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Another brick in the wall? Technology leaders, patents, and the threat of market entry

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Abstract

Technology leaders protecting a technological headstart with a patent are provided with a powerful legal measure to restrict market entry. We analyze the impact of knowledge spillover on the decision to patent and the effect of varying patent breadth on the threat of market entry. An empirical test of our theoretical results suggests that (i) a large technological lead is protected by a patent only in industries with high knowledge spillover, and that (ii) patent breadth can mitigate the market entry threat.

Keywords: patenting decision, disclosure requirement, patent breadth, market entry threat, IPC codes

JEL Classifications: L13, O33, O34

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1. Introduction

A broad patent can deter market entry of competitors (see Yiannaka and Fulton, 2006). While this benefits the inventor, one backside of patenting is that compulsory information disclosure causes knowledge spillover which benefit competitors. This paper investigates whether a technological leader can build effective market entry barriers through patenting his innovative technology. Empirical surveys identified information disclosure as a major reason for firms to refrain from patenting (see, e.g., Cohen et al., 2000). Thus, one tradeoff an inventor faces is that between seeking patent protection to prevent market entry and the drawback of knowledge disclosure. While entry deterrence is more effective, the broader a patent is, disclosure costs are heterogenous across industries (see Heger and Zaby, 2013).

Suppose a successful inventor can protect a new technology by a patent or secrecy. In a market with vertically differentiated products he can produce a marketable product embodying the new technology earlier than his rival due to a technological headstart. Additionally a patent protects a given quality range from the entry of the rival, at the same time weakening the headstart through compulsory information disclosure. Theory predicts that the inventor will patent his invention whenever his technological headstart is moderate and that he will rather rely on secrecy whenever his technological headstart is high. Our empirical analysis confirms that the propensity to patent increases with the extent of technological leadership in industry sectors with high spillover. Substantial knowledge spillover weaken the effectiveness of secrecy meaning that patenting becomes the preferred protective measure: the backside of patenting is less prominent as spillover occur in either case – patent or secrecy. Concerning the effectiveness of patenting we find that the breadth of patent protection has a detrimental effect on the market entry threat, meaning that broader patents may lead to an increasing propensity to patent.

The data used combines information on innovative activity and on the competitive environment of firms. It is drawn from the German contribution to the

Community Innovation Survey (CIS), the Mannheim Innovation Panel (MIP). To determine the effect of varying patent breadth, the theoretical model implements different degrees of patent breadth. The empirical analysis implements this by using a measure based on the International Patent Classification (IPC) codes following Lerner (1994), and additionally a more traditional measure of patent scope based on forward citations.

Many approaches to the economics of patents view a patent as sufficient deterrent to market entry (see, e.g., Gilbert and Newbery, 1982, Reinganum, 1983), whereas more recent approaches come to the conclusion that firms use patent thickets or fences to secure their monopoly power (see, e.g., Shapiro, 2001, Schneider, 2008). A different strand of literature argues that patents do not create a monopoly, but rather affect product varieties as competitors invent around a patent and are forced to differentiate further, the broader patent scope is (see Klemperer, 1990, Waterson, 1990). We follow this latter view by assuming that a patent does not deter market entry completely: a sufficient variation of the patented product suffices to bypass the patent. Following Denicolo and Zanchettin (2002) we interpret patent breadth as "leading breadth" in a setting of vertically differentiated products. Increasing leading breadth increases the time needed to invent around a patent. Hence, the possible entry of a competitor is postponed further into the future reducing the market entry threat for the innovator. One of the contributions of this paper is that we use a direct measure for this subjective perception of the threat of market entry. Methodologically we introduce an innovative measure of patent breadth refining Lerner's approach based on IPC codes (Lerner, 1994). Our main contributions are (i) the containment of the stylized fact that the greater the technological advance a leading firm accomplishes, the higher is its propensity to patent: contrary to the "little patents and big secrets"-result of Anton and Yao (2004), we find that firms do patent big innovations but only in industries characterized by substantial knowledge spillover, and (ii) patent breadth reduces the threat of market entry.

The rest of the paper is organized as follows.[1] In section 2 we present a brief version of the underlying theoretical model. Section 3.1 then states the model's predictions and presents their empirical implementation. The following section 3.2 describes the data set and sample definition whereas section 3.3 presents variable definitions and descriptive statistics. Section 3.4 presents our empirical results. Section 4 concludes.

2. The theoretical model

The model presented in this section is a sketch of the model presented in Zaby (2009). In a setting of dynamic vertical product differentiation, a successful inventor decides between a patent or secrecy in order to protect his invention, before determining the timing of his market entry. The decisions of the inventor are modeled in a three stage game.

On the first stage, the inventor − denoted by subscript i − chooses how to protect his discovery: either by a patent or secrecy. On the second stage, the inventor and a competitor, firm j, choose whether to market a product of low or high quality given the inventor's protection decision. On the third stage, firms compete in prices. The game is solved by backward induction.

One crucial assumption of the model is the dynamic evolvement of product quality. Following Dutta et al. (1995) and Hoppe and Lehmann-Grube (2001) we assume that investing more time in research activities suffices to improve the quality of the new technology over time. More precisely, the quality of the invention, x, increases by one unit in every period, i.e., the time the inventor needs in order to reach quality x is given by

$$t_i(x) = x. \tag{1}$$

The inventor has a technological headstart of γ over his rival meaning that

[1] The analyses presented here in some parts build on Alexandra Zaby's dissertation, see Zaby (2010).

the non-inventor needs to invest γ periods more than the inventor to reach the same quality level, i.e., his research time is given by $t_j(x) = x + \gamma$.

Whenever the inventor patents, he loses his lead so that $\gamma = 0$.[2] If the inventor chooses secrecy to protect his invention, his intellectual property is not perfectly appropriable. We measure knowledge spillover in the case of secrecy by parameter λ and distinguish the *initial* headstart of the inventor, $\tilde{\gamma}$, from his *effective* headstart, γ, which is defined by $\gamma \equiv \tilde{\gamma}(1-\lambda)$. The non-inventor thus profits from increasing knowledge spillover as his research time

$$t_j(x) = x + \tilde{\gamma} - \lambda\tilde{\gamma} = x + \gamma \tag{2}$$

is shortened by $\lambda\tilde{\gamma}$ for $\lambda > 0$.

2.1. Price competition

Subsequent to the protection decision on the first stage and the quality decisions of the firms on the second stage of the game, firms compete in prices. During the temporary monopoly the first adopter earns monopoly profits π_m per period. The entrance of the late adopter changes the market structure to an asymmetric duopoly where the firm offering the lower quality, i.e., the first adopter, earns π_l per period and the firm offering the higher quality, i.e., the late adopter, realizes profits π_h per period, with $\pi_m > \pi_h > \pi_l$.

The entry date of the early adopter is denoted by t_l and that of the late adopter by t_h. All future profits are discounted with the interest rate $r > 0$.

An early adopter's overall profit consists of two parts: the monopoly profits he realizes from his adoption in t_l until the second firm enters in t_h and the

[2]Note that actually the impact of such a *disclosure effect* is subject to the implemented patent law. While in Europe a statutory research use exemption exists which allows the use of patented knowledge for research purposes, in other countries, such as the U.S. a statutory research use exemption does not exist. In terms of the underlying theoretical model the lack of a research use exemption would mitigate the impact of the *disclosure effect*.

subsequent duopoly profits

$$L(x_l) = \int_{t_l}^{t_h} e^{-rt}\pi_m \, dt + \int_{t_h}^{\infty} e^{-rt}\pi_l \, dt. \tag{3}$$

A late adopter earns duopoly profits π_h per period starting with his entry into the market in t_h with a high quality x_h

$$H(x_h, x_l) = \int_{t_h}^{\infty} e^{-rt}\pi_h dt. \tag{4}$$

2.2. Quality choices

The quality choices of the inventor and his rival depend on the inventor's protection decision on the first stage of the game meaning that the possible cases *secrecy* and *patent* have to be distinguished. To avoid confusion, choice variables will carry the superscript S if the inventor chooses secrecy and the superscript P if he patents his invention.

