# Tit for tat – Patent Cross-Licensing and How It Is Driven by IP (Inter-) Dependency in Small, Medium, and Large Companies

(Working Paper)

Florian Köhler
(TU Berlin)

## Abstract

This paper analyzes driving factors for companies' motivation to engage in cross-licensing transactions. It gives evidence on how these driving factors vary by the size of the firms. I discuss several hypotheses concerning company size and the degree to which a firm has to rely on its competitors' intellectual property (IP dependency). Although cross-licensing has been seen as relevant only among large firms, IP dependency exists also among smaller firms, which tend to have relevant previous licensing experience through out-licensing agreements. Findings here suggest that the connection of firm size as well as IP dependency with the importance of cross-licensing cannot be regarded separately. There is an interaction between firm size and IP dependency: The effect of IP dependency on the relevance of cross-licensing seems to be high for small with a decrease for larger companies. The results show a underinvestigated potential relevance of cross-licensing among SME.

## 1. Introduction

The boom in patent applications worldwide over the 1980s and 90s is a well documented and extensively analyzed fact among industrial economists. Patent application numbers worldwide have doubled from 1994 to 2005, for actual grants the growth rate is lower, but still at about 50% (see for example Cohen et al., 2000; Hall, 2005; Kortum and Lerner, 1999)[1]. The reasons for this surge are manifold: policy changes and court decisions in favour of patent holders (e.g. Hall, 2007), expanding the relevance of pat-

[1] For Germany see also Blind et al. (2006).

ents to new fields of technology (Kortum und Lerner, 1999), and changes in patenting strategies. These strategies include a more prominent use of patents as a means to block competitors, to boost the own technological image, to influence standard-setting processes, and to build up patent portfolios in order improve the firm' position in licensing negotiations. This last point of patent licensing, which has become more and more important in recent years, will be analyzed in this paper.

In specific I will focus on the exchange of patent rights via cross-licensing. These transactions are mainly concentrated in "complex" industries which are characterised by products consisting of large numbers of separately patentable elements and a high fragmentation of relevant intellectual property rights. Thus, the need to get access to competitors' IP (IP dependency) is high in these industries. With respect to the question of which firms are actually involved, empirical studies in the field of cross-licensing exhibit a strong focus on analyzing large firms' behaviour. The main reason seems to be that cross-licensing is widely known to be an important issue in large multinationals (Grindley and Teece, 1997). However, with a growing number of patents and an increasing fragmentation of the IP landscape, (research-intensive) SME are forced into dealing with this issue as well.

In this paper, I argue that there is an interaction effect between firm size and the actual need to exchange patents – the dependence on competitors' IP. Firms which operate in "complex" industries or depend on competitors' IP for other reasons generally have a higher likelihood to see cross-licensing as important. The relevance of cross-licensing rises furthermore with the ability to actually do so. This depends on either previous experience with (out-) licensing (prevalent especially in small firms as they often use licensing transactions to overcome their limited production facilities) and/or the capacities to have IP/licensing experts work on the subject (prevalent especially in large firms). On the other hand, larger firms have better chances to work around blocking IP. I argue that there is an interaction effect between size and IPR dependency: If IPR dependency is high, all firms will pose a higher importance to cross-licensing compared to firms with a low IPR dependency. With increasing firm size on the other hand, I argue that this is less the case because the capacities for the alternative strategy of a work around become available and the chances to achieve a work around rise.

The main contribution of this analysis is therefore an extension of the analysis of factors on firms and industry level that have been identified in the literature as important for cross-licensing to a sample of firms of all sizes. A focus will be on the interrelationship between firm size and IPR dependency. Additionally, the data used here contains a rather broad range of industries in manufacturing and therefore avoids the limitations of the majority of research on cross-licensing which focuses on specific (complex) industries only.

In the following I will elaborate in more detail on the theoretical reasoning why cross-licensing can be of relevance for small firms[2] and give a short overview on relevant existent literature. In section 3, I derive a set of hypotheses, section 4 presents the data, methods and results of the empiric work. Results are discussed in detail in section 5, before the work is rounded off by some concluding remarks concerning implications and limitations of the study.

## 2. Theoretical Background

In order to keep up with technological pace, firms more and more refrain from limiting themselves to only using technology developed in-house, but open up to sources from outside their own research lab. Firms, however, do not only consider to license in technology from other companies, but are increasingly open to exploit their own IP externally. One possible objective is the generation of revenue through patent royalties. As IP management has stepped out from under the shadow of physical or financial asset management, the importance of firms exploiting (unused) patents through out-licensing has been described as selling the so far undiscovered precious “Rembrandts in the Attic” (Rivette and Kline, 2000). Even if one does not thoroughly share the enthusiasm triggered by examples like IBM's licensing revenues for unused patents of over $1 billion in 1999, the need to trade patent rights not for money but for other patents has become a major issue in certain industries. These industries can be characterised as “complex” industries. Following the definition of Cohen et al. (2000) and other authors, a new commercializable product or process in complex industries is built of numerous separately patentable elements. In "discrete" industries, on the other hand, there might

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

exist a one-to-one relationship between product and patent (or at least the product is comprised of relatively few separately patentable parts). The likelihood for a single company to possess all relevant patent rights is much lower operating in a complex industry than in a discrete one and as a consequence, the strategic incentives for patenting differ between industries. Cohen et al. (2000) find that the exchange motive plays a more pronounced role in complex industries. Other authors like Blind et al. (2006) object that the differences between these two groups of industries increasingly blur and do not find strong support for differing importance of the exchange motive among German companies. However, anecdotal evidence shows that cross-licensing is indeed of high importance for some firms (see for example Grindley and Teece 1997).

These firms do not necessarily need to be the large multinationals like Texas Instruments or Hewlett-Packard that have been analyzed in the study by Grindley and Teece (1997). A recent OECD survey on the amount of and the motivation for licensing (Guellec and Zuniga, 2008) asked Japanese and European firms in size classes "more than 250" / "less than 250 employees" to report the share of licensing transactions in 2003 to 2006 that was done for cross-licensing reasons. Results suggest similar numbers for Japanese firms in both size classes, the actual figures amounted to 19% and 16% respectively. An analysis of mutual technology exchange among smaller firms seems therefore useful for a broader understanding of cross-licensing incentives.

To show the potential relevance of cross-licensing for smaller firms, two short examples can be brought up here: In August 1998, QuickLogic, a California based, semiconductor company with around 130 employees and sales of $31.9 million in 2008, agreed with Actel (584 employees and $218.4 million revenue in 2008) to mutually grant each other a "nonexclusive, royalty-free, worldwide license" to use all patents that the two parties "now own or may hereafter during the term of this Agreement own". A second example is an agreement between the two US automative and transport equipment manufacturers Amerigon Incorporated and BSST with 70 and 21 employees respectively. They agree that each firm become "the assignee of certain U.S. applications for patents which disclose technology developed by [the other firm]" and are therefore able to use the technology of both firms.[3]

[3] Information on the mentioned cross-licensing agreements comes from the website www.tech-agreements.com, a database of reference agreements of various kinds.

