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Diana Heger
Alexandra K. Zaby

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Diana Heger* and Alexandra K. Zaby†

Abstract
This paper empirically investigates a firm's propensity to patent. It thereby builds on a theoretical model on a firms' patenting decision in a market with vertically differentiated products. We deduce and empirically test several hypotheses from the theoretical results regarding patenting and rival's market entry decision presented in *Zaby* (2009). Our main finding is that in industries which are characterized by easy-to-use knowledge spillover, the technological lead of the inventor is reduced to such an extent that the propensity to patent increases. Furthermore, the intensity of patent protection has a delaying impact on rival's market entry.

Keywords: patenting decision, secrecy, disclosure requirement, patent height, vertical product differentiation
JEL Classifications: L13, O14, O33, O34

*Centre for European Economic Research, L7, 1, D-68165 Mannheim. E-mail: heger@zew.de

†Universität Tübingen, Wirtschaftswissenschaftliche Fakultät, Mohlstraße 36, D-72074 Tübingen. E-mail: alexandra.zaby@uni-tuebingen.de

1 Introduction

The fact that not every innovation is patented has long since been discussed in economic literature (see e.g. *Horstmann et al.* (1985)). Empirical evidence points in the same direction: With data from the 1993 European Community Innovation Survey (CIS), *Arundel* (2001) explicitly analyzes the relative importance of secrecy versus patents and finds that a higher percentage of firms in all size classes rate secrecy as more valuable than patents. In their seminal empirical study *Cohen et al.* (2000) find that a major reason for the firm's decision *not* to patent is the disclosure requirement that is linked to a patent. Thus it is the loss of a technological leadership caused by the required disclosure of proprietary knowledge which drives the propensity not to patent: The patentee has to fear that the transfer of enabling knowledge included in the patent application may benefit his rivals instantaneously by facilitating a rapid catch-up.

This paper empirically investigates the disclosure requirement's significance for the propensity to patent and the competitor's market entry behaviour subsequent to the innovator's patenting decision. It thereby builds on the theoretical model presented in *Zaby* (2009). In line with patent law, *Zaby* assumes that a patent requires the immediate and full disclosure of all technical details concerning a patented discovery.[1] This transfer of enabling knowledge benefits a non-inventor instantaneously so that due to the *disclosure effect* the profits of the innovator will decrease. This negative effect of patenting is opposed by a positive *protective effect*. Overall the patenting decision of an inventor thus has to balance the tradeoff between the benefits of temporary monopoly power on the one hand, and the drawback of the complete disclosure of enabling knowledge on the other. Naturally, the positive effect may be enhanced by stronger property rights while the negative effect is subject to the impact of the disclosure requirement.

In *Zaby* (2009) the patenting decision of a successful inventor is introduced into a market with vertically differentiated products. She considers two firms which are asymmetric in their capabilities to adopt a new technology: one firm is a successful inventor and possesses the complete technological knowledge about its invention. Its rival, the non-inventor, has failed to invent so far, but has accumulated some know-how. Assuming that the quality of the invention increases costlessly over time, the decision when to market the new technology, i.e. when to innovate, is equivalent to the decision at which quality level to market it. The first adopter of a new product will realize monopoly profits offering the innovative technology at a relatively

[1] See *Johnson*, *Popp* (2003) for empirical evidence concerning this assumption.

low quality up to the point in time when a rival firm enters and offers the new technology incorporated in a product of higher quality. Subsequently, both firms compete in an asymmetric duopoly. Additionally to the adoption decision the inventor faces the choice between a patent and secrecy to protect his discovery. A patent protects a given quality range from the entry of a rival and due to the setting with vertically differentiated products *Zaby* (2009), following *van Dijk* (1996), denotes the intensity of patent protection as the *height* of a patent. Assuming that patent protection is not perfect in the sense that it cannot cover all possible product qualities, the non-inventor may still enter the market with a non-infringing product in spite of a patent. As the non-innovator is forced to realize a given level of product quality to enter the market without infringing the patent, his date of market entry is possibly postponed by a patent. From the viewpoint of the innovator one can say, that the threat of market entry is mitigated by patenting.
From the date of market entry, the innovator profits from temporary monopoly power until a competitor is able to enter with a sufficiently improved – non-infringing – version of the basic innovation. At the same time he faces the drawback of the disclosure requirement linked to the patent which may enable the competitor to accomplish the follow-up innovation at an earlier point in time. Methodically the strategic decisions form a three stage game: On the first stage the inventor decides whether to patent or to rely on secrecy, on the second stage both firms choose their qualities and on the last stage of the game they compete in prices.
Due to the dynamic setting, patent protection may eventually come into operation even before the inventor decides to launch the new product on the market, thus leaving him more time to improve the basic invention in order to make a delayed market entry more profitable without facing the threat of a rival's entry. Our main result is 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. The latter is due to the fact that the positive protective effect of a patent is outweighed by its negative effect of the required disclosure.