On the second stage, the late adopter H has to decide when to adopt the new technology after the early adopter L has already adopted the low quality x_l. Optimization of equation (4), with respect to the quality level x_h yields the optimum differentiation strategy given the early adopter's quality decision, x_l,

$$x_h^* = x_l + \frac{1}{r}. \tag{5}$$

In deriving the optimum quality choices two possible scenarios can arise: in scenario (I), the inventor is the early adopter and in scenario (II) the non-inventor is the first adopter. It is shown in Zaby (2009) that the latter scenario never prevails in equilibrium.

In scenario (I) the respective research time functions are $t_i(x_l) = x_l$ and $t_j(x_h^*) = x_l + 1/r + \gamma$. Inserting the latter into equation (4) yields the overall profits of the non-inventor, $H_j(x_l)$. The innovator as early adopter anticipates this optimum differentiation strategy: inserting x_h^* and $t_j(x_h^*)$ into equation (3) yields the overall profit of the inventor as early adopter, $L_i(x_l)$. Optimization of $L_i(x_l)$ with respect to x_l then yields the profit maximizing adoption quality for the inventor, x_l^*.

Given that the non-inventor could reach a marketable quality level before the inventor reaches x_l^*, the non-inventor could preempt the inventor's entry. In the absence of patent protection this market entry threat forces the technology leader to enter before x_l^* is reached. This gives us

Result 1. *If the inventor chooses to keep his invention secret, he adopts first offering the low quality and the non-inventor is the late adopter offering the high quality.*

If the inventor chooses to patent his invention, a given range of quality levels, which we denote as the breadth of the patent ϕ, is protected by the patent. As a consequence the non-inventor can only enter the market with a quality that exceeds the protected range. This positive effect of patenting is opposed by the drawback that the inventor loses his technological lead due to the compulsory disclosure of information leading to $\gamma = 0$. The inventor has an incentive to patent in every situation where he is not able to adopt his profit maximizing quality level, x_l^*, due to the possibility of a preemptive market entry of his rival. A patent mitigates this threat of entry as it protects a given range of product space from entry what allows the inventor to postpone his entry long enough to realize a higher product quality, $x_i^P > x_i^S$.

We distinguish three patent types: *narrow* patents, *broad* patents and *delaying* patents. Patents with breadth $\underline{\phi} \in]x_i^S, x_i^*[$ are defined as *narrow* patents protecting the quality range up to $\underline{\phi}$. Patents with breadth $\phi \in [x_i^*, x_h^*[$ are defined as *broad* patents as they allow the inventor to reach his profit maximizing quality x_i^*. Both patent types modestly mitigate the threat of entry as they still admit the non-inventor to follow his best differentiation strategy, $x_j^* > \phi$. The strongest protectional degree is reached with *delaying* patents. They are defined as patents with breadth $\overline{\phi} \geq x_h^*$ and affect the differentiation strategy of the non-inventor forcing him to postpone adoption into the future.

Given that the inventor patents his invention, three alternative unique Nash equilibria in the subgame *patent* exist, depending on the breadth of protection. They are summarized in

Result 2. *If the inventor chooses to patent his invention the subgame* patent *has three alternative unique and stable Nash Equilibria.*

(i) The perceived threat of entry is weakly mitigated with a narrow patent*: the inventor adopts quality* $\underline{\phi}$ *and the non-inventor quality* x_j^**.*

(ii) The perceived threat of entry is modestly mitigated with a broad patent*: the inventor adopts quality* x_i^* *and the non-inventor quality* x_j^**.*

(iii) The perceived threat of entry is strongly mitigated with a delaying patent*: the inventor adopts quality* x_i^* *and the non-inventor is forced to wait until he reaches the quality* $\overline{\phi} + \epsilon$*.*

Thus, a patent reduces the threat of entry perceived by the inventor because it broadens his possible quality choices. The extent of this effect is subject to the breadth of a patent.

2.3. The patenting decision

On the first stage of the game, the inventor decides whether to patent or to keep his invention secret. The subgame perfect Nash equilibrium of the three stage game can be derived by comparing the inventor's alternative payoffs subject to the chosen protection mechanism: he will choose to patent whenever this yields higher profits than keeping the invention secret. Due to compulsory information disclosure in case of patenting, the inventor faces a tradeoff between a positive and a negative effect of patenting.

The positive effect can be isolated by calculating the difference between the inventor's profit with and without a patent, ignoring the effect of disclosure by keeping $\gamma > 0$. By patenting the inventor is able to choose the higher quality x_i^P, while with secrecy he realizes x_i^S, where $x_i^P > x_i^S$. This defines

$$\Delta^+ = L_i(x_i^P)|_{\gamma>0} - L_i(x_i^S)|_{\gamma>0} \tag{6}$$

as the positive effect of patenting. It is opposed by the negative effect of information disclosure. Technically speaking the technological headstart of the inventor, γ, becomes zero whenever he patents. Consequently, as a rival is now able to enter at an earlier point in time, $t_j^P(x) = x$ instead of $t_j^S(x) = x + \gamma$, the duration of the patent holder's monopoly is narrowed. This negative patent effect can be measured by the difference between the profit of the inventor with and without a technological lead,

$$\Delta^- = L_i(x_i^P)|_{\gamma>0} - L_i(x_i^P)|_{\gamma=0}. \tag{7}$$

Combining both effects yields $\Delta_P = \Delta^+ - \Delta^-$. Inserting equations (6) and (7) this total patent effect can be derived as

$$\Delta_P = L_i(x_i^P)|_{\gamma=0} - L_i(x_i^S)|_{\gamma>0}. \tag{8}$$

Whenever the total patent effect Δ_P is positive, the positive overcompensates the negative effect and the inventor has an incentive to patent.

< Insert figure 1 about here. >

Figure 1 depicts the total patent effect for broad patents. The intersection point of the Δ_P- curve with the x-axis defines a critical value of the technological lead, γ^P. For $\gamma = \gamma^P$ the positive and the negative effect cancel each other out. If the effective technological lead is small, $\gamma < \gamma^P$, the positive effect dominates the negative effect and the inventor is better off with a patent. If the technological lead exceeds the critical value γ^P the negative effect of disclosure outweighs the positive effect so that the overall effect of patenting becomes negative and the inventor prefers secrecy. Summarizing this gives us

Result 3. *The patenting decision of the inventor depends on his technological headstart. He will choose to* *(i) patent if his technological lead is small* $\gamma \leq \gamma^P$,

(ii) keep his invention secret if his technological lead is high, $\gamma > \gamma^P$.

Increasing knowledge spillover λ increase the propensity to patent as the effective technological lead, $\gamma \equiv \tilde{\gamma}(1-\lambda)$, declines in the absence of patent protection. In figure 1 this corresponds to an upward shift of the Δ_P- curve: the negative effect of disclosure is weakened due to high knowledge spillover in case of secrecy. This gives us

Result 4. *The propensity to patent increases whenever knowledge spillover,* λ*, increase.*

3. Empirical investigation

3.1. Predictions

The results of the theoretical model are driven by three parameters: *extent of the technological lead*, γ, *knowledge spillover*, λ, and *strenght of a patent*, ϕ.

The effect of knowledge spillover is linked to the technological lead: following result 3 we suppose that the relation between the technological lead and the propensity to patent is negative and state

Prediction 1. *The higher the technological lead, the lower is an inventor's propensity to patent.*

The theoretical model assumes that increasing knowledge spillover weaken the alternative "secrecy" such that the propensity to patent will be high whenever knowledge spillover, λ, are high (see result 4). This gives us

Prediction 2. *The propensity to patent is high whenever an initial technological lead is reduced by high knowledge spillover.*

To translate these predictions into an estimation equation we come back to the definition of the effective technological lead stated in the theoretical model:

$$\gamma \equiv \tilde{\gamma} - \lambda\tilde{\gamma},$$

which is included in the following estimation equation

$$P = \beta_1 + \beta_2 TL + \beta_3 KS + \beta_4 TL * KS + Controls, \quad (9)$$

where P denotes the patenting decision, TL the (initial) technological lead and KS knowledge spillover. In line with the theoretical findings, we conjecture a negative influence of the technological lead (TL) and a positive effect of the interaction term of TL and KS. As in the theoretical model spillover we expect to find no significant effect of KS empirically.

