Access to Intellectual Property for Innovation:

Evidence on Problems and Coping Strategies from German Firms

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Abstract

Transaction costs and contracting problems associated with proliferation of patents may have a negative impact on innovation. We present novel data on how frequently innovative German firms encountered problems with access to intellectual property (IP) for their innovation activities. While a small percentage of firms reported having abandoned or not started innovation projects because of IP issues, larger fractions reported having pursued their projects after modifying them. Using "coping mechanisms" such as acquisition of additional IP rights or taking legal action to limit the IP held by others was quite common. Much of the incidence of self-reported IP problems and coping activity was concentrated in firms which were larger, more R&D intensive, and had more patents than the corresponding median firm. After controlling for firm characteristics, we find that firms operating in technology areas with higher concentration of IP ownership experience a lower probability of reporting IP-related problems.

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1. Introduction

The monopoly rights represented by patents have traditionally been viewed as a short-run sacrifice of consumer surplus for the sake of long-run increases in economic growth through innovation. Recent decades have registered a sharp increase in patent applications in most OECD countries, and most policy discussions appear to presume that greater patenting activity reflects more innovation. The reality may be more complex. On the one hand, the increase in patenting may not have been driven solely by increase in innovative activity. Although technological opportunity appears to have increased significantly in areas such as software and biotechnology, leading to more innovation and thus to more patents, patenting activity may also have increased independent of the underlying rate of innovation. The institutions that grant and enforce patents have evolved over the years, lowering the costs and raising the benefits of acquiring patents, while patent applicants appear to have become more aware of the competitive value of patents, and more sophisticated and strategic in their use (Hall and Ziedonis [2001]; Reitzig et al. [2010]). On the other hand, greater numbers of patents may have negative effects on innovators, particularly in the context of cumulative innovation and multiple blocking patents where the costs associated with patents may outweigh any positive impact on R&D incentives.[1]

In this paper we present empirical evidence of the impact of patenting on the activities of firms other than the patent holder, specifically the incidence of firms reporting problems with "freedom to operate" caused by lack of access to relevant intellectual property, and the extent to which the firms utilized what we term here "coping mechanisms" to mitigate these problems. Despite the importance of these potential negative effects, there is little evidence to date on their impact, particularly on the number and types of the firms affected and how they responded to these challenges. While much of the existing empirical evidence focuses on whether firms operating in fragmented IP markets incur higher costs because of higher transaction costs involved in negotiating with multiple parties over access to patented technologies, evidence on even the stifling effect of patents of innovation, if any, remains at best indirect. This paper provides what is to our knowledge the first cross-industry survey evidence on the rate at which

[1] A theoretical literature has shown that when research is sequential and builds upon previous innovations, stronger patents may discourage follow-on inventions (Merges and Nelson (1990), Scotchmer (1991), etc.).

problems of access to IP are associated with consequences such as abandonment, avoidance, or modification of R&D projects, which types of firms and industries were most likely to have faced these problems, and the degree to which they could mitigate the negative effects by participating in the market for intellectual property.

The data presented here on these phenomena come from the 2008 wave of the Mannheim Innovation Panel (MIP), a survey in which the respondents themselves reported the occurrence of various events in connection with the right to use intellectual property rights. These events included problems such as not starting, abandoning, modifying innovation projects because their firms did not have the rights to the relevant IP, or taking the risky course of proceeding without access to that IP. They also included coping strategies that can be viewed as attempts to deal with the problems of access to IP, such as exchanging or acquiring IP, or attempting to limit competitors' IP by participating in patent opposition proceedings, or engaging in negotiations with patent holders to avoid legal disputes.[2] We examine variation in these responses across different types of firms and different industrial sectors, and across markets and technologies where we are able to measure the degree of concentration of ownership of IP in the market for patents.

The results of present analysis can be described in terms of three main findings. First, it is rather rare for the median firm to stop projects or avoid them because of access to IP. Instead, many firms were engaged in such activities as acquiring additional IP rights or taking legal action to deal with or avoid problems of access to IP. Second, the incidence of self-reported IP problems and coping activity was confined mostly to firms which were larger, more R&D intensive, and had more patents than the median firms. While the larger firms had greater resources and capabilities than smaller or less experienced competitors to deploy coping mechanisms, they also experienced IP access problems more frequently. Overall, being a large, innovative firm does not *per se* appear to ensure protection against problems due to IP. Finally, after controlling for firm characteristics, we find that firms operating in technology areas, with

[2] As an alternative to the wording used here, it is possible to classify problems as unilateral coping strategies and their coping strategies as bilateral coping strategies. For example, the modification of a project to adapt to the prevailing IP situation can be seen as a solution, rather than a problem.

higher concentration of IP ownership, experienced a lower probability of being confronted with problems. This finding, which is consistent with prior literature, may reflect a lower probability that negotiations break down when there are a smaller number of potential litigants.[3]

2. Prior Literature

Much economic analysis of the patent system has focused on the effectiveness of patents as a means of appropriating returns for the innovator. Surveys of R&D performing firms[4] have identified the patent paradox: increases in patenting across many industrial sectors and types of firms, but at the same time general agreement that (outside a few sectors) the effectiveness of patents in preventing imitation or securing returns from R&D is limited. Recent research in economics has increasingly highlighted a variety of other roles for patents beyond their direct role in excluding product market competitors from use of the patented technology. These include supporting transactions in the "market for technology" (Arora et al. [2001]; Gans et al. [2002]), disclosing information (Anton and Yao [2004]), signaling to investors (Haeussler et al. [2009]; Hall and MacGarvie [2010]; Hsu and Ziedonis [2008]), mitigating expropriation risks (Ziedonis [2004], or creating opportunities to extract industry-wide rents through holding up standards-setting (Rysman and Simcoe [2008]). Patents may be surprisingly valuable in these indirect roles, stimulating innovation by raising returns to innovator firms through mechanisms other than directly foreclosing competitors' access to product markets.

But it has also been increasingly argued that the patent system may now be at risk of stifling innovation (Bessen and Meurer [2008]; Federal Trade Commission [2003]; Jaffe and Lerner [2004]; and Merrill et al. [2004]). While much of this criticism is focused on fixable flaws in the operation of the system, such as poor quality of examination, it has also highlighted the potential for escalation of patent costs that fall outside the traditional tradeoffs between incentives for the innovator and high prices to be paid by consumers. These may include problems, such as dissipative rent seeking in patent races

[3] See Ziedonis (2004), Noel and Schankerman (2006), and Galasso and Schankerman (2010).
[4] These go back to Mansfield (1986) and the Levin et al. (1987) "Yale Survey", and more recently the Cohen et al. (2000) "CMU Survey" and various rounds of the Community Innovation Surveys in EU countries.

(Reinganum [1983]), defensive investment in IP not directly related to an innovator's core business, or abandoning promising research projects when the projects run into unresolvable patent problems.

One increasingly influential line of research points to the potential of cost escalation associated with fragmentation of IP ownership. Fragmentation may increase transaction costs associated with patent thickets (or "an overlapping set of patent rights requiring that those seeking to commercialize a new technology obtain licenses from multiple patentees" Shapiro [2001], p. 119) and create greater potential for holdup or opportunistic behavior whenever a firm tries to obtain freedom to operate in an environment where it has to negotiate with multiple rival licensors (Lemley and Shapiro [2007]; Noel and Schankerman [2006]). In extreme cases, proliferation of patents may lead to an "anti-commons" situation where too many rights lead to a gridlock among would-be innovators (Heller and Eisenberg [1998]). One issue that still needs to be understood is the extent to which problems related to fragmentation of rights can be efficiently resolved through licensing transactions. The evidence available in this regard is not only limited, but contradictory too. Some authors argue that problems such as royalty stacking can be effectively resolved through negotiations (Galasso and Schankerman [2010]; Geradin et al. [2007]). However, Siebert and von Graevenitz (2006) find a negative association between licensing activity and fragmentation, and Cockburn et al. (2010) find more licensing activity but poorer innovation performance by licensees in industries with more fragmented IP ownership.[5]

Another way in which this paper contributes to the literature is in providing more evidence on the impact of firm size or patenting intensity on the incidence of IP problems. Prior work, like Lanjouw and Schankerman (2004) and Galasso, Schankerman and Serrano (2011), finds that the patents of firms with larger patent portfolios are less likely to be involved in patent litigation, conditional on the characteristics of the patents. Bessen and Meurer (2005) find that the risk of being sued increases with the size of the firm's patent portfolio and R&D intensity[6]. In contrast to the relatively well-developed research on patent

[5] In the context of software, Cockburn and MacGarvie (2009) and (2011) find a negative relationship between the number of patents in a software market and the rate at which new firms enter the market or obtain financing.
[6] Bessen and Meurer (2005) do find that larger patent portfolios reduce litigation when firms are technologically close. However, a large share of lawsuits are between firms that are technologically distant.

litigation, not much is known about the relationship between firm size and patent or R&D intensity, and more generally IP-induced problems, such as abandoning, not starting, or product modification.

