 Results

Table 5.4 presents the results for the estimation using kernel matching method with an optimal bandwidth parameter according to Silverman (1986) and Gaussian kernel. The standard errors are boot-strapped with 200 replications (Abadie and Imbens 2008). A simple comparison of the imitated with the non-imitated companies yields a highly significant difference for the use of formal protection instruments. The imitated firms tend to see this strategy as much more relevant, their answers average to 3.34 whereas the control group's average is at 2.62 on the 5-point scale. However, this simple comparison is not appropriate as discussed above, valid are rather the results after the matching. After the matching, the difference between the groups becomes smaller, although the results are qualitatively similar and are still significant on a 10%-level. We can thus conclude that companies, which are directly affected by unauthorized imitation of their proprietary technology, seem to rely even stronger on formal protection methods as a result of the imitation. On the other hand, informal protection methods seem not to be more strongly relevant for the imitated companies. The control group shows even slightly higher answers than the treatment group, but the differences are not at all significant. This suggests that a shift from formal protection into informal protection methods seems not to be a more relevant strategy among the directly imitated companies compared to the other companies in the sample.

To check the sensitivity of the results, I tested a number of other specifications for the estimation of the ATT. I used different bandwidth parameters for the kernel matching and furthermore estimated the ATT using nearest-neighbor and radius matching with different specifications for the number of neighbors and the width of

[16] In the robustness tests I also tested matching within industries, the results are not sensitive to this change.

Outcome	Sample	Treated	Controls	Difference	S.E.	T-stat
Formal Protection	Unmatched	3.3393	2.6170	.7223	.1983***	3.64
	ATT	3.3393	2.7425	.5968	.3100*	1.93
Informal Protection	Unmatched	3.3068	3.4	-.0931	.2295	-0.41
	ATT	3.3068	3.3968	-.0899	.2371	-0.38

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.4. Average treatment effect for both outcome variables

the calipers. Additionally, I tested a hybrid matching approach, where the pairs are still matched on the propensity score, but have to be a member of the same industry. The results are generally substantiated, although the estimations for the ATT are not significant for all specifications. For the formal protection outcome, the ATT ranges between .38 and .65. The main result for the ATT presented in table 5.4 lies within this range. For the informal protection, none of the specifications shows significant differences between treatment and control group, which backs the conclusion that differences caused by imitation incidences are not to be expected.

An important aspect regarding the interpretation of these results should be stressed: The missing ATT for the informal protection methods can not be interpreted as evidence for a lack of relevance of informal protection methods *per se*. There are many companies which use technological means to deter copying or product piracy. In fact, the overall responses of all companies in the survey are higher for the informal protection methods than for the formal ones and especially smaller firms seem to rely on them more often. However, the results can be interpreted as evidence that a *direct* effect of cases of unauthorized reproduction, i.e. a reaction among companies which actually were affected, on the use of informal protection seems not to be given, independently from the question whether there is a general tendency towards a stronger use of informal protection instruments.[17]

5.5 Summary, Implications and Conclusions

In this analysis, I have examined how cases of unauthorized reproduction influence the subsequent IP protection behavior of companies. Using a propensity score matching approach, I compare companies with at least one case of unauthorized reproduction in 2007 with a control group of firms, which are similar in terms of their prior IP strategy and other firm characteristics. I find that imitation incidences induce an even stronger use of formal protection rights. Based on company responses, firms

[17] In figure 5.1 this would be shown by a small dark area (direct effect) and a comparatively large area for the indirect effect, represented by the light blue field.

Outcome: Formal Protection

Matching Algorithm	Outcome Treated	Outcome Controls	ATT	S.E.	T-stat	Observations Imitated	Observations Non-Imitated
Kernel Matching							
Bandwidth 0.02	3.3393	2.9632	.3761	.2908	1.29	165	47
Bandwidth 0.04	3.3393	2.8392	.5001	.3082	1.62	165	47
Bandwidth 0.06	3.3393	2.7604	.5788	.3118	1.86*	165	47
Bandwidth 0.08	3.3393	2.7164	.6229	.3047	2.04**	165	47
Bandwidth 0.10	3.3393	2.6822	.6571	.2947	2.23**	165	47
Nearest Neighbour							
2 NN	3.3393	2.8848	.4545	.3364	1.35	165	47
6 NN	3.3393	2.7060	.6333	.3415	1.85*	165	47
10 NN	3.3393	2.5187	.8206	.3201	2.56***	165	47
Caliper							
Caliper 0.02	3.2647	2.9313	.3333	.2892	1.15	136	47
Caliper 0.06	3.3393	2.8768	.4625	.2586	1.79*	165	47
Caliper 0.10	3.3393	2.7136	.6257	.3295	1.90*	165	47