The final prediction focuses on the impact on the *threat of entry* which is subject to the breadth of a patent. Result 2 describes how a patent can mitigate the threat of market entry. Using this finding we propose our final

Prediction 3. *The threat of entry decreases with the breadth of a patent.*

This translates into the following empirical model

$$TOE = \beta_1 + \beta_2 TL + \beta_3 KS + \beta_4 PB + Controls,$$

where TOE is the threat of entry and PB reflects patent breadth. As predicted by the theoretical model, patent breadth and technological lead should have a negative effect on the perceived intensity of the threat of entry.

3.2. Data set and sample definition

The empirical analysis employs the Mannheim Innovation Panel (MIP) of the year 2005. The MIP is an annual survey which is conducted by the Centre for European Economic Research (ZEW) Mannheim. Regularly – currently every two years – the MIP is the German contribution to the Community Innovation Survey (CIS). In 2005, the survey additionally contained an investigation of firms' perception of their competitive situation. To capture patent scope we merge patent information provided by the European Patent Office (EPO)[3], by condensing the EPO data to the firm level.[4]

In a next step we translate the theoretical assumptions into empirical terms: the setting in which the model and its results are valid is one of innovative firms and vertically differentiated products. In order to test our predictions, we restrict our sample to innovative firms, i.e., we exclude firms which did not launch a new product or process within the period 2002 to 2004.[5] Furthermore, we only include firms with a competitive situation characterized by quality competition.[6] Finally, as patents are the only legal protection measure requiring the disclosure of the technological know-how embodied in an invention, we exclude all other legal protection measures like trademarks from the sample and only include firms which indicate that they either use patenting or secrecy (or both). Our empirical analyses are based on 771 firms.

3.3. Variable definition and descriptive statistics

In the following, we describe the definition of our core variables: the inventor's patenting decision and competitors' threat of entry. Table 2 provides an overview of all variables, their descriptive statistics, and a short description.

To test predictions 1 and 2, we introduce the variable *patenting* which indicates whether a firm uses patents to protect its intellectual property. In our

[3]The merge was conducted by Thorsten Doherr, ZEW, Mannheim, using a computer assisted matching algorithm on the basis of firm names and addresses.

[4]We take all patent applications which have been filed by the sampled firms up to the year 2003. We identified only few firms that stated to hold a patent in the MIP survey but had no equivalent entry in the EPO data. Due to the missing information we dropped these observations.

[5]Alternatively, we could look at firms conducting R&D. This group, however, would comprise a broad range of firms which is not in the focus of our theoretical model. Patenting is only relevant for firms which have successfully completed the R&D process and are about to launch the new product. R&D performing firms could also stand at the beginning of the R&D process having a longer time before needing to decide how to protect their IP.

[6]In the 2005 survey, one question was included which refers to a characterization of the competitive situation on the main product market as perceived by the questioned firm. The firms were asked to rank the following choices according to their importance: quality, price, technological advance, advertisement, product variety, flexibility towards customers. In our sample, we keep all observations where firms indicated that quality is the most, second or third most important feature of their competitive situation.

data set, about 60% of the firms applied for a patent in the relevant period (see table 2).

< *Insert table 2 about here.* >

The central variables of the propensity to patent estimation are technological leadership and knowledge spillover. Both are not straightforward to implement empirically. Following the definition in the theoretical model, we define *technological leadership* by the variable "temporal headstart over competitors". Respondents indicated whether the importance of a temporal headstart was high, medium or low and our dummy variable indicates whether a respondent chose high. Knowledge spillover may arise through different channels such as absorptive capacity of competitors, easiness of reverse engineering, or technological proximity. If firms' competitive environment is characterized by easy-to-substitute products the relevance of the technology is high for competitors in the same industry. *Knowledge spillover* takes unit value if a firm's relevant market is characterized by easy-to-substitute products to capture a high level of spillover. From the theoretical model we know that the technological leadership of a firm may be reduced by knowledge spillover. To implement this fact in our empirical analysis we employ an interaction term (TL * KS).[7]

Furthermore, we control for several factors that may influence innovation activities, like firm size, human capital, R&D intensity, R&D cooperation, public R&D subsidies and diversification, firm location (eastern Germany) and industry affiliation according to NACE codes. We also reflect the structure and the

[7]The empirical translation of the theoretically identified core driving forces of the propensity to patent is not perfect – particularly concerning knowledge spillover which we implemented as the easiness of substitutability. Although a close relation between both concepts exists in some circumstances this relation does not always hold, e.g. it is a valuable strategy for competitors to find adequate substitutes for an innovative product if its imitation is blocked by a patent (see e.g. Polidoro and Toh, 2011's argumentation for the pharma industry). A possible remedy for this limitation would be to use shifts in patent legislation influencing the impact of disclosure requirements.

characteristics of a firm's relevant market by controlling for the number of competitors, the geographical dimension of the relevant market, characteristics of the product life cycle (products become obsolete rapidly) and changes in production technology.

Our second estimation tests prediction 3, i.e., the effect of patent breadth on the threat of entry. We use a firm's perception whether its market position is threatened by the entry of new rivals, which is ranked on a 4-digit Likert scale (*fully applies*, *rather applies*, *hardly applies*, *does not apply*). This ordered variable is our indicator showing to what extent the *effect of patent breadth* relates to the threat of market entry perceived by the inventor: we assume that firms rank the *threat of entry* higher, the sooner a rival may be able to enter the market. Thus, if a firm expects that the time until a rival enters is rather short, it should rank the *threat of entry* higher than when it assumes that a rival's market entry will take place at a later point in time. For our measure of patent breadth we follow Lerner (1994) and refer to the International Patent Classification (IPC) codes. The classification codes relate a patent into specific technology clusters which vary in their aggregational level. As a robustness check for this measure, we use a firm's average number of patent citations per patent application.[8]

Table 1: International Patent Classification (IPC) Code of the European Patent Office

Section	**Class**	**Subclass**	**Group**	
			Main Group	Subgroup
A	01	B	33/0	33/08

Lerner (1994) argues that patent scope can be captured by a variation of the first four digits of the IPC codes assigned to a patent (see also Austin, 1993). He used several alternative approaches to validate this implementation. His

[8]Patent breadth is often measured by (forward) patent citations (e.g. Hall et al., 2005, Harhoff et al., 2003). The caveat of patent citations is that they evaluate patent breadth ex post, making it necessary to use patent data of sufficient age.

argumentation mainly built on a regression of the number of patent citations on the number of variations in the assigned IPC codes; additionally, he conducted interviews with 12 intellectual property attorneys. All validation procedures revealed that patent scope can be appropriately implemented by variations in IPC codes. For the empirical definition of *narrow*, *broad* and *delaying* patents, we need a more detailed differentiation than that proposed in Lerner (1994). In order to capture the different levels of patent scope we distinguish between variations of IPC codes at the class, the subclass or the group level.[9] The IPC Guide gives a quite clear statement on the relation between the IPC code and the scope of the respective patent.

> *The titles of sections, subsections and classes are only broadly indicative of their content and do not define with precision the subject matter falling under the general indication of the title. In general, the section or subsection titles very loosely indicate the broad nature of the scope of the subject matter to be found within the section or subsection, and the class title gives an overall indication of the subject matter covered by its subclasses. By contrast, it is the intention in the Classification that the titles of subclasses [...] define as precisely as possible the scope of the subject matter covered thereby. The titles of main groups and subgroups [...] precisely define the subject matter covered thereby [...]*
>
> (§68, IPC Guide)

In line with the above quote, since *"the class title gives an overall indication of the subject matter covered by its subclasses"* and as variations at the sectional level (including subsections), only *"very loosely indicate the scope"* of the

[9] To examine whether this distinction of variations in the IPC codes is an appropriate measure for patent scope we used the regression-based robustness check implemented by Lerner (1994). We use patent data from 1995 and its citations up to 2005 to escape the problem of recentness. Our Poisson regressions reveal two significant effects: A strongly positive effect of our *delaying* patent indicator and a negative effect for the indicator of *narrow* patents.

respective patent, we define *narrow*, *broad* and *delaying* patents starting with variations at the class level. Whenever a classification symbol differs on the level of classes or subclasses, we characterize the respective patent as *delaying*. We define a patent as *broad* if the IPC codes vary in groups and as *narrow* if the IPC codes differ in subgroups. Additionally, all patents with a single IPC code are classified as *narrow* patents. For every firm we count all delaying, broad and narrow patents and divide them by the number of employees as we assume that larger firms tend to have larger patent portfolios. For further robustness checks, we move the borders of each category.