It is a fact that smaller firms have substantial experience with respect to licensing transactions, primarily in out-licensing technology. They do this to exploit technology for which they lack the complementary or down-stream assets like production facilities or marketing capacity (see for example Arora and Ceccagnoli, 2006; Gambardella et al., 2007) or face a better trade-off between the profit dissipation and revenue effect (Arora and Fosfuri, 2002). Thus they are much more likely to license out patents than large firms and therefore have a potential ability for managing cross-licensing as well. Furthermore, some authors have found that previous experience in licensing matters is one crucial point in explaining the observation of licensing activity (Kim, 2004; Kim and Vonortas, 2006). Smaller firms might then use their experience and know-how gained in out-licensing for engaging in cross-licensing as well.

Studies explicitly addressing cross-licensing are relatively scarce.[4,5] One theoretical contribution is Fershtman and Kamien (1992), who model the connection between the innovation race and cross-licensing in the development of two complementary technologies. In the empiric literature, Grindley and Teece (1997) present case study evidence from large U.S. companies in the semiconductors and electronics industry and discuss how those companies deal with increasing dependence on other companies' patents by cross-licensing whole portfolios of current and future patents rights. Shapiro (2000) includes the use patent pools and discuss the importance of licensing in the context of standard setting and patent thickets. Hall and Ziedonis (2001) conducted interviews and analyzed the patent behavior of 95 semiconductor firms. They show evidence of patent portfolio races of firms in order to secure bargaining power in licens-

---

4 Early literature on technology licensing not limited to cross-licensing has been mainly theoretical. This work includes Gallini and Winter (1985), who develop a non-cooperative R&D game and show that licensing can have ambiguous effects on research activities depending on the cost structure of the companies involved (similar research on R&D incentives includes for example Katz and Shapiro, 1985). Another research topic is the relationship of licensing and market structure. Gallini (1984) shows theoretically how an incumbent firm can employ licensing to deter potential entrants from market entry. More recent theory contributions on licensing include Fershtman and Kamien (1992) and Farrell and Shapiro (2008), with the latter concentrating on licensing of patents whose validity is uncertain and the impacts licensing of "weak" patents can have on incentives for invention. With respect to empirical research on licensing in general, recent work on this subject has been introduced by several authors (for example Anand und Khanna, 2000; Arora et al., 2001a; Fosfuri, 2006; Kim und Vonortas, 2006). However, the focus has been mostly on the incentives for licensing out technology and implications for innovation incentives or market structure.

5 A reason for the scarcity of empirical research especially on smaller firms' cross-licensing behavior is data availability: company databases often do not dispose of detailed information on smaller firms, because disclosure requirements are less rigid for them. Frequently used sources of information about licensing deals in the US used by researchers are the annual reports (10-ks) filed with the Security and Exchange Commission. As this is only required for publicly traded firms, smaller firms are often omitted from analysis. For Germany, where the companies analyzed in this paper come from, publication requirements of data connected to licensing transactions are even less strict and empiric research has therefore less data to work with.

ing transactions. Further research focusing explicitly on cross-licensing was done by Nagaoka and Kwon (2006) for Japanese firms. They present a stochastic model suggesting that a higher symmetry between firms tends to raise the probability of cross-licensing. They subsequently analyze data on a contract and industry level and show that licensing is more probable among larger firms and for patent licensing compared to know how licensing. A last widely cited study by Anand and Khanna (2000) provides large-scale econometric evidence on contract characteristics including the frequency of cross-licensing. The largest incidence of licensing is reported in the chemical industry, cross-licensing shows to be prevalent in computer and electronics. They also show that a significant fraction of cross-licensing is the result of litigation settlements.

The following section will present a number of hypotheses with respect to the characteristics of firms and industries, which are seen to be influential for cross-licensing activities and will discuss how the context of smaller firms affects these driving factors. I will first present the argumentation with respect to the influence of firm size and technological interdependence as well as the interaction effects of these two aspects. In the next step, additional influencing factors on the propensity to cross-license are discussed, before an empiric test will be carried out in the subsequent section.

## 3. Hypotheses

A first argument for larger firms having to rely more often on an exchange of patent rights is the notion that they generally dispose of a broader technological portfolio than smaller, possibly more specialised firms. Due to capacity reasons, the number of R&D projects in the pipeline at large companies is higher than in SMEs. This leads to a higher probability that at least one of the R&D projects faces a situation where IP needed to proceed with the research or to market the results is already held by other companies. A rising number of external patents is needed for the own production process and – as a consequence – (in-) licensing becomes a phenomenon observed more commonly among larger companies. At the same time, a larger patent portfolio increases the probability that technology, which is essential for the entire industry, is held by the company itself. This would make the firm more relevant as a “technology supplier” for competitors. Therefore not only in-licensing becomes more important, but also

cross-licensing.[6] An argument against this hypothesis is that in case of a competitor's patent blocking a large firms R&D efforts the number of possible alternatives is higher when the firm disposes of an extensive technology portfolio. This is more likely in large firms, which therefore might have better chances of managing a workaround and thus avoiding the licensing arrangement.

In favour of a positive relationship firm size-cross-licensing is the notion that the administrative costs of arranging complex IPR exchange mechanisms can only be borne when there are enough resources available. This refers to both the existence of an IPR department and a sufficient number of IPR managers as well as the relevant competences of the staff. In many smaller firms, the responsibility of IPR issues lies with only one person. That person is in many cases also the General Manager of the company, which means that the allocation of time specific to IPR issues is limited making the practical relevance of cross-licensing somewhat limited if there exists an alternative strategy.

One other point should be mentioned here: Nagaoka and Kwon (2006) show that the incidence of cross-licensing is higher when codified knowledge, such as a patent, is involved compared with the transfer of know-how only. It is a well known fact that the propensity to use the patent system increases with firm size. The reasoning refers again to the costs involved with patenting technology, which are characterised by sunk costs as well as decreasing marginal costs. As a consequence, large firms are unequally more involved in the patent system and thus meet a critical prerequisite of licensing to a higher extent.

The arguments above add up to the derivation of

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

It is clear that companies would not engage in cross-licensing transactions if they did not need to do so because of problems with their "freedom to operate" within their technological field. This problem of overlapping technology is observed in specific industries and can be explained in a number of ways.

---

[6] Using contract level data, Nagaoka and Kwon (2006) show empirically that cross-licensing is indeed more prevalent among large firms as licensor and licensee.

One addresses the nature of the technology in the industry and whether one technology heavily relies on previous R&D results. This concept is referred to as “sequential innovations”. Bessen and Maskin (2008), for instance, bring up the well-known argument that in industries like software, computers, and semiconductors innovation strongly builds on the imitation of previous technology. Product or process innovations are merely improvements of this existing technology. In such a setting, intellectual property rights like patents can inhibit the innovative activity of firms. As a result they are forced to share patents via institutions like patent pools or cross-licensing agreements.

