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Patent blocking and infringement and their effects on firms? participation in markets for technology

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Abstract

In recent years, firms have increasingly contributed to and been confronted with a patent landscape characterized by numerous but marginal inventions, overlapping claims and patent fences. As a result, firms risk to be blocked in their patent applications or to be infringed upon by rivals. While both aspects constitute major challenges for the appropriation of returns to inventive activity, extant literature suggests that participation in the market for technology might actually resolve or at least alleviate these problems. In this paper, we investigate the effect of patent blocking and infringement on firms? engagement in in- and cross-licensing. Based on a sample of more than 1000 German manufacturing firms our results show that firms engage in in-licensing as a reaction to patent blocking and in both in- and cross-licensing if their protected IP was infringed upon. However, these effects vary depending on the fragmentation of technology fields and whether the firm operates in a discrete or complex product industry.

Jelcodes:L24,O34

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Abstract

In recent years, firms have increasingly contributed to and been confronted with a patent landscape characterized by numerous but marginal inventions, overlapping claims and patent fences. As a result, firms risk to be blocked in their patent applications or to be infringed upon by rivals. While both aspects constitute major challenges for the appropriation of returns to inventive activity, extant literature suggests that participation in the market for technology might actually resolve or at least alleviate these problems. In this paper, we investigate the effect of patent blocking and infringement on firms' engagement in in- and cross-licensing. Based on a sample of more than 1000 German manufacturing firms our results show that firms engage in in-licensing as a reaction to patent blocking and in both in- and cross-licensing if their protected IP was infringed upon. However, these effects vary depending on the fragmentation of technology fields and whether the firm operates in a discrete or complex product industry.

Keywords: In-licensing, cross-licensing, blocking, infringement

JEL: L24, O34

1 Introduction

Patents have frequently been characterized as the "gold standard" in protecting a firm's intellectual property (IP) (Scotchmer, 2004). They grant the holder the right to exclude third parties from using the protected technology and by that establish a temporary monopoly. As a result, patents allow firms to appropriate the returns from their inventive activities and they provide the incentives to further engage in technology development. In recent years, however, firms using patents with the ambition to protect their inventions have been confronted with two major problems.

On the one hand, firms experience – to an increasing extent – a patent landscape characterized by numerous but marginal inventions (Gallini, 2002), overlapping claims and multiple patent ownerships for complementary technologies (Heller and Eisenberg, 1998; Scotchmer, 2004), as well as by patent fences of substitute technologies owned by a single firm or a group of firms (Cohen et al., 2000; Schneider, 2008). As a result, a firm that wishes to protect an invention may be blocked by rivals' patents (Graff et al., 2003; Grimpe and Hussinger, 2008). Rival patents might have deliberately been written to include broad claims so that they preempt another firm's ambition to file for patent protection (Guellec et al., 2012). On the other hand, a firm's granted patents may be infringed upon by competitors since many areas of research are so extensively protected by patents that new projects are likely to touch existing patents (Arora and Gambardella, 2010). Both problems suggest that a firm's opportunities to appropriate the returns from its inventions decrease, providing lower incentives to innovate in the first place.

An aggregate response to these two problems has been an increase in the overall filing of patents because a large patent portfolio enhances firms' bargaining power in disputes over IP rights with rivals (Ziedonis, 2004). This may lead to "overfencing" in technology markets (David, 2001), thereby perpetuating the patent thicket (Shapiro, 2001). At the same time, patents also provide the basis of markets for technology (Cockburn et al., 2010). Markets for technology may improve the efficiency in innovation because patents constitute property rights over inventions that can be contracted and exchanged, either by transferring the patent itself or by licensing (Arora et al., 2004). The ability to negotiate licensing contracts should in principle alleviate the two problems described above. First, licenses allow firms to commercialize their inventions and hence to appropriate value because they can license-in the required IP. If the firm disposes of valuable IP itself, it might also negotiate a cross-licensing

contract. Second, licensing, and particularly cross-licensing, may enable a firm to still appropriate value despite its IP being infringed upon by rivals. Since rivals face the threat of being sued for infringement, the firm might be able to negotiate favorable licensing terms.

While the possibility of licensing has been found to support the functioning of the market for technology (Arora et al., 2004), empirical evidence on a firm's use of licensing as a response to blocking and infringement is rather scarce. In this paper, we seek to look into a firm's licensing activities, both in the form of in-licensing and cross-licensing, when patent filings by the firm had been blocked and technological inventions had been infringed upon. We investigate whether these two major challenges in the appropriation of returns from invention influence the likelihood of in-licensing and cross-licensing, while controlling for firm, industry and technology characteristics.

Our analysis reflects the special characteristics of today's patent landscape that firms are exposed to in two ways. First, we control for the extent to which ownership rights to external technologies are distributed among different firms by including a citation-based measure of fragmentation (Ziedonis, 2004; von Graevenitz et al., 2008). Potential hold-up problems are more likely to occur in fragmented technology areas which might have strong implications for a firm's licensing activities. Second, we distinguish between complex product industries and discrete product industries (Cohen et al., 2000). Industries characterized as complex are associated with products that require a large number of patentable elements while industries characterized as discrete produce products based on relatively few patentable elements. Recent contributions have shown that technology landscapes in complex product industries are characterized by a high fragmentation (Ziedonis, 2004). As a result, the transaction costs associated with licensing activities increase due to a large number of assignees. Differentiating between complex and discrete product industries in this context is important because the writing of contracts about technologies is easier and less costly in discrete product industries, on the one hand. On the other hand, hold-up is more likely in complex product industries so that licensing is expected to be more important to mitigate such hold-up problems. The overall effect on firms' licensing activities thus remains an empirical question.

Analytically, we will derive two hypotheses regarding the effect of patent blocking and infringement on in-licensing and cross-licensing. The contribution of this paper is thus threefold: First, we analyze the effects of a firm's technologies being blocked or infringed upon on licensing activities. We focus on both in- and cross-licensing of technologies which extends prior studies that exclusively focus on in-licensing (e.g., Cockburn et al., 2010;

Siebert and von Graevenitz, 2010). Moreover, our research is one of the first studies that looks into the extent of patent infringement and its consequences (Weatherall et al., 2009). Second, our analysis reflects the characteristics of the patent landscape that firms experience by accounting for fragmentation and complex versus discrete product industries (Cohen et al., 2000; Ziedonis, 2004). Our research thus provides a more nuanced understanding of the effects of blocking and infringement on both in- and cross-licensing with an eye on the conditions under which those effects are likely to emerge. Third, our analysis rests on a comprehensive sample of 1162 manufacturing firms in Germany that experienced blocking and infringement of their technologies. The sample combines survey and patent data from the European Patent Office (EPO) which, contrary to the U.S. Patent and Trademark Office, allows for a precise identification to what extent patent applications filed by a firm are being blocked.

The remainder of this paper is organized as follows. Section 2 provides the literature background and details our theoretical framework. Section 3 shows our empirical methods while the results are presented in section 4. We discuss key findings as well as limitations and future research avenues in section 5.