Again, we control for several factors that may influence our dependent variables. Most of the control variables coincide with those of the propensity to patent–estimation. We further include *capital intensity* as a measure of market entry barriers and an indicator for market novelty.

3.4. Empirical results

Predictions 1 and 2

To test predictions 1 and 2 we estimate a probit model with robust standard errors and display marginal effects evaluated at the sample means with standard errors calculated using the delta method. The estimation includes an interaction term of technological lead and knowledge spillover to test prediction 2. We calculate its marginal effect using the method proposed by Ai and Norton (2003) and present a graphical analysis of its marginal effects as suggested by Hoetker (2007) referring to the continuous nature of the technological lead.

In our theoretical model, patenting and secrecy are mutually exclusive protection strategies. In contrast to this theoretical construct, many survey firms state the use of both, patents and secrecy. There are several explanations for this observation, e.g., firms may conduct several innovation projects which they protect by different means. Alternatively, only parts of an invention may be patented, especially those which may be re-engineered easily, or specific components of the invention are not patentable. In this case both, patents and secrecy, protect the same invention at the same time. Following these arguments patenting and secrecy should not be seen as exclusive protection strategies. To take this into account, we define a new dependent variable and estimate a multinomial logit model using the following measure[10]

$$patent\_secrecy = \begin{cases} 0 & \text{if patent} = 0 \ \& \ \text{secrecy} = 1 \\ 1 & \text{if patent} = 1 \ \& \ \text{secrecy} = 0 \\ 2 & \text{if patent} = 1 \ \& \ \text{secrecy} = 1 \end{cases}$$

with the base outcome 0.[11] As, again, the interplay of technological lead and knowledge spillover and its relation to the propensity to patent is a crucial part of the investigation, we analyze the interplay graphically in figure 3.

The theoretical model assumes that firms only conduct one innovation project. The empirical data, however, only allow us to analyze the firm level. To account for this we include a robustness check estimating the empirical models with a sample including only firms with less than 250 employees. In this reduced sample, firms should only have one (or only few) innovative product(s).[12] The estimation results of the probit and the multinomial logit can be found in table 3 and in figures 2 and 3.

In line with prediction 1, our empirical results display a negative sign of the respective marginal effect, whereas the overall effect of the technological lead

[10]When defining the estimation sample we explicitly excluded firms which stated that they use neither patenting nor secrecy to protect their innovative product. This is the reason why category "patent=0 & secrecy=0" does not exist.

[11]Note that for the probit *"patent"* $= 1$ if *"patent_secrecy"* $= 1,\ 2$

[12]We acknowledge that this robustness check can only be interpreted as an indicator for one-innovation firms. However, we are confident that the test is of relevance, as the emergence of multiple innovation projects should be positively correlated with firm size. Furthermore, we presume that small firms conduct research in technologically related areas meaning that their protection strategies as well as the respective competitive environments are most likely similar. To better reflect a one-innovation firm, information on specific innovation projects and the related protection strategies would be essential. This would allow for a deeper understanding of the role of knowledge spillover for the patenting decision and the effect of patent breadth on the threat of entry. Note that reducing the sample to small firms does not mean that the contemporaneous use of patenting and secrecy decreases. As pointed out earlier the choice of a protection mechanism rather depends on technology than on firm size.

turns out to be insignificant.[13] Taking into account the fact that firms' intellectual property protection strategies possibly involve the combination of both protective measures, the results of the multinomial logit in table 3 allow us to draw a more accurate picture. Regarding the technological lead the multinomial logit reveals that using patenting as the only protection mechanism for innovative products is indeed negatively linked to the technological lead, whereas a positive relation is found for the contemporaneous use of patenting and secrecy. Both results are relative to the base category of choosing only secrecy. This finding is in line with prediction 1 and further supports earlier results suggesting that firms only patent and disclose that part of an invention, which can most easily be re-engineered and thereby try to omit the disclosure of essential know-how in their patents (see Hall and Harhoff, 2012).

< Insert table 3 about here. >

To test prediction 2 we introduce an interaction term of technological lead and knowledge spillover ($TL * KS$) and analyze its relation to the propensity to patent. Our findings support the prediction: for the probit estimation, figure 2 shows graphically that in industries characterized by high knowledge spillover, the relation between technological lead and the propensity to patent is positive. Figure 3 displays the results for the interaction term in the multinomial logit setting. We see that the alternative of protecting intellectual property only by patents relative to the alternative of only choosing secrecy exhibits no difference between firms in industries characterized by high or low knowledge spillover. Thus, the effect of the interaction term is dominated by the negative

[13] A first tentative explanation for this finding could be that the theoretical model disregards several mandatory patentability requirements, e.g. a sufficiently high inventive step. Thus, while the model predicts that the propensity to patent is high whenever the technological lead is small, it actually may be the case that the technological headstart leading to a patent in theoretical terms, is de facto not eligible for patent protection empirically as it does not incorporate a sufficient inventive step.

link between technological lead and the propensity to use only patents. The multinomial logit accounts for a strategy mix, i.e., the contemporaneous use of patenting and secrecy to protect newly generated knowledge. From figure 3 we can deduce that high knowledge spillover and an increasing technological lead positively influence the joint use of patenting and secrecy. Finally, as predicted by the theoretical model, appropriability itself displays no statistically significant relation with the propensity to patent in all variants of the empirical test.

< *Insert figure 2 about here.* >

< *Insert figure 3 about here.* >

As a robustness check, we look at the reduced sample of firms with a maximum of 250 employees. We can confirm that our results also hold for this reduced sample. Assuming that these firms rather meet the theoretical assumption of one-product firms we are able to interpret our results as follows: in line with prediction 1 and 2, firms display a higher propensity to patent in situations in which their technological lead is low. A high technological lead may be associated with an increasing attractiveness of secrecy or a mixture of patenting and secrecy. Particularly, in environments in which the technological lead may be largely reduced by knowledge spillover, firms may opt for a mixture of patenting and secrecy as the relation between the propensity to use patenting and secrecy and the interaction term is significantly positive compared to the propensity to only use secrecy.

Turning to the control variables our results are in line with stylized facts: the patenting behavior of firms as well as the joint use of patenting and secrecy is positively linked to the size of a firm, to its R&D intensity, to R&D subsidies as well as to the engagement of a firm in R&D cooperations. Interestingly, the control variables reflecting the strength of competition with respect to competitors, customers and regional dimensions are mainly insignificant. One exception is a significantly positive relation with *non_EU*. A possible explanation for this result is that firms which are inter alia active in non-EU markets tend to rate protection in their home-market as more important than firms operating solely in the German home-market. This effect may prevail due to the fact that those firms fear the entry of foreign firms with substitute products. Further, we find that R&D cooperation has a significantly positive link to the propensity to patent, whereas being located in Eastern Germany has a negative effect. Generally, empirical evidence based on firm-level surveys finds that the propensity to patent varies by industry sectors. Our industry dummies are jointly significant hinting at such structural differences between industry sectors.

Prediction 3

We test the effect of *patent breadth* on the threat of entry by estimating an ordered probit with robust standard errors for the threat of entry. As before, marginal effects of the estimation are evaluated at the samples means and the respective standard errors are obtained using the delta method. Patent breadth is implemented as described in Section 3.3. As market structure and characteristics are endogenous, we first estimate a *basic model* ignoring the specificities of the relevant market and then stepwise include the *technology* dimension of the relevant market and the *competitive* side. Furthermore, we conduct robustness checks (i) estimating the model with a reduced sample of firms with not more than 250 employees, (ii) altering the definition of patent breadth, and (iii) using alternative measures for patent breadth. The results including all robustness checks are displayed in tables 4 and 5.