Outcome: Informal Protection

Matching Algorithm	Outcome Treated	Outcome Controls	ATT	S.E.	T-stat	Observations Imitated	Observations Non-Imitated
Kernel Matching							
Bandwidth 0.02	3.3068	3.4617	-.1549	.2484	-0.62	45	88
Bandwidth 0.04	3.3068	3.4169	-.1101	.2372	-0.46	45	88
Bandwidth 0.06	3.3068	3.3971	-.0903	.2371	-0.38	45	88
Bandwidth 0.08	3.3068	3.3784	-.0716	-0.30	0.766	45	88
Bandwidth 0.10	3.3068	3.3594	-.0526	.2447	-0.22	45	88
Nearest Neighbour							
2 NN	3.3068	3.4375	-.1306	.2477	-0.53	45	88
6 NN	3.3068	3.3977	-.0909	.2223	-0.41	45	88
10 NN	3.3068	3.4261	-.1193	.2529	-0.47	45	88
Caliper							
Caliper 0.02	3.3255	3.4666	-.1411	.2188	-0.64	45	86
Caliper 0.06	3.3068	3.4139	-.1071	.2348	-0.46	45	88
Caliper 0.10	3.3068	3.3745	-.0677	.2213	-0.31	45	88

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.5. Robustness checks with different matching algorithms

with an imitation incidence report significantly higher values on questions regarding the relevance of future use of formal protection instruments such as patents. Informal protection such as secrecy, however, is not seen as more relevant in the "treatment" group compared to the control group.

As mentioned above, the finding that informal protection cannot be expected to occur more frequently among those affected by direct unauthorized reproduction than among the control companies does not imply that informal protection is generally irrelevant. Specifically SMEs without the financial means to prosecute patents worldwide will still take informal strategies into consideration, especially a fast time to market. For the management in larger firms, however, it could be a dominant strategy to continue to rely on patents. A possible explanation is that responsibility for IP protection can be shifted to the IP department when protection strategy focuses clearly on formal IP rights. The development of management methods to prevent copying or the use of technical elements to complicate reverse engineering is likely to be more challenging to implement than filing a patent. Management might thus favor formal protection over informal protection. A problem arises if the choice between the two groups of strategies is not free. Small firms are often disadvantaged in the patent system. If, as a result of rising levels of unauthorized reproduction or product piracy, the need to obtain more patents is intensified, this disadvantage is growing. The gap in patent use between SMEs and large firms might thus be widening, which can put in danger the innovative activity by smaller firms, entrepreneurs, or start-ups.

Finally, some limitations of this analysis should be mentioned. First, I was only able to use survey data on the expected behavior of the respondent firms after an self-reported incidence of unauthorized reproduction. Furthermore, the outcome variables were only measured on a 5-point Likert scale, which might be problematic to interpret. It would thus be interesting to explore how this reported future IP protection behavior translates into real business decisions. The integration of patent data for the subsequent years could be a further step to validate these results. However, this is limited by the fact that the use of informal protection methods cannot be observed. This limitation would have to be overcome by additional surveys among the affected firms. A further limitation refers to the level of observation. Companies might rely on different protection methods for different products or product groups. Furthermore, they presumably use different IP strategies in different markets or in different countries. In this analysis, I can only rely on information of the IP strategy on the company level. Further analysis on the product level or a differentiation of the IP strategy over different markets (e.g. developed countries versus developing or emerging countries) could thus be addressed in future research and would allow more detailed insights.

Bibliography

Abadie, A. and G. W. Imbens (2008), On the Failure of the Bootstrap for Matching Estimators, Econometrica, 76(6): 1537–1557.

Arora, A., A. Fosfuri, and A. Gambardella (2001), Markets for Technology. The Economics of Innovation and Corporate Strategy, MIT Press, Cambrige, MA.

Arundel, A. (2001), The relative effectiveness of patents and secrecy for appropriation, Research Policy, 30(4): 611–624.