2 Theoretical framework

2.1 Literature background

Despite the prominence of patents as instruments to appropriate the returns from inventive activity, there is ample evidence for the U.S. and Europe that the protection of IP is often not the most attractive feature of patents (Arundel et al., 1995; Cohen et al., 2000; Encaoua et al., 2006; Amara et al., 2008). The value of patents is rather determined by their importance as bargaining chips in the market for technology, e.g. in licensing or M&A negotiations, and by their potential to block the inventions of competitors (Graff et al., 2003; Grimpe and Hussinger, 2008). Although patents facilitate bargaining in technology markets, they are difficult to value, their boundaries are often blurry and difficult to define, and parties owning related, previously patented technologies are often unknown in advance (Merges and Nelson, 1990). This is, for one, because the patent system in practice works like a “signpost” system in which the patent specification is rather indicative of the patented idea (e.g. Meurer, 1989; Waterson, 1990) rather than providing an exact coverage of the patented idea like in a “fencepost” system where there is no role for courts to judge over questions of interpretation (e.g. Horstmann et al., 1985). Moreover, this is the result of enhanced incentives to patent

strategically (Levin et al., 1987; Arundel et al., 1995; Duguet and Kabla, 1998; Cohen et al., 2000; Blind et al., 2006) in the presence of fragmented technology landscapes, patent thickets and patent fences (Ziedonis, 2004) and of increased attempts to build up own patent portfolios explicitly for a better bargaining position in licensing negotiations and disputes over IP rights (Reitzig, 2004; Blind et al., 2009). In consequence, fragmentation accelerates and multiple ownership, overlapping claims, patent thickets and patent fences occur more frequently, leaving patenting firms in an increasingly opaque and uncertain environment (Ziedonis, 2004). Ziedonis (2004) finds that firms which are confronted with fragmented property rights required to commercialize an innovation will patent more aggressively to reduce the uncertainty of being litigated or to threaten competitors with a reciprocal suit. In fact, the surge in patent applications worldwide over the past two decades has been accompanied by an increase in the number of legal disputes over patent rights (Lanjouw and Schankerman, 1997). As a consequence, using patents as instruments to protect a firm's IP has actually become more complicated. On the one hand, patent applications are being blocked by rivals' patents. On the other hand, patents are being infringed upon as a result of rivals' new technology development. Both aspects constitute major problems in a firm's efforts to appropriate the returns from invention.

Several recent contributions have dealt with patent blocking. In general, existing patents can block successive patent applications by threatening their novelty requirements (Scotchmer, 1991; Shapiro, 2001; Jaffe and Lerner, 2004; Ziedonis, 2004; Grimpe and Hussinger, 2008). However, even though an invention may involve an inventive step, rival patents might have deliberately been written to include broad claims so that they preempt the firm's ambition to file for patent protection (Guellec et al., 2012). A recent survey of German firms shows that more than 40 percent of patenting firms apply for patents in order to block competitors (Blind et al., 2009). Blind et al. (2009) find particularly striking evidence of "defensive blocking" through patenting. They define this as a forward-looking protection strategy directed at protecting the firm's position in technology markets. In this regard, blocking patents can be used to hinder competitors from developing a competing alternative technology or to remove existing patent fences. In fact, von Graevenitz et al. (2008) find for the U.S. semiconductor industry that a firm's patenting activity increases with the density of patent thickets threatening to block its patent applications.

Relatively little is known about the extent of patent infringement (Weatherall et al., 2009). Based on a survey in Australia, Weatherall and Webster (2009) report that 31 percent of all

patents owned by SMEs were infringed upon. Another study on European SMEs reports even twice that rate (Kingston, 2004). Infringement may however also be unintentional. Since many areas of research are so extensively protected by patents, new projects are likely to touch existing patents without knowing (Arora and Gambardella, 2010). If the firm had made large sunk investments into a particular technology, it may end up in a hold-up situation.

Prior literature has suggested that licensing and hence participation in the market for technology provides a way to cope with problems resulting from blocking and infringement in fragmented fields of technology (Arora et al., 1999). However, several problems are associated with trading IP rights at arm's length (Heller and Eisenberg, 1998; Somaya and Teece, 2000; Graff et al., 2003). First, fragmented technology markets and blurry boundaries of IP rights lead to diffuse entitlement problems (Heller and Eisenberg, 1998). Second, the difficulty of valuing IP rights leads to value allocation problems between the technology owner and the licensee (Graff et al., 2003). Third, the dynamic and uncertain environment of technology markets causes difficulties when setting up and enforcing the contract due to monitoring and metering problems (Ziedonis, 2004). Lastly, strategic problems may arise if IP rights are traded at arm's length. For example, rent-dissipation effects can result when technologies are licensed out to other firms, because the licensees may become new competitors in product markets (Graff et al., 2003).[1] All the problems associated with arm's-length contracts lead to higher transaction costs which reduce the propensity to engage in licensing. Moreover, since higher fragmentation of technology markets is associated with higher licensing expenditure of the firm (Cockburn et al., 2010), lower funds are available for own technology development.

Licensing and the participation in the market for technology may also be complicated by the characteristics of industries and the product markets these industries serve. Product industries characterized as complex exhibit a large number of patentable elements per product while product industries characterized as discrete contain relatively few patentable elements per product. Hence, the number of patents available in a technology area is determined by the existence of these technological opportunities and their facets (Cohen et al., 2000; von Graevenitz et al., 2008). Complexity arises when several facets within technological opportunities can be patented. A higher number of patentable facets increases the potential

[1] It should be noted that there are also strategic reasons for firms to license technologies to competitors since out-licensing for instance increases their costs and grants the patent holder a cost advantage (e.g., Shapiro, 1985; Wang, 1998).

number of firms owning patents that refer to the same technological opportunity. Firms therefore tend to pile up a stack of patents to counter the threat of hold-up. In contrast to complex product industries, discrete product industries refer only to one facet of the technological opportunity that is needed for the creation of a product. The value of each patent will thus be independent from other firms' patents. This implies that, for discrete product industries, there are relatively clear standards to evaluate the patent's validity and protect it against infringement. Complex product industries, on the contrary, are characterized by a less transparent link between patenting and value appropriation as it is unclear whether it will be feasible to defend the IP rights because of interdependent technologies (Levin et al., 1987; Cohen et al., 2000).

2.2 Hypotheses

The above arguments suggest that licensing may in principle mitigate the problems associated with patent blocking and infringement. However, little evidence exists as to whether in-licensing and cross-licensing are affected similarly or differently. First, we may expect that licenses allow firms to commercialize their inventions and hence to appropriate value, even though their patent applications had been blocked by rival patents, i.e. they may just license-in the required IP (Cockburn et al., 2010). If the firm disposes of valuable IP itself, it might also negotiate a cross-licensing contract. The fact that patent applications of a firm had been blocked by rivals however also suggests that the applications were not strong in the light of existing prior art. As a consequence, such a firm might need to obtain a license in order to commercialize an invention. Since patent applications had been (partly) blocked, that firm does not – or to a lower extent – possess relevant patents as bargaining chips that would put it into a position to negotiate a cross-licensing agreement. This increases the likelihood that a firm will engage into in-licensing compared to cross-licensing. Hence, our first hypothesis reads:

Hypothesis 1 (H1): The effect of patent blocking on in-licensing is greater than it is on cross-licensing.