Several empirical studies aim at analyzing the propensity to patent. Using the first wave of the German part of the CIS, *König*, *Licht* (1995) investigate the importance of patents compared to non-legal appropriation methods of research output. They find that the non-legal intellectual protection tools are more effective than patents. Moreover, *König*, *Licht* (1995) conclude that firms rather rely on a bundle of legal and non-legal appropriation mechanisms instead of solely patenting. In a direct comparison of the use of patents versus secrecy *Hussinger* (2006), using data from the year 2000 CIS on German

manufacturing firms, finds that patents are effective to protect innovations, i.e. commercialized inventions, while secrecy is rather important for inventions which are in the pre-market phase. She implements the measure *sales of new products* – which reflect the market success of innovations – as dependent variable and thereby obtains a new measure of the importance of intellectual property protection.
Arundel, *Kabla* (1998) use the data from the PACE survey of Europe's largest industrial firms to calculate the sales-weighted patent propensity rates for 19 industries. They find that only four industry sectors reveal patent propensities which exceed 50 %.[2]

This paper's empirical analysis is based on the Mannheim Innovation Panel of the year 2005 which includes characteristics of firms' innovation activities, like expenditures, R&D activities, IP protection mechanisms, but also firms' assessment of their competitive situation.
The analysis first looks at firms' propensity to patent which is linked to the technological lead and its reduction due to the usability of unintended knowledge spillover prevailing in the prospective industry. In order to reflect the reduction of the technological lead due to the usability of unintended knowledge spillover, we include an interaction term in our probit estimation. From the theoretical model we expect that the impact of the technological lead is negative, whereas the interaction term should turn out to be positive. The second empirical test analyzes the competitors' market entry decision. For its operationalization we use the firms' assessment of whether their market position is threatened by rivals' entry. This variable is measured on a four point Likert scale ranging from "fully applies" to "does not apply at all" and thus reflects the degree of entry threat. A high entry threat should in this setting reflect a soon market entry by competitors. To analyze the perceived entry threat we estimate an ordered probit and relate it to technological lead, the usability of unintended knowledge spillover and patent breadth. According to the theoretical model, we conjecture that technological lead and patent breadth lead to a lower threat of entry whereas we hypothesize the opposite effect for the interaction term of technological lead and the usability of spillover.
The rest of the paper is organized as follows. In Section 2 we state the hypotheses which summarize the underlying theoretical model and present their empirical implementation. The following section 3 describes the data set and our proceeding in restricting the data sample and defining the variables. Section 4 presents our empirical results and Section 5 concludes.

[2]These are pharmaceuticals, chemicals, machinery, and precision instruments.

2 Hypotheses and their empirical implementation

In this section, we derive hypotheses based on the theoretical model presented in *Zaby* (2009). Contrary to the theoretical procedure which uses backward induction we will use a chronological approach for the empirical analysis, i.e. we will first empirically investigate the driving factors behind the patenting decision and will then, in a second step, examine the theoretical results concerning rival's timing of market entry, i.e. the threat of entry the innovator faces. Some crucial assumptions were made to solve the theoretical model: The setting in which the model and its results are valid is one of vertically differentiated products, i.e. the firms compete in quality.

The patenting decision on the first stage of the three-stage game entails two opposing effects: a protective effect and a disclosure effect. Obviously, a firm decides to patent if profits generated by the protective effect exceed the reduction of profits by the disclosure effect, otherwise the results of the R&D activities are appropriated by secrecy. Both effects are driven by the three parameters: extent of the technological lead, γ, usability of technological spillover, λ, and intensity of patent protection, ϕ. The spillover are expected to be higher in industries where reverse engineering is easy. While, for example, in *pharmaceuticals* the patenting rate is rather high, in an industry sector such as *precision instruments* the patenting rate is found to be rather low. Relating this observation to the fact that a patent forces the disclosure of technological knowledge and therefore facilitates the research efforts of rival firms, some industry specific differences concerning the usability of the disclosed information have to exist, which account for the difference in patenting rates. In the theoretical model, this aspect was captured by linking the technological headstart of a successful inventor to an industry specific parameter that reflects the easiness of reverse engineering (see *Arundel et al.* (1995)). Summarizing the theoretical results concerning the patenting decision, we derive the following hypotheses:

