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The Research Use Exemption from Patent Infringement and the Propensity to Patent

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Abstract

This article explores the propensity to patent in the light of a statutory research use exemption from patent infringement. Unlike earlier approaches concerned with the patenting decision, we take into account that a statutory research use exemption may decrease the merits of patenting by facilitating inventing around the patent. We find that a research use exemption ? contingent on the competitive environment of the inventor ? possibly has substantial negative effects on the propensity to patent. An empirical investigation of the theoretical results finds support for the proposed effects.

Jelcodes:O34,L13

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Abstract

This article explores the propensity to patent in the light of a statutory research use exemption from patent infringement. Unlike earlier approaches concerned with the patenting decision, we take into account that a statutory research use exemption may decrease the merits of patenting by facilitating inventing around the patent. We find that a research use exemption – contingent on the competitive environment of the inventor – possibly has substantial negative effects on the propensity to patent. An empirical investigation of the theoretical results finds support for the proposed effects.

Keywords: research use exemption, patenting decision, secrecy, disclosure requirement, patent breadth, horizontal product differentiation, circular city

JEL Classifications: L13, L24, O34

1 Introduction

In Europe, most recently Belgium and Switzerland amended their statutory patent law to include a research use exemption from patent infringement. In other countries, where a statutory research use exemption does (de facto) not exist, e.g. the U.S., Australia, New Zealand, or where its application is not clearly defined, e.g. U.K., a continuous discussion about the usefulness of the introduction (or extension/clarification) of a research use exemption is taking place.[1] This paper is motivated by the ongoing discussion regarding the effects of a research use exemption on the propensity to patent of successful innovators.

Patents basically have two functions: The first is to mitigate the problem of unintended spillover of R&D outcomes by providing an effective tool of temporary knowledge protection. This protective effect of a patent enables the inventor to appropriate the returns from his research efforts. The second function of a patent is to contribute to the diffusion of inventions by requiring the disclosure of the invention to society. The introduction of exemptions from patent infringement strengthens this negative disclosure effect of patenting in areas for which the exemption is applicable. Thus the question arises whether a research use exemption has a detrimental effect on the propensity to patent.

So far only little economic research sheds light on this issue. In two related papers, *Nagaoka*, *Aoki* (2006, 2007) building on *Scotchmer* (2004) analyze the effect of a research use exemption on the R&D activities of firms. Concerning the impact of a research use exemption on the propensity to patent to our best knowledge no theoretical approach exists so far. *Thumm* (2003) provides the only empirical survey which explicitly includes an investigation of the research use exemption. He finds that participants consider the introduction of a broad research use exemption relatively beneficial. Two main reasons are stated as substantial for this positive assessment: a broad research use exemption increases the access to genetic inventions, and it promotes the dissemination of technology.

Our investigation of the effect a research use exemption has on the propensity to patent goes one step further: It is quite straightforward that firms will benefit from a research use exemption when the exempted knowledge forms the basis for their own further research. Nevertheless, they are not only consumers of previous innovations, but also producers of innovations

[1]In the United States, the Hatch-Waxman Act implemented a research use exemption for drugs and food. However, this act is interpreted very narrowly by the courts so that for profit-seeking firms the research use exemption does de facto not exist or is insecure (e.g. Roche vs. Bolar, Merck vs. Integra, see *Kumar et al.* (2010)).

in the future. We aim to tackle the question how a research use exemption influences an innovator's propensity to patent if his proprietary innovation serves competitors as input for their further research.

To be able to analyze the impact of a research use exemption on the propensity to patent we need a setting in which patent protection is imperfect, i.e. competitors have the possibility to legally invent around a patent. Further, the mandatory disclosure of information if the innovator patents should be profitable for competitors subject to the impact of the research use exemption. Our theoretical analysis builds on a model presented in *Zaby* (2010).[2] To capture imperfect patent protection, the decision to patent is introduced into a setting with horizontally differentiated products where competitors may enter the market despite of a patent, i.e. invent around the patent. The impact of a research use exemption influences the easiness of inventing around the patent. Whenever the research use exemption has a substantial impact, the mandatorily disclosed information in a patent specification profits the innovator's competitors as inventing around becomes easier. The inventor has to balance this negative effect of patenting against the positive protective effect. This positive effect stems from the fact that a patent restricts the strategies of competitors: The broader the scope of the patent, the narrower is the area in which competitors may enter the market without infringing the patent.