Second, in case a firm's IP is infringed upon by rivals, licensing, and particularly cross-licensing, may enable a firm to appropriate value (Shapiro, 2001). The firm might be able to negotiate favorable cross-licensing terms because rivals face the threat of being sued for infringement. The firm might also be required to license in patents that infringe upon the firm's patents but that might cover certain aspects of the technology to be commercialized by

the firm. Overall, however, we expect the effect on cross-licensing to be higher than the effect on in-licensing since the firm – in contrast to the blocking case – does have bargaining chips in hand that put the firm into a better negotiation position. It has to be noted, though, that we can only expect such effects on licensing in case the firm's IP is actually protected through patents. As a result, our second hypothesis reads as follows:

Hypothesis 2 (H2): The effect of infringement on cross-licensing is greater than it is on in-licensing.

A firm's decision to engage in licensing may, however, change depending on the characteristics of the technology. Since higher fragmentation of technology markets is associated with higher licensing expenditure, firms might refrain from licensing in the required IP. Moreover, differentiating between complex and discrete product industries is important because of two diverging effects. On the one hand, writing licensing contracts should be easier, less costly and hence more likely in discrete product industries. On the other hand, licensing might be more important in complex product industries where innovative products typically employ more than one patent. Firms operating in complex product industries may also more likely engage in cross-licensing if firms' technology development is mutually interdependent, as for example in the information and communications technology (ICT) industry. The overall effects of patent blocking and infringement on in- and cross-licensing thus remain an empirical question.

3 Empirical methods

3.1 Data

We test our research questions using data from the Mannheim Innovation Panel (MIP), a survey which has been conducted annually by the Centre for European Economic Research (ZEW) on behalf of the German Federal Ministry of Education and Research (BMBF) since 1992. The MIP is the German part of the Community Innovation Survey (CIS) of the European Commission. In 2008, firms were asked about their in- and cross-licensing activities during the period from 2005 to 2007. This year constitutes a cross-sectional database for our empirical analysis. The firm information was linked to the firms' patent records at the European Patent Office (EPO). Based on firm names and addresses the respondents of the survey were linked to corresponding patent applicants. The link was

supported by a computerized text field based search algorithm and every firm-patent applicant match proposed by the program was manually checked.

We restrict the sample to manufacturing firms as patents and hence licensing is likely of a different nature in service industries. Further, only firms that applied for at least one patent at the EPO are taken into account. The latter restriction is necessary because patent blocking and infringement are irrelevant for non-patenting firms. This leaves us with a sample of 1162 firms in the manufacturing sector that applied for at least one patent at the EPO.

3.2 Measures

Dependent variables

In the survey, firms were asked whether they in-licensed and whether they cross-licensed technology during the period from 2005 to 2007. Since no information on the actual amount spent is available, our dependent variables are two dummy variables that take the value of one (and zero otherwise) if respectively in-licensing or cross-licensing had occurred.

Explanatory variables

Our first main explanatory variable is patent blocking. This measure is based on detailed information of the patent application procedure at the EPO (Guellec et al., 2012). Each EPO patent application is evaluated by a patent examiner who scrutinizes whether a patent can be granted. The result of this examination is summarized in the so-called “search report”. An important information given in the search report is a list of all documents which are considered as relevant prior art for the patent application in question. Based on the review of prior art a decision is made as to whether a technology is novel enough to get granted patent protection. An interesting feature of the EPO search reports is that references to prior art are classified according to their importance for the patent application in question. Prior art which threatens the novelty requirement of the patent application can thus be distinguished from previous inventions that belong to the state of the art in a particular technology field but do not challenge the novelty of the patent application. References to prior art are marked with an “X” if the invention cannot be considered to be novel or cannot be considered to involve an inventive step when the referenced document alone is taken into consideration. References are marked with a “Y” if the invention cannot be considered to involve an inventive step when the referenced document is combined with one or more other documents of the same category, such a combination being obvious to a person skilled in the art (Harhoff *et al.*, 2005). If a patent has many references classified with X or Y it can still be granted (although

this is less likely). This can be the case for patent applications with many claims. X and Y references may only pertain to some claims and the remaining claims can be strong enough to get a (modified) application granted. The information on patent references is taken from the EPO/OECD patent citation database. An earlier version of this database is fully described and analyzed in Webb et al. (2005).

We use the information on prior art in the search report to construct a measure for patent blocking. We build on the fact that a patent application with many X and Y references can be considered a weak patent application with a high likelihood of not being granted. Guellec et al. (2012) provide empirical evidence for the significance of patent citation categories for the identification of blocking patents. They find that blocking references increase the likelihood of patents not being granted or being withdrawn. We exploit this correlation to construct the measure for patent blocking, i.e. we use the share of patent applications that received at least one blocking cite in the period from 2000 to 2004. The period from 2000 to 2004 is chosen because the survey information refers to the period from 2005 to 2007 and we seek to measure the reaction of firms to blocking in terms of their licensing activities.

The second main explanatory variable is infringement. In the survey, firms were asked to indicate whether or not technological inventions had been infringed upon by other firms during the period from 2005 to 2007. The question includes a follow-up question that asks whether the IP infringed was actually protected by a patent. Our regressions use both indicator variables alternatively in order to investigate whether infringement is generally associated with licensing or only when infringement refers to a patent.

Fragmentation is measured following the method originally proposed by Ziedonis (2004). It is based on the concentration of cited IP ownership patents as measured by backward citations in patents. We follow von Graevenitz et al. (2012) who calculated this measure for the 30 different Fraunhofer technology classes for patents at the EPO. Other than focusing on all patent citations to third parties as done by Ziedonis (2004) for U.S. patents, von Graevenitz et al. (2012) only focus on X and Y citations because these are the critical backwards citations. Such information is not available for the U.S.[2] Since the fragmentation index is available to us as an aggregated measure for the 30 different Fraunhofer technology classes we transformed it into a firm level measure by weighting the fragmentation index with the firms' patent activities across the 30 technology classes in the period from 2000 to

[2] We thank Georg von Graevenitz for providing us with data on fragmentation.

2004. We use the fragmentation index from 2003 because this is the latest year available to us. Our final measure captures the extent to which each individual firm faces fragmentation in its fields of technological activity.

The fragmentation measure has been suggested to be higher in complex than in discrete product industries (von Graevenitz et al., 2012). In order to assess the robustness of our results we hence use the distinction between complex and discrete product industries as an alternative to the fragmentation index. The definition of complex and discrete product industries follows Cohen et al. (2000). Discrete product industries include chemicals, food, paper, and metals, and the group of complex product industries consists of machinery and equipment, electronics, and transportation equipment, i.e. NACE 15-28 and NACE 29-35, respectively. All other manufacturing sectors are defined as complex product industries.