3. Theoretical Model

Consider a firm that has one or more inventions which it intends to commercialize, let it be assumed that, each of its inventions *i*, has one or more granted patents that cover related inventions, and therefore there will be potential for a dispute over the profits accruing from invention *i*. Thus, the more inventions a firm has (assuming there is at least one patent on a related invention), the more disputes the firm can be expected to face. Assuming that each patent on a related invention has some constant probability of covering some feature of invention *i*, the probability of invention *i* infringing on at least one patent increases as the number of patents on related inventions increases. However, assume that the firm will not enter into disputes with itself. Then, if the firm holds a larger share of the patents related to invention *i*, the firm will be by definition less likely to infringe upon another firm's patent.

Let the number of potential disputes faced by a firm be *D*. A firm is expected to be involved in more disputes if it has more inventions, and/or it already has more patents on related inventions; if the firm holds a higher share of the patents on similar inventions, then fewer disputes can be expected.

D = f(Number of inventions, Number of patents on related inventions, Share of patents on related inventions held by firm *k*)

Now, for each dispute, the firm can choose to either abandon or modify the affected project, thus rendering the dispute moot, or it can attempt to resolve the dispute by employing a coping mechanism (*M*) such as negotiating for a license. If it chooses the former option, it incurs costs such as additional R&D expenses and/or forgone expected profits. If it chooses the latter option, it incurs costs such as payments to acquire patents, legal fees, or licensing fees, but anticipates the same level of profits from the innovation (gross of any licensing fees.) However, there is uncertainty about whether the coping mechanism will work. For example, the firm may enter into negotiations with a patent-holder, but the negotiations may break down and the firm may have to abandon the project. Or, the firm may be involved in litigation and may lose the suit. Coping mechanisms will either successfully resolve the dispute (with probability q) or fail to resolve the dispute (with probability $1-q$).

Net of the costs of employing M, which for simplicity we set at a fixed amount Fwhich is independent of the number of disputes, let the expected negative profit impact (or profit reduction) of an unresolved dispute be c, while the expected profit impact of a successfully resolved dispute is 0. The impact of an unresolved dispute can be thought of as damages paid to litigants, or loss of sales and unrecoverable investments in R&D or complementary assets associated with abandoning a project. Aggregating over all disputes, the expected cost of using the mechanism is $D[q*0 + (1-q)*c]+ F = (1-q)Dc + F$. If the firm does not use the mechanism, then the expected cost will be cD.

So, we will observe firms using the coping mechanism if the cost of using it is less than the expected cost of not using it, i.e. when $(1-q)Dc + F < cD$. In other words, firms use the mechanism if the expected cost savings from using the mechanism (qDc) exceeds the fixed cost of using it (F) This suggests a simple binary choice equation for use of a given coping mechanism:

(1) $M = 1$ if $qDc - F > 0$, and 0 otherwise.

Given M, the expected number of unresolved disputes, or problems, P, will simply be given by

$P = (1-q)D*M + (1-M)*D$, that is,

(2) $P = D(1-Mq)$.

Thus the number of problems is increasing in the number of disputes, decreasing in the use of coping mechanisms (as long as q>0), and decreasing in the probability of success of dispute resolution.[7]

Let us assume that the probability of successful resolution using the coping mechanism has both observed and unobserved (to the econometrician) components. We assume that the observed component depends on the characteristics of firm and market (size, concentration of IP, etc.). Note that a key determinant of the incidence of both the use of coping mechanisms and reports of encountering problems

[7] If we think of M as function M(D, q) increasing in p and D, then the effect of D and q on P needs to be considered as well. In this case, the relationship between the number of disputes D and the occurrence of a problem P is ambiguous.

is D, the number of potential disputes, which depends positively on the firm's number of inventions. Standard litigation models show that the risk of litigation increases with the size of the stakes involved. Thus, larger or more R&D-intensive firms can be expected to report both more use of coping mechanisms and more problems. Another potential determinant of the likelihood of problems is the concentration of IP holdings. For example, if patent holdings are concentrated among a smaller number of assignees, then a potentially infringing firm will have to negotiate with fewer parties, and the risk of breakdown of such negotiations may be lower.[8] In the empirical analysis described below, the model is enriched with additional control variables (e.g. firm age and industry) and potential determinants of coping and problems (e.g. IP concentration, the share of the firm's products in an area).

There is also an unobserved component in the probability of successful resolution, which is denoted γ. As a result, both the *M* (coping mechanism) equation (1) and the *P* (problem) equation (2) will contain the unobservable component γ, which will lead to a correlation in the errors of these two equations, denoted ρ, motivating the use of a bivariate probit model in the econometric application below.

4. Data Source and Variable Definition

The analysis is based on the Mannheim Innovation Panel (MIP), an annual survey which focuses on the innovative activities of German firms. The survey is conducted annually by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry of Education and Research since 1992. Every second year, the survey is part of the Community Innovation Survey (CIS) sponsored by Eurostat. The questionnaire used for this study follows the guidelines of the Oslo Manual for collecting innovation data (OECD and Eurostat [1997]). The target population of the MIP comprises legally independent firms in Germany, each with at least five employees. For the present analysis, we use information from the survey wave conducted in 2008. Patent information from the European Patent Office (EPO) was merged in, based on the applicant's name and address. A computer algorithm was used to suggest potential matches, which were later manually checked.

[8] In the model of Galasso and Schankerman (2010), more concentrated rights lead to faster resolution of disputes over IP, and this is confirmed by data on patent suits at U.S. federal district courts.

German firms can file patent applications at the German Patent Office or at the European Patent Office. Alternatively, they can choose an international application according to the patent cooperation treaty (PCT). Whereas the number of filings to the German patent office remained relatively constant between 2003 and 2009, the filings at the EPO (direct filings and regional phase of PCT applications) increased by 11% in the same period.[9] Typically, firms choose patent protection beyond Germany for the more valuable inventions.

A total of 6,110 firms responded to the survey questionnaire. The regression sample was restricted to firms that reported innovative activities (i.e. introducing a new product or a process in the three years preceding the survey), abandoning innovation projects or working on innovation projects. The sample was further restricted to the manufacturing sector, because what was needed in the regressions for firms with patent applications was the concentration of product market sales as a control and this measure is only available for the manufacturing sector. The sample analyzed thus has full information on 1,647 firms with innovative activities. For the parts of our analysis in which we require characteristics of technology markets, we need to restrict the sample to firms with at least one patent application, since we rely on information from patent applications to determine in which technology market the firm is mainly active in. This part of our analysis is based on a total of 562 firms.

In the survey wave conducted in 2008, a series of questions were focused on whether innovative activities were affected by lack of access to IP and whether firms used certain coping strategies. More specifically, firms were asked whether, in the years 2005-2007, any of the following events happened in their firms in conjunction with the access to intellectual property rights: Innovation projects were not started, because there was no access to necessary IP (*NOTSTARTED*); abandonment of innovation projects that were already started, because there was no access to necessary IP (*ABANDON*); modification of innovation projects to comply with available IP (*MODIFY*); conducting innovation projects without access to any of the necessary IP (*NOIPR*); acquisition of IP (purchase, licensing) (*ACQUIRE*); exchange of IP (cross licensing, patent pools) (*EXCHANGE*); opposition/litigation against IP held by other

[9] German Patent and Trade Mark Office (2010), http://www.epo.org/about-us/office/statistics/patent-applications.html, last accessed on July 13, 2011

firms/institutions (*OPPOSING*); negotiations/out-of-court settlements to avoid disputes about IP (*NEGOTIATE*). Detailed descriptive statistics on these variables are discussed in the following section.

Table 1 presents descriptive statistics of the sample for the remaining firm characteristics. Firms with innovative activities had, on average, 1,140 employees with a substantially lower median of 82 employees.[10] Only 23% of the firms were below 10 years of age. The R&D intensity, measured as R&D expenditure divided by sales, was on average 2.9%. Thirty-eight percent of the firms had at least one patent application at the EPO. On average, the firms had an application stock of 57 patents. All applications to the EPO were counted. Applications that were withdrawn, not granted or not renewed after grant were not subtracted.[11] Seventy percent of the firms with patent applications answered that patents were of high importance for protecting their intellectual property. To the remaining firms, they were of medium or low importance. The average number of patent applications filed at the EPO in the firm's main technological area in 2007 was 5,597.4 and the average share of those applications held by a patent-holding firm in the present sample is 2.9%. There are three observations for which the number of applications held by a firm exceeds the number of applications in the market.[12] The latter two variables and the way they are used in the regressions are shown in logs in Table 1.