Our main finding is that the weaker the impact of the research use exemption is, the higher is the propensity to patent. Subsequent to the theoretical analysis we investigate our findings empirically. Due to the fact that Germany implemented one of the broadest definitions of a research use exemption in Europe (*OECD* (2006)), we concentrate our empirical analysis on German firms.

To our best knowledge, besides own previous work, no theoretical literature and only very sparse empirical literature exists which analyzes the impact of a research use exemption on patenting activity. As this exemption from patent infringement allows a competitor to use the disclosed information, the impact of the research use exemption is decisive for the strength of the

[2] Introducing patent protection into a setting with horizontally differentiated products goes back to *Klemperer* (1990).The main focus of his paper is to analyze a patent's optimal design with regard to its length and breadth, whereas the patenting decision per se is not considered. This is accomplished by two subsequent papers: *Waterson* (1990) focusses on a comparison of alternative patent systems with regard to social welfare, and *Harter* (1994) examines the propensity to patent accounting for a disclosure effect. The major drawback of the latter modeling approach is that only one potential competitor profits from the merits of the mandatory disclosure. This fact, which largely delimitates the impact of the disclosure requirement, in the end leads *Harter* (1994) to conclude that there is no causal relation between the required disclosure and the propensity to patent.

disclosure effect of a patent. Whenever the impact of a research use exemption is neglectable, a patent solely has a positive protective effect as the disclosed information cannot be used by the patentee's competitors without infringing the patent. Whenever a research exemption has a strong impact, the positive protective effect is opposed by a negative disclosure effect and consequently the inventor's patenting decision will take the tradeoff between both effects into account. Following along this line, most of the economic literature implicitly assumes that a research use exemption does not exist (or has a very low impact), as the disclosure effect of a patent is disregarded. For our empirical investigation we assume that the extent of the disclosure effect depends on the market specific capability of rival firms to appropriate and actually use the disclosed information. As we will show, variations of the appropriability lead to changes in the interplay of the counter-effects of patenting, i.e. protection versus disclosure, which in the end may result in an alteration of the propensity to patent.
Our work relates to several contributions which also consider that patenting has a disclosure effect. In the work of *Scotchmer*, *Green* (1990) and *Erkal* (2005) the extent of the disclosure requirement remains fixed whereas *Bhattacharya*, *Guriev* (2006), *Aoki*, *Spiegel* (2009) and *Harter* (1994) assume that the impact of the required disclosure may vary. However, the latter contributions do not explicitly focus on the consequences that a varying impact of the disclosure requirement has on the counter-effects of patenting and in the end on the propensity to patent. *Aoki*, *Spiegel* (2009) focus on the influence of alternative filing procedures on the propensity to patent, *Bhattacharya*, *Guriev* (2006) analyze the choice of alternative licensing contracts and *Harter* (1994) even comes to the conclusion that the propensity to patent is not at all influenced by the impact of the disclosure requirement.

Our analysis proceeds as follows. In Section 2 we introduce the theoretical model. The considered three stage game is solved backward, beginning with the analysis of the price competition on the last stage of the game in Section 2.1, proceeding with the market entry decisions on the second stage of the game in Section 2.2 and finally the innovator's patenting decision on the first stage of the game in Section 2.3. The empirical investigation of our theoretical findings is presented in Section 3. Section 4 concludes. Proofs can be found in *Zaby* (2010).

2 The Model

Assume that one of n firms has successfully accomplished a drastic product innovation and decides to release the new product immediately. The innovator will be monopolist in the new market as long as no other firm successfully invents. The new product may be varied horizontally in its product characteristics which are assumed to be continuously distributed on a circle of unit-circumference. The innovator (and any other entering firm) can only offer one variant of the good. We denote the total number of firms that operate in this differentiated oligopoly as $N = n + 1$, consisting of the innovator and n entering firms. Consumers are assumed to be uniformly distributed over the circle, with density normalized to one. The preference of a consumer z is given by his position on the circle, $x_z \in [0, 1]$, and we assume without loss of generality that the innovator of the new product is located at $x_\rho = 0$. If a consumer cannot buy a good according to his preference he incurs a disutility that rises quadratically with the distance between his preferred good and the offered good. We will refer to this disutility as mismatch costs. Each consumer purchases one unit of the good which yields the highest net utility, $U_x = v - p_z - (x - x_z)^2 \geq 0$. We assume throughout the paper that the reservation price v is very high so that no consumer prefers the outside option.[3]

The structure of the model is as follows: on the first stage of a three-stage game the innovator, already located in the new market, decides whether to patent his innovation or to keep it secret, $\sigma_\rho^1 = \{\phi, s\}$. A patent protects a given range of product space on the unit circle against the entry of rival firms. The extent of protection is defined by the breadth of the patent, $\beta \in]0, 1[$, which is exogenously given.[4] We assume that the protected product space is situated symmetrically around the location of the patentee's product. As we set $x_\rho = 0$, this point on the circle defines the middle of the protected product space, see Figure 1. From there patent protection covers $\beta/2$ of the neighboring product space on either side of the innovation.