Control variables

We control for several firm characteristics that might influence a firm's engagement in licensing. We include measures of the firm's R&D intensity (R&D expenditure divided by the number of employees) and patent intensity (patent stock divided by the number of employees) to control for the technology orientation of the firm. Particularly the patent intensity should be positively correlated with licensing since patent rights are tradable on markets for technology. The patent stock is calculated using the perpetual inventory method on all the firm's patent applications at the EPO with a knowledge depreciation rate of 0.15 as is standard in the literature (e.g., Hall, 1990). Moreover, we control for a firm's collaboration activities in technology development with various types of partners. Collaboration reflects a firm's open innovation strategy that may also influence licensing activity (e.g., Laursen and Salter, 2006; Grimpe and Kaiser, 2010). We therefore include six dummy variables indicating whether the firm had collaborated with customers (other firms or private consumers), suppliers (materials or services), competitors, or universities and research institutes. Further, we include a dummy variable indicating whether a firm is an exporter, and whether it is part of a group of firms. Firm size is measured as the number of employees (in log). We also include a regional control variable indicating whether a firm is located in East Germany, a region within Germany that is still economically lacking behind the West. Finally, industry affiliation is controlled for by including a set of industry dummies based on the NACE 2-digit classification system.

3.3 Model

We estimate probit and bivariate probit models for a firm's decision to engage in in-licensing and in cross-licensing using different model specifications. We first test for the direct effect of patent blocking and infringement on licensing, while controlling for fragmentation of technologies, before we calculate interaction terms between fragmentation and patent blocking and infringement, respectively. The idea is to test whether the relationship between patent blocking and infringement changes depending on the level of fragmentation. Finally, we conduct a split-sample analysis for the effects of patent blocking and infringement in discrete versus complex product industries.

4 Results

4.1 Descriptive statistics

Table 1 shows descriptive statistics for our sample of patenting firms in German manufacturing. The first column presents means and standard deviations for the variables of interest for the full sample; the second and third columns distinguish between discrete and complex product industries.

Table 1: Descriptive statistics

	Full sample		Discrete industries NACE 15-28; 36-37		Complex industries NACE 29-35	
	mean	st.d.	mean	st.d.	mean	st.d.
In-licensing	0.25	0.43	0.24	0.43	0.25	0.44
Cross-licensing	0.07	0.25	0.06	0.23	0.08	0.28
Log(emplyment)	4.71	1.72	4.66	1.68	4.76	1.76
R&D/ employment	0.01	0.02	0.01	0.02	0.01	0.02
Patentstock/ employment	0.01	0.06	0.01	0.07	0.02	0.04
Patent blocking	0.18	0.35	0.15	0.32	0.22	0.36
Infringement	0.24	0.43	0.16	0.36	0.32	0.47
Infringement (not protected)	0.08	0.28	0.06	0.23	0.11	0.31
Infringement (protected)	0.15	0.35	0.10	0.30	0.19	0.39
Fragmentation index	0.01	0.03	0.01	0.02	0.02	0.03
Export dummy	0.88	0.33	0.86	0.34	0.89	0.31
Part of a firm group	0.49	0.50	0.49	0.50	0.48	0.50
Collaboration B2B	0.84	0.37	0.84	0.37	0.83	0.37
Collaboration B2C	0.27	0.45	0.33	0.47	0.22	0.41
Collaboration w/ mat. suppliers	0.60	0.49	0.65	0.48	0.56	0.50
Collaboration w/ serv. suppliers	0.38	0.49	0.38	0.49	0.38	0.49
Collaboration w/ competitors	0.22	0.41	0.23	0.42	0.21	0.41
Collaboration w/ universities	0.54	0.50	0.49	0.50	0.60	0.49
East Germany	0.29	0.45	0.29	0.45	0.29	0.45
Food, tobacco, textile, leather	0.08	0.28	0.17	0.38	0.00	0.00
Wood, pulp, coke, chemicals	0.17	0.38	0.36	0.48	0.00	0.00
Rubber, plastics	0.05	0.22	0.11	0.31	0.00	0.00
Non-metallic minerals	0.05	0.21	0.09	0.29	0.00	0.00
Basic metals	0.05	0.21	0.09	0.29	0.00	0.00
Fabricated metals	0.09	0.28	0.17	0.38	0.00	0.00
Machinery	0.16	0.37	0.00	0.00	0.31	0.46
Office machinery	0.02	0.13	0.00	0.00	0.03	0.18
Electrical machinery	0.07	0.26	0.00	0.00	0.15	0.35
Radio, tv, communication	0.04	0.20	0.00	0.00	0.08	0.27
Medical instruments	0.12	0.33	0.00	0.00	0.24	0.43
Motor vehicles	0.10	0.30	0.00	0.00	0.19	0.39
Number of observations	1162		570		592	

The descriptive statistics reveal some interesting insights. First of all, they show that 25 percent of the firms license patents in from third parties but only 7 percent engage in cross-licensing. The percentages do not vary significantly for complex and discrete product industries, although the share of firms engaged in cross-licensing is marginally higher in complex product industries. Regarding blocking, it turns out that on average 18 percent of a firm's patent applications received a blocking citation. Moreover, 24 percent of the firms report some form of infringement of their technological inventions. The largest share refers to infringement of protected technologies. It turns out that both blocking and infringement occur much more often in complex than discrete product industries. Table 1 further shows for most control variables that there is on average no significant difference between firms in complex

and discrete product industries, e.g. in terms of labor force, R&D intensity or their patent stock per employee. To further explore the relationships between the variables used in the empirical analysis, Table 4 in the appendix reports the bivariate correlations.

4.2 Multivariate results

In order to analyze the effect of patent blocking and infringement on the likelihood to be involved in in-licensing and cross-licensing we run a series of probability models. Table 2 shows the results. Models 1 and 2 include all control variables and the fragmentation index. Interestingly, we do not find a significant effect of fragmentation on in- and cross-licensing. This finding contrasts with results found by Cockburn et al. (2010) who report a positive relationship between fragmentation and a firm's expenditures for in-licensing. However, their result does not hold if they restrict their sample to positive observations on licensing expenditure as a share of sales. These inconsistent findings indicate that licensing might primarily be driven by other factors such as blocking and infringement.

Models 3 to 6 include our measure of patent blocking and subsequently the measure of infringement. We find that patent blocking is a significant determinant of in-licensing, while no significant effect can be found for cross-licensing. Moreover, we find that infringement is positively associated with both in- and cross-licensing. Models 7 and 8 split up the infringement variable into infringement of legally protected and unprotected IP. It turns out that only infringement of protected technology increases the likelihood of both in-licensing and cross-licensing. Since both hypotheses are relative, comparing the effects on in-licensing and cross-licensing, we need to inspect the marginal effects in order to test the hypotheses. Models 3 and 4 in Table 5 in the appendix provide support for our first hypothesis. Models 7 and 8 show that the effect of infringement on in-licensing is actually twice the size of the effect on cross-licensing. Therefore, although we can substantiate positive effects as our theoretical arguments suggested, we have to reject the second hypothesis which assumed the effect of infringement on cross-licensing to be larger than the effect on in-licensing.