Arundel, A. and I. Kabla (1998), What percentage of innovations are patented? empirical estimates for European firms, Resesearch Policy, 27(2): 127–141.

Audretsch, D. B. (2002), The dynamic role of small firms: Evidence from the US, Small Business Economics, 18(1-3): 13–40.

Augurzky, B. and J. Kluve (2007), Assessing the performance of matching algorithms when selection into treatment is strong, Journal of Applied Econometrics, 22(3): 533–557.

Austin, P. C., P. Grootendorst, and G. M. Anderson (2007), A comparison of the ability of different propensity score models to balance measured variables between treated and untreated subjects: a Monte Carlo study, Stat. Med., 26(4): 734–753.

Bessen, J. and M. J. Meurer (2008), Patent Failure: How Judges, Bureaucrats, and Lawyers Put Innovators at Risk, Princeton University Press.

Brookhart, M. A., S. Schneeweiss, K. J. Rothman, R. J. Glynn, J. Avorn, and T. Sturmer (2006), Variable selection for propensity score models, American Journal of Epidemiology, 163(12): 1149–1156.

Bryson, A., R. Dorsett, and S. Purdon (2002), The use of propensity score matching in the evaluation of labour market policies, Working Paper No. 4, Department for Work and Pensions.

Caliendo, M. and S. Kopeinig (2008), Some practical guidance for the implementation of propensity score matching, Journal of Economic Surveys, 22(1): 31–72.

Castro, J. O. D., D. B. Balkin, and D. A. Shepherd (2008), Can entrepreneurial firms benefit from product piracy?, Journal of Business Venturing, 23(1): 75–90.

Cohen, W., R. Nelson, and J. Walsh (2000), Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (Or Not), NBER Working Paper 7552.

Conner, K. R. and R. P. Rumelt (1991), Software piracy - an analysis of protection strategies, Management Science, 37(2): 125–139.

de Rassenfosse, G. and B. van Pottelsberghe de la Potterie (2007), Per un pugno di dollari: a first look at the price elasticity of patents, Oxford Review of Economic Policy, 23(4): 588–604.

Givon, M., V. Mahajan, and E. Muller (1995), Software piracy - estimation of lost sales and the impact on software diffusion, Journal of Marketing, 59(1): 29–37.

Grindley, P. and D. Teece (1997), Managing intellectual capital: Licensing and cross-licensing in semiconductors and electronics, California Management Review, 39(2): 8 – 41.

Hall, B. and R. Ziedonis (2001), The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995, Rand Journal of Economics, 32(1): 101–128.

Harabi, N. (1995), Appropriability of technical innovations - An empirical analysis, Research Policy, 24(6): 981–992.

Harhoff, D., K. Hoisl, B. Reichl, and B. van Pottelsberghe de la Potterie (2009), Patent validation at the country level-The role of fees and translation costs, Research Policy, 38(9): 1423–1437.

Keupp, M. M., A. Beckenbauer, and O. Gassmann (2009), How managers protect intellectual property rights in China using de facto strategies, R & D Management, 39(2): 211–224.

Kingston, W. (2000), Enforcing small firms' patent rights, European Commission, DG Enterprise.

Landes, W. M. and R. A. Posner (2003), The Economic Structure of Intellectual Property Law, Harvard University Press, Cambridge, Mass.

Lanjouw, J. O. (1998), Patent protection in the shadow of infringement: Simulation estimations of patent value, Review of Economic Studies, 65(4): 671–710.

Lanjouw, J. O. and M. Schankerman (2004), Protecting intellectual property rights: Are small firms handicapped?, Journal of Law and Economics, 47(1): 45–74.

Mandeville, T. (1996), Understanding Novelty: Information, Technological Change and the Patent System, Ablex Publishing, Norwood, NJ.

OECD (2007), The Economic Impact of Counterfeiting and Piracy, Organisation for Economic Co-operation and Development, Paris.

OECD (2009), Magnitude of counterfeiting and piracy of tangible products – November 2009 update, Organisation for Economic Co-operation and Development, Paris.

Olsen, J. E. and K. L. Granzin (1992), Gaining retailers assistance in fighting counterfeiting - conceptualization and empirical-test of a helping model, Journal of Retailing, 68(1): 90–109.

Qian, Y. (2008), Impacts of entry by counterfeiters, Quarterly Journal of Economics, 123(4): 1577–1609.