Hypothesis 1 *Whenever the disclosure requirement has an impact, the protective effect of mitigating the threat of entry may be overcompensated by the disclosure effect so that the higher the technological lead of the inventor, the lower is his propensity to patent.*

Hypothesis 2 *In industries in which spillover are easy to use, e.g. because they are characterized by easy-to-achieve reverse engineering, the technological lead will diminish and hence the propensity to patent will increase.*

In a next step, we present how we implement our theoretical results into an estimation equation. From the theoretical model we know that the effective technological lead consists of the initial headstart of the inventor which is eventually decreased by an industry-specific spillover effect:

$$\gamma = \tilde{\gamma}(1 - \lambda) = \tilde{\gamma} - \lambda\tilde{\gamma}.$$

As stated in Hypotheses 1 and 2, the decision to patent is mainly driven by the initial headstart. We translate the theoretical result into the following empirical equation:

$$P = \beta_1 + \beta_2 TL + \beta_3 RE + \beta_4 TL * RE + Controls, \quad (1)$$

where P denotes the patenting decision, TL the technological lead and RE the easiness of reverse engineering. 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 RE. As in the theoretical model reverse engineering has no direct effect on the propensity to patent, we expect to find no significant effect empirically.
Given the patenting decision on the second stage of the game firms decide on when to enter the market. As *Zaby* (2009) finds that the inventor always takes the lead, the adoption choice of the non-inventor crucially depends on the extent of the inventor's technological headstart. Hence, we come to our next hypotheses.

Hypothesis 3 *The rival's market entry is delayed if the effective technological headstart of the leading innovator is large. Reverse engineering has a detrimental effect on the technological lead and hence increases the threat of rival's entry.*

Furthermore, if an inventor chooses to patent, the mandatory disclosure of the invention enables its rival to enter the market at an earlier point in time as the inventor loses his lead. As the disclosure effect is opposed by the protective effect of a patent, the patentee's competitor might be forced to postpone his market entry in order to develop a non-infringing product. This mitigates the threat of entry that the patentee faces and naturally this effect should be stronger, the higher the level of patent protection is. Thus we propose the following Hypothesis.

Hypothesis 4 *The threat of entry decreases with the intensity of patent protection, i.e. patent height.*

From Proposition 2 of the theoretical model (see *Zaby* (2009)) we know that the threat of entry is weakened with either a weak or strongly protective patent and that the threat of entry is strongly mitigated with a delaying patent. In combination with Hypothesis 3 this translates into the following empirical model:

$$TOE = \beta_1 + \beta_2 TL + \beta_3 RE + \beta_4 TL * RE + \beta_5 DP + \beta_6 SP + \beta_7 WP + Controls,$$

where TOE is the threat of entry, DP reflects delaying patents, SP strongly and WP weakly protective patents. For a definition of TL and RE see the previous equation. The technological lead, TL, should now have a negative effect on the threat of entry, i.e. the time until entry increases with the extent of the technological headstart. The interaction term with reverse engineering should again reveal the opposite effect while the sole effect of RE should not be significant. As the theoretical model predicts, a delaying patent should have a negative effect on the perceived intensity of the threat of entry, while strong and weak patents should have a negative or an insignificant effect.

3 Data set

The basis for the empirical analysis is 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. The aim of the survey is to provide a tool to investigate the innovation behavior of German manufacturing and service firms. Regularly – currently every two years – the MIP is the German contribution of Community Innovation Survey (CIS). Our empirical investigations are based on about 740 firms.

In the year 2005, the survey contained additional questions concerning the firm's perception of the competitive situation. Questions concerning the characteristics and the importance of specific competitive factors like price or quality are asked as well as the perceived competitive situation with respect to the number of competitors and their relative size.