[3]See *Zaby* (2010) for a relaxation of this assumption.

[4]Patent breadth can also be interpreted as a strategic decision variable of the innovator, see *Yiannaka*, *Fulton* (2006).

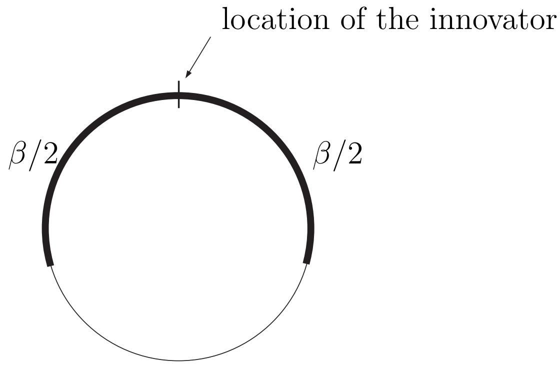


Figure 1: Patent breadth

On the second stage potential rivals simultaneously decide whether to enter the new market, given the patenting decision of the innovator, $\sigma_n^2 = \{\text{entry, no entry}\}$.
Upon entry all firms face market entry costs. These can be understood as the costs necessary to achieve the capability to produce a variant of the new product. If the innovator decides to patent his discovery, according to patent law he is required to disclose sufficient information so that anyone *skilled in the art* is able to reproduce the patented product. Although competitors are not allowed to enter the market with an exact imitation of the protected product, they have the possibility to invent around the patent as long as patent breadth does not deter entry completely, $\beta < 1$. As we assume that a statutory research use exemption from patent infringement exists, entering rivals profit from the disclosed information: If a rival firm is able to appropriate and use the information included in the patent application, achieving the capability to enter the new market is easier and thus becomes less costly. To capture this theoretically, we assume that market entry costs decrease by patenting. Denoting market entry costs in the case of secrecy by f_s, in the case of a patent they decrease to f_ϕ with $f_\phi \equiv \alpha f_s$, $0 \leq \alpha \leq 1$, where α is a measure for the extent to which the disclosed information may be appropriated and used by competitors. The difference between market entry costs with and without a patent yields the amount of mandatorily disclosed information, $\Delta f = f_s(1 - \alpha)$. The parameter α can thus be interpreted as a measure for the impact of the research use exemption as it is decisive for the amount of information lost due to patenting, Δf, i.e. the strength of the disclosure effect.
Concerning the location of firms, we will use the well established principle of maximum differentiation: Firms will locate as far away from each other

as possible to soften price competition.[5] Thus, if secrecy prevails firms will locate equidistantly on the unit circle. With a patent the non-patentee firms cannot freely locate on the unit circle due to the protective effect of a patent. Still, they will try to move as close as possible to their profit maximizing, equidistant locations. Consequently, in the case of a patent, when the choice of location is restricted to the product space $1-\beta$, the direct neighbors of the patentee will locate at the borders of the patent and all other entrants will locate equidistantly between them.
On the third stage all firms in the new market compete in prices, $\sigma^3_{\rho,N} = p$.

2.1 Price Competition

To find the subgame perfect Nash equilibrium, we solve the game by backward induction, setting off with the last stage. Here we have to distinguish the cases:

(i) the innovator has not patented, $\sigma^1_\rho = \{s\}$,

(ii) the innovator has patented $\sigma^1_\rho = \{\phi\}$

We will consider the cases subsequently, starting with case (i).

(i) the innovator has not patented $\sigma^1_\rho = \{s\}$

In the case that the innovator refrains from patenting and chooses secrecy to protect his innovation, our model simplifies to the well known *Salop* (1979) model of a circular city which we will briefly analyze in the following: All firms are symmetric so that it suffices to analyze the decision of one representative firm denoted by k. With moderate market entry costs, every consumer in the non-protected market buys one unit of the differentiated product from the firm that offers the variant which is closest to his preferences.[6]
Standard computations then yield equilibrium prices,

$$p^* = 1/(N^s)^2, \tag{1}$$

and profits

$$\pi^*_n = 1/(N^s)^3 - f_s \tag{2}$$

[5] *Kats* (1995) shows that this principle leads to a subgame perfect Nash equilibrium in a location then price game in a circular market.