A connected, but slightly different concept is stressed by Cohen et al. (2000) and other authors. They put forward that there are industries in which a given product necessarily consists of more than a few elements which can be patented separately. If an industry is a “complex” one, a high number of different patents, potentially held by different companies, are needed to commercialize a given product. This fact, again, leads to a necessity of an interchange of patent rights. The issues of “sequentiality” and “complexity” are quite similar ones. They both lead to the assumption that firms which have to rely more heavily on competitors IP (possibly because they operate in certain industries namely electrical engineering, computers, semiconductors) pose a higher importance on cross-licensing. In other words:

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

The two hypotheses stated above are quite straightforward. In the following, I argue however, that firm size and IPR dependency must not be considered independently from each other. On the contrary, I hypothesize that the influence of IP dependency on the propensity to cross-license differs with firm size classes. My reasoning is as follows: There are at least two factors that influence the likelihood of a company engaging in cross-licensing when its dependency on competitors' IP is high: previous experience in licensing issues and the feasibility of an alternative “work around strategy”. Small firms show a much higher propensity to license out than larger firms, they therefore tend to have previous experience and licensing-specific know-how. If they are in a situation in which there is a high technological interrelationship (e.g. in certain industries), they are

therefore able to deal with cross-licensing. On the other end of the scale, large multinationals have their own IP department (and/or even licensing department) and the according experts working there. If they are in a situation of technological interdependence they certainly are able to cope with it and are additionally likely to have existent experience with (cross-) licensing. Cross-licensing could take different forms in smaller firms than in multinationals. In the latter, cross-licensing is often realized as an exchange of large number of patents or even entire patent portfolios. In the former these arrangements might be more focused on a specific technological hold-up situation where only a relatively small number or IPR are transferred. The impact of (lacking) resources on the ability to manage cross-licensing is in this case somewhat easened by the fact that smaller firms simply realize cross-licensing on a smaller scale. Concerning the trade of between licensing and working around, the odds of managing a work around are considerably better for large companies and their technological portfolio might even contain possible technologies to be used instead of the one held by the competitor. The trade-off licensing versus working around might therefore shift towards the latter strategy.

All in all, the argumentation adds up to

> Hypothesis 3: The dependency of other IP raises the importance of cross-licensing more for smaller firms than for larger firms.

There are other factors which can potentially influence the importance of licensing in general and cross-licensing in particular. The economic rationale behind them will be shortly discussed in the following.

A number of authors have analyzed the impact of intellectual property rights' (IPR) effectiveness on the licensing of patents.[7] Anand and Khanna (2000) also interpret their findings of clear differences in the licensing behavior between industries as being the result of differing IPR strength. In the context of unilateral licensing, Arora and Ceccagnoli (2006) argue that stronger IPR can have a positive (e.g. through lower transaction

7 Those contributions include Arora and Ceccagnoli (2006) (showing that patent effectiveness influences the propensity to license on the firm level in certain circumstances) or Yang and Maskus (2001) (finding a positive relationship between the strength of IPR regimes and technology flows on a country level).

costs) or a negative influence (because with stronger patents the IP holder can rely better on the granted monopoly rights and has a higher incentive to commercialize the technology in-house only). The last point, however, does not refer to cross-licensing, where a mutual dependence from each others patents is assumed. One can therefore conclude that industries with stronger IP might have a higher rate of cross-licensing. Because of the nature of the data in the empiric analysis below this last argument can not be addressed properly, however. The reason is that the data refers to the importance of cross-licensing and has its primary focus on the significance of exchanging patent rights, not the feasibility of those contracts.

Another influencing factor of the licensing decision is competition both in the product and the technology market. Arora et al. (2001b) specify two effects which influence the decision of licensing a patent or keeping it in-house only. The first one, which they call “revenue effect”, simply refers to the income generated by the royalties from licensing out the patent. The second effect, called the “profit dissipation effect”, comprises the reduced profit which is the result of one additional company having the technology and thus acting in the relevant product market. The two effects are traded off against each other when deciding whether to license a patent or not. A company will only license if the revenue effect is higher than the profit dissipation effect. However, as cross-licensing is not about generating income but about securing the own freedom to operate, in the context of this study, the link to the technology market seems to be more relevant. With a higher competition among companies on the market for technologies, more companies are involved in the patent race. This raises the likelihood of the relevant patents being distributed among a number of different firms. This, in turn, can have a positive influence on the importance of exchanging patents via cross-licensing.

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

A further possible influence might constitute the status of a firm being an independent entity or part of a (national or international) group of firms. Statistics like the Technological Balance of Payments on the one hand indicate that a significant portion of licensing takes place between members of a group of firms. One of the primary reasons seems to be dislocating profits in order to optimise the tax burden. Patents are held by one single entity within the group, which licenses out the relevant rights to the firms. In cross-licensing agreements, however, there is normally no payment involved, therefore optimizing the tax burden does not seem to be relevant here. Still it could be argued that the members of a group mutually give each other access to their relevant IP. On the other hand, it seems reasonable that R&D activities within groups are organized in such a way that the need for cross-licensing does not come up. Instead, research tasks with high interdependency would be concentrated within one specialized firm (Nagaoka and Kwon, 2006; Von Hippel, 1990). Expectations regarding the influence of a group affiliation are therefore ambiguous.

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

# 4. Survey Results

## 4.1. Data

The data for the subsequent analysis was collected as a survey among German firms. About 2700 firms were asked to fill out a paper-and-pencil questionnaire, with an additional possibility to access the same set of questions online. A pretest was conducted before the actual field work in order to clear out possible difficulties. The sample is deliberately focused on patent-active firms, which is especially suitable for this study as it concentrates on the licensing of patents. German firms which have applied for more than 10 patents in 2002-2004 were identified, considered were applications at the German Patent Office (DPMA), the European Patent Office (EPO) and under the PCT. In addition, a randomly drawn sample of companies which have been identified as being R&D-active through the Hoppenstedt company database was contacted. The same database was used to identify a relevant contact person, which was defined as the head of R&D, the head of the IPR/law department or – especially for the smaller companies – the firms' General Manager. Despite the direct addressing and two reminder letters, a response rate of only 10% was obtained. Due to non response and deliberately limiting the sample to manufacturing firms there are 219 companies available for the multivariate analysis further down. A number of firms were contacted by phone to get further information about the reasons for non-participation. Results suggested that in some firms there is an increasing reluctance of participating in voluntary surveys irrespective of the concrete subject. A non-response bias (e.g. towards more patent-active or licensing-active firms) seems not to be a major problem. Table 1 gives an overview of the size and industry distribution of the sample which answered all questions relevant in this study.

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

ure 1 shows the mean values attributed to some of the motives, in order of overall importance.

Table 1 and Figure 1 here (see appendix)

## 4.2. Econometric Model

In the following section I will discuss the method applied to test the hypothesis and describe the construction of the variables.

The dependent variable in the model is firms' assessment of the importance of cross-licensing. As said above, the item was measured on a five point ordinal scale. The most appropriate approach in this case is an ordinal regression (Long, 1997). Here a General Ordered Logit Model is applied to avoid the parallel regression assumption. Due to data restrictions there are no sufficient numbers of observations for some categories of the dependent variable. It is therefore recoded into a new variable with three levels, indicating low, medium or high importance of cross-licensing.

The expectations regarding the direction of influence of the independent variables in the model are as follows.

Firm size is measured by the number of employees of a firm. I interpret this variable as a proxy for a larger technological portfolio that raises the likelihood of having at least one R&D project that has to rely on other companies' IP. As one can see from the figure above, the importance seems to rise with company size, but we can not assume a completely linear relationship. The difference in the assessment between the small and medium firms seems to be more pronounced than between medium and large firms. I therefore use a log-transformed version of the original employment variable, similar to e.g. Arora and Ceccagnoli (2006) or Blind et al. (2006). I expect – as described above – a positive sign of the coefficient. However, the higher values for cross-licensing among larger firms might in fact not be due to the firms' size, but a higher dependency on competitors' IP. Figure 1 might therefore be delusive and the interaction effect discussed below has to be taken into account.