Table 4 shows the results of the ordered probit for the estimation of the threat of entry on patent breadth. The findings are robust to variations $(i)-(iii)$ and confirm that broader patents (reflected by the number of delaying patents per 100 employees) are negatively related to the threat of entry. This finding supports prediction 3.

$<$ *Insert table 4 about here.* $>$

For robustness check (*ii*) (see table 5), we first moved the somewhat arbitrary separation of delaying and broad patents to the left so that delaying patents are defined as patents with varying IPC codes at the level of Sections and Classes. Broad patents are then defined by variations in Subclasses and Main Groups. Second, using this new border between delaying and broad patents we varied the border between broad and narrow patents between Subclasses and Main Groups. All variations in the definition of delaying, broad and narrow patents do not alter the previous results. The final robustness check (*iii*) using the number of forward citations per patent application as a measure for patent scope and additionally accounting for the number of patent applications per 100 employees shows that even using alternative measures of patent scope does not change our results as we find a negative link between citations and the threat of entry. Summarizing we conclude that empirical evidence supports prediction 3, i.e., broader patents lead to a delayed market entry of competitors.

$<$ *Insert table 5 about here.* $>$

In contrast to the theoretical conjecture, we find no significant link of the threat of entry with technological lead. Nevertheless, a positive relation with knowledge spillover is apparent. This is relatively intuitive as competitors benefit from the spillover. A positive relation can also be confirmed for quickly changing technologies and the number of firms in a market.

4. Conclusion

This paper provides theoretical and empirical evidence regarding the interplay of technological leadership, patent breadth and the threat of market entry. We analyze a technology leader's decision to patent in the context of his competitive environment. Given varying breadth of patent protection, we find that broader patents mitigate the perceived threat of market entry. The first part of the paper sketches a theoretical model (Zaby, 2009) from which we draw our predictions which are tested in the second part.

We condense the theoretical results into three predictions reflecting the effects of patenting. Predictions 1 and 2 refer to the effects of compulsory information disclosure: the fear of losing a large technological lead by patenting reduces the propensity to patent, while in industries with high knowledge spillover large technological advances are patented. Prediction 3 states that increasing patent breadth decreases the threat of market entry.

Predictions 1 and 2 are tested using a probit model of the decision patent vs secrecy. As empirical evidence suggests that patenting and secrecy are not mutually exclusive we extend the analysis to a multinomial logit accounting for three different protection strategies: the sole use of secrecy (patents) or the joint use of patenting and secrecy. The multinomial logit provides an explanation why the probit estimation does not support prediction 1: while the technological lead is negatively related to the propensity to use only patenting, the joint use of patenting and secrecy turns out to be positively related to the technological lead. Both results support prediction 1. Both estimations – the probit and the multinomial logit – also provide evidence supporting prediction 2. The probit result – that a technological lead is positively related to the propensity to patent – is confirmed by the multinomial logit for the mixed protection strategy. If firms opt for patents as exclusive protective measure the link is reversed. The multinomial logit results thus allow us to draw a more detailed picture of how technology leaders protect their technological advancements.

Because the threat of entry is measured on a four-digit Likert scale, we use an ordered probit estimation to analyze prediction 3. We interpret a lower threat of entry as an indicator that potential competitors postpone their market entry. To implement the differences in patent breadth we extend the approach of Lerner (1994) using variations in IPC codes. To test the robustness of our new measure we vary the definition of patent breadth. An alternative measure based on forward citations which confirm prediction 3.

Aside from the advancement of Lerner's measure for patent scope one contribution is the containment of a stylized fact: the common economic intuition that the propensity to patent is higher, the larger the technological advance an innovation embodies, actually only holds in industry sectors with high knowledge spillover. Thus we have "big patents and little secrets" with high, but "little patents and big secrets" with low knowledge spillover. Further, we show that patent breadth indeed mitigates the threat of market entry.

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Figures

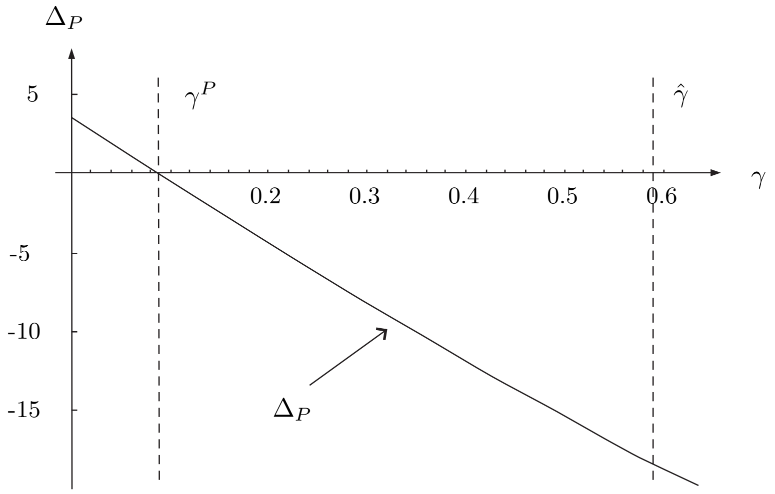

Figure 1: Total patent effect for $\phi = x_l^{i*}$

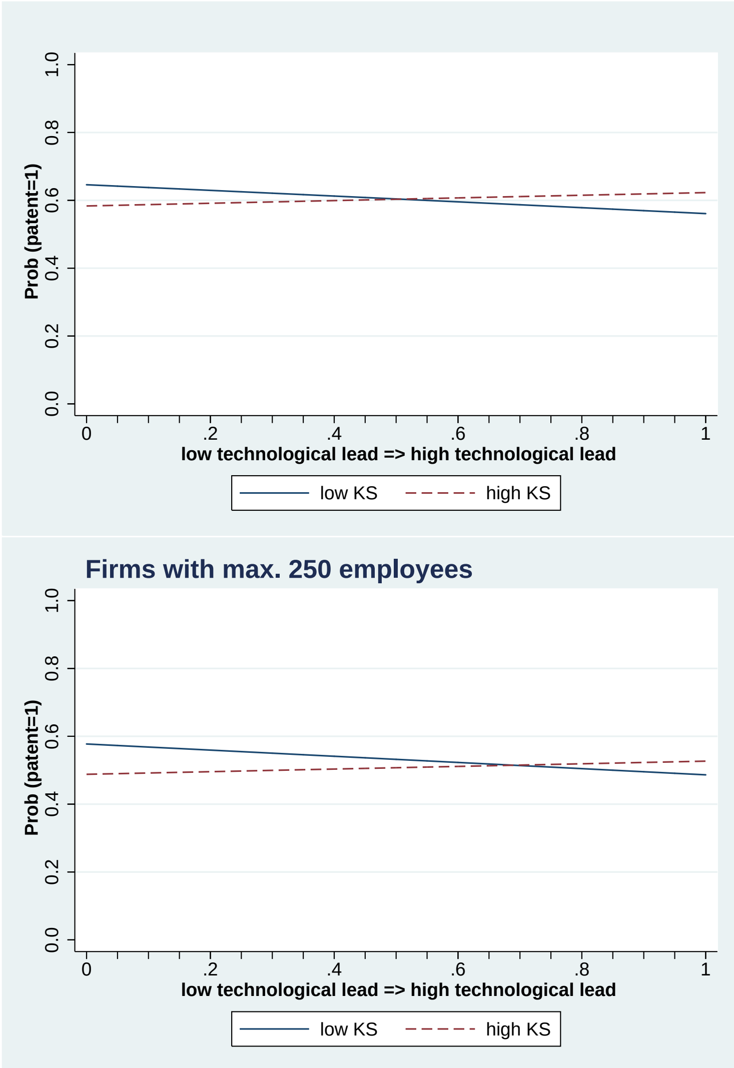

Figure 2: Relation of the propensity to patent with varying technological lead for different levels of knowledge spillover – probit estimation

Source: MIP 2005, authors' calculations.

Note: Average predictions for probit estimation. We look at two different levels of KS: 0 and 1.