[6] In this paper we exclude the monopoly case. See *Zaby* (2010) for an extensive analysis of this issue.

for the N^s entering firms. Note that the profit of the innovator amounts to

$$\pi_\rho^* = 1/(N^s)^3 \tag{3}$$

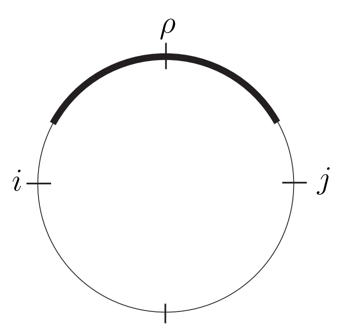
as he does not face market entry costs.

(ii) the innovator has patented $\sigma_\rho^1 = \{\phi\}$

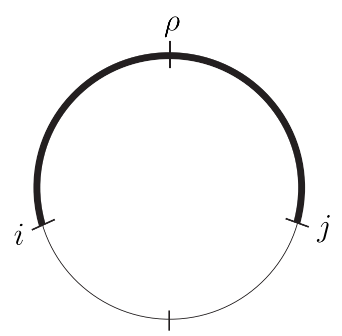
Now let us turn to case (ii) and look at the situation when the innovator decides to protect the new product by a patent. As long as the breadth of the patent is rather moderate, $\beta/2 < 1/N^s$, the patent does not influence the location of rival firms and the symmetric result derived above emerges. Note though, that market entry costs decrease subject to the extent of the appropriation capabilities of competitors in the respective market. If the non-patentee firms are able to use the disclosed information to a rather large extent, i.e. the impact of the research use exemption is high, more firms than in the case with secrecy might enter the market so that $N^\phi > N^s$. To start with, we will exclude this possibility and assume that the number of firms is left unchanged by a patent, $N^\phi = N^s$. If the protectional degree of the patent is high,

$$\beta \geq \beta^{\text{res}} \equiv \frac{2}{N^s}\,, \tag{4}$$

equidistant locations on the entire circumference of the circle are no longer possible as the patent restricts the locations for entering firms to the product space $1 - \beta$. We will define patents in a setting where patent breadth, β, fulfills condition (4) as *restrictive* patents. The following figure depicts firms' locations with $N^\phi = 4$ for the cases (a) that the patent is not restrictive $(\beta < 1/2)$, and (b) that the patent is restrictive $(\beta \geq 1/2)$.



(a) non-restrictive patent



(b) restrictive patent

Figure 2: Firm's locations with a patent, $N^\phi = 4$

In the case that the innovator patents, firms' neighborhoods are no longer uniform, but are dependent on the respective location of a firm. To distinguish firms' locations we will refer to the left and right neighbor of the innovator as firms i and j. Further we will denote the first right (left) neighbor of i (j) by $i+1$ ($j+1$), the second by $i+2$ ($j+2$) and so on. Consequently, with a restrictive patent an equilibrium can no longer be derived by analyzing a representative firm, as the respective neighborhood of a firm now plays a crucial role for its pricing decision. We have to distinguish three types of firms, differing by their respective neighborhood:

a) the patentee has a uniform neighborhood consisting of firms i and j

b) the „border" firms i and j have a non-uniform neighborhood with the patentee on the one side and either each other or, if $n > 2$, a non-patentee, non-border firm $i + 1$ or $j + 1$ on the other side

c) a non-patentee, non-border firm $i + \kappa$, $\kappa \geq 1$ always has a non-uniform neighborhood ($i + \kappa - 1$ to the left, $i + \kappa + 1$ to the right side) as long as it is not the firm with the greatest distance to the patentee.[7]

As all non-patentee firms are ex-ante symmetric they will come to the same decision whenever facing the same neighborhood. Thus, if an even number of firms enters, every firm has a symmetric "partner" that faces the same neighborhood. In the following, we will refer to this as *semi-circle symmetry.* If an uneven number of firms enters the market then the firm located furthest away from the patentee has no symmetric "partner", we will refer to this case as *semi-circle asymmetry.*

As we are analyzing the last stage of the game we take the number of firms that have entered the market as given. Due to the fact that the neighborhood of every firm is crucial for its individual demand and thus pricing decision, we will have to distinguish the indifferent consumer between every pair of