For measuring dependence of other companies' technologies, a self assessment of firms is used. The questionnaire included an item referring to the importance of com-

petitors' technologies for the firm, measured on a five point scale from one (“low importance”) to five (“high importance”). A technological interdependence caused by differences between industries is caught by introducing industry dummies for Chemicals/Pharma, Plastics, Mechanical Engineering, Metal Processing, Electrical Engineering, Consumer Goods, and “Other manufacturers”, which mainly covers production of construction as well as packaging materials. For the estimations below, Electrical Engineering will be the base category. As previous research suggests that cross-licensing has a particular importance here, the coefficients of the other industry dummies are expected to have a negative sign. For reasons shown below, a greater aggregation into “complex industries” and “discrete industries” is needed below. Following Cohen et al. (2000) the former include Mechanical Engineering and Electrical Engineering. Whether a firm belongs to a complex industry is indicated by a dummy variable *complexity*, which is expected to have a positive coefficient.[8]

The argumentation above regarding the interaction between firm size and IPR dependency will be addressed with an interaction term of firm size and IPR dependency (variable employeesXipr_dep). As argued above, small firms potentially acquire expertise in licensing through a more prevalent experience in out-licensing and lack means for working around the needed technology. In the last point they differ from medium-sized and especially larger firms. That leads to the assumption that small firms with high technological dependence tend to regard cross-licensing as more important than medium-sized and large firms and I therefore expect a negative sign for the interaction term.

The remaining variables (Competition Intensity, Cooperation Intensity, Group Affiliation and R&D Intensity) are defined as follows. For the first one, competition intensity, firms' self assessment on a five point scale is used. I assume that competition in the product market correlates positively with competition in the technology market. This is reasonably since the firms in the sample are all involved in research and development and ultimately compete for patents in its specific technological environment. It is expected that

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

stronger competition in the product market proxies the competition in the technology market and therefore a positive sign of the coefficient is expected.

Firms were asked whether they engage in R&D cooperations of several kinds: with suppliers, customers, competing companies in the same industry, private R&D service providers, or public research institutes. The reasoning above, where cross-licensing was regarded as a means to let all partners in the cooperation benefit from the research results, holds only true for vertical cooperation with suppliers or customers and horizontal cooperations (with competitors in the industry). In the other two forms (cooperation with R&D service providers and public research institutes) the firm takes more the role of an ordering party which assigns certain R&D tasks to the contractor. Cross-licensing agreements are rather unlikely to originate from these forms of cooperation. Cooperation intensity is thus defined as a dummy variable with 1 indicating a “frequent” or “very frequent” cooperation in any of the other three alternatives.

With regard to the legal status of the firm the variable *group* takes the value 1 if a firm is affiliated to a national or international group. As seen before, expectations regarding the sign of the coefficient are ambiguous.

The last variable in the model is the R&D intensity. Firms were asked both for their sales figures and R&D expenditure. Both statements were apparently (and as expected) regarded as sensitive data, with corresponding high non-response rates of 30 to 40%. I therefore proxy the R&D intensity with the ratio of employees in R&D divided by the overall number of employees. Both figures were asked in the questionnaire. Again, the discussion above yielded arguments for both a possible negative as well as a positive impact on the importance of cross-licensing.

Table 2 gives an overview of all variables for the model and corresponding descriptives.

Table 2 here (see appendix)

### 4.3. Results

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

Table 3 about here (see appendix)

As I use a General Ordered Logit model[10] with three outcome values of the dependent variable, two different coefficient panels are reported, the first one referring to the probability of a firm stating medium or high importance for cross-licensing (compared to reporting low importance) and the second one showing the coefficients for a firm giving a high importance (compared to giving a low or medium value). Comparing the second panel with the first one, several coefficients lose their significance, indicating that the main influence of the parameters is connected with attributing medium or high importance to cross-licensing compared to low importance. The influence of several factors of the first panel on giving the highest value (compared to values 1 and 2) cannot be confirmed. In the subsequent section I thus concentrate on the first panel, discussing which factors influence a “medium or high” relevance of cross-licensing compared to a low one.

---

[9] The McFadden-(Pseudo-)-R2 ranges from .12 to .14. It was however found to severly underestimate the “true” $R^2$ in ordinal logit models. The Pseudo- $R^2$ reported above are considered to be more informative (see Veal and Zimmermann 1992).

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

I will first concentrate on Model 1 and 3. They show that firm sizes as well as IPR dependency have the expected positive influence on the importance of cross-licensing. As the main focus of this paper is on the interaction of these two factors, their interpretation has to focus on Model 2 and 4, they will be discussed in detail further down. With respect to other factors in Model 1 and 3, R&D intensity raises the relevance of cross-licensing, in the first as well as the second panel. This backs the hypothesis that firms that are more active in research more often have to deal with other firms' IP in order to proceed. Additionally, they are more able to integrate external technology into own production processes (absorptive capacity). The influence of competition intensity, cooperation intensity, and group affiliation is uncertain. The significance of the corresponding coefficients is weak, not existent, or changing between specifications. With regard to the industry dummies, there is a weakly significant negative influence for Metal Processing, but only in the second panel. This industry seems to attribute less importance to cross-licensing than the reference category of Electrical Engineering. The relevance of industry characteristics becomes more obvious with industries concentrated in the two technological categories, according to their technology complexity. The variable turns out to be significant, showing that the fact whether an industry is a complex or a discrete one significantly influences the importance of cross-licensing on both levels (panel 1 as well as panel 2).

The interpretation of the influence of firm size and IP dependency as well as their interaction will be addressed in detail in the following paragraph. The first panel of Model 2 and Model 4 shows a negative sign for the interaction term's coefficient.[11] One might be tempted to interpret this as the negative interaction effect under scrutiny here. However, when calculating the marginal effect based on the interaction term's coefficient only, the result cannot be regarded as the correct whole interaction effect. The "true" interaction effect is the cross derivative of the function

(1) $$E(y>1) = \Lambda(\beta_{employees} x_{employees} + \beta_{ipr_dep} x_{ipr_dep} + \beta_{employeesXipr_dep} x_{employees} x_{ipr_dep} + X\beta)$$

11 The insignificance of the interaction terms coefficient does not imply that it should not be included in the specification. There might nevertheless exist a conditional relationship between the two variables (see e.g. Brambor et al. (2006) or Ai and Norton (2003)).

with respect to the two constitutive terms $x_{employees}$ and $x_{ipr_dep}$ (all other variables captured by X•). In formal terms this is $\frac{\partial E(y>1)}{\partial x_{employees}\partial x_{ipr_dep}}$ and does not correspond to the marginal effect based on $\bullet_{employeesXipr_dep}$, which is $\frac{\partial E(y>1)}{\partial x_{employees}x_{ipr_dep}}$. Furthermore, the coefficients (and corresponding marginal effects) of the constitutive terms as they are reported in Table 3 (employees and ipr_dep) can only be interpreted as the effect of one variable under the condition that the other constitutive term takes the value zero. The influence of IP dependency on the importance of cross-licensing for a firm with zero employees is a parameter without relevance. For better interpretation, the marginal effects for the variable IP dependency (ipr_dep) are therefore calculated for a firm in one specific industry (Electrical Engineering) with average characteristics in all control variables, but varying firm sizes. In formal terms this corresponds to the derivative on equation (1) with respect to $x_{ipr_dep}$

$$(2)\ \frac{\partial E(y>1)}{\partial x_{ipr_dep}} = \Lambda'(\beta_{employees}x_{employees} + \beta_{ipr_dep}x_{ipr_dep} + \beta_{employeesXipr_dep}x_{employees}x_{ipr_dep} + X\beta) * (\beta_{ipr_dep} + \beta_{employeesXipr_dep}x_{employees})$$