Raustiala, K. and C. Sprigman (2009), The piracy paradox revisited, Stanford Law Review, 61(5): 1201–1225.

Rosenbaum, P. R. and D. B. Rubin (1983), The central role of the propensity score in observational studies for causal effects, Biometrika, 70(1): 41–55.

Rubin, D. B. (1974), Estimating causal effects of treatments in randomized and nonrandomized studies, Journal of Educational Psychology, 66(5): 688–701.

Shapiro, C. (2001), Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting, in: A. Jaffe, J. Lerner, and S. Stern, eds., Innovation Policy and the Economy I, 119–150, The MIT Press, Cambrigde, Massachussetts.

Sianesi, B. (2004), An evaluation of the Swedish system of active labour market programmes in the 1990s, Review of Economics and Statistics, 86(1): 133—-155.

Silverman, B. (1986), Density Estimation for Statistics and Data Analysis, Chapman and Hall, London.

Thumm, N. (2001), Management of intellectual property rights in European biotechnology firms, Technological Forecasting and Social Change, 67(2-3): 259–272.

van Pottelsberghe de la Potterie, B. and D. François (2006), The Cost Factor in Patent Systems, CEB Working Paper 06/002.

von Hippel, E. (1988), The sources of innovation, Oxford University Press, New York.

Appendix

Variables	1	2	3	4	5	6	7	8	9	10	11
1 Stronger use of formal protection	1.000										
2 Stronger use of informal protection	0.264	1.000									
	(0.000)										
3 Unauthorized Reproduction (technical elements)	0.225	−0.033	1.000								
	(0.000)	(−0.597)									
4 Importance of Patents	0.330	0.109	0.307	1.000							
	(0.000)	(−0.063)	(0.000)								
5 Importance of Brands	0.181	0.084	0.218	0.167	1.000						
	(−0.002)	(−0.148)	(0.000)	(−0.003)							
6 Importance of Trade Secrets	0.165	0.408	−0.027	0.129	0.181	1.000					
	(−0.005)	(0.000)	(−0.658)	(−0.023)	(−0.001)						
7 Importance of Market-/Product-based Protection Methods	0.102	0.315	0.125	0.125	0.134	0.431	1.000				
	(−0.086)	(0.000)	(−0.04)	(−0.028)	(−0.018)	(0.000)					
8 Importance of Defensive Publication	0.153	0.162	0.034	0.147	0.039	0.271	0.305	1.000			
	(−0.009)	(−0.006)	(−0.581)	(−0.009)	(−0.488)	(0.000)	(0.000)				
9 Foreign Sales	0.054	−0.055	0.221	0.244	0.128	0.021	0.103	0.029	1.000		
	(−0.354)	(−0.351)	(0.000)	(0.000)	(−0.021)	(−0.715)	(−0.072)	(−0.614)			
10 Foreign Manufacturing	0.179	−0.031	0.322	0.181	0.157	0.000	0.148	0.002	0.368	1.000	
	(−0.002)	(−0.591)	(0.000)	(−0.001)	(−0.005)	(−0.999)	(−0.009)	(−0.974)	(0.000)		