We also estimate bivariate probit models that include the same variables as presented above. Table 7 in the appendix shows the results. It turns out that the empirical specification is very robust against ignoring the possibility of correlated error terms of the in- and cross-licensing equation when compared to the estimated coefficients of the probit models. The correlation coefficients of the error terms turn out to be highly significant and in all models and range between 0.41 and 0.45. This finding indicates a positive correlation in the unobserved

determinants of in- and cross-licensing activities which suggests they may be considered as complementary activities.

The bivariate models further allow to formally test whether the coefficients for blocking and infringement are significantly different from each other in the in-licensing and cross-licensing equation. We test the null hypothesis whether the estimated coefficients of the blocking and infringement variable are equal in models 3 and 4 in Table 7. Two-sided Chi^2-tests reject the null hypothesis that the estimated coefficients for blocking are equal at the 10 percent level of statistical significance (Chi^2=3.09*; Chi^2=3.09*), providing additional support to hypothesis 1. The null hypothesis that the effect of infringement is significantly different in both equations is rejected at the at 1 percent and 10 percent level of statistical significance (Chi^2=9.70*** for infringement in specification 3; Chi^2=3.34* for infringement of protected IP in specification 4), which confirms that hypothesis 2 has to be rejected.

Overall, these findings show, first, that blocking is in fact an important motivation for firms to license-in technology in order to be able to commercialize inventions and to appropriate the returns. The insignificant finding for cross-licensing indicates that blocked firms, for various reasons, seem to be unable to negotiate a cross-licensing contract. This may be attributed to the assumed lower strength that the firm's patent applications exhibit. Second, the results for infringement show that firms are able to engage in cross-licensing and still appropriate value despite being infringed upon. Interestingly, the positive relationship with in-licensing, even higher in magnitude as the marginal effects reported in Table 5 show, indicates that firms also engage in in-licensing. This result may be driven by the motivation to protect one's own position in technology markets by pro-actively licensing-in required technologies. Moreover, the firm might be required to license in patents that infringe upon its patents but that might cover certain aspects of the technology to be commercialized by the firm.

Table 2: Probit models for in- and cross-licensing

	1	2	3	4	5	6	7	8
	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing
Log(employment)	0.20***	0.35***	0.17***	0.35***	0.16***	0.31***	0.15***	0.30***
	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
R&D/ employment	8.45***	6.20**	8.61***	6.20**	8.53***	6.87**	8.36***	6.56**
	(2.36)	(2.60)	(2.40)	(2.61)	(2.39)	(2.69)	(2.38)	(2.67)
Patentstock/ employment	0.55	2.47***	0.11	2.48***	0.11	2.65***	0.11	2.50***
	(0.70)	(0.79)	(0.72)	(0.82)	(0.72)	(0.82)	(0.73)	(0.82)
Export dummy	-0.12	0.10	-0.13	0.11	-0.16	0.08	-0.16	0.05
	(0.14)	(0.24)	(0.14)	(0.24)	(0.14)	(0.26)	(0.14)	(0.25)
Part of a firm group	0.14	0.10	0.14	0.10	0.14	0.10	0.15	0.11
	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.17)	(0.10)	(0.17)
Collaboration B2B	0.14	0.15	0.12	0.15	0.11	0.05	0.12	0.08
	(0.13)	(0.21)	(0.13)	(0.21)	(0.13)	(0.22)	(0.13)	(0.22)
Collaboration B2C	0.40***	0.02	0.40***	0.02	0.38***	0.06	0.37***	0.01
	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)
Collaboration with	0.06	0.16	0.06	0.16	0.07	0.16	0.06	0.18
material suppliers	(0.09)	(0.16)	(0.10)	(0.16)	(0.10)	(0.17)	(0.10)	(0.17)
Collaboration with	0.03	0.21	0.02	0.21	0.01	0.19	0.01	0.17
service suppliers	(0.09)	(0.14)	(0.09)	(0.14)	(0.09)	(0.15)	(0.09)	(0.14)
Collaboration with	0.07	0.21	0.07	0.21	0.08	0.25	0.10	0.32*
competitors	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)
Collaboration with	0.25***	0.18	0.24***	0.18	0.22**	0.10	0.23**	0.15
universities	(0.09)	(0.15)	(0.09)	(0.15)	(0.09)	(0.16)	(0.09)	(0.16)
East Germany	-0.11	-0.25	-0.09	-0.25	-0.05	-0.11	-0.05	-0.17
	(0.10)	(0.20)	(0.11)	(0.20)	(0.11)	(0.21)	(0.11)	(0.21)
Fragmentation index	1.48	-2.32	0.01	-2.30	-0.32	-3.40	-0.17	-2.53
	(1.54)	(2.46)	(1.65)	(2.58)	(1.65)	(2.73)	(1.66)	(2.66)
Patent blocking			0.38***	-0.01	0.38***	-0.05	0.36**	-0.06
			(0.14)	(0.21)	(0.14)	(0.22)	(0.14)	(0.22)
Infringement					0.34***	0.85***		
					(0.10)	(0.15)		
Infringement (unprotected)							0.15	0.25
							(0.16)	(0.24)
Infringement (protected)							0.43***	0.74***
							(0.12)	(0.16)
Constant	-2.34***	-4.24***	-2.22***	-4.24***	-2.22***	-4.28***	-2.17***	-4.14***
	(0.27)	(0.48)	(0.27)	(0.49)	(0.27)	(0.51)	(0.28)	(0.51)
N	1162	1162	1162	1162	1162	1162	1162	1162
ll	-565.16	-209.79	-561.61	-209.79	-556.24	-193.77	-555.51	-199.63

Reported figures are coefficients; standard errors in parentheses.
*** (**, *) indicate a significance level of 1% (5%, 10%).
Industry dummies are included, but not reported.

Table 3 shows results from probit regressions in which the technological context is taken into account. Models 9 to 12 report the interaction effects between fragmentation and patent blocking and infringement, respectively. We find a negative interaction effect between fragmentation and blocking for the in-licensing decision but not for cross-licensing. This finding indicates that, although blocking increases the likelihood to license-in technology, this likelihood is reduced when fragmentation increases. This suggests that markets for technology actually do not work well in case of patent blocking and fragmentation. We can attribute this finding to high transaction costs that occur when licensing contracts are to be negotiated in a fragmented field of technology. The transaction cost in this case foreclose a firm's ability to license-in a required technology and hence to appropriate the returns from invention (Graff et al., 2003). Moreover, it turns out that fragmentation does not moderate the effect of infringement on in- and cross-licensing. Apparently, fragmentation does not alter the reaction to infringement on both licensing activities. This finding may be attributed to the ability of the infringed firm to sue a rival and to negotiate favorable licensing terms independent of how fragmented the field of technology is.