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

In Figure 1 and Table 1, I split the firm in three size categories: “up to 249 employees”, “250 to 999 employees” and “100 or more employees”. Calculating the marginal effect (and standard errors) for three firms with the average firm size within each class returns values of .12 (.043), .11 (.033) and .08 (.037) for small, medium and large firms, respectively.[12] This can be seen as a first hint to confirm Hypothesis 3, showing that indeed the effect of IP dependency changes for firms of different sizes: a higher degree of IP dependency leads smaller firms to attribute higher importance to exchanging patents via cross-licensing, while this effect seems to be less relevant for growing firm sizes firms. In order to present further evidence on the marginal effects' relative sizes

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

for different firms, Figure 2 graphs the marginal effects of IP dependency with respect to firms' size.[13] One can clearly see a declining interaction effect, the marginal effect first stays relatively even and begins to fall at a value of around 4, corresponding to a firm size of less than 100 employees (ln(100)=4,6). The graph suggests that for larger firms, the effect of IPR dependency gets continuously lower. I interpret this development as the effect of better possibilities to gain a workaround instead of cross-licensing.

Figure 2 (see appendix)

From Figure 2 it becomes also clear that the computed confidence intervals are rather wide, meaning that despite the clear trend in the marginal effect for the different firm sizes one has to be careful about the statistical significance of the difference between them. As a robustness check I therefore calculate a model with dummy variables for the size classes instead of the continuous variable "employees". The size classes correspond to the categorisation above into firms with less than 250 employees, more than 250 but less than 1000 employees and companies with 1000 or more employees. Table 4 shows the results corresponding to the four previous specifications, again only the results for Panel 1 yield clear results and will be discussed here. Size dummies in Model 1 have significantly positive values supporting the impact of firm size. When entering the interaction terms (both dummies are interacted with the variable IPR Dependency) variable size_class3 loses significance and only the interaction term for size_class2 turns out significant. As stated above, considering only coefficients' signs and significance levels in logit models with interaction terms can lead to wrong conclusions. I therefore again estimated the marginal effect of IPR dependency on the importance of cross-licensing for a medium sized firm (size_class2=1) and compared it with a company in the reference category "small firm". The latter is estimated to 0.2180 (s.e.= 0.0626, $p< 0.01$), whereas the former one is not significantly different from zero (-.0136, s.e.= 0.0430). The same value for large firm (size_class3=1) amounts to .1418 (s.e.= .0427, $p<0.01$). We can thus conclude that the effect for small firms seems to be more important than for the medium firms and is in fact significantly higher as the 10% confidence intervals do not have common areas ([0.1150;0.3211] for the small firms

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

and [-.0844; .0570] for the medium sized firms). Surprisingly, comparing the group of large firms with the reference group of small firms the difference of the difference in the effect of IPR between the groups is not sufficiently large to allow a clear conclusion of group differences in a statistical sense. Moreover, the calculation of the interaction effect itself (size_class2xipr_dep, size_class3xipr_dep) yields a significantly negative value for the medium firms, but a non-significant one for large firms backing the results above. Some caution regarding the implications of IPR dependency in large firms is therefore appropriate. A reason could be that the argument of better means to work around needed IP does not apply to the largest firms, because they have the means to manage cross-licensing deals and do not bother with trying to achieve a workaround every time they are blocked by a competitor's IP.

## 5. Summary and Implications

In the following section, I will shortly summarize the empirical findings and highlight aspects which should be discussed against this background.

We have seen that the perceived importance of cross-licensing changes with firm size as well as with the degree to which the firm has to rely on competitors' IP. However the two variables should not be analyzed separately as there is an interaction effect between them. The effect of IP dependency is high for smaller firms. I argue that this has to be ascribed to the lack of means to achieve a work-around of the technology and the experience of out-licensing that smaller firms tend to gather in order to exploit there IP efficiently. Larger firms, however, have better odds to avoid the arrangement of cross-licensing and in addition they have better chances to either have an alternative technology in its portfolio.

How can these findings be consolidated with a high observed relevance of cross-licensing among large multinationals in certain industries like electronics and semiconductors? Even if the effect of IPR dependency seems to be getting lower in larger companies the positive size effect might be more important: The fact that they have the highly specialised IP staff that can deal more easily with complex transactions than a smaller firms makes cross-licensing agreements more realistic. Additionally, larger firms do not engage in exchanging particular patents, but trade entire patent portfolios or sign contracts mutually waiving all possible future infringement charges. For smaller

firms trading a particular patent (or a small set of patents) might be more relevant. If firms referred to cross-licensing as an arrangement of trading only particular patents it would be just reasonable to explain the higher impact of IPR dependency for smaller firms: it has an impact for them in terms of a connected higher importance of trading certain rights, for larger firms this is less the case because they deal with IP dependency via patent pools or large-scale patent portfolio exchanges.

The fact that large firms are known to be active in cross-licensing brings some well-known problems with it: In order to be in a good position in cross-licensing bargaining, firms will intensify their patenting activities in an attempt to win the patent races against their competitors. One option in this race is applying for more patents and seeking protection for smaller inventions. Another strategy is to seek broader patents by a suitable design of the patent claims[14]. Both problems could partly be resolved by rigorous patent examiners and/or stricter rules concerning firms' application behavior at patenting offices. With rising patent applications and a higher work load for patent offices, however, requirements regarding the inventive step might be getting lower (for the USPTO see Hunt, 1999; Jaffe and Lerner, 2007).[15] This could result in a kind of vicious circle, as the resulting surge in patents increases IP fragmentation, which in turn raises the need to exchange patent rights.

As a consequence of tighter patent thickets, smaller firms might be disadvantaged as they have a weaker bargaining position compared to large multinational firms.[16] As we have seen that smaller firms in a situation of technological interdependency attribute a high importance to cross-licensing too, this might be critical to the role SME play for technological progress. Institutions like patent pools, where a number of companies bundle the relevant patents for a specific technology, could help small and medium firms to get access to relevant IP without the organizational overhead of multiple cross-licenses. On the other hand if IP dependency in smaller firms is only about a limited

---

[14] Hall (2007) calls this problem (patents with up to 20,000 claims are reported) the “super-size phenomenon”.

[15] An argument against this fear and for a rigorous examination practice at the USPTO might be the fact, that the patent allowance rate (the percentage of applications reviewed by examiners that are approved) at the USPTO has been plummeting since 1999 to an all-time low of 54%.

[16] In contrast, Grindley and Teece (1997) argue that firm size does not matter in this case. According to them, the crucial question is within the technology and which company holds the core patents for a certain technology field.

number of relevant patents held by a competitor, the cost of joining a patent pool might outweigh the benefits of accessing only a few crucial patents.

In order to reduce the need to cross-licensing in the first place, the controversial US Supreme Courts ruling *KSR vs. Teleflex*, which tightened the definition of non-obviousness, could potentially be a step into the right direction, as it raises the bar for obtaining patents and thus slows down the concentration of patent thickets. Similar efforts are part of a strategic renewal process at the European Patent Office (see the EPO's Annual report 2007)

Another point should be addressed here. With high IP fragmentation, companies have to invest more time and effort in monitoring the IP landscape. This can be the case in two ways: Checking competitors' products for possible infringement of own patents and screening a high number of alien patents in order to avoid unintentional infringement of other firms' IP. This means that highly qualified staff has to invest a considerable amount of time in patent monitoring, which ultimately translates into higher costs for the companies. Of course, it has to be the natural behavior of an innovative firm to review the existing state-of-the-art. The effort to accomplish this task in an efficient manner, however, increases significantly as patent numbers go up. Especially the problem of an unintended infringement of another firms' patent can result in severe financial consequences as the business model of “patent trolls” gets more attractive. Firms face the possibility of exorbitant financial claims and longsome lawsuits with firms who acquire relevant patent rights for the only goal of suing companies which infringe – knowingly or not – a particular patent.