3.1 Sample definition

In order to test our hypotheses, we need to 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. Furthermore, the theoretical model is designed for vertically differentiated products, i.e. the competitive situation is characterized by quality competition. In the 2005 survey, one question is aimed at the characterization of the competitive situation on the main product market. The firms are asked to rank the following choices according to

their importance: quality, price, technological advance, advertisement, product variety, flexibility towards customers. We keep those observations for which firms have indicated that quality is the most, second or third most important feature of competition.
The first part of the empirical analyzes deals with the propensity of patenting vs. secrecy and whether it depends on technical leadership (Hypotheses 1 and 2). In the theoretical model, patenting and secrecy are excluding categories: A firm can either patent or keep the R&D results secret.[3]
For the investigation of the threat of entry (Hypotheses 3 and 4), we need to include patent height in the data set. For this we used patent information from the European Patent Office (EPO) for the observation period 2002 to 2004 including the IPC codes stated in every patent application. The complete classification codes assign a patent into specific clusters which vary in their aggregational level, see the following table.[4]

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

As a patent may be codified by more than one IPC Code, the variation of codes is a good indicator for different levels of patent scope.[5]

[3]For the empirical implementation, this assumption needs to be treated carefully. In the data set, we find several examples of firms which use both patenting and secrecy. Hence, we observe that firms may have more than one innovation and that these may be treated differently. Assuming that firms which indicate patents as highly important use patenting as their main IP protection strategy, all other protection strategies are ignored. Furthermore, all firms which use other formal mechanisms like trademarks are dropped even if they indicate that they use secrecy. A reason for this procedure is that formal protection dominates strategic mechanisms and we do not account for other formal protection methods besides patenting (*Blind et al.* (2006)).

[4]Actually also any additional information complementing the invention information which may be useful for search purposes can be classified by IPC codes through the patent authorities (§123, IPC Guide). To distinguish the Classification symbols referring to the invention information and those referring to additional information, the invention information symbols are displayed in bold font style while the additional information symbols are displayed in non-bold font style (§160, IPC Guide). We are currently working on implementing this distinction in our estimation.

[5]The IPC Guide gives a quite clear statement on the relation between the IPC code and the scope of the respective patent.

Following the theoretical model we define three alternative intensities of patent protection: *weakly protective*, *strongly protective* and *delaying* patents. We implement the alternative patent heights from the theoretical model as follows: Whenever a classification symbol differs on the level of classes or subclasses, we characterize the respective patent as *delaying*. We define a patent as *strongly protective*, if the IPC codes vary in groups and as *weakly protective*, if the IPC codes differ in subgroups. Additionally all patents with a single IPC code are classified as *weakly protective* patents.
In a next step we merge this information to the MIP data set we defined above.[6] By this we condense the EPO data to the firm level. Hence, we now observe firms holding various numbers of *delaying*, *strongly* and/or *weakly protective* patents. We identified only few firms that stated to hold a patent in the MIP survey but had no equivalent entry in the EPO data set. Due to the missing information we dropped these observations.

3.2 Variable definition and descriptive statistics

In this section we describe how we define the core variables of the estimations. First, we take a look at our dependent variables: *Patenting* is measured as a dummy variable indicating whether an inventor uses patenting to protect his intellectual property. In our data set about 60% of the firms applied for a patent in the relevant period (see Table 2).
To reflect the extent of the *threat of entry* (TOE) we refer to a firm's perception on whether its market position is threatened by the entry of new rivals, which is ranked on a 4-digit Likert scale.[7] This ordered variable is our indicator whether technological lead and the opposing effect of reverse engineering induce early market entry by rivals. If the time until the rival's entry is short,

> *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)

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

[7]Respondents could choose between *fully applies*, *rather applies*, *hardly applies* and *does not apply*.

the variable *threat of entry* should be ranked higher than if the time until market entry is longer and the effective technological lead is larger. Hence, we assume that firms rank the *threat of entry* higher when they fear rival's entry.

Table 2: Descriptive Statistics for Patenting Decision Estimation with Vertically Differentiated Products

	Mean	**Std. Dev.**	**Min**	**Max**
patent	0.595	0.491	0	1
technological lead	0.589	0.492	0	1
reverse engineering	0.684	0.465	0	1
*tech. lead * rev. eng.*	0.382	0.486	0	1
complexity	0.378	0.485	0	1
log(employees)	4.563	1.696	0.693	9.077
human capital	0.267	0.266	0.000	1.000
R&D intensity	0.066	0.130	0.000	1.100
strong competition	0.132	0.339	0	1
medium competition	0.209	0.407	0	1
EU	0.673	0.469	0	1
non_EU	0.491	0.500	0	1
subsidy	0.419	0.494	0	1
customer power	0.303	0.460	0	1
obsolete	0.089	0.285	0	1
tech. change	0.465	0.499	0	1
cooperation	0.453	0.498	0	1
diversification	0.658	0.241	0.003	1.000
east	0.292	0.455	0	1
No. of observation		740		

Next we define the explanatory variables. The central variables of the theoretical model are technical leadership and the easiness of reverse engineering. Both constructs are not straightforward to implement empirically. In MIP 2005, *technical leadership* is defined by the variable temporal headstart over competitors. Hence, we create a dummy variable indicating whether the importance of technological leadership is high. About 60% of all firms state that technological leadership is a substantial characteristic of the competitive environment in their main product market.