Models 13 to 16 show the results when we distinguish between firms in discrete versus firms in complex product industries. As the distinction between discrete and complex product industries has been argued to proxy for the level of fragmentation (Cohen et al., 2000), we do not include the fragmentation measure in these models. The results show little difference between the two groups of industries. The previous result on patent blocking holds in both contexts: we find positive effects on in-licensing. Contrary to what the interaction with the fragmentation index would have suggested, we do not find that in-licensing as a reaction to blocking actually becomes less likely in complex product industries. There is a positive significant effect on in-licensing for both discrete and complex product industries. When the effect of infringement is considered it turns out that infringement of protected IP increases only the likelihood of cross-licensing in discrete technologies but of both in-licensing and cross-licensing in complex product industries. However, the effect in discrete product industries disappears altogether when marginal effects are considered (Table 6).[3] In that sense, we find important differences between operating in a fragmented field of technology and in an industry characterized by complex products. The finding also cautions against equating an industry characteristic with a technology characteristic in a licensing context.

[3] Since probit models are non-linear models, the level of significance of marginal effects may differ from that of coefficients.

Looking at the control variables in Table 2 and Table 3, we find consistent results across all model specifications. The patent stock of firms is as expected a strong predictor of firms' involvement in markets for technology. Cross-licensing, of course, depends on the ownership of patents. A strong patent position further seems to shield firms from having to license-in technology themselves. Higher R&D intensity as well as larger firm size are both strong and significant predictors of in- and cross-licensing. Moreover, several effects of collaboration can be observed. Particularly, and as expected, we find that collaboration with competitors increases the likelihood to engage in cross-licensing while collaboration with universities increases the likelihood of in-licensing. No significant effects can be observed for the remaining control variables.

Table 3: Probit models for in- and cross-licensing (cont.)

	9	10	11	12	13	14	15	16
					Discrete industries		Complex industries	
	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing
Log(employment)	0.14***	0.29***	0.16***	0.31***	0.13**	0.35***	0.18***	0.31***
	(0.03)	(0.06)	(0.03)	(0.05)	(0.05)	(0.10)	(0.05)	(0.07)
R&D/ employment	8.10***	6.29**	8.55***	6.85**	7.32**	14.07**	9.27***	5.11
	(2.37)	(2.68)	(2.39)	(2.68)	(3.63)	(6.08)	(3.27)	(3.39)
Patentstock/ empl.	-0.20	2.28***	0.11	2.66***	0.15	2.34**	-0.92	3.28
	(0.74)	(0.83)	(0.72)	(0.82)	(0.83)	(0.96)	(1.64)	(2.06)
Export dummy	-.14	0.08	-0.16	0.08	-0.01	-0.08	-0.29	-0.00
	(0.14)	(0.25)	(0.14)	(0.26)	(0.19)	(0.45)	(0.20)	(0.33)
Part of a firm group	0.15	0.12	0.14	0.10	0.16	0.22	0.12	0.08
	(0.10)	(0.17)	(0.10)	(0.17)	(0.15)	(0.33)	(0.14)	(0.21)
Collaboration B2B	0.12	0.08	0.11	0.04	0.27	0.67	-0.04	-0.04
	(0.13)	(0.22)	(0.13)	(0.22)	(0.20)	(0.55)	(0.17)	(0.26)
Collaboration B2C	0.38***	0.03	0.39***	0.06	0.55***	-0.36	0.17	0.25
	(0.10)	(0.16)	(0.10)	(0.16)	(0.14)	(0.27)	(0.15)	(0.21)
Collaboration with material suppliers	0.06	0.17	0.06	0.16	0.07	0.69*	0.05	0.09
	(0.10)	(0.17)	(0.10)	(0.17)	(0.14)	(0.40)	(0.14)	(0.20)
Collaboration with service suppliers	0.01	0.18	0.01	0.19	0.02	-0.13	0.03	0.34*
	(0.09)	(0.15)	(0.09)	(0.15)	(0.13)	(0.25)	(0.13)	(0.19)
Collaboration with competitors	0.12	0.34**	0.08	0.25	0.29**	0.53**	-0.11	0.16
	(0.11)	(0.16)	(0.10)	(0.16)	(0.14)	(0.27)	(0.16)	(0.22)
Collaboration with universities	0.22**	0.15	0.22**	0.10	0.26**	0.80**	0.21	-0.22
	(0.10)	(0.16)	(0.09)	(0.16)	(0.13)	(0.31)	(0.14)	(0.21)
East Germany	-0.03	-0.16	-0.05	-0.11	-0.12	0.01	0.01	-0.29
	(0.11)	(0.21)	(0.11)	(0.21)	(0.16)	(0.37)	(0.15)	(0.27)
Fragmentation index	2.90	0.72	0.14	-1.58				
	(2.06)	(3.25)	(2.00)	(3.99)				
Patent blocking	0.65***	0.23	0.37***	-0.06	0.40**	0.05	0.37**	-0.30
	(0.19)	(0.28)	(0.14)	(0.22)	(0.20)	(0.34)	(0.19)	(0.29)
Infringement			0.37***	0.91***				
			(0.12)	(0.18)				
Infringement (unprotected)	0.12	0.24			0.10	0.07	0.21	0.36
	(0.16)	(0.24)			(0.27)	(0.45)	(0.20)	(0.29)
Infringement (protected)	0.42***	0.74***			0.25	0.94***	0.49***	0.64***
	(0.12)	(0.16)			(0.20)	(0.29)	(0.16)	(0.21)
Fragmentation * blocking	-9.22**	-10.24						
	(3.81)	(6.59)						
Fragmentation * infringement			-1.26	-3.03				
			(3.10)	(5.04)				
Constant	-2.17***	-4.16***	-2.22***	-4.29***	-2.22***	-5.52***	-2.01***	-3.76***
	(0.28)	(0.51)	(0.28)	(0.52)	(0.37)	(1.08)	(0.37)	(0.61)
N	1162	1162	1162	1162	570	570	592	592
ll	-565.16	-209.79	-561.61	-209.79	-556.24	-193.77	-555.51	-199.63

Reported figures are coefficients; standard errors in parentheses.
*** (**, *) indicate a significance level of 1% (5%, 10%).
Industry dummies are included, but not reported.

5 Conclusion and future research

Our research has demonstrated that both patent blocking and infringement matter considerably for a firm's participation in the market for technology in terms of in- and cross-

licensing. Patent blocking significantly drives the in-licensing behavior of firms while infringement makes both in- and cross-licensing more likely. Interesting results emerge when we take a closer look at how these two major problems for appropriating the returns from innovation interact with the technology and industry context in which the firm is operating. Higher fragmentation actually decreases the likelihood of in-licensing as a reaction to patent blocking. We attribute this finding to prohibitively high transaction costs that result from high dispersion of patent ownership. Fragmentation does not, however, influence the effect of infringement on licensing. Infringement implies that the firm already holds the rights on IP which it subsequently tries to leverage in the market for technology, for example by negotiating favorable cross-licensing terms. Our results further show that it is not so much the fragmentation of technology areas that drives licensing activity (Cockburn et al., 2010) but rather the perceived problems in value appropriation that arise from blocking and infringement. In that sense, our study qualifies the results by Siebert and von Graevenitz (2010), who conclude that licensing is less effective in industries characterized by a high degree of fragmentation. We show that fragmentation needs to be more considered as an indirect effect in connection with patent blocking, rather than as having a direct effect on licensing activities. Moreover, our results show that the relationship between fragmentation of technologies and discrete versus complex product industries is not that clear-cut. We had expected to find similar effects to fragmentation in complex product industries which was, however, not the case.