11 Foreign R &D	0.159	0.037	0.275	0.114	0.079	0.071	0.043	0.064	0.192	0.492	1.000
	(−0.006)	(−0.524)	(0.000)	(−0.04)	(−0.157)	(−0.209)	(−0.447)	(−0.261)	(−0.001)	(0.000)	
12 Participation in Formal Standardization	0.142	0.078	0.186	0.19	0.127	0.105	0.095	−0.013	0.237	0.346	0.203
	(−0.015)	(−0.186)	(−0.002)	(−0.001)	(−0.024)	(−0.069)	(−0.100)	(−0.816)	(0.000)	(0.000)	(0.000)
13 Cooperation Intensity	0.061	0.113	−0.088	0.058	0.028	0.057	0.021	0.032	0.053	0.048	0.170
	(−0.300)	(−0.056)	(−0.147)	(−0.309)	(−0.616)	(−0.323)	(−0.718)	(−0.578)	(−0.352)	(−0.399)	(−0.003)
14 R&D Intensity	−0.040	0.042	−0.288	−0.019	−0.170	0.027	−0.023	0.115	−0.235	−0.294	−0.055
	(−0.508)	(−0.494)	(0.000)	(−0.745)	(−0.003)	(−0.654)	(−0.702)	(−0.051)	(0.000)	(0.000)	(−0.347)
15 ln(employees)	0.139	−0.067	0.229	0.210	0.154	−0.017	−0.011	−0.001	0.267	0.509	0.344
	(−0.017)	(−0.248)	(0.000)	(0.000)	(−0.006)	(−0.759)	(−0.848)	(−0.983)	(0.000)	(0.000)	(0.000)
16 Competition Intensity	0.083	0.045	0.171	0.068	0.032	0.080	0.106	−0.009	0.052	0.171	0.190
	(−0.158)	(−0.444)	(−0.004)	(−0.226)	(−0.574)	(−0.160)	(−0.064)	(−0.874)	(−0.352)	(−0.002)	(−0.001)
17 IPR Dependency	0.180	−0.032	0.136	0.172	−0.031	0.121	0.026	0.018	−0.014	0.183	0.187
	(−0.002)	(−0.582)	(−0.023)	(−0.002)	(−0.585)	(−0.033)	(−0.650)	(−0.750)	(−0.808)	(−0.001)	(−0.001)
18 Plastics	−0.186	0.039	−0.041	−0.077	−0.087	−0.178	−0.024	−0.043	−0.012	0.091	0.000
	(−0.003)	(−0.544)	(−0.530)	(−0.204)	(−0.153)	(−0.004)	(−0.696)	(−0.489)	(−0.838)	(−0.134)	(−1.000)
19 Mechanical Engineering	0.111	0.071	0.077	0.139	−0.059	0.139	0.121	0.110	0.127	0.015	−0.042
	(−0.078)	(−0.265)	(−0.230)	(−0.022)	(−0.332)	(−0.024)	(−0.051)	(−0.074)	(−0.036)	(−0.81)	(−0.485)
20 Metall Processing	−0.059	−0.143	0.115	0.110	0.120	−0.047	−0.039	−0.119	−0.063	0.021	−0.006
	(−0.349)	(−0.024)	(−0.075)	(−0.070)	(−0.048)	(−0.449)	(−0.530)	(−0.054)	(−0.301)	(−0.725)	(−0.925)
21 Electrical Engineering	0.135	0.046	−0.141	0.018	0.041	0.042	−0.054	0.096	−0.045	−0.082	−0.004
	(−0.032)	(−0.464)	(−0.028)	(−0.762)	(−0.502)	(−0.499)	(−0.388)	(−0.120)	(−0.464)	(−0.177)	(−0.944)
22 Consumer Goods	−0.046	−0.032	−0.010	−0.147	0.080	0.009	0.019	−0.091	−0.114	−0.048	0.007
	(−0.467)	(−0.611)	(−0.874)	(−0.016)	(−0.189)	(−0.883)	(−0.758)	(−0.141)	(−0.060)	(−0.432)	(−0.909)
23 Other manufacturing	−0.021	0.006	−0.032	−0.155	−0.073	−0.088	0.031	−0.026	0.052	0.029	−0.004
	(−0.738)	(−0.926)	(−0.625)	(−0.011)	(−0.227)	(−0.152)	(−0.619)	(−0.678)	(−0.391)	(−0.629)	(−0.942)

(continued on next page)