The degree to which technology markets can be characterized as fragmented or concentrated is important for this paper. This was measured here using the Herfindahl index of concentration of ownership of IP in a technology market, calculated as the sum of squared shares of patent applicants and then scaled by 10. The market share of a patent applicant is taken to be the share of the applicant's patent applications in a specific technology relative to all applications in the respective technology. Technologies were defined up to 3-digit level (section+class) of the International Patent Classification (IPC). All applications to the EPO were taken as the basis, regardless of the applicant's country of origin. The

[10] The sampling frame of the survey included only those firms that had at least five employees each. However, if a company happened to shrink after its inclusion, it was not dropped from the survey. In fact, the minimum number of employees in the sample studied was one.
[11] We count all patents since first patent of the firm without using a depreciation rate. It is also possible to define a patent stock for a fixed time period or to use a depreciation rate. To the degree that inventions become obsolete over time, the measure of the patent stock contains measurement error.
[12] This can happen for very large firms, because technology applications are measured at annual level, and the firm measure as a stock variable.

Herfindahl index was calculated for the years 2003-2007 and then the average value used to smooth out annual variations. There were markets with average concentration, e.g. IPC class A24 "Tobacco, Cigars, Cigarettes, Smokers' Requisites" with a Herfindahl of 0.06, and markets with very low concentration, e.g. E04 "Building" with a Herfindahl of 0.01. We determined in which technology markets a MIP firm was active, based on the 3-digit technology classes included in its patent applications. The Herfindahl index of concentration of IP ownership was weighted with the relative importance of the 3-digit technology classes in the firms' patent stock to approximate the concentration in the IP markets to which the focal firm was exposed. It is to be noted that concentration at the technology market could be measured only for firms that applied at least for one patent. The Herfindahl index for the concentration in the technology market had a mean of 0.06.[13]

The Herfindahl index of the product market measures the sales concentration, defined at the 3-digit industry level, to control for the competitive situation in the product market. This index is based only on the sales of German firms within Germany and is published by the German Monopoly Commission. The Herfindahl index for the concentration in the product market had a mean of 0.05.

5. Results

5.1. Economy-wide Incidence of Problems and Coping Strategies

We begin by describing the summary statistics of the dataset weighted to be representative of the German economy in Table 2. The weights were based on information on the number of firms in Germany with specific characteristics according to industry, size group and region. For each industry-size-region cell, the number of active firms was determined from official statistics and from information provided by a credit rating agency. The size of the cell, in relation to the overall population of firms in Germany,

[13] We also experimented with the firm-level fragmentation measure developed by Ziedonis (2004). Higher fragmentation had a marginally significant positive correlation with the negotiation event in the simple probit regression, but was otherwise insignificant. This fragmentation measure was less informative about the patent landscape faced by the firms under study than the technology-level concentration measure, because patents from the EPO had fewer references than patents from the USPTO, and many firms in the study sample had only a small patent stock. The number of references available to calculate fragmentation of ownership is therefore quite limited. We also experimented with the inclusion of a dummy variable for the most important 3-digit technology class of a firm's patent stock belonging to a discrete technology and found it to be always insignificant in the regressions.

determines the cell's weight. The mean values of the outcome variables for each cell were calculated by using information from only those firms that fit the cell characteristics and by weighting the means by the relative importance of the cell. Thus, representative values were obtained. The sampling procedure incorporated an oversampling of firms with the following characteristics: large firms, firms from Eastern Germany, and firms from industries with a high variability in labor productivity.[14]

The present analysis will focus on firms with innovative activities. It is possible that lack of access to IP may prevent firms from undertaking any innovative activities. Of the firms without innovative activities (excluded from the regression sample but covered by the survey), it was found that 1.2% of them did not start an innovative project because of lack of access to IP. Although such firms were very few, it implies that IP could have been an entry barrier to innovation for some firms. In representative values, 44% of German firms had no innovative activities. There is no information on the other three problem categories, because firms without innovative activities do not currently work on innovative projects.

Approximately 2.8% of non-innovating firms reported that they were unable to start a project owing to the lack of IP. A slightly higher percentage of German innovative firms – 3.13% – abandoned a project because of lack of IP, and for the same reason 9.1% of such firms were required to modify innovative projects. By contrast, 7.3% of firms proceeded with their projects, although they had no access to the necessary IP. These rates differ in some cases between manufacturing and services firms, the former being three times as likely to report modifying a product (16.7% vs. 5.7%) and almost twice as likely to report going forward without access to IP (10.5% vs. 5.9%).

The second set of questions about coping mechanisms received somewhat higher rates of positive response. 13.9% of German firms with innovative activities reported acquisition of IP, 7.6% engagement in negotiation, and 5.3% opposition to another firm's application. However, a surprisingly low share of firms – 1.5% – was engaged in the exchange of IP via cross-licensing or patent pools. The biggest differences in responses between manufacturing and services firms were in the use of opposition (9.9%

[14] Because there is no official statistic for the age distribution of German firms, it is difficult to say how the regression sample deviates from the population, but we expect that young firms are underrepresented. The results presented here, therefore, need to be interpreted in the light of that fact.

and 3.3% respectively) and negotiation (12.6% and 5.4% respectively). These differences presumably reflect the relative strategic importance of patents in the manufacturing sector.

There were substantial differences across industries. Incidence of IP problems was well below the overall mean in mining and business services, but well above the same in industries such as pharmaceuticals, electronics, and instruments. The highest rates of patent acquisition were in chemicals and pharmaceuticals, computers and telecommunications, and (interestingly) financial intermediation, all of which were in the range of 30%. Slightly more than half of the firms in motion picture and broadcasting reported acquisitions of IP, which reflects the importance of licensing the rights to creative products in this industry.

The previous discussion indicates the prevalence of problems and solutions to IP access across German economy sectors. Now, the basic patterns in the dataset used for the regressions (see Table 3) are discussed; it should be noted that the statistics discussed here are not weighted to be representative of the population of German firms. Comparing various subsets of the data, it is seen that the mean rate of reporting of adverse effects or use of coping mechanisms was substantially lower for firms below the median of employment in the sample (82 employees). As expected, large firms had more innovation projects and therefore a higher probability of encountering problems. It is also seen that lower rates of adverse effects and coping mechanisms for firms with sales were highly concentrated in a single product. Interestingly, young firms did not report more problems than old ones. Rates of adverse effects were lower for less innovative firms: non-R&D performers, firms without sales of new products or without patents, and firms for which patents were of low importance as a way of protecting IP. In summary, no matter how innovativeness was measured, both problems and coping activities were more common among more innovative firms.

Firms with only product innovations reported somewhat higher rates of problems and coping than firms with only process innovations. This could point to greater importance of IP for product, relative to process innovation. The highest rates of problems and coping were found for firms with both product and process innovations.

For firms with at least one patent, the concentration of ownership of IP was computed. Firms with higher concentration reported lower rates of problems, with the exception of proceeding without access to IP, which was higher when IP was more concentrated. The reported rate of IP exchange almost doubled when IP concentration was higher, which may reflect lower transaction costs of negotiating in more concentrated markets. In contrast, problems appear to have been *more* common for firms facing greater concentration in the *product* market (as measured by the Herfindahl of sales in the firm's 3-digit industry).

In most instances, a higher incidence of problem and coping strategies was seen for firms with a higher share of own patents in the technology, which can be interpreted mainly as a size effect. More interestingly, a higher incidence of problem and coping strategies was seen for firms in technologies with more patent applications. A more crowded environment may necessitate more activities by firms to deal with access to the required IP.

The incidence of reporting IP problems was correlated across different kinds of problems and coping strategies as shown in Table 4. For example, 58% of firms that reported abandoning a project owing to lack of IP also reported not starting a project. The use of coping mechanisms, conditional on reporting a problem, was 2 to 3 times higher for firms reporting problems, such as not starting or abandoning projects. Interestingly, however, the reported rate of using coping mechanisms was still quite high even for firms that did not report IP problems. We interpret this as evidence that these mechanisms were quite effective in allowing firms to avoid or mitigate difficulties presented by lack of freedom to operate.

5.2. Determinants of Problems

Though interesting, these differences in means are vulnerable to confounding, and the responses were correlated across answers (jointly determined). In Tables 5-6, simple Probit models that control for a variety of characteristics of the firm and technology area were estimated. Table 5 focuses on questions relating to problems or potential stifling effects of patents. In the first five columns, the results are presented based on the sample of firms with innovative activities; in columns 6-10, the results are restricted to firms that had filed at least one patent application in the past. For most outcome variables, firms were more likely to have answered ‘yes’ to the survey question if they were larger and more R&D-intensive, the notable exception being *ABANDON*, where the relation of ‘firm size’ and ‘competence’ to the likelihood of abandoning a project was insignificant. Larger size is also not significantly associated with *NOIPR*, after controlling for R&D intensity. Firms younger than ten years old were insignificantly related to all the survey responses, implying that young firms, particularly, were not vulnerable to problems.[15]

The relationship between firm patenting and the survey questions reveals an interesting pattern. Having at least one patent application was positively and significantly associated with abandoning, not starting, and with proceeding without access to IP or modifying a project. It is associated with a 15.4 percentage point increase in the probability of having to modify a product, all else equal, but only a 2.7 percentage point increase in the probability of abandoning a project. However, of those questions only modification is significantly related to the share of patent applications in the technological area filed by a firm.