Our research contributes to the literature in several ways. First, we are able to analyze not only in-licensing but we take account of joint in- and cross-licensing activities, extending prior findings by Cockburn et al. (2010) and Siebert and von Graevenitz (2010). Hence, our analysis provides a more complete picture of a firm's involvement in the market for technology. Moreover, our research is one of the first studies that looks into the extent of patent infringement and its consequences (Weatherall et al., 2009). For the first time, we establish a relationship between infringement and both in- and cross-licensing activities of firms, contributing to a better understanding of what factors actually drive a firm's participation in markets for technology. Second, our analysis reflects the characteristics of the patent landscape that firms experience by accounting for fragmentation of technology areas and complex versus discrete product industries (Cohen et al., 2000; Ziedonis, 2004). Our research thus provides a more nuanced understanding of the effects of blocking and infringement on both in- and cross-licensing while acknowledging the conditions under

which those effects are likely to emerge. Third, our research combines survey data from a large sample of the manufacturing sector in Germany with patent data from the EPO which enables a precise identification of patent blocking by making use of the information recorded during the patent examination procedure.

Our research is, however, limited by the data that is available to us. We can only observe whether a firm is engaged in licensing or not. Hence, we miss information on the number of licenses a firm sells or acquires and the nature of the technologies that are licensed, e.g. whether licensed technologies are core to the firm versus non-core technologies. Moreover, we do not have information on the licensing partner and a detailed description of the actual licensing contract. Also, we do not observe the motivation for licensing and the returns to licensing activities. Firms might for instance license to rivals in order to increase their costs via royalties (Shapiro, 1985; Wang, 1998). It would be interesting to use a more detailed dataset on licensing in order to exploit the nature of licensing in the context of patent blocking and infringement.

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Appendix

Table 4: Bivariate correlations

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	In-licensing																		
2	Cross-licensing	0.27																	
3	Log(emplyment)	0.27	0.34																
4	R&D/ employment	0.13	0.07	-0.08															
5	Patentstock/ employment	0.06	0.11	-0.02	0.18														
6	Patent blocking	0.21	0.18	0.39	0.07	0.24													
7	Infringement	0.19	0.29	0.26	0.04	0.05	0.18												
8	Infringement (unprotected)	0.01	-0.01	-0.01	-0.01	-0.01	0.02	0.53											
9	Infringement (protected)	0.21	0.28	0.30	0.04	0.03	0.21	0.67	-0.13										
10	Fragmentation index	0.10	0.04	0.17	0.14	0.13	0.41	0.17	0.09	0.11									
11	Export dummy	-0.03	-0.02	0.03	0.02	0.03	0.08	0.07	0.05	0.04	0.09								
12	Part of a firm group	0.17	0.17	0.52	0.00	0.02	0.21	0.12	0.02	0.12	0.11	0.06							
13	Collaboration B2B	0.06	0.04	0.01	0.02	-0.01	0.02	0.05	0.04	0.02	-0.02	-0.01	0.06						
14	Collaboration B2C	0.12	0.01	-0.01	-0.02	0.04	0.01	0.01	0.01	0.03	-0.04	-0.07	-0.06	0.14					
15	Collaboration with material suppliers	0.09	0.10	0.18	-0.04	0.01	0.07	0.04	-0.01	0.07	0.02	0.00	0.15	0.23	0.09				
16	Collaboration with service suppliers	0.08	0.11	0.11	0.06	0.04	0.09	0.05	-0.02	0.08	0.07	-0.07	0.09	0.02	0.04	0.20			
17	Collaboration with competitors	0.07	0.07	0.03	0.01	0.04	0.04	-0.01	0.02	-0.06	0.06	-0.04	0.07	0.12	0.18	0.09	0.05		
18	Collaboration with universities	0.15	0.12	0.22	0.15	0.07	0.14	0.15	0.08	0.10	0.12	0.02	0.13	0.09	-0.04	0.07	0.10	0.09	
19	East Germany	-0.11	-0.11	-0.27	-0.01	-0.07	-0.20	-0.17	-0.06	-0.16	-0.12	-0.05	-0.12	-0.03	0.00	-0.07	0.00	-0.01	0.04

Table 5: Marginal effects after probit regressions

	1	2	3	4	5	6	7	8
	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing
Log(employment)	0.06***	0.02***	0.05***	0.02***	0.05***	0.02***	0.04***	0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
R&D/ employment	2.49***	0.40**	2.54***	0.40**	2.51***	0.37**	2.46***	0.38**
	(0.70)	(0.17)	(0.71)	(0.17)	(0.71)	(0.15)	(0.70)	(0.16)
Patentstock/ employment	0.16	0.16***	0.03	0.16***	0.03	0.14***	0.03	0.15***
	(0.21)	(0.05)	(0.21)	(0.06)	(0.21)	(0.05)	(0.21)	(0.05)
Export dummy	-0.04	0.01	-0.04	0.01	-0.05	0.00	-0.05	0.00
	(0.04)	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)
Part of a firm group	0.04	0.01	0.04	0.01	0.04	0.01	0.04	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
Collaboration B2B	0.04	0.01	0.04	0.01	0.03	0.00	0.03	0.00
	(0.03)	(0.01)	(0.03)	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)
Collaboration B2C	0.13***	0.00	0.12***	0.00	0.12***	0.00	0.12***	0.00
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
Collaboration with Material suppliers	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
Collaboration with service suppliers	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
Collaboration with competitors	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
Collaboration with universities	0.07***	0.01	0.07***	0.01	0.06**	0.01	0.07**	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
East Germany	-0.03	-0.01	-0.03	-0.01	-0.01	-0.01	-0.01	-0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)
Fragmentation index	0.44	-0.15	0.00	-0.15	-0.09	-0.18	-0.05	-0.15
	(0.45)	(0.16)	(0.49)	(0.17)	(0.49)	(0.15)	(0.49)	(0.16)
Patent blocking			0.11***	-0.00	0.11***	-0.00	0.11**	-0.00
			(0.04)	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)
Infringement					0.11***	0.07***		
					(0.03)	(0.02)		
Infringement (unprotected)							0.04	0.02
							(0.05)	(0.02)
Infringement (protected)							0.14***	0.07***
							(0.04)	(0.02)

Reported figures are coefficients; standard errors in parentheses.
*** (**, *) indicate a significance level of 1% (5%, 10%).
Industry dummies are included but not reported.

Table 6: Marginal effects after probit regressions (cont.)