Table 5.6. Correlation matrix

Variables	12	13	14	15	16	17	18	19	20	21	22	23
12 Participation in Formal Standardization	1.000											
13 Cooperation Intensity	−0.014	1.000										
	(−0.813)											
14 R&D Intensity	−0.174	0.067	1.000									
	(−0.003)	(−0.256)										
15 ln(employees)	0.302	0.132	−0.446	1.000								
	(0.000)	(−0.020)	(0.000)									
16 Competition Intensity	0.208	0.144	−0.021	0.214	1.000							
	(0.000)	(−0.011)	(−0.722)	(0.000)								
17 IPR Dependency	0.170	0.254	0.009	0.207	0.208	1.000						
	(−0.003)	(0.000)	(−0.871)	(0.000)	(0.000)							
18 Plastics	−0.048	0.025	−0.078	−0.043	0.013	−0.090	1.000					
	(−0.438)	(−0.690)	(−0.214)	(−0.482)	(−0.826)	(−0.141)						
19 Mechanical Engineering	0.029	0.048	−0.098	0.113	0.016	0.061	−0.174	1.000				
	(−0.638)	(−0.436)	(−0.122)	(−0.064)	(−0.790)	(−0.319)	(−0.004)					
20 Metall Processing	0.077	−0.141	−0.078	0.018	−0.065	0.047	−0.094	−0.264	1.000			
	(−0.208)	(−0.022)	(−0.216)	(−0.768)	(−0.290)	(−0.447)	(−0.120)	(0.000)				
21 Electrical Engineering	0.014	−0.01	0.348	−0.132	−0.045	0.043	−0.153	−0.426	−0.231	1.000		
	(−0.821)	(−0.867)	(0.000)	(−0.029)	(−0.458)	(−0.487)	(−0.012)	(0.000)	(0.000)			
22 Consumer Goods	−0.005	0.028	−0.111	−0.062	0.029	−0.047	−0.074	−0.207	−0.112	−0.181	1.000	
	(−0.931)	(−0.657)	(−0.078)	(−0.311)	(−0.631)	(−0.443)	(−0.223)	(−0.001)	(−0.065)	(−0.003)		
23 Other manufacturing	−0.042	0.011	−0.118	0.018	0.038	−0.092	−0.056	−0.156	−0.085	−0.137	−0.066	1.000
	(−0.496)	(−0.859)	(−0.060)	(−0.774)	(−0.537)	(−0.131)	(−0.357)	(−0.010)	(−0.164)	(−0.024)	(0.275)	

Table 5.6: Correlation matrix(continued)

Dependent (outcome) variables: Stronger use of formal or informal protection as result of unauthorized imitation	Formal Protection		Informal Protection	
Importance of Patents	0.657***	(3.20)	0.290	(1.44)
Importance of Brands	0.225	(1.26)	-0.00424	(-0.02)
Importance of Trade Secrets	0.00447	(0.04)	0.441***	(3.86)
Importance of Market-/Product-based Protection	0.0975	(0.73)	0.359***	(2.69)
Importance of Defensive Publication	0.00689	(0.09)	-0.0388	(-0.53)
Foreign Sales	-0.290	(-0.75)	-0.639*	(-1.68)
Foreign Manufacturing	0.339	(1.41)	-0.227	(-0.97)
Foreign R&D	0.0461	(0.23)	0.193	(0.96)
Participation in Formal Standardization	-0.194	(-1.04)	0.0849	(0.47)
Cooperation Intensity	0.0929	(0.52)	0.418**	(2.40)
R&D Intensity	-0.172	(-0.25)	-0.760	(-1.12)
ln(employees)	0.0589	(1.16)	-0.0669	(-1.33)
Competition Intensity	0.100	(0.90)	0.0514	(0.47)
IPR Dependency	0.0599	(0.87)	-0.116*	(-1.71)
Plastics	-0.612	(-1.44)	0.338	(0.80)
Mechanical Engineering	0.530*	(1.71)	-0.0175	(-0.06)
Metal Processing	0.232	(0.65)	-0.317	(-0.89)
Electrical Engineering	0.629*	(1.94)	-0.0385	(-0.12)
Consumer Goods	0.306	(0.81)	-0.320	(-0.85)
Other manufacturing	0.528	(1.22)	0.112	(0.26)
Observations	214		213	
R^2	0.224		0.273	

Marginal effects; t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.7. OLS regressions of stronger formal/informal protection as result of product piracy (outcome variables) on potential balancing variables

	Factor1	Factor2	Factor3	Factor4
Confidentiality of production processes	.625	.170	.096	.070
Confidentiality provisions with suppliers	.683	.113	.003	.007
Confidentiality provisions with employees	.705	.123	.154	.101
Long term staff retention	.427	.182	.416	.068
Exclusive customer relationships	.201	.486	.170	.018
Fast time to market	.261	.469	.238	.005
Technological protective features	.117	.515	-.030	.173
Management tools to prevent legal copying	.289	.339	.127	.296
Defensive publication	.354	.221	.073	.278

Note: Variables are assigned to the factor for which they have the highest factor loading. Three factors are extracted: “Importance of trade secrets” (Factor 1, consisting of 4 variables), “Importance of market-/product-based protection methods (Factor 2, consisting of 4 variables) and “Importance of defensive publication (Factor 4, consisting of only one variable)

Table 5.8. Rotated loading matrix (varimax) after factor analysis with 9 informal protection methods