Patenting firms were asked about the importance of patents for protecting their intellectual property; a dummy equal to 1 was included if the firm reported that patents were “of high importance”. This variable was not significantly associated with any of the survey questions about problems, holding constant covariates. Also included was a variable that captures the concentration of IP rights in the technology classes cited by the firm (the Herfindahl of IP). The coefficients on this variable were negative and significant for abandoning, not starting, and modifying projects. These results are consistent with the hypothesis that less concentrated holdings of IP may be associated with less potential hold-up of firms commercializing complementary technologies. The relation of the Herfindahl of sales in the product market to all the survey questions holding constant other covariates is insignificant.

[15] Even when age or the logarithm of age was used as a continuous measure, the influence was found to be insignificant.

In columns 5 and 10 we present results based on an aggregate *PROBLEM* variable equal to 1 if the firm answered affirmatively to any of *ABANDON, NOTSTARTED*, and *MODIFY*.[16] We see that larger, more R&D-intensive firms are more likely to experience problems. This is consistent with these firms having more innovative projects but also with the possibility that they are "bigger targets" for potential litigants. Firms operating in technological areas with more patents, and firms holding a larger share of those patents experience more problems, while firms facing more concentrated IP landscapes are less likely to have experienced problems, all else being equal.

5.3. Determinants of Coping Strategies

Table 6 presents the results on the determinants of the questions relating to coping mechanisms. Large firms and R&D-intensive firms were more likely to have used these mechanisms, although when only firms with patents are considered, the coefficients on R&D/sales become insignificant in the regressions for which the dependent variables are *OPPOSING* and *NEGOTIATE*. Having at least one patent application was insignificantly associated with acquisitions of IP, but positively and significantly related to all other trade or legal mechanisms. The share of applications in the market held by the firm is positively and significantly associated with each of these questions except *ACQUIRE*. The number of applications in the market is positively and significantly associated with *OPPOSING* and *NEGOTIATE*, but not *ACQUIRE* and *EXCHANGE*.

Firms that responded that patents were of high importance were significantly more likely to have reported at least one coping mechanism, but this variable was only significantly related to *EXCHANGE* and *OPPOSING* at the 10% level. It is interesting to note that the firm's R&D intensity appears to be most strongly correlated with acquisition and exchange of IP, while its share of patents in the market (and not R&D) is correlated with opposition and negotiation.[17]

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[16] *NOIPR* is not included in this definition of "problems", because in some sense it is a solution. Taking this route allows firms to proceed with innovative projects, though it may be a risky course.

[17] In additional analyses, not reported here, we considered the choice between what one might call "judicial" (opposition and negotiation) and "market" (acquisition and exchange) mechanisms, conditional on the use of any coping mechanism. Considering only those firms that chose either a judicial mechanism or a market mechanism (and not both), it was found that firms with more patents in their technology area, and firms holding a larger share of those patents, were more likely to have chosen judicial mechanisms.

The variable *COPING* also was included to capture whether any of the "coping" questions, i.e. *ACQUIRE*, *EXCHANGE*, *OPPOSING* and *NEGOTIATE*, was answered affirmatively (columns 5 and 10). For our aggregate coping measure it is again seen that firms which were larger and more active in innovation were more likely to have used coping mechanisms, as were the firms which operated in areas with more patents and firms that held a larger share of the patents in their area.

We have observed that increases in scale and R&D intensity are associated with increases in the likelihood of both problems and coping. One question that naturally emerges from this finding is whether the correlation between these variables and coping is driven by the higher incidence of problems among large, R&D intensive firms. In Table 7 (columns 1-4), the results for the coping equation, conditional on *PROBLEM*=1 or *PROBLEM*=0, are presented.

Conditioning on the set of firms that reported at least one problem reduces the sample size to 433. The marginal effect of the "any patents" dummy falls from 0.15 to 0.10 and is no longer significant at the 5% level (though it is borderline significant with a p-value of 0.06). R&D intensity is also no longer significant at the 5% level. The results for patenting firms are relatively robust. For example, the concentration measure and share of patents held by the firm remain significant at the 5% level in the regression with "cope" as the dependent variable, while the number of patents in the market is no longer significant. Furthermore, size and R&D intensity are both insignificant in the regression restricted to firms with problems, while they are the only significant variables in the regression restricted to firms that did not report any problems. Thus, we conclude that firm size and R&D intensity are not correlated with the use of coping mechanisms simply because they are correlated with the number of problems. Rather, these firms might have incurred lower costs in using coping mechanisms, independent of the number of problems encountered. This is consistent with a lower value of *F*, the fixed cost of using coping mechanisms, in our model.

5.4. Joint Determination of Problems and Coping Strategies

The question-by-question analysis described above should be interpreted bearing in mind that many firms answered more than one question affirmatively. This relates to the fact that firms which are more engaged in innovative activity may be more likely to encounter more than one problem or seek more than one type of solution to a problem. Furthermore, the probability of facing an IP problem and the decision to use a coping mechanism may be jointly determined (for example, firms that are more likely to face a problem may have stronger incentives to use coping mechanisms). To correct for this, a Bivariate Probit (BVP) model was used with separate equations for the probability of the firm facing an IP problem and the decision to using a coping mechanism. This empirical approach allowed us to model the correlation in the errors of the problem and coping equations.

The BVP model takes the following form: define dummy variables $y_1 = 1$ if the firm faces a problem, and 0 otherwise, and $y_2 = 1$ if the firm uses a coping mechanism and zero otherwise.[18] Let x be a vector of variables influencing problems and coping. We then specify a two-equation model where

$$y^*_1 = \beta_1'x + \varepsilon_1 \qquad y_1 = 1 \text{ if } y^*_1 > 0, 0 \text{ otherwise}$$

$$y^*_2 = \beta_2'x + \varepsilon_2 \qquad y_2 = 1 \text{ if } y^*_2 > 0, 0 \text{ otherwise}$$

$$E[\varepsilon_1] = E[\varepsilon_2] = 0, \quad Var[\varepsilon_1] = Var[\varepsilon_2] = 1, \quad Cov[\varepsilon_1, \varepsilon_2] = \rho$$

Table 7 (columns 5a-6b) contains marginal effects from a BVP model. We find that many of the previously reported results persist, for example that firm size, R&D intensity and patents are positively associated with both problems and coping. The correlation term ρ is around 0.4 and significantly different from zero. Firms that filed patents were 15 percentage points more likely to have faced problems and 14 percentage points more likely to have used coping mechanisms. An increase in the share of patents of a given technology held by the firm was positively and significantly associated with both outcomes, but the number of patents in the area was significantly associated with problems at the 10% level and coping at the 5% level (though the estimates are quite comparable: a marginal effect of 0.052 for problems and a standard error of 0.029 and a marginal effect of 0.059 for coping and a standard error of 0.029).

[18] When did the firms report *PROBLEM* = 0 and *COPING* = 1? The majority (60%) of the firms in this category reported acquisition of IP, 41% reported negotiations, 37% reported opposition to or litigation of patents held by competitors, and 7% exchange of IP. 18% proceeded without access to IP, which is classified here as not having faced a problem; these firms might have ended up facing problems at a later date. Firms which reported both problems and coping strategies were considerably more likely to have used the coping mechanisms mentioned, with the exception of the acquisition of IP for which a similar value was found. These results are probably due to a size effect. Smaller firms with fewer innovative projects were less likely to have used certain coping mechanisms, but because they had fewer projects, it was more likely that the coping mechanisms solved all the problems.

We also experimented with calculating the marginal effects for the Bivariate Probit model conditional on the other event being equal to one. We find that the marginal effects relating to size (number of employees) and volume of innovative activities (R&D/sales and share of own patents in the technology) tend to be smaller by around one third. The significance levels of these and the remaining marginal effects stay generally very constant.

Relating back to the theoretical model in Section III, our empirical results could confirm that firms facing more patents in the technology area are confronted with more problems. However, we found that holding a higher share of these patents led to an increase, instead of a decrease, in the likelihood of problems. This means that the size effect of having more innovative activities dominates any influence of having larger bargaining power over competitors with relevant IP.

The model in Section II suggests the use of a recursive Bivariate Probit model in which the coping variable was included in the problem equation, that is $y^*_1 = \beta_1'x + \gamma_1'y_2 + \varepsilon_1$. However, to identify such a model, one would need instrumental variables that affect coping, but not problems. Because access to such variables was not available, a non-recursive Bivariate Probit model was estimated, which accounts for the correlation in the errors of the two equations but does not identify the impact of coping on problems.

6. Interpretation

One of the intriguing findings of this analysis is that, at least by these measures, large firms and R&D-intensive firms were much more likely, than smaller firms, to have faced problems in pursuing innovation in the face of IP held by other entities. Furthermore, young firms appear to have been at no particular disadvantage relative to old firms with greater experience. Clearly, large, R&D-intensive firms were more likely, relative to smaller firms, to have encountered IP problems owing to their greater scale and complexity of operation, and to have had patents asserted against them—either because unrecoverable investments in complementary assets rendered them vulnerable to hold-up, or because of their ability to pay settlements or damages awards. It is striking, however, that these firms faced problems more frequently in spite of their presumably greater resources for preventing failures, e.g. expertise in the legal and patent systems, prior experience in product development, or other complementary assets and capabilities.