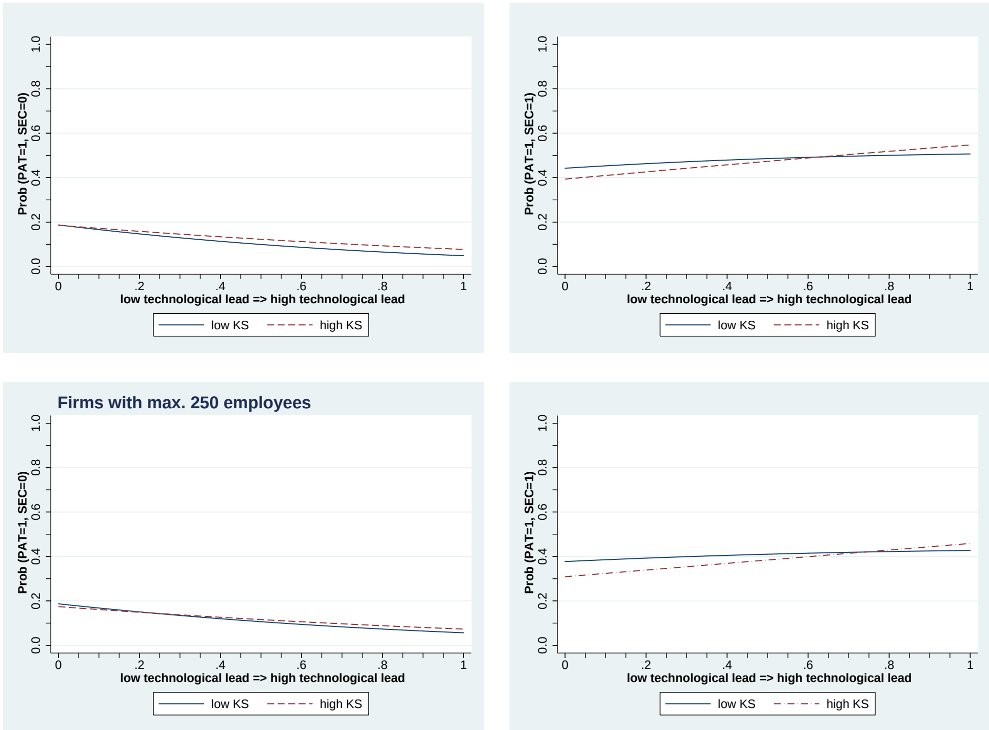

Figure 3: Relation of the patenting and secrecy with varying technological lead for different levels of knowledge spillover – multinomial logit estiamtion

Source: MIP 2005, authors' calculations.

Note: Average predictions for multinomial logit. We look at two different levels of KS: 0 and 1.

Tables

Table 2: Descriptive Statistics

	Mean	**Std.Dev.**	**Min**	**Max**	**Description**
patent	0.599	0.490	0	1	Patent application between 2002 and 2004
secrecy	0.885	0.320	0	1	Trade secrecy to protect innovation between 2002 and 2004
technological lead	0.594	0.491	0	1	Temporal headstart over competitors highly important
knowledge spillover	0.682	0.466	0	1	easy-to-substitute products in main market fully or rather applies
log(employees)	4.577	1.696	0.693	9.152	Number of employees in 2002
human capital	0.263	0.264	0.000	1.000	Share of employees holding a university degree in 2002
R&D intensity	0.062	0.116	0.00	0.792	Expenditures for in-house R&D per sales in 2003
cooperation	0.455	0.498	0	1	Research cooperation with competitors, customers, universities
diversification	0.657	0.244	0	1	sales share generatedby three most important customers
subsidy	0.418	0.493	0	1	Public subsidies
large no. of firms	0.134	0.340	0	1	More than 15 competitors in main market
medium no. of firms	0.204	0.403	0	1	Between 6 and 15 competitors in main market
product old	0.091	0.287	0	1	competitive environment: products rapidly obsolete (fully applies)
tech. obsolete	0.466	0.499	0	1	competitive environment: technologies change quickly (fully and rather applies)
EU	0.676	0.468	0	1	Main product market: EU without Germany
non_EU	0.489	0.500	0	1	main product market: outside EU
east	0.284	0.451	0	1	Firm located in eastern Germany
threat of entry	1.455	0.767	0	3	Market position threatened by entry (3=applies)
capital intensity	0.089	0.144	0.000	1.575	Tangible assets per employee in 2002
market novelty	0.615	0.487	0	1	Market novelty introduced XXX
delaying	0.171	0.572	0.000	4.505	No. of patents with delaying scope (per 100 employees)
broad	0.028	0.121	0.000	1.066	No. of patents with large scope (per 100 employees)
narrow	0.062	0.237	0.000	2.041	No. of patents with small scope (per 100 employees)
citations	0.312	0.634	0.000	3.333	No. of citations per patent
patent stock	0.564	1.600	0.000	13.993	Patent stock per 100 employees
PAT = 1, SEC = 0		11.5%			
PAT = 1, SEC = 1		48.4%			
PAT = 0, SEC = 1		40.1%			
PAT = 0, SEC = 0		00.0%			
No. of observations		771			

Notes: The 11 industries we control for are *ind*1: Agriculture, Food, Textile; *ind*2: Mining, Coke, Fuel, Electricity; *ind*3: Wood, Paper, Publishing, Printing, Furniture, Recycling; *ind*4: Chemicals, Plastics, Glass; *ind*5: Metals; *ind*6: Machinery, Motor Vehicle without Aerospace; *ind*7: Office Machinery; *ind*8: Precision Instruments, Aerospace; *ind*9: Telecommunication and Computer Services; *ind*10: R&D services; and *ind*11: Consumer-related Services like hotels, gastronomy.

Table 3: Results of the Patenting Decision Estimation

	all firms			firms with ≤ 250		
	Probit	**Multinomial Logit**		**Probit**	**Multinomial Logit**	
		PAT=1,SEC=0	**PAT=1,SEC=1**		**PAT=1,SEC=0**	**PAT=1,SEC=1**
	Marg. Eff. (Std. Err)	**Marg. Eff.** (Std. Err.)	**Marg. Eff.** (Std. Err.)	**Marg. Eff.** (Std. Err)	**Marg. Eff.** (Std. Err.)	**Marg. Eff.** (Std. Err.)
technological lead	-0.071	-.060***	0.122***	-0.011	-0.033***	0.098*
	(0.060)	(0.015)	(0.046)	(0.050)	(0.011)	(0.052)
knowledge spillover	-0.053	0.012	-0.010	-0.018	0.003	-0.018
	(0.061)	(0.012)	(0.051)	(0.051)	(0.009)	(0.056)
*TL * KS*	0.124*			0.130		
	(0.070)			(0.085)		
log(employees)	0.061***	-0.002	0.104***	0.072***	0.001	0.080***
	(0.011)	(0.004)	(0.017)	(0.024)	(0.003)	(0.026)
human capital	0.095	-0.051	0.239*	-0.017	-0.027	0.033
	(0.085)	(0.033)	(0.134)	(0.125)	(0.023)	(0.139)
R&D intensity	0.667***	0.169***	0.993***	1.029***	0.120***	0.986***
	(0.156)	(0.049)	(0.337)	(0.291)	(0.032)	(0.333)
cooperation	0.077*	-0.014	0.130**	0.087	-0.008	0.123**
	(0.040)	(0.013)	(0.052)	(0.059)	(0.010)	(0.062)
diversification	-0.134**	-0.021	-0.139	-0.209**	-0.023	-0.164
	(0.065)	(0.020)	(0.093)	(0.103)	(0.014)	(0.113)
subsidy	0.074*	-0.000	0.113**	0.107*	0.000	0.116*
	(0.040)	(0.013)	(0.056)	(0.061)	(0.010)	(0.064)
large no. of firms	-0.067	-0.024	0.031	-0.097	-0.010	-0.058
	(0.048)	(0.018)	(0.074)	(0.076)	(0.012)	(0.086)
medium no. of firms	-0.011	0.004	-0.017	-0.008	0.003	-0.015
	(0.042)	(0.013)	(0.061)	(0.063)	(0.009)	(0.071)
product old	0.012	-0.045	0.056	0.001	-0.039	0.066
	(0.056)	(0.032)	(0.081)	(0.084)	(0.024)	(0.088)
tech. obsolete	-0.049	-0.014	-0.042	-0.101**	-0.011	-0.082
	(0.032)	(0.011)	(0.047)	(0.049)	(0.008)	(0.055)
EU	0.026	0.012	0.003	-0.023	0.001	-0.035
	(0.043)	(0.014)	(0.058)	(0.059)	(0.009)	(0.064)
non_EU	0.104***	0.003	0.132***	0.152***	0.007	0.149**
	(0.038)	(0.011)	(0.050)	(0.055)	(0.008)	(0.060)
east	-0.093**	0.007	-0.149**	-0.064	-0.003	-0.060
	(0.039)	(0.012)	(0.058)	(0.054)	(0.008)	(0.060)
industry dummies	*included*	*included*		*included*	*included*	
Log likelihood	-394.35	-573.20		-305.45	-418.56	
McFadden's adjusted R^2	0.240	0.231		0.176	0.189	
$\chi^2(all)$	194.97***	2909.62***		113.11***	3061.68***	
$\chi^2(ind)$	31.26***	1066.02***		13.69	2015.12***	
No. of observations	771	771		535	535	