	9	10	11	12	13	14	15	16
					Discrete industries		Complex industries	
	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing
Log(employment)	0.04***	0.02***	0.05***	0.02***	0.04**	0.01*	0.05***	0.02***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
R&D/ employment	2.38***	0.36**	2.51***	0.36**	2.10**	0.20	2.75***	0.41
	(0.70)	(0.16)	(0.71)	(0.15)	(1.04)	(0.13)	(0.98)	(0.28)
Patentstock/ employment	-0.06	0.13**	0.03	0.14***	0.04	0.03	-0.27	0.26
	(0.22)	(0.05)	(0.21)	(0.05)	(0.24)	(0.02)	(0.49)	(0.17)
Export dummy	-0.04	0.00	-0.05	0.00	-0.00	-0.00	-0.09	-0.00
	(0.04)	(0.01)	(0.04)	(0.01)	(0.06)	(0.01)	(0.07)	(0.03)
Part of a firm group	0.04	0.01	0.04	0.01	0.04	0.00	0.04	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.04)	(0.01)	(0.04)	(0.02)
Collaboration B2B	0.03	0.00	0.03	0.00	0.07	0.01	-0.01	-0.00
	(0.04)	(0.01)	(0.04)	(0.01)	(0.05)	(0.00)	(0.05)	(0.02)
Collaboration B2C	0.12***	0.00	0.12***	0.00	0.17***	-0.00	0.05	0.02
	(0.03)	(0.01)	(0.03)	(0.01)	(0.04)	(0.00)	(0.05)	(0.02)
Collaboration with material suppliers	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.04)	(0.01)	(0.04)	(0.02)
Collaboration with service suppliers	0.00	0.01	0.00	0.01	0.01	-0.00	0.01	0.03
	(0.03)	(0.01)	(0.03)	(0.01)	(0.04)	(0.00)	(0.04)	(0.02)
Collaboration with competitors	0.04	0.02*	0.02	0.02	0.09*	0.01	-0.03	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.05)	(0.01)	(0.04)	(0.02)
Collaboration with universities	0.06**	0.01	0.06**	0.01	0.08**	0.01*	0.06	-0.02
	(0.03)	(0.01)	(0.03)	(0.01)	(0.04)	(0.01)	(0.04)	(0.02)
East Germany	-0.01	-0.01	-0.01	-0.01	-0.03	0.00	0.00	-0.02
	(0.03)	(0.01)	(0.03)	(0.01)	(0.04)	(0.01)	(0.04)	(0.02)
Fragmentation index	0.85	0.04	0.04	-0.08				
	(0.60)	(0.18)	(0.59)	(0.21)				
Patent blocking	0.19***	0.01	0.11***	-0.00	0.11**	0.00	0.11**	-0.02
	(0.05)	(0.02)	(0.04)	(0.01)	(0.06)	(0.01)	(0.06)	(0.02)
Infringement			0.11***	0.08***				
			(0.04)	(0.02)				
Infringement (unprotected)	0.04	0.02			0.03	0.00	0.06	0.04
	(0.05)	(0.02)			(0.08)	(0.01)	(0.07)	(0.04)
Infringement (protected)	0.13***	0.07***			0.08	0.04	0.16***	0.07**
	(0.04)	(0.02)			(0.07)	(0.03)	(0.06)	(0.03)
Fragmentation * blocking	-2.71**	-0.58						
	(1.12)	(0.38)						
Fragmentation * infringement			-0.37	-0.16				
			(0.91)	(0.27)				

Reported figures are marginal effects; standard errors in parentheses.
*** (**, *) indicate a significance level of 1% (5%, 10%).
Industry dummies are included, but not reported.

Table 7: Bivariate probit models

	1		2		3		4	
	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing	In-licensing	Cross-licensing
Log(employment)	0.20***	0.34***	0.18***	0.34***	0.16***	0.31***	0.15***	0.30***
	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
R&D/ employment	8.14***	6.14**	8.26***	6.19**	8.26***	6.72**	8.11***	6.42**
	(2.26)	(2.56)	(2.32)	(2.57)	(2.32)	(2.66)	(2.31)	(2.64)
Patentstock/ employment	0.55	2.51***	0.11	2.50***	0.10	2.68***	0.10	2.50***
	(0.72)	(0.82)	(0.74)	(0.84)	(0.74)	(0.85)	(0.75)	(0.85)
Export dummy	-0.12	0.13	-0.14	0.13	-0.16	0.10	-0.16	0.07
	(0.14)	(0.24)	(0.14)	(0.24)	(0.14)	(0.25)	(0.14)	(0.25)
Part of a firm group	0.13	0.12	0.13	0.13	0.13	0.12	0.14	0.13
	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.17)	(0.10)	(0.17)
Collaboration B2B	0.14	0.18	0.13	0.19	0.11	0.09	0.12	0.12
	(0.13)	(0.21)	(0.13)	(0.21)	(0.13)	(0.22)	(0.13)	(0.21)
Collaboration B2C	0.40***	0.03	0.39***	0.03	0.38***	0.05	0.37***	0.01
	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)
Collaboration with	0.06	0.16	0.06	0.16	0.06	0.16	0.06	0.18
material suppliers	(0.09)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)
Collaboration with	0.04	0.20	0.03	0.21	0.02	0.18	0.01	0.17
service suppliers	(0.09)	(0.14)	(0.09)	(0.14)	(0.09)	(0.15)	(0.09)	(0.14)
Collaboration with	0.07	0.18	0.08	0.18	0.09	0.21	0.11	0.28*
competitors	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)	(0.10)	(0.16)
Collaboration with	0.26***	0.23	0.25***	0.23	0.22**	0.15	0.24**	0.20
universities	(0.09)	(0.15)	(0.09)	(0.15)	(0.09)	(0.16)	(0.09)	(0.16)
East Germany	-0.10	-0.23	-0.08	-0.24	-0.04	-0.11	-0.05	-0.16
	(0.10)	(0.20)	(0.11)	(0.20)	(0.11)	(0.21)	(0.11)	(0.20)
Fragmentation index	1.49	-2.64	0.01	-2.60	-0.30	-3.81	-0.15	-2.83
	(1.54)	(2.46)	(1.65)	(2.56)	(1.66)	(2.72)	(1.66)	(2.65)
Patent blocking			0.37***	-0.02	0.37***	-0.06	0.36**	-0.07
			(0.14)	(0.21)	(0.14)	(0.22)	(0.14)	(0.22)
Infringement					0.33***	0.86***		
					(0.10)	(0.15)		
Infringement							0.13	0.22
(unprotected)							(0.16)	(0.24)
Infringement (protected)							0.42***	0.76***
							(0.12)	(0.16)
Constant	-2.35***	-4.26***	-2.24***	-4.29***	-2.23***	-4.33***	-2.18***	-4.17***
	(0.27)	(0.48)	(0.28)	(0.49)	(0.28)	(0.51)	(0.28)	(0.50)
rho	0.43***		0.44***		0.42***		0.41***	
	(0.09)		(0.09)		(0.10)		(0.10)	
N	1162		1162		1162		1162	
ll	-763.47		-759.79		-740.61		-745.52	

Reported figures are coefficients; standard errors in parentheses.
*** (**, *) indicate a significance level of 1% (5%, 10%).
Industry dummies are included, but not reported.