To break the vicious circle of patent races, IP fragmentation, and subsequent high costs of cross-licensing, patent offices should run a strict strategy and grant patents only for applications with a significant inventive step. This limits the patent system to what it is intended to do: stimulate innovation and economic growth by securing the appropriability of the returns for inventors and innovative companies.

This study was a first attempt to identify the role cross-licensing plays for small firms in situations of high technological interdependency. Limitations include the sample size of just over 200 companies. Further research could be done in case study approach among SMEs in order to shed more light on cross-licensing among smaller firms.

# References


Anand, B. N. & Khanna, T., 2000: The structure of licensing contracts., *Journal of Industrial Economics*, Vol. 48, No. 1, pp. 103-135.

Arora, A. & Ceccagnoli, M., 2006: Patent protection, complementary assets, and firms' incentives for technology licensing., *Management Science*, Vol. 52, No. 2, pp. 293-308.

Arora, A., Fosfuri, A., & Gambardella, A., 2001a: Markets for Technology and their Implications for Corporate Strategy., *Industrial and Corporate Change*, Vol. 10, No. 2, pp. 419-449.

Arora, A. & Fosfuri, A., 2002: Licensing the market for technology., *Journal of Economic Behavior and Organization*, Vol. 52, pp. 277-295.

Arora, A., Fosfuri, A., & Gambardella, A. 2001b: *Markets for Technology. The Economics of Innovation and Corporate Strategy,* MIT Press, Cambrige, MA.

Bessen, J. & Maskin, E., 2008: Sequential Innovation, Patents, and Imitation., *Rand Journal of Economics*.

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

Brambor, T., Clark, W. R. & Golder, M., 2006: Understanding Interaction Models: Improving Empirical Analysis., *Political Analysis*, Vol. 14, No. 1, pp. 63-82.

Cohen, W. M. & Levinthal, D. A., 1989: Innovation and Learning - the 2 Faces of R-And-D., *Economic Journal*, Vol. 99, No. 397, pp. 569-596.

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

Farrell, J. & Shapiro, C., 2008: How strong are weak patents?, *American Economic Review*, Vol. 98, No. 4, pp. 1347-1369.

Fershtman, C. & Kamien, M. I., 1992: Cross Licensing of Complementary Technologies., *International Journal of Industrial Organization*, Vol. 10, No. 3, pp. 329-348.

Fosfuri, A., 2006: The licensing dilemma: Understanding the determinants of the rate of technology licensing., *Strategic Management Journal*, Vol. 27, pp. 1141-1158.

Gallini, N. T., 1984: Deterrence by Market Sharing - A Strategic Incentive for Licensing., *American Economic Review*, Vol. 74, No. 5, pp. 931-941.

Gallini, N. T. & Winter, R. A., 1985: Licensing in the Theory of Innovation., *Rand Journal of Economics*, Vol. 16, No. 2, pp. 237-252.

Gambardella, A., Giuri, P., & Luzzi, A., 2007: The market for patents in Europe., *Research Policy*, Vol. 36, pp. 1163-1183.

Grindley, P. C. & Teece, D. J., 1997: Managing intellectual capital: Licensing and cross-licensing in semiconductors and electronics., *California Management Review*, Vol. 39, No. 2, p. 8-&.

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

Hall, B. H., 2007: Patents and patent policy., *Oxford Review of Economic Policy*, Vol. 23, No. 4, pp. 568-587.

Hall, B. H., 2005: Exploring the Patent Explosion, Journal of Technology Transfer

Hall, B. H. & Ziedonis, R. H., 2001: The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995., *Rand Journal of Economics*, Vol. 32, No. 1, pp. 101-128.

Hunt, R. M., 1999: Nonobviousness and the Incentive to Innovate: An Economic Analysis of Intellectual Property Reform., *Federal Reserve Bank Working Paper*, Vol. 99, No. 3.

Jaffe, A. & Lerner, J. 2007: *Innovation and its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do About It,* Princeton University Press, Princeton.

Katz, M. L. & Shapiro, C., 1985: On the Licensing of Innovations., *Rand Journal of Economics*, Vol. 16, No. 4, pp. 504-520.

Kim, Y., (2004): Market structure and technology licensing: evidence from US manufacturing., *Applied Economics Letters*, Vol. 11, No. 10, pp. 631-637.

Kim, Y. & Vonortas, N. S., 2006: Determinants of Technology Licensing - The Case of Licensors., *Managerial and Decision Economics*, Vol. 27, pp. 235-249.

Kortum, S. & Lerner, J., 1999: What is behind the recent surge in patenting?, *Research Policy*, Vol. 28, No. 1, pp. 1-22.

Long, J. S. 1997: *Regression Models for Categorical and Limited Dependent Variables,* Sage Publications, Thousand Oaks, CA.

Nagaoka, S. & Kwon, H. U., 2006: The incidence of cross-licensing: A theory and new evidence on the firm and contract level determinants., *Research Policy*, Vol. 35, No. 9, pp. 1347-1361.

Rivette, K. G. & Kline, D. 2000: *Rembrandts in the Attic: Unlocking the Hidden Value of Patents,* Harvard Business School Press, Boston.

Shapiro, C. 2000: "Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting" in *Innovation Policy and the Economy I*, A. Jaffe, J. Lerner, & S. Stern (Hrsg.), The MIT Press, Cambrigde, Massachussetts, pp. 119-150.

Veal, M. R & Zimmermann K.F. (1992): Pseudo-R2 in the ordinal probit model., Journal of Mathematical Sociology, Vol. 16, No.4, pp. 151-164.

Von Hippel, E., 1990: Task Partitioning - An Innovation Process Variable., *Research Policy*, Vol. 19, No. 5, pp. 407-418.

Yang, G. F. & Maskus, K. E., 2001: Intellectual property rights and licensing: An econometric investigation., *Weltwirtschaftliches Archiv-Review of World Economics*, Vol. 137, No. 1, pp. 58-79.