*** (**, *) indicate significance of 1 % (5 %, 10 %) respectively.
Notes: This table depicts the marginal effects of the probit estimations regarding the determinants of the patenting decision and of the multinomial logit model. Marginal effects are calculated at the sample means. The marginal effect of the probit's interaction term is obtained according to Ai and Norton (2003) and analyzes graphically (see Figures 2 and 3). Standard errors are calculated with the delta method.
The definition of the industry dummies can be found in the notes of Table 2.
$\chi^2(all)$ displays a test on the joint significance of all variables.
$\chi^2(ind)$ displays a test on the joint significance of the industry dummies.

Table 4: Ordered Probit for Threat of Entry Estimation

	Basic Model				**Technology**				**Competition**				**Firms with ≤ 250**			
threat	**strong**	**medium**	**weak**	**no**	**strong**	**medium**	**weak**	**no**	**strong**	**medium**	**weak**	**no**	**strong**	**medium**	**weak**	**no**
delaying	-0.034**	-0.047**	0.051**	0.030**	-0.035**	-0.048**	0.052**	0.031**	-0.029**	-0.040**	0.043**	0.026**	-0.033**	-0.049**	0.056**	0.026**
	(0.015)	(0.020)	(0.023)	(0.012)	(0.015)	(0.020)	(0.022)	(0.010)	(0.014)	(0.019)	(0.021)	(0.012)	(0.016)	(0.022)	(0.026)	(0.011)
broad	0.022	0.030	-0.032	-0.019	0.039	0.054	-0.059	-0.035	0.049	0.068	-0.074	-0.044	0.053	0.078	-0.090	-0.041
	(0.061)	(0.085)	(0.092)	(0.054)	(0.058)	(0.087)	(0.086)	(0.052)	(0.053)	(0.075)	(0.080)	(0.048)	(0.087)	(0.131)	(0.149)	(0.069)
narrow	0.020	0.028	-0.031	-0.018	0.003	0.036	-0.003	-0.002	-0.001	-0.002	0.002	0.001	-0.003	-0.004	0.005	0.002
	(0.048)	(0.066)	(0.072)	(0.042)	(0.047)	(0.065)	(0.070)	(0.041)	(0.044)	(0.061)	(0.066)	(0.039)	(0.069)	(0.102)	(0.118)	(0.054)
tech. lead	0.007	0.010	-0.011	-0.007	0.006	0.007	-0.007	-0.004	0.006	0.009	-0.009	-0.006	0.004	0.006	-0.007	-0.003
	(0.016)	(0.023)	(0.025)	(0.015)	(0.016)	(0.023)	(0.025)	(0.014)	(0.016)	(0.022)	(0.024)	(0.014)	(0.019)	(0.028)	(0.032)	(0.015)
spillover	0.053***	0.073***	-0.079***	-0.046***	0.059***	0.082***	-0.089***	-0.056***	0.078***	0.078***	-0.084***	-0.050***	0.052**	0.077***	-0.088***	-0.040**
	(0.018)	(0.022)	(0.025)	(0.015)	(0.018)	(0.023)	(0.025)	(0.016)	(0.018)	(0.022)	(0.025)	(0.016)	(0.020)	(0.027)	(0.032)	(0.016)
log(emp.)	0.004	0.006	-0.006	-0.004	0.007	0.005	-0.007	-0.004	0.003	0.004	-0.004	-0.002	0.011	0.017	-0.019	-0.009
	(0.006)	(0.008)	(0.009)	(0.005)	(0.006)	(0.008)	(0.009)	(0.005)	(0.006)	(0.008)	(0.008)	(0.005)	(0.009)	(0.013)	(0.015)	(0.007)
cap. intensity	-0.050	-0.069	0.075	0.044	-0.033	-0.045	0.049	0.029	-0.029	-0.040	0.043	0.025	-0.045	-0.067	0.077	0.035
	(0.055)	(0.077)	(0.083)	(0.048)	(0.055)	(0.076)	(0.083)	(0.048)	(0.053)	(0.075)	(0.081)	(0.048)	(0.096)	(0.141)	(0.163)	(0.074)
cooperation	-0.020	-0.028	0.030	0.018	-0.019	-0.027	0.029	0.017	-0.011	-0.016	0.017	0.010	-0.027	-0.040	0.047	0.021
	(0.016)	(0.022)	(0.024)	(0.014)	(0.016)	(0.021)	(0.023)	(0.014)	(0.015)	(0.021)	(0.023)	(0.014)	(0.019)	(0.027)	(0.032)	(0.015)
market novelty	-0.024	-0.036	0.040	0.023	-0.021	-0.030	0.030	0.021	-0.022	-0.030	0.033	0.019	-0.001	-0.001	0.001	0.000
	(0.017)	(0.023)	(0.025)	(0.015)	(0.017)	(0.024)	(0.023)	(0.015)	(0.017)	(0.024)	(0.025)	(0.015)	(0.020)	(0.030)	(0.035)	(0.016)
diversification	0.023	0.032	-0.034	-0.020	0.025	0.033	-0.037	-0.022	0.025	0.034	-0.037	-0.022	0.028	0.042	-0.048	-0.022
	(0.033)	(0.045)	(0.049)	(0.028)	(0.033)	(0.024)	(0.049)	(0.028)	(0.032)	(0.044)	(0.048)	(0.028)	(0.037)	(0.053)	(0.061)	(0.028)
large # of firms									0.052**	0.072**	-0.078**	-0.046**	0.045	0.067	-0.077	-0.035
									(0.025)	(0.033)	(0.037)	(0.022)	(0.030)	(0.043)	(0.051)	(0.023)
med. # of firms									0.066***	0.092***	-0.099***	-0.059***	0.058**	0.086***	-0.099***	-0.045**
									(0.020)	(0.026)	(0.029)	(0.018)	(0.023)	(0.032)	(0.037)	(0.018)
product old					0.036	0.050	-0.055	-0.032	0.039	0.055	-0.059	-0.035	0.022	0.032	-0.037	-0.017
					(0.024)	(0.034)	(0.036)	(0.022)	(0.024)	(0.034)	(0.036)	(0.022)	(0.025)	(0.038)	(0.043)	(0.020)
tech. obsolete					0.056***	0.078***	-0.085***	-0.049***	0.056***	0.078***	-0.085***	-0.050***	0.052**	0.077***	-0.088***	-0.040**
					(0.017)	(0.022)	(0.024)	(0.015)	(0.017)	(0.022)	(0.024)	(0.015)	(0.020)	(0.028)	(0.032)	(0.017)
EU									-0.008	-0.11	0.012	0.007	-0.011	-0.016	0.019	0.009
									(0.021)	(0.028)	(0.031)	(0.018)	(0.023)	(0.033)	(0.038)	(0.017)
non_EU									-0.006	-0.009	0.010	0.006	0.003	0.004	-0.004	-0.002
									(0.018)	(0.025)	(0.027)	(0.016)	(0.021)	(0.030)	(0.035)	(0.016)
east	0.021	0.028	-0.031	-0.018	0.017	0.023	-0.025	-0.015	0.010	0.014	-0.015	-0.009	0.014	0.021	-0.024	-0.011
	(0.017)	(0.024)	(0.025)	(0.015)	(0.017)	(0.024)	(0.026)	(0.015)	(0.017)	(0.024)	(0.025)	(0.015)	(0.018)	(0.027)	(0.030)	(0.014)
industries	included				included				included				included			
Log likelihood	-571.82				-563.72				-556.33				-369.05			
Adj. R^2	0.032				0.045				0.058				0.054			
$\chi^2(all)$	40.16***				60.99***				80.99***				48.48***			
$\chi^2(ind)$	13.78				14.73				17.16*				10.43			
No. of obs.	527				527				527				360			