The other theoretical concept that has to be transformed into empirical terms is the easiness of reverse engineering. Reverse engineering can also be thought of as the usability of spillover. As stated in *Arundel et al.* (1995), reverse engineering is a characteristic of the industry and not of the firm. We construct a dummy variable which has unit value if the market is characterized by easy-to-substitute products. Hence, we assume that if the firm's most important product is easy to substitute, reverse engineering is a mechanism that is at work in the industry where it operates. In our data set almost 70% of the innovating firms operate in a market where reverse engineering prevails.

From the theoretical model we know that the technological leadership of a firm may be reduced by the possibility of reverse engineering. To implement this fact in our empirical analysis we create an interaction term (*tech. lead * rev. eng.*). From Table 2 we know that 38% of all innovating firms state that their competitive environment is characterized by a high relevance of technical leadership and at the same time reverse engineering plays an important role.

For the definition of *weak*, *strong* and *delaying* patents see the above section. According to the descriptive statistics in Table 3 16% of the firms applied for at least one delaying patent, while only 10% applied for a strong, and 18% for a weak patent. Note that it is possible that a firm holds various patents belonging to different categories.

Furthermore, we control for several factors that may influence our dependent variables. Firm size is represented by the number of *employees* in the year 2002, *human capital* by the share of employees holding a university degree. Market structure is reflected by two dummy variables indicating whether the number of main competitors is between 6 and 15 (*medium competition*) or exceeds 15 (*strong competition*). Finally we describe the competitive situation with respect to the geographical dimension of the product market. We control for two world regions, the *EU* and *non-EU*. Germany is considered separately as it serves as reference category in the regression. Thus it is not contained in the variable *EU*.

Costumer power refers to the fact that the share of sales by the three most important customers exceeds 50% of total sales.

In order to capture whether the market is characterized by certain market entry barriers, we control for *capital intensity* defined as tangible assets per employee and for *R&D intensity* defined as expenditures for in-house R&D activities per sales. If firms cooperate with others, e.g. competitors, customers, universities, in conducting R&D this may influence their IP protection strategy. Therefore we include a dummy variable reflecting whether research cooperations take place. We also control for *public* R&D subsidies by either regional, national or European authorities.

Table 3: Descriptive Statistics for Threat of Entry Estimation

	Mean	**Std. Dev.**	**Min**	**Max**
threat of entry	1.517	0.806	0	3
technological lead	0.413	0.493	0	1
reverse engineering	0.698	0.459	0	1
*tech. lead * rev. eng.*	0.273	0.446	0	1
delaying	0.160	0.367	0	1
strong	0.096	0.295	0	1
weak	0.183	0.387	0	1
complexity	0.275	0.447	0	1
secrecy	0.525	0.500	0	1
log(employees)	4.147	1.732	0.000	9.077
R&D intensity	0.060	0.281	0.000	6.427
capital intensity	0.124	0.363	0.000	4.554
strong competition	0.191	0.393	0	1
medium competition	0.223	0.417	0	1
new to market	0.434	0.496	0	1
subsidy	0.294	0.456	0	1
obsolete	0.098	0.297	0	1
tech. change	0.484	0.500	0	1
diversification	0.677	0.243	0.005	1.000
east	0.316	0.465	0	1
No. of observations		748		

To capture relevant product characteristics, we include an indicator whether a product becomes *obsolete* quickly. As the fact that a rapid change of production or service generating technologies may play an important role concerning the decision to patent and the perceived threat of market entry the respective indicator *tech. change* is included as control variable. Furthermore we control for the individual *complexity* of product design.[8] Additionally a firm's degree of *diversification* might be an impact factor in our estimations so that we use a measure reflecting the share of sales originating from a firm's top-selling product or service.

The intensity of the *threat of entry* may be strongly influenced by the fact that a product is *new* to the market. Therefore we include a dummy variable reflecting whether the responding firm has introduced such a product in the relevant time period.

In order to capture regional and sectoral differences we include an indicator whether the firm is located in eastern Germany (*east*) and define 11 *industry dummies*. For the definition of the industry dummies see Table 6 in the Appendix.