# Appendix

Table 1: Sector and size distribution of the sample

| *Industry* | *size_class up to 249 em-ployees* | *250 to 999 em-ployees* | *1000 or more employees* | *Total* |
|---|---|---|---|---|
| | *No.* | *No.* | *No.* | *No.* |
| Chemicals and Pharma | 4 | 5 | 10 | 19 |
| Plastics | 5 | 4 | 3 | 12 |
| Mechanical Engineering | 15 | 26 | 32 | 73 |
| Metal Processing | 10 | 6 | 13 | 29 |
| Electrical Engineering | 28 | 10 | 22 | 60 |
| Consumer Goods | 2 | 8 | 7 | 17 |
| Other manufacturing | 3 | 2 | 4 | 9 |
| Total | 67 | 61 | 91 | 219 |

Figure 1: Importance of licensing motives (mean values by firm size)

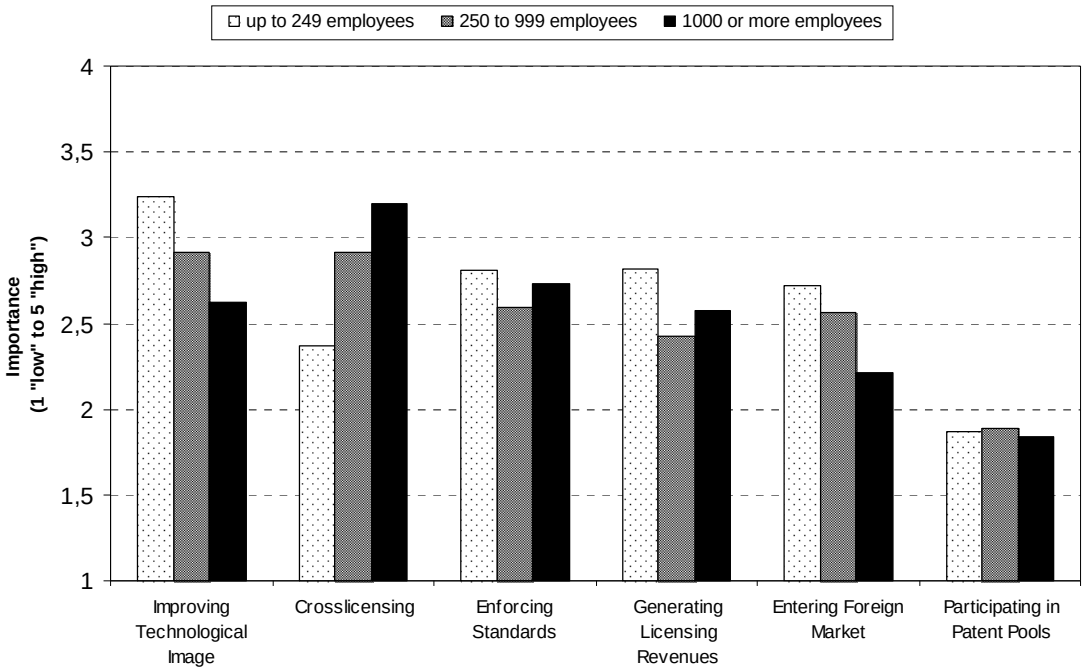

Table 2: Descriptive statistics of the explanatory variables

| *Variable* | *Description* | *Mean* | *Std. Dev.* | *Min* | *Max* |
|---|---|---|---|---|---|
| size | Firm Size (log (number of employees)) | 6.39 | 2.10 | 1.38 | 11.62 |
| comp_int | Competition Intensity (self assessment on five point scale) | 4.29 | 0.78 | 2 | 5 |
| coop_int | Cooperation Intensity (Value 1: frequent cooperation with at least one of the following: suppliers, customers, or competitors) | 0.49 | 0.50 | 0 | 1 |
| ipr_dep | Importance of competitors´ IP (self assessment on five point scale) | 2.84 | 1.29 | 1 | 5 |
| group | Group Affiliation (Value 1: affiliation to national of international group) | 0.58 | 0.49 | 0 | 1 |
| rd_int | R&D Intensity (percentage of R&D personnel of total employees) | 0.11 | 0.15 | 0.00 | 8.33 |

Table 3: Estimation Results (Coefficients)

| | Importance of cross-licensing | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Specification 1 | | | | Specification 2 | | | |
| Panel 1 (Y>1) | (1) | | (2) | | (3) | | (4) | |
| employees | 0.294** | (3.29) | 0.327* | (1.73) | 0.263** | (3.01) | 0.288+ | (1.55) |
| ipr_dep | 0.476*** | (3.75) | 0.551+ | (1.47) | 0.475*** | (3.86) | 0.534 | (1.42) |
| employeesxipr_dep | | | -0.0125 | (-0.22) | | | -0.00787 | (-0.14) |
| comp_int | -0.304+ | (-1.56) | -0.302+ | (-1.55) | -0.222 | (-1.18) | -0.229 | (-1.22) |
| coop_int | 0.229 | (0.73) | 0.230 | (0.73) | 0.281 | (0.91) | 0.303 | (0.97) |
| group | 0.454 | (1.34) | 0.441 | (1.28) | 0.435 | (1.35) | 0.457 | (1.39) |
| rd_int | 3.168** | (2.58) | 3.165** | (2.58) | 3.148** | (2.77) | 3.130** | (2.74) |
| Chemicals and Pharma | -0.617 | (-1.17) | -0.625 | (-1.18) | | | | |
| Plastics | -0.834 | (-1.16) | -0.831 | (-1.17) | | | | |
| Mechanical Engineering | -0.0633 | (-0.16) | -0.0604 | (-0.15) | | | | |
| Metal Processing | -0.516 | (-0.98) | -0.512 | (-0.98) | | | | |
| Consumer Goods | -0.0834 | (-0.14) | -0.0929 | (-0.15) | | | | |
| Other manufacturing | -1.062 | (-1.11) | -1.064 | (-1.11) | | | | |
| complexity | | | | | 0.583* | (1.86) | 0.607* | (1.92) |
| _cons | -1.946* | (-2.21) | -2.149* | (-1.65) | -2.730** | (-3.17) | -2.914* | (-2.20) |
| Panel 2 (Y>2) | | | | | | | | |
| employees | 0.122 | (1.27) | 0.132 | (0.55) | 0.146+ | (1.60) | 0.283 | (1.35) |
| ipr_dep | 0.368** | (2.97) | 0.393 | (0.87) | 0.378** | (3.16) | 0.656+ | (1.61) |
| employeesxipr_dep | | | -0.00412 | (-0.06) | | | -0.0447 | (-0.72) |
| comp_int | 0.250 | (1.15) | 0.251 | (1.14) | 0.203 | (1.02) | 0.231 | (1.14) |
| coop_int | 0.198 | (0.61) | 0.202 | (0.62) | 0.269 | (0.83) | 0.263 | (0.82) |
| group | 0.564* | (1.66) | 0.566+ | (1.60) | 0.573* | (1.74) | 0.516+ | (1.50) |
| rd_int | 2.182+ | (1.49) | 2.182+ | (1.49) | 2.292* | (1.80) | 2.286* | (1.80) |
| Chemicals and Pharma | -0.293 | (-0.49) | -0.296 | (-0.49) | | | | |
| Plastics | -0.315 | (-0.42) | -0.316 | (-0.43) | | | | |
| Mechanical Engineering | -0.345 | (-0.88) | -0.344 | (-0.87) | | | | |
| Metal Processing | -1.514* | (-2.38) | -1.520* | (-2.29) | | | | |
| Consumer Goods | -0.00552 | (-0.01) | -0.00963 | (-0.02) | | | | |
| Other manufacturing | -0.925 | (-1.05) | -0.927 | (-1.05) | | | | |
| complexity | | | | | 0.663* | (1.99) | 0.643* | (1.92) |
| _cons | -3.836027*** | (-3.51) | | | -4.709*** | (-4.54) | -5.622*** | (-3.39) |
| N | 219 | | 219 | | 219 | | 219 | |
| pseudo R-sq (Aldrich-Nelson with Veal-Zimmermann correction) | 0.207 | | 0.207 | | 0.184 | | 0.186 | |

t statistics in parentheses; + p<0.15 * p<0.1, ** p<0.05, *** p<0.01 (t-statistics based on robust standard errors)

Figure 2: Marginal Effect of IPR dependency on the importance of cross-licensing for firms with average characteristics and changing number of employees