*** (**, *) indicate significance of 1 % (5 %, 10 %) respectively.
This table depicts marginal effects for an ordered probit for the estimation of threat of entry. Marginal effects are calculated at the sample means and standard errors are calculated with the delta method. The effect of the interaction term is included in the overall effects of its components $technologicallead$ and $knowledgespillover$.
Adj. R^2 is equivalent to McFadden's adj. R^2.
$\chi^2(all)$ displays a test on the joint significance of all variables.
$\chi^2(ind)$ displays a test on the joint significance of the industry dummies.

Table 5: Ordered Probit for Threat of Entry Estimation – Robustness Checks

	new delaying def.				**new broad def.**				**Citations**			
threat	**strong**	**medium**	**weak**	**no**	**strong**	**medium**	**weak**	**no**	**strong**	**medium**	**weak**	**no**
delaying	-0.029**	-0.040**	0.043**	0.025**	-0.030**	-0.041**	0.045**	0.026**				
	(0.014)	(0.019)	(0.021)	(0.012)	(0.014)	(0.019)	(0.021)	(0.012)				
broad	0.025	0.035	-0.037	-0.022	-0.018	-0.024	0.026	0.016				
	(0.044)	(0.062)	(0.066)	(0.040)	(0.087)	(0.120)	(0.130)	(0.077)				
narrow	-0.004	-0.006	0.007	0.004	0.016	0.023	-0.024	-0.014				
	(0.046)	(0.063)	(0.068)	(0.041)	(0.029)	(0.041)	(0.044)	(0.026)				
citations									-0.025*	-0.034*	0.037*	0.022*
									(0.014)	(0.018)	(0.020)	(0.012)
patent stock									0.160	0.215	-0.233	-0.142
									(0.429)	(0.577)	(0.623)	(0.383)
technological lead	0.006	0.009	-0.010	-0.006	0.007	0.009	-0.010	-0.006	0.007	0.013	-0.010	-0.010
	(0.016)	(0.022)	(0.024)	(0.014)	(0.016)	(0.022)	(0.024)	(0.014)	(0.016)	(0.022)	(0.023)	(0.016)
knowledge spillover	0.056***	0.078***	-0.084***	-0.050***	0.056***	0.077***	-0.084***	-0.050***	0.055***	0.086***	-0.082***	-0.059***
	(0.018)	(0.023)	(0.025)	(0.016)	(0.018)	(0.023)	(0.025)	(0.016)	(0.015)	(0.024)	(0.021)	(0.018)
log(employees)	0.003	0.004	-0.004	-0.002	0.003	0.004	-0.004	-0.002	0.005	0.007	-0.007	-0.004
	(0.006)	(0.008)	(0.008)	(0.005)	(0.006)	(0.008)	(0.008)	(0.005)	(0.006)	(0.008)	(0.008)	(0.005)
capital intensity	-0.028	-0.039	0.042	0.025	-0.029	-0.041	0.044	0.026	-0.028	-0.038	0.041	0.025
	(0.053)	(0.075)	(0.080)	(0.048)	(0.053)	(0.075)	(0.081)	(0.048)	(0.054)	(0.073)	(0.078)	(0.048)
cooperation	-0.012	-0.017	0.018	0.011	-0.009	-0.017	0.018	0.011	-0.014	-0.019	0.020	0.012
	(0.015)	(0.021)	(0.023)	(0.014)	(0.015)	(0.021)	(0.023)	(0.014)	(0.016)	(0.021)	(0.022)	(0.014)
market novelty	-0.022	-0.030	0.033	0.019	-0.012	-0.031	0.033	0.020	-0.017	-0.022	0.024	0.015
	(0.017)	(0.024)	(0.025)	(0.015)	(0.015)	(0.024)	(0.025)	(0.015)	(0.017)	(0.023)	(0.025)	(0.015)
diversification	0.024	0.034	-0.037	-0.022	0.025	0.035	-0.037	-0.022	0.021	0.028	-0.030	-0.018
	(0.032)	(0.044)	(0.048)	(0.028)	(0.032)	(0.044)	(0.048)	(0.028)	(0.032)	(0.043)	(0.046)	(0.028)
large no. of firms	0.052**	0.072**	-0.078**	-0.046**	0.051**	0.072**	-0.077**	-0.046**	0.048*	0.064**	-0.070**	-0.043*
	(0.025)	(0.033)	(0.037)	(0.022)	(0.025)	(0.033)	(0.037)	(0.022)	(0.025)	(0.032)	(0.036)	(0.022)
medium no. of firms	0.066***	0.092***	-0.099***	-0.059***	0.066***	0.092***	-0.099***	-0.059***	0.055***	0.075***	-0.081***	-0.049***
	(0.020)	(0.026)	(0.029)	(0.018)	(0.020)	(0.026)	(0.029)	(0.018)	(0.020)	(0.026)	(0.028)	(0.018)
product old	0.040*	0.055	-0.060*	-0.035	0.040*	0.056	-0.060*	-0.036	0.037	0.050	-0.054	-0.033
	(0.024)	(0.034)	(0.036)	(0.022)	(0.024)	(0.034)	(0.036)	(0.022)	(0.023)	(0.031)	(0.033)	(0.021)
tech. obsolete	0.056***	0.078***	-0.085***	-0.050***	0.056***	0.077***	-0.084***	-0.050***	0.057***	0.077***	-0.083***	-0.051***
	(0.017)	(0.022)	(0.024)	(0.016)	(0.017)	(0.022)	(0.024)	(0.015)	(0.017)	(0.022)	(0.023)	(0.016)
EU	-0.008	-0.011	0.011	0.007	-0.007	-0.011	0.012	0.007	-0.008	-0.010	0.011	0.007
	(0.021)	(0.028)	(0.031)	(0.018)	(0.021)	(0.028)	(0.031)	(0.018)	(0.021)	(0.028)	(0.030)	(0.019)
non_EU	-0.007	-0.009	0.010	0.006	-0.008	-0.009	0.009	0.006	-0.015	-0.020	0.022	0.013
	(0.018)	(0.025)	(0.027)	(0.016)	(0.021)	(0.025)	(0.027)	(0.016)	(0.018)	(0.024)	(0.026)	(0.016)
east	0.011	0.015	-0.016	-0.009	0.010	0.013	-0.014	-0.009	0.006	0.008	-0.009	-0.005
	(0.017)	(0.024)	(0.026)	(0.015)	(0.017)	(0.024)	(0.025)	(0.015)	(0.017)	(0.023)	(0.025)	(0.016)
industry dummies		included				included				included		
Log likelihood		-556.42				-556.42				-572.28		
McFadden's adjusted R^2		0.058				0.058				0.055		
$\chi^2(all)$		79.10***				80.42***				73.15***		
$\chi^2(ind)$		17.03*				17.09*						
No. of observations		527				527				539		

*** (**, *) indicate significance of 1 % (5 %, 10 %) respectively.
This table depicts marginal effects for an ordered probit for the estimation of threat of entry. Marginal effects are calculated at the sample means and standard errors are calculated with the delta method. The effect of the interaction term is included in the overall effects of its components $technologicallead$ and $knowledgespillover$.
$\chi^2(all)$ displays a test on the joint significance of all variables.
$\chi^2(ind)$ displays a test on the joint significance of the industry dummies.