At the same time, the results reported here hint at the possibility that large firms might have dealt with their problems more effectively; they were more likely to have modified a product or not started a project, but not more likely to have abandoned a project or proceeded without access to IP. The last two possibilities may be seen as less desirable, because abandoning a project may be costlier than not starting it at all, and proceeding without access to IP is a potentially risky strategy. Thus, though larger firms may face more problems, they may be better equipped to deal with them through efficient use of coping mechanisms.

Another interesting result was found in the patent-related variables. Firms that had patents were significantly more likely to have reported running into problems, and to have abandoned, not started, or modified innovation projects, or to have proceeded without access to IP. Firms with a larger share of the total number of patents in their technology area were also more likely to have reported exchanging IP or participating in oppositions or negotiations to resolve disputes. In general, it was found that increases in the size of the firm's patent stock (holding constant the number of patents in the area) were associated with increased use of coping mechanisms, but these increases did not completely prevent or solve the problems. Finally, it was found that when the ownership of IP in the firm's technology area was concentrated among a smaller number of patent-holders, the incidence of problems decreased. This may be related to greater ease of negotiating with patent holders. However, greater use of coping strategies was not observed in more concentrated IP markets, all else being equal. These puzzles may simply be artifacts of the data, which preclude observe the timing of when firms encounter problems and deploy coping mechanisms. But they suggest a complex relationship between concentration of ownership of IP in markets and that in technologies. The frequency with which firms encounter and are able to resolve IP problems may be a fertile area for further research.

Several caveats associated with these findings should be kept in mind. The results are based on a limited, and to some extent, a selected sample. First, only active firms were surveyed, excluding firms that were deterred from entering the market because of IP problems. Because of this limitation, what one sees may only be the "tip of the iceberg." For example, only a few firms in the sample reported having abandoned or failed to start a project because of lack of IP. This is because the data used here did not include the firms that exited or avoided the industry for that reason. Second, much of the analysis was restricted to patent-holding firms, because our ability to measure the number of patents in the market and the concentration of ownership of those patents depends on knowledge of the technology classifications in which the firms patent. Firms without patents could potentially be affected by these variables, but these broader effects could not be measured with the current dataset.

Reliance on self-reporting implies that one can measure only those IP problems of which the firms were aware. Firms that did not thoroughly search outstanding patents may not be able to identify problems that could arise later. This is more likely to be the case with smaller or less experienced firms. Furthermore, it is important to bear in mind that the present data do not permit determining whether a firm tried, but failed, to use a coping mechanism, did not try because of perceived high costs, or had no need to try.

Finally, it is also not clear how relevant these results are to the contexts other than that of German economy. In the US, for example, despite the absence of an opposition procedure, patents have proliferated at least as fast as in Germany. US firms may, therefore, be more likely to face some of the problems identified here and to have fewer coping mechanisms.

7. Conclusions

We examined the evidence collected from a survey of innovative German firms that responded to the queries relating to problems of accessing IP required for innovation. It was found that a small percentage of firms abandoned or not started innovation projects because of lack of access to IP. Acquiring IP or modifying innovation projects to comply with existing IP or proceeding without access to requisite IP was found to be common among the firms. Larger and more R&D-intensive firms were more likely to have used mechanisms to deal with problems of access to IP. An increase in the size of a firm's patent portfolio relative to other patents in a technology area, all else being equal, facilitated the use of solutions like negotiation or exchange of IP, but could not prevent the incidence of problems. This suggests the possibility that concentration in the market for intellectual property has a rather different effect than that of concentration in the product market. The available evidence suggests that increasing concentration of holdings of relevant IP may actually *enhance* competition by reducing problems of access to IP. This finding suggests an intriguing nuance for competition policy that should be better understood.

Thus, the overall picture that emerges from this analysis is one in which firms rarely stopped projects or avoided them because of lack of access to IP. Rather, many firms were engaged in activities designed to deal with or avoid such problems. This raises the question of the opportunity costs of using these mechanisms and how they could be reduced. All else being equal, using coping mechanisms diverts resources that could otherwise be utilized for innovation activities by firms; policymakers must, therefore, promote innovation by finding ways to improve the efficiency of the institutions that facilitate access to IP. For example, centralization of national courts for patent litigation into a single European court could save legal expenses of European firms. The development of a standardized contract to license technology by public research institutions could reduce transaction costs and act as a blueprint for licensing between private partners as well. Furthermore, additional applications of recent advances in search technology could reduce the costs of prior art searches and make prior art easier to find.[19]

These results highlight the need for a better understanding of the private and social costs of coping with or adapting to an increasingly complex IP environment. Given the nature of the survey data reported here, it is clear that little is known about the nature and value of the projects that were abandoned or not started in the face of IP access problems neither do we know the costs of accommodating or avoiding these problems. When a product was modified, was the modification radical or minor? Was the cost of acquiring requisite IP offset by the increase in revenues associated with the innovative project? Were the legal costs associated with the negotiations conducted to avoid problems of access to IP large or small? Without adequate information on the magnitude of the private and social costs imposed by IP access

[19] For example, free access to services, such as Google patents and Espacenet (provided by the European Patent Office), has already been facilitating prior art searches.

problems, it is difficult to draw definitive policy conclusions. The present findings suggest that the attention of researchers and policymakers could be usefully directed towards improving our understanding of the economic burden of IP.

References

Anton, J.J. and Yao, D.A., 2004. Little Patents and Big Secrets: Managing Intellectual Property. RAND Journal of Economics 35, 1-22.

Arora, A., Fosfuri, A. and Gambardella, A., 2001. Markets for Technology: Economics of Innovation and Corporate Strategy. MIT Press, Cambridge MA.

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

Bessen, J. and Meurer, M., 2005. Lessons for Patent Policy from Empirical Research on Patent Litigation. Lewis & Clark Law Review 9, 1-27.

Cockburn, I., MacGarvie, M. and Mueller, E., 2010. Fragmented Intellectual Property Rights, Licensing and Innovative Performance. Industrial and Corporate Change 19, 899-925.

Cockburn, I. and MacGarvie, M., 2009. Patents, Thickets and the Financing of Early Stage Firms: Evidence from the Software Industry. Journal of Economics & Management Strategy 18, 729-777.

Cockburn, I. and MacGarvie, M., 2011. Entry and Patenting in the Software Industry. Management Science 57, 915-933.

Cohen, W., Nelson, R.R. and Walsh, J., 2000. Protecting their intellectual assets: Appropriability conditions and why U.S. manufacturing firms patent (or not). NBER Working Paper 7552.

Federal Trade Commission, 2003. To Promote Innovation: The Proper Balance of Competition and Patent Law and Policy. Federal Trade Commission, Washington, DC.

Galasso, A. and Schankerman, M., 2010. Patent Thickets, Courts, and the Market for Innovation. RAND Journal of Economics 41, 472-503.

Galasso, A., Schankerman, M. and Serrano, C., 2011. Trading and Enforcing Patent Rights. CEPR Discussion Paper No. 8573.

Gans, J., Hsu, D. and Stern, S., 2002. When Does Start-up Innovation Spur the Gale of Creative Destruction? RAND Journal of Economics 33, 571-586.

Geradin, D., Layne-Farrar, A. and Padilla, A. J., 2007. Royalty Stacking in High Tech Industries: Separating Myth from Reality. CEPR Discussion Paper No. 6091.

German Patent and Trade Mark Office, 2010. Annual Report 2009. Munich, Germany.

Haeussler, C., Harhoff, D. and Mueller, E., 2009. To Be Financed or Not… - The Role of Patents for Venture Capital Financing. CEPR Discussion Paper No. 7115.

Hall, B.H. and MacGarvie, M., 2010. The Private Value of Software Patents. Research Policy 39, 994-1009.

Hall, B.H. and Ziedonis, R.H., 2001. The Patent Paradox Revisited: An Empirical Study of Patenting in the US Semiconductor Industry, 1979-95. RAND Journal of Economics 32, 101-128.

Heller, M. A. and Eisenberg, R. S., 1998. Can Patents Deter Innovation? The Anti-commons in Biomedical Research. Science 280, 698-701.

Hsu, D. and Ziedonis, R., 2008. Patents as Quality Signals for Entrepreneurial Ventures. Academy of Management Best Paper Proceedings.

Jaffe, A. B. and Lerner, J., 2004. Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It. Princeton University Press, Princeton.

Lemley, M. and Shapiro, C., 2007. Patent Holdup and Royalty Stacking. Texas Law Review 85.

Lanjouw, J. O. and Schankerman, M., 2004. Protecting Intellectual Property Rights: Are Small Firms Handicapped? Journal of Law and Economics 47, 45-74.