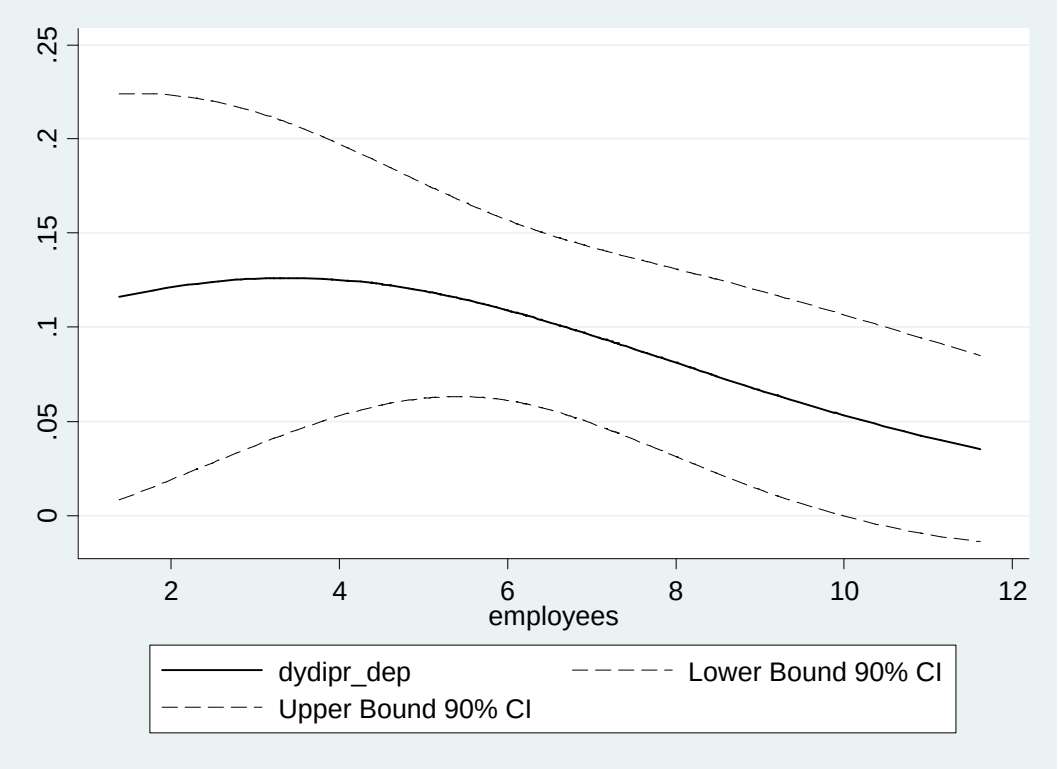

Table 4: Estimation Results (alternative specification/robustness check with size dummies; coefficients)

| | Importance of cross-licensing | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Specification 1 | | | | Specification 2 | | | |
| Panel 1 (Y>1) | (1) | | (2) | | (3) | | (4) | |
| size_class2 | 0.775* | (1.91) | 3.237** | (3.23) | 0.691* | (1.73) | 2.651** | (2.71) |
| size_class3 | 1.004** | (2.70) | 1.291 | (1.22) | 0.979** | (2.63) | 1.120 | (1.09) |
| ipr_dep | 0.507*** | (3.80) | 0.877*** | (3.48) | 0.507*** | (3.98) | 0.803** | (3.26) |
| size_class2xipr_dep | | | -0.939** | (-2.93) | | | -0.771* | (-2.49) |
| size_class3xipr_dep | | | -0.0916 | (-0.27) | | | -0.0465 | (-0.14) |
| comp_int | -0.220 | (-1.13) | -0.275 | (-1.34) | -0.177 | (-0.94) | -0.235 | (-1.21) |
| coop_int | 0.321 | (1.02) | 0.332 | (1.00) | 0.364 | (1.18) | 0.384 | (1.20) |
| group | 0.588* | (1.85) | 0.550+ | (1.58) | 0.555* | (1.81) | 0.589* | (1.81) |
| rd_int | 2.719* | (2.38) | 2.944* | (2.28) | 2.750** | (2.63) | 3.030** | (2.62) |
| Chemicals and Pharma | -0.535 | (-0.96) | -0.501 | (-0.89) | | | | |
| Plastics | -0.704 | (-1.00) | -1.251* | (-1.76) | | | | |
| Mechanical Engineering | -0.0765 | (-0.19) | -0.0284 | (-0.07) | | | | |
| Metal Processing | -0.525 | (-1.02) | -0.619 | (-1.08) | | | | |
| Consumer Goods | -0.132 | (-0.21) | -0.412 | (-0.72) | | | | |
| Other manufacturing | -0.956 | (-1.10) | -1.154+ | (-1.50) | | | | |
| complexity | | | | | 0.599* | (1.91) | 0.701* | (2.12) |
| _cons | -1.238 | (-1.36) | -1.985* | (-1.87) | -2.013* | (-2.30) | -2.681* | (-2.50) |
| Panel 2 (Y>2) | | | | | | | | |
| size_class2 | 0.704+ | (1.56) | 0.240 | (0.17) | 0.801* | (1.86) | 1.438 | (1.24) |
| size_class3 | 0.770* | (1.77) | -0.00441 | (-0.00) | 0.861* | (2.04) | 1.241 | (1.01) |
| ipr_dep | 0.402** | (3.16) | 0.244 | (0.75) | 0.403** | (3.28) | 0.517* | (1.83) |
| size_class2xipr_dep | | | 0.0815 | (0.21) | | | -0.221 | (-0.66) |
| size_class3xipr_dep | | | 0.214 | (0.52) | | | -0.116 | (-0.32) |
| comp_int | 0.259 | (1.20) | 0.204 | (0.87) | 0.245 | (1.21) | 0.246 | (1.15) |
| coop_int | 0.159 | (0.48) | 0.195 | (0.58) | 0.223 | (0.69) | 0.274 | (0.82) |
| group | 0.540* | (1.65) | 0.633* | (1.74) | 0.551* | (1.75) | 0.616* | (1.74) |
| rd_int | 2.082+ | (1.48) | 1.931 | (1.30) | 2.220* | (1.82) | 2.159* | (1.71) |
| Chemicals and Pharma | -0.453 | (-0.76) | -0.467 | (-0.80) | | | | |
| Plastics | -0.364 | (-0.48) | -0.385 | (-0.47) | | | | |
| Mechanical Engineering | -0.355 | (-0.90) | -0.397 | (-0.99) | | | | |
| Metal Processing | -1.445* | (-2.26) | -1.876* | (-2.36) | | | | |
| Consumer Goods | -0.108 | (-0.21) | 0.113 | (0.21) | | | | |
| Other manufacturing | -0.898 | (-1.07) | -0.527 | (-0.60) | | | | |
| complexity | | | | | 0.638* | (1.89) | 0.724* | (2.02) |
| _cons | -3.658*** | (-3.39) | -2.840* | (-1.75) | -4.549*** | (-4.45) | -5.035*** | (-3.56) |
| N | 219 | | 219 | | 219 | | 219 | |
| pseudo R-sq (Aldrich-Nelson with Veal-Zimmermann correction) | 0.193 | | 0.242 | | 0.178 | | 0.213 | |

t statistics in parentheses; + p<0.15 * p<0.1, ** p<0.05, *** p<0.01 (t-statistics based on robust standard errors)