The estimation of the threat of entry further incorporates a control variable for the use of *secrecy* as an IP appropriation mechanism. As secrecy may provide similar protection compared to a patent without the drawback of mandatory disclosure choosing this protection strategy may have a relevant impact on the dependent variable .

4 Empirical results

To test our hypotheses regarding firm's patenting behavior, we estimate a probit model and calculate the marginal effects evaluated at the sample means. The standard errors are obtained by using the delta method. The calculation of the marginal effect of the interaction term is based on *Ai, Norton* (2003). The results are displayed in Table 4.

The theoretical model defines the technological lead by $\gamma = \tilde{\gamma} - \lambda\tilde{\gamma}$ so that the effect of λ, the easiness of reverse engineering, is only included in the interaction term $\lambda\tilde{\gamma}$. For a correct empirical implementation of the theoretical model our estimation equation nevertheless needs to contain the sole effect of λ which is implemented by the variable RE. Actually we find an insignificant effect of RE, so that the theoretical model is confirmed.

The theoretical model predicts that the patenting behavior is negatively influenced by the technological lead of the innovator. This is the basic statement of Hypothesis 1. Our empirical results correctly display a negative sign of the respective marginal effect, but it turns out to be insignificant. At first view this is a puzzling result. The insignificance of the effect states that

[8] Note that we need to distinguish individual complexity and industry-specific complexity which can be described by the substitutability of products in the respective competitive environment of a firm.

whether there is a technological lead or not does not influence firms' patenting propensity if the industry is characterized by the absence of easiness of reverse engineering. Suppose a firm's technological lead is small, then our theoretical model predicts that the propensity to patent is high. In practice, patent law requires a sufficiently high inventive step incorporated in the invention in order to fulfil the patentability requirements. Consequently a small technological lead is not eligible for patent protection – a fact which is disregarded by the theoretical model. Hence our empirical finding that the technological lead has an insignificant effect can be properly substantiated.
Additionally, *Zaby* (2009) states that in an industry, in which the easiness of reverse engineering is high, the technological lead is reduced so that patenting becomes more attractive to an innovator. This effect is implemented empirically by the interaction term of technological lead and reverse engineering which we expect to have a positive effect (see Hypothesis 2). This is confirmed by the empirical findings.
Interestingly the control variables reflecting the strength of competition with respect to competitors, customers and regional dimensions are mainly insignificant for the patenting decision. An exception is the positive effect for *non_EU*. An intuition for this surprising 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. A possible explanation is that those firms fear the entry of foreign firms with substitute products. Further we find that R&D cooperation has a positive significant effect on the propensity to patent whereas being located in Eastern Germany has a negative impact.

Table 4: Results of the Patenting Decision Estimation with Vertically Differentiated Products

	Marginal Effect	**Standard Error**
technological lead	-0.012	0.040
reverse engineering	0.006	0.043
*tech. lead * rev. eng.*	0.143*	0.085
complexity	-0.060	0.041
log(employees)	0.081***	0.015
human capital	0.128	0.109
R&D intensity	0.781***	0.219
strong competition	-0.042	0.061
medium competition	-0.021	0.049
EU	0.030	0.050
non_EU	0.112**	0.045
subsidy	0.102**	0.050
customer power	-0.070	0.046
obsolete	0.000	0.072
tech. change	-0.042	0.041
cooperation	0.099**	0.047
diversification	-0.138	0.088
east	-0.110**	0.049
industry dummies	*included*	
Log likelihood	-382.08	
McFadden's adjusted R^2	0.235	
$\chi^2(all)$	235.05***	
$\chi^2(ind)$	42.33***	
Number of observations	740	

*** (**, *) indicate significance of 1 % (5 %, 10 %) respectively.

This table depicts marginal effects of a probit estimation regarding the determinants of the patenting decision. Marginal effects are calculated at the sample means and those of the interaction terms are obtained according to *Ai*, *Norton* (2003). Standard errors are calculated with the delta method.

$\chi^2(all)$ displays a test on the joint significance of all variables.

$\chi^2(ind)$ displays a test on the joint significance of the industry dummies. For a definition of the industry dummies refer to Table 6.

Our industry dummies are jointly significant hinting at structural differences between industry sectors. However, due to the fact that we explicitly include the main factors driving these differences in our estimation, e.g. reverse engineering, complexity, technical change, we are not able to confirm significant differences between sectors.[9]

After the discussion of the results concerning the first stage of the theoretical game we now turn to the findings regarding the second stage where the market entry decision of competitors is analyzed. This decision is empirically implemented by using firms' statement with respect to the perceived importance of the threat of market entry by potential rivals. As threat of entry is measured on a four-point Likert scale we estimate an ordered probit model. Marginal effects are calculated at the sample means and standard errors using the delta method. For the calculation of the interaction effect we rely on *Mallick* (2009). The results are depicted in Table 5.