Levin, R., Kievorick, A., Nelson, R.R. and Winter, S. G., 1987. Appropriating the returns from industrial R&D. Brookings Papers on Economic Activity, 783-820.

Mansfield, E., 1986. Patents and innovation: an empirical study. Management Science 32, 173-81.

Merges, R.P. and Nelson, R., 1990. On the Complex Economics of Patent Scope. Columbia Law Review 90, 839-916.

Merrill, S., Levin, R. and Myers, M. (eds.), 2004. A Patent System for the 21st Century”. National Academies Press, Washington DC.

Noel, M. and Schankerman, M., 2006. Patent Thickets and Software Innovation: Theory and Evidence from a Panel of U.S. Firms. CEPR Discussion Paper No. 5701.

OECD and Eurostat, 1997. Oslo Manual - Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. OECD/Eurostat, Paris.

Rammer, C. and Bethmann, N., 2009. Schwerpunktbericht zur Innovationserhebung 2008, Innovationspartnerschaften – Schutz und Verletzung von intellektuellem Eigentum. ZEW Dokumentation Nr. 09-01, Mannheim, Germany.

Reinganum, J.F., 1983. Uncertain Innovation and the Persistence of Monopoly. American Economic Review 73, 741-47.

Reitzig, M., Henkel, J., and Schneider, F., 2010. Collateral damage for R&D manufacturers: how patent sharks operate in markets for technology. Industrial and Corporate Change 19, 947-967.

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

Scotchmer, S., 1991. Standing on the Shoulders of Giants: Cumulative Research and the Patent Law. Journal of Economic Perspectives 5, 29-41.

Shapiro, C. (2001). Navigating the Patent Thicket: Cross-licenses, Patent Pools, and Standard-Setting, in: Jaffe, A., Lerner, J. and Stern, S. (Eds), Innovation Policy and the Economy, Vol. 1. MIT Press for the National Bureau of Economic Research.

Siebert, R. and von Graevenitz, G., 2006. How Licensing Resolves Hold-Up: Evidence from a Dynamic Panel with Unobserved Heterogeneity. CEPR Discussion Paper No. 5436.

Ziedonis, R., 2004. Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms. Management Science 50, 804-820.

Table 1: Descriptive Statistics for Regression Variables

	Firms with innovative activities					Firms with patent applications				
	Mean	**Median**	**St dev**	**Min**	**Max**	**Mean**	**Median**	**St dev**	**Min**	**Max**
Employees	1,139.7	82	12,224	1	400,000	2,989.7	274.5	20,761	2	400,000
Young (0/1)	0.23	0	0.42	0	1	0.22	0	0.41	0	1
R&D/sales (in %)	2.95	0.74	6.48	0	82.84	3.95	1.23	7.63	0	82.84
Application (0/1)	0.38	0	0.49	0	1	1	1	0	1	1
Application stock	57.41	0	950.65	0	31,587	169.51	6.5	1,623.3	1	31,587
Sales share main product (in %)	66.29	70	25.19	5	100	60.92	60	26.17	5.2	100
No finished inno projects (0/1)	0.14	0	0.34	0	1	0.12	0	0.33	0	1
Product inno only (0/1)	0.31	0	0.46	0	1	0.28	0	0.45	0	1
Process inno only (0/1)	0.12	0	0.32	0	1	0.04	0	0.20	0	1
Product and process inno (0/1)	0.44	0	0.50	0	1	0.55	1	0.50	0	1
Manufacturing (discrete industries) (0/1)	0.44	0	0.50	0	1	0.32	0	0.47	0	1
Chemical industry (0/1)	0.09	0	0.28	0	1	0.09	0	0.29	0	1
Manufacturing (complex industries) (0/1)	0.47	0	0.50	0	1	0.58	1	0.49	0	1
ln(applications technology)*						8.21	8.22	0.97	4.75	10.23
ln(share technology)**						-5.85	-5.93	1.77	-9.54	1.29
Patent protection high importance (0/1)						0.70	1	0.46	0	1
Concentration of IP ownership						0.06	0.05	0.04	0.01	0.37
Concentration of product market sales						0.05	0.02	0.07	0.003	0.38

Note: There are 1647 observations for firms with innovative activities and 562 observations for firms with at least one patent application. The samples cover firms from the manufacturing sector.
* Natural logarithm of the total number of applications in the main technology area of the firm. ** Natural logarithm of the share of patent applications in the main technology area filed by the firm.

Table 2: Mean Values of Problems and Coping Strategies Representative for German Firms

	Problems				Coping strategies			
Variable	**NOTSTARTED**	**ABANDON**	**MODIFY**	**NOIPR**	**ACQUIRE**	**EXCHANGE**	**OPPOSING**	**NEGOTIATE**
				Firms without innovative activities				
Full sample	1.19	-	-	-	3.08	0.33	1.59	1.74
				Firms with innovative activities				
Full sample	2.79	3.13	9.07	7.34	13.90	1.54	5.30	7.64
Manufacturing, all	3.91	3.20	16.71	10.51	13.80	2.41	9.89	12.63
Services, all	2.29	3.10	5.69	5.94	13.95	1.16	3.27	5.42
Mining and quarrying (10-14)	0.00	0.98	1.31	1.31	5.90	0.00	2.95	0.00
Food/beverages/tobacco (15-16)	1.07	4.21	6.45	7.21	12.76	1.69	7.62	11.35
Textiles/clothing/leather (17-19)	1.22	0.00	10.12	6.25	19.46	0.52	10.82	16.04
Wood/paper/printing/ publish. (20-22)	2.66	3.57	8.76	4.96	10.33	0.99	1.85	4.29
Chemicals/pharmaceuticals/ oil (23-24)	9.98	5.43	26.16	18.09	29.63	5.33	17.65	21.03
Rubber/plastics (25)	3.29	3.18	12.51	12.81	8.11	3.03	16.58	13.88
Glass/ceramics/mineral products (26)	11.15	8.89	32.19	10.60	21.90	0.94	20.73	19.41
Metal production/ processing (27-28)	4.54	2.68	13.87	7.84	10.01	1.75	6.44	9.84
Mechanical engineering (29)	3.59	1.21	22.84	11.09	9.80	2.50	12.64	15.31

Electrical eng./electronics (30-32)	3.75	5.26	23.39	18.17	19.12	4.92	14.94	15.65
Instruments (33)	6.21	4.20	25.11	15.12	18.86	3.47	9.99	14.54
Transport equipment (34-35)	2.72	1.72	24.64	15.22	19.02	6.07	8.33	21.11
Furniture/toys/recycling (36-37)	0.65	2.59	9.01	11.48	18.78	0.71	7.18	11.24
Electricity/gas/water supply (40-41)	0.00	0.00	3.00	1.20	12.00	0.96	2.88	6.72
Wholesale trade (51)	1.07	4.80	0.28	6.50	8.73	0.00	9.88	9.15
Transport/post (60-63, 64.1)	0.62	2.27	2.29	0.21	14.42	5.04	0.19	7.56
Financial intermediation (65-67)	0.00	0.00	1.76	0.66	32.24	1.16	2.49	4.85
Computer activit./ telecomm. (72, 64.3)	6.39	7.77	16.13	17.20	27.85	1.25	6.10	9.33
Engineering services/R&D (73, 74.2-74.3)	1.61	0.92	12.44	2.86	11.87	0.71	3.06	2.36
Consultancy/advertising (74.1, 74.4)	3.69	3.73	3.84	7.86	9.55	0.00	0.23	3.51
Other business services (74.5-74.8, 90)	0.94	0.18	2.45	3.15	11.35	0.18	2.30	1.84
Motion picture/broadcasting (92.1, 92.2)	2.71	2.71	23.15	23.52	51.35	0.37	20.44	7.88

Note: Values are representative for German firms. Values given in percent. NACE code is given in brackets. Manufacturing, all covers industries 10-41; services, all covers industries 51-92.2. The representative values are taken from Rammer and Bethmann (2009).

Table 3: Average Incidence of Problems and Coping Strategies Based on the Regression Sample

	Problems				Coping strategies				
Variable	**NOTSTARTED**	**ABANDON**	**MODIFY**	**NOIPR**	**ACQUIRE**	**EXCHANGE**	**OPPOSING**	**NEGOTIATE**	**N**
					Firms with innovative activities				
Full sample	5.83	3.89	24.23	13.96	20.70	5.22	18.15	18.34	1647
Employment<=82	3.64	2.67	14.93	12.5	12.99	1.82	8.01	9.47	824
Employment>82	8.02	5.10	33.54	15.43	28.43	8.63	28.31	27.22	823
Age<=10 years	5.91	3.41	24.55	16.14	22.73	6.36	18.41	20.45	440
Age>10 years	5.80	4.06	24.11	13.17	19.97	4.81	18.06	17.56	1207
R&D/sales =0	1.09	0.82	4.08	2.72	7.61	1.09	6.25	8.70	368
R&D/sales >0 and R&D/sales<=1.32	7.03	5.63	24.69	14.53	22.66	3.75	20.78	19.06	640
R&D/sales >1.32	7.36	3.91	35.37	19.87	26.29	9.08	22.38	23.16	639
Firm has no patent applications	3.33	2.35	12.65	9.80	13.92	1.57	8.82	10.00	1020
Firm's application stock<=6	7.10	6.21	31.36	19.82	22.78	3.55	18.34	18.93	338
Firm's application stock>6	13.15	6.57	56.75	21.80	42.21	20.07	50.87	47.06	289
Share of sales new to the firm<=20%	6.02	3.77	26.20	17.17	23.04	4.82	22.14	20.33	664
Share of sales new to the firm>20%	6.29	5.48	33.06	15.21	23.73	8.32	22.11	23.53	493
Share of sales new to the market=0	3.30	2.02	19.63	10.64	16.88	2.20	13.21	13.39	545
Share of sales new to the market>0	8.52	6.56	36.89	21.64	28.52	9.34	29.18	28.36	610
Sales share main product <=60%	6.83	5.72	29.99	15.90	26.64	6.42	22.45	23.29	717

Sales share main product>60%	5.05	2.47	19.78	12.47	16.13	4.30	14.84	14.52	930
No finished innovation project	4.85	2.64	11.89	7.93	13.22	0.88	7.05	6.61	227
Product innovation only	3.92	2.75	21.37	12.94	19.61	3.33	14.90	15.88	510
Process innovation only	4.21	1.58	9.47	5.79	11.58	2.11	7.37	12.11	190
Product and process innovation	7.92	5.69	34.03	18.75	26.25	8.75	26.81	25.42	720
Firms with patent applications									
Full sample	10.50	6.76	46.98	21.17	34.34	12.28	36.83	34.52	562
Significance of patent protection: low or medium	8.43	4.82	34.94	21.69	24.70	3.61	24.70	24.70	166
Significance of patent protection: high	11.36	7.58	52.02	20.96	38.38	15.91	41.92	38.64	396
Concentration of IP ownership <= median	13.88	8.54	51.25	18.51	35.94	8.54	36.65	36.30	281
Concentration of IP ownership > median	7.12	4.98	42.70	23.84	32.74	16.01	37.01	32.74	281
Concentration of product market sales <= median	8.54	6.41	43.42	19.22	29.18	10.32	39.86	34.52	281
Concentration of product market sales > median	12.46	7.12	50.53	23.13	39.50	14.23	33.81	34.52	281
ln(applications technology) <= median	7.83	5.69	40.57	20.28	31.32	11.39	34.52	30.25	281
ln(applications technology) > median	13.17	7.83	53.38	22.06	37.37	13.18	39.15	38.79	281
ln(share technology) <= median	8.90	7.47	39.50	22.78	30.25	4.63	28.83	25.98	281
ln(share technology) > median	12.10	6.05	54.45	19.57	38.43	19.93	44.84	43.06	281

Note: Cells shows the mean value of the variable listed in the column heading, conditional on the value of the variable listed in the row heading. Values show the variation in the sample but are not representative for German firms. Values given in percent.

Table 4: Cross-tabulation of Incidence of Problems and Coping Strategies Based on the Regression Sample

	Problems				Coping strategies				
	NOTSTARTED	**ABANDON**	**MODIFY**	**NOIPR**	**ACQUIRE**	**EXCHANGE**	**OPPOSING**	**NEGOTIATE**	**N**
	Firms with innovative activities								
NOTSTARTED=0	0.000	0.017	0.213	0.132	0.193	0.046	0.163	0.165	1551
NOTSTARTED=1	1.000	0.385	0.719	0.271	0.427	0.156	0.479	0.469	96
ABANDON=0	0.037	0.000	0.221	0.135	0.198	0.049	0.172	0.172	1583
ABANDON=1	0.578	1.000	0.766	0.250	0.438	0.125	0.422	0.469	64
MODIFY=0	0.022	0.012	0.000	0.091	0.146	0.018	0.093	0.102	1248
MODIFY=1	0.173	0.123	1.000	0.291	0.398	0.160	0.459	0.439	399
NOIPR=0	0.049	0.034	0.200	0.000	0.191	0.040	0.155	0.154	1417
NOIPR=1	0.113	0.070	0.504	1.000	0.304	0.126	0.343	0.365	230
ACQUIRE=0	0.042	0.028	0.184	0.123	0.000	0.025	0.120	0.124	1306
ACQUIRE=1	0.120	0.082	0.466	0.205	1.000	0.158	0.416	0.411	341
EXCHANGE=0	0.052	0.036	0.215	0.129	0.184	0.000	0.152	0.154	1561
EXCHANGE=1	0.174	0.093	0.744	0.337	0.628	1.000	0.709	0.721	86
OPPOSING=0	0.037	0.027	0.160	0.112	0.148	0.019	0.000	0.091	1348
OPPOSING=1	0.154	0.090	0.612	0.264	0.475	0.204	1.000	0.599	299
NEGOTIATE=0	0.038	0.025	0.167	0.109	0.149	0.018	0.089	0.000	1345
NEGOTIATE=1	0.149	0.099	0.579	0.278	0.464	0.205	0.593	1.000	302

Note: Cells shows the mean value of the variable listed in the column heading, conditional on the value of the variable listed in the row heading. Values show the variation in the sample but are not representative for German firms.

Table 5: Marginal Effects from Probit Models on Problems

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Firms with innovative activities					Firms with patent applications				
Dependent variable	NOT STARTED	ABANDON	MODIFY	NOIPR	PROBLEM	NOT STARTED	ABANDON	MODIFY	NOIPR	PROBLEM
Young (0/1)	-0.002	-0.008	-0.018	0.022	-0.028	0.026	-0.004	-0.040	0.052	-0.024
	(0.011)	(0.009)	(0.024)	(0.020)	(0.025)	(0.030)	(0.021)	(0.056)	(0.044)	(0.056)
ln(employees)	0.010***	0.001	0.048***	0.001	0.048***	0.021**	0.009	0.045**	-0.011	0.052**
	(0.003)	(0.003)	(0.008)	(0.005)	(0.008)	(0.009)	(0.007)	(0.021)	(0.014)	(0.021)
ln(R&D/sales)	0.007	-0.005	0.079***	0.043***	0.086***	0.018	-0.018	0.069**	0.036*	0.075***
	(0.006)	(0.004)	(0.013)	(0.009)	(0.013)	(0.014)	(0.012)	(0.028)	(0.021)	(0.028)
Application (0/1)	0.036***	0.027**	0.154***	0.076***	0.158***					
	(0.013)	(0.012)	(0.026)	(0.021)	(0.027)					
Sales share main product	-0.000	-0.000***	-0.001*	-0.000	-0.001	0.000	-0.001**	-0.001	-0.001	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
ln(applications technology) *						0.004	0.001	0.062*	0.009	0.060*
						(0.017)	(0.014)	(0.033)	(0.024)	(0.033)
ln(share technology) **						0.000	-0.008	0.064***	0.007	0.057***
						(0.010)	(0.008)	(0.021)	(0.015)	(0.021)
No finished inno project (0/1)	0.003	0.013	0.012	0.011	0.024	-0.086**	-0.004	-0.145	-0.043	-0.143
	(0.023)	(0.026)	(0.053)	(0.041)	(0.054)	(0.027)	(0.058)	(0.115)	(0.095)	(0.116)
Product inno only (0/1)	-0.015	0.007	0.072*	0.063*	0.045	-0.064	0.021	0.109	0.045	0.083
	(0.018)	(0.019)	(0.045)	(0.039)	(0.045)	(0.041)	(0.060)	(0.109)	(0.101)	(0.108)
Product and process inno (0/1)	0.006	0.029	0.135***	0.100***	0.130***	-0.065	0.039	0.152	0.056	0.137
	(0.019)	(0.019)	(0.042)	(0.036)	(0.042)	(0.054)	(0.049)	(0.104)	(0.092)	(0.103)
Manufacturing, complex (0/1)	-0.012	-0.003	0.026	-0.027	0.015	-0.010	-0.001	0.026	-0.070	0.027
	(0.012)	(0.009)	(0.024)	(0.019)	(0.025)	(0.032)	(0.021)	(0.054)	(0.043)	(0.054)
Chemical industry (0/1)	0.055**	0.028	0.050	-0.022	0.073*	0.094*	-0.006	0.122	-0.028	0.167*

	(0.027)	(0.021)	(0.042)	(0.027)	(0.044)	(0.067)	(0.033)	(0.091)	(0.062)	(0.087)
Patent protection high imp. (0/1)						0.002	0.018	0.068	-0.022	0.050
						(0.028)	(0.019)	(0.050)	(0.040)	(0.051)
Concentration of IP ownership						-0.658*	-0.669**	-1.555**	0.441	-1.592**
						(0.358)	(0.318)	(0.687)	(0.440)	(0.679)
Conc. of product market sales						-0.143	0.048	-0.239	0.047	-0.374
						(0.189)	(0.132)	(0.354)	(0.256)	(0.356)
Baseline probability	0.058	0.039	0.242	0.140	0.263	0.105	0.068	0.470	0.212	0.489
Log likelihood	-337.94	-251.99	-749.17	-623.72	-792.93	-174.58	-127.97	-340.29	-283.56	-342.32
Observations	1647	1647	1647	1647	1647	562	562	562	562	562