The Hypothesis 3 stating that the interaction term, $TL * RE$, has a positive impact on the intensity of threat of entry is not confirmed by the estimation results. However, we find a positive effect of reverse engineering which has to be interpreted as the effect of reverse engineering in the absence of technological lead. A possible reasoning behind this finding is that the detrimental effect of reverse engineering on technological lead is not sufficiently high to induce a significant impact on the threat of entry, i.e. a significant effect of the interaction term $TL * RE$.

Regarding Hypothesis 4 the predictions of the theoretical model are underlined by the empirical findings. To test the hypothesis we implement three alternative measures for the intensity of patent protection. The strongest level of protection, i.e. a delaying patent, has a significant negative effect on the threat of entry while lower intensities of patent protection, i.e. weak and strong patents, reveal no significant effect.

Firm's capital intensity, which can be interpreted as a barrier to market entry for competitors, is found to have a negative significant effect on the threat of entry. However, our control variables reflecting the number of competitors operating in a market show positive significant effects. This opposes our conjecture that more intensive competition decreases the perceived intensity of the threat of entry. Our interpretation of this result is that the number of competitors implicitly reflects the market size. More competitors in the market may be an indicator for the fact that the market has the potential of absorbing even more firms. Furthermore it could also be an indicator for a market with low entry barriers. Following this argument the fact that many competitors operate in a market can either signal low market entry costs or

[9]This result originates from tests on the equality of coefficients of industry dummies.

can signal that the market bears no room for further entry. As we find a positive significant effect of a market with a large number of competitors, it must be that market entry barriers are low so that firms perceive a high threat of further market entry.
In line with economic intuition the empirical results state that if services or products become obsolete quickly or production technologies change rapidly this has a positive significant effect on the intensity of the threat of entry. Further our estimation results show that the lower the level of diversification in a firm is, the higher this firm rates the intensity of the market entry threat.

Table 5: Ordered Probit for Threat of Entry Estimation

threat	**strong**	**medium**	**weak**	**no**
	Marg. Eff. **(Std. Err.)**	**Marg. Eff.** **(Std. Err.)**	**Marg. Eff.** **(Std. Err.)**	**Marg. Eff.** **(Std. Err.)**
technological lead	0.020 (0.016)	0.028 (0.022)	-0.029 (0.024)	-0.019 (0.015)
reverse engineering	0.039** (0.015)	0.061*** (0.021)	-0.056** (0.022)	-0.043** (0.017)
*tech. lead * rev. eng.*	0.009 (0.026)	0.000 (0.041)	-0.014 (0.037)	0.006 (0.031)
delaying	-0.040** (0.018)	-0.067* (0.036)	0.057** (0.025)	0.050 (0.031)
strong	-0.019 (0.023)	-0.029 (0.039)	0.027 (0.033)	0.021 (0.030)
weak	0.011 (0.024)	0.016 (0.031)	-0.017 (0.035)	-0.010 (0.020)
complexity	0.021 (0.017)	0.028 (0.022)	-0.030 (0.025)	-0.018 (0.015)
secrecy	-0.022 (0.016)	-0.031 (0.023)	0.032 (0.024)	0.021 (0.016)
log(employees)	0.005 (0.004)	0.007 (0.007)	-0.007 (0.006)	-0.005 (0.005)
R&D intensity	0.026 (0.025)	0.036 (0.035)	-0.037 (0.036)	-0.025 (0.024)
capital intensity	-0.047** (0.022)	-0.066** (0.031)	0.068** (0.033)	0.045** (0.022)
strong competition	0.060** (0.025)	0.069*** (0.022)	-0.086*** (0.033)	-0.044*** (0.015)