Robust standard errors in parentheses, marginal effects shown. For dummies the effect for a change from 0 to 1 is given. Manufacturing (discrete) and Process inno only are basis categories.
* Natural logarithm of the total number of applications in the main technology area of the firm. ** Natural logarithm of the share of patent applications in the main technology area filed by the firm.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 6: Marginal Effects from Probit Models on Coping Strategies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Firms with innovative activities					Firms with patent applications				
Dependent variable	AQUIRE	EXCHANGE	OPPOSING	NEGOTIATE	COPING	AQUIRE	EXCHANGE	OPPOSING	NEGOTIATE	COPING
Young (0/1)	0.024	0.004	-0.002	0.030	0.029	-0.010	0.019	-0.025	0.002	-0.032
	(0.024)	(0.008)	(0.020)	(0.022)	(0.030)	(0.051)	(0.027)	(0.053)	(0.050)	(0.056)
ln(employees)	0.057***	0.015***	0.056***	0.048***	0.088***	0.073***	0.030***	0.074***	0.035*	0.076***
	(0.007)	(0.003)	(0.006)	(0.006)	(0.009)	(0.018)	(0.009)	(0.019)	(0.019)	(0.020)
Ln(R&D/sales)	0.048***	0.017***	0.019*	0.026**	0.072***	0.078***	0.035***	-0.008	0.014	0.069**
	(0.012)	(0.004)	(0.011)	(0.011)	(0.015)	(0.027)	(0.014)	(0.028)	(0.028)	(0.028)
Application (0/1)	0.037	0.017**	0.099***	0.093***	0.154***					
	(0.023)	(0.008)	(0.022)	(0.023)	(0.030)					
Sales share main product	-0.001***	0.000	0.000	-0.001*	-0.001	-0.001	0.000	0.001	-0.000	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
ln(applications technology) *						0.012	0.023	0.092***	0.106***	0.064**
						(0.031)	(0.017)	(0.032)	(0.032)	(0.033)
ln(share technology) **						0.019	0.025***	0.063***	0.071***	0.054***
						(0.018)	(0.008)	(0.019)	(0.019)	(0.021)
No finished inno project (0/1)	0.006	-0.016	-0.013	-0.085**	-0.022	0.181		-0.046	-0.253***	0.042
	(0.045)	(0.011)	(0.043)	(0.029)	(0.054)	(0.142)		(0.123)	(0.068)	(0.109)
Product inno only (0/1)	0.045	-0.002	0.060	-0.001	0.073	0.189	0.116*	0.082	-0.172*	0.086
	(0.040)	(0.013)	(0.040)	(0.034)	(0.048)	(0.129)	(0.070)	(0.121)	(0.085)	(0.100)
Product and process inno (0/1)	0.050	0.010	0.109***	0.030	0.130***	0.188	0.101**	0.186*	-0.061	0.192*
	(0.037)	(0.014)	(0.037)	(0.032)	(0.045)	(0.113)	(0.042)	(0.109)	(0.094)	(0.099)
Manufacturing, complex (0/1)	-0.018	-0.003	-0.015	-0.005	-0.031	-0.027	-0.024	-0.032	-0.024	-0.028
	(0.023)	(0.008)	(0.020)	(0.021)	(0.028)	(0.051)	(0.028)	(0.053)	(0.053)	(0.051)
Chemical industry (0/1)	0.110***	0.003	0.053	0.067*	0.087*	0.112	-0.031	0.082	-0.014	0.047
	(0.043)	(0.013)	(0.038)	(0.039)	(0.049)	(0.086)	(0.031)	(0.095)	(0.080)	(0.084)

Patent protection high imp. (0/1)						0.053	0.043*	0.071*	0.033	0.100**
						(0.047)	(0.022)	(0.049)	(0.047)	(0.048)
Concentration of IP ownership						-0.599	0.485*	-0.591	-0.236	-0.520
						(0.634)	(0.289)	(0.614)	(0.632)	(0.593)
Conc. of product market sales						0.259	-0.130	-0.752*	0.044	0.031
						(0.332)	(0.172)	(0.404)	(0.343)	(0.355)
Baseline probability	0.207	0.052	0.182	0.183	0.355	0.343	0.123	0.368	0.345	0.609
Log likelihood	-740.96	-254.67	-635.62	-669.32	-898.60	-327.22	-150.91	-311.07	-316.03	-330.09
Observations	1647	1647	1647	1647	1647	562	562	562	562	562

Robust standard errors in parentheses. Marginal effects shown. For dummies the effect for a change from 0 to 1 is given. Manufacturing (discrete) and Process inno only are basis categories.
* Natural logarithm of the total number of applications in the main technology area of the firm. ** Natural logarithm of the share of patent applications in the main technology area filed by the firm.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: Problems and Coping

	(1)	(2)	(3)	(4)	(5a)	(5b)	(6a)	(6b)
	Single-equation Probit				Bivariate Probit			
	Firms with innovative activities	Firms with patent applications	Firms with innovative activities	Firms with patent applications	Firms with innovative activities		Firms with patent applications	
Dependent variable	COPING (Conditional on PROBLEM=1)		COPING (Conditional on PROBLEM=0)		PROBLEM	COPING	PROBLEM	COPING
Young (0/1)	-0.009	-0.144**	0.049*	0.089	-0.027	0.023	-0.020	-0.029
	(0.060)	(0.070)	(0.030)	(0.080)	(0.022)	(0.025)	(0.048)	(0.049)
ln(employees)	0.068***	0.030	0.065***	0.083**	0.043***	0.074***	0.045**	0.066***
	(0.015)	(0.020)	(0.009)	(0.030)	(0.007)	(0.007)	(0.018)	(0.018)
Ln(R&D/sales)	0.027	0.009	0.049***	0.089**	0.078***	0.062***	0.066***	0.059**
	(0.029)	(0.033)	(0.015)	(0.037)	(0.011)	(0.013)	(0.024)	(0.024)
ln(applications technology) *		0.039		0.056			0.052*	0.059**
		(0.037)		(0.046)			(0.029)	(0.029)
ln(share technology) **		0.048**		0.035			0.049***	0.047***
		(0.021)		(0.032)			(0.018)	(0.018)
Application (0/1)	0.105*		0.101***		0.149***	0.140***		
	(0.057)		(0.032)		(0.026)	(0.028)		
Sales share main product	0.000	0.001	0.000	0.002	-0.001*	-0.000	-0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)
No finished inno project (0/1)	-0.147	-0.082	-0.004	0.139	0.023	-0.016	-0.120	0.034
	(0.140)	(0.176)	(0.049)	(0.153)	(0.047)	(0.045)	(0.104)	(0.098)
Product inno only (0/1)	-0.021	0.074	0.068	0.082	0.043	0.061	0.076	0.077
	(0.109)	(0.110)	(0.045)	(0.149)	(0.039)	(0.040)	(0.092)	(0.089)
Product and process inno (0/1)	0.047	0.197	0.084*	0.153	0.120***	0.113***	0.125	0.174*
	(0.105)	(0.141)	(0.044)	(0.141)	(0.039)	(0.040)	(0.092)	(0.092)

Manufacturing, complex (0/1)	0.002	0.019	-0.050*	-0.088	0.012	-0.029	0.022	-0.026
	(0.054)	(0.060)	(0.028)	(0.073)	(0.023)	(0.024)	(0.047)	(0.046)
Chemical industry (0/1)	0.029	0.088	0.077	-0.044	0.068*	0.073*	0.148*	0.042
	(0.078)	(0.066)	(0.052)	(0.130)	(0.038)	(0.042)	(0.077)	(0.077)
Patent protection high imp. (0/1)		0.110*		0.069			0.044	0.094**
		(0.067)		(0.063)			(0.045)	(0.043)
Concentration of IP ownership		-1.796**		0.820			-1.326**	-0.433
		(0.738)		(0.774)			(0.574)	(0.519)
Conc. of product market sales		-0.013		0.138			-0.304	-0.002
		(0.397)		(0.491)			(0.305)	(0.314)
Baseline probability	0.672	0.778	0.242	0.446	0.263	0.355	0.489	0.609
Rho					0.444		0.390	
					(0.041)		(0.066)	
Log likelihood	-244.22	-124.43	-603.96	-180.86	-1643.58		-657.55	
Observations	433	275	1214	287	1647		562	

Robust standard errors in parentheses. Marginal effects shown. For dummies the effect for a change from 0 to 1 is given. Manufacturing (discrete) and Process inno only are basis categories.
* Natural logarithm of the total number of applications in the main technology area of the firm. ** Natural logarithm of the share of patent applications in the main technology area filed by the firm.
* significant at 10%; ** significant at 5%; *** significant at 1%