Table continued on the next page

threat	strong	medium	weak	no
	Marg. Eff. (Std. Err.)	**Marg. Eff. (Std. Err.)**	**Marg. Eff. (Std. Err.)**	**Marg. Eff. (Std. Err.)**
medium competition	0.046**	0.057***	-0.067**	-0.037***
	(0.022)	(0.021)	(0.030)	(0.014)
new to market	-0.019	-0.027	0.028	0.019
	(0.015)	(0.021)	(0.021)	(0.015)
subsidy	0.012	0.016	-0.017	-0.011
	(0.017)	(0.022)	(0.024)	(0.015)
obsolete	0.051*	0.058**	-0.072*	-0.036**
	(0.031)	(0.029)	(0.042)	(0.018)
tech. change	0.034**	0.047**	-0.049**	-0.032**
	(0.015)	(0.020)	(0.022)	(0.015)
diversification	0.063**	0.089**	-0.092**	-0.060**
	(0.028)	(0.042)	(0.041)	(0.031)
east	-0.029	-0.029	0.029	0.020
	(0.015)	(0.022)	(0.022)	(0.016)
industry dummies	*included*	*included*	*included*	*included*
Log likelihood		-417.94		
McFadden's adjusted R^2		0.037		
$\chi^2(all)$		65.21***		
$\chi^2(ind)$	8.72			
Number of observations		748		

*** (**, *) indicate significance of 1 % (5 %, 10 %) respectively.

This table depicts marginal effects for an ordered probit of the estimation of threat of entry. Marginal effects are calculated at the sample means and those of the interaction terms are obtained according to *Mallick* (2009). Standard errors are calculated with the delta method.

$\chi^2(all)$ displays a test on the joint significance of all variables.

$\chi^2(ind)$ displays a test on the joint significance of the industry dummies. For a definition of the industry dummies refer to Table 6.

5 Conclusion

This paper intended to empirically test the theoretical results and predictions obtained in *Zaby* (2009). Several hypotheses summarizing the theoretical results concerning the propensity to patent with vertically differentiated products thereby formed the basis of the empirical examination.
From the theoretical analysis of the propensity to patent in a market with vertically differentiated products we deduced four hypothesis. Two refer to

the first stage of the theoretical model, i.e. the patenting decision of the inventor, while the others concern the second stage of the model, the market entry decisions of the firms.

The first, Hypothesis 1, proposes that the higher the technological lead of the inventor, the lower is his propensity to patent. This could not be confirmed by our empirical estimation. A possible explanation for this is that the theoretical approach ignores the fact that minor technological advances are not applicable for patent protection.

Hypothesis 2 states that if reverse engineering is easy to achieve, the technological lead is reduced so that patenting becomes more attractive, i.e. the propensity to patent increases. To test this hypothesis we implemented an interaction term of technological lead and reverse engineering. As the effect of the interaction term is found to be positive and significant, this hypothesis is confirmed.

Regarding the second stage of the theoretical model, Hypothesis 3 suggests that reverse engineering reduces the technological lead so strongly that the threat of entry increases. This finding is not confirmed empirically. Since we find that the single effect of reverse engineering is positive, the effect of reverse engineering on the technological lead is obviously not strong enough to induce a positive effect of the interaction term. Nevertheless we can confirm empirically that the threat of market entry decreases with the intensity of patent protection, which is a result of the theoretical model formulated in Hypothesis 4. For a delaying patent, i.e. very strong patent protection, we find a significant negative effect on the threat of entry.

The probably most puzzling and equivocative result of our theoretical analysis is the finding that the propensity to patent decreases the higher the technological lead of an innovator is. The commonly perceived intuition suggests the opposite, namely that an innovation is patented, the greater the technological advance it embodies. Our empirical estimation offers the solution to this puzzle: we find that in the model setting the commonly suggested interdependence of technological lead and the propensity to patent only holds if the respective market is characterized by easy-to-achieve reverse engineering. Thus the theoretical findings of *Zaby* (2009) do not contradict common intuition but constrain its validity to markets where reverse engineering is easy. Consequently, in a market where reverse engineering is difficult, our findings propose that the propensity to patent decreases when the technological lead rises.

Appendix

Table 6: Definition of Industry Dummies

ind_	**NACE code**	**description**
1	1, 15, 17, 18, 19	agriculture, food, textile, leather
2	10, 14, 23, 40, 41	mining, coke, fuel, electricity
3	20, 21, 36, 37, 90	wood, paper, publishing, printing, furniture, recycling, sewage
4	24, 25, 26	chemicals and pharmaceuticals, plastics, non-metallic mineral products, glass
5	27, 28	metals
6	29, 34, 350, 351, 352, 354, 355	machinery, motor vehicles without aerospace
7	30, 31, 32	office machinery, electrical machinery, radio television communication
8	33, 353	medical, precision and optical instruments, aerospace
9	64, 72	telecommunication, post and communication, computer services
10	73	research & development
11	74	business activities

Industry category 11 is the reference category and is not included in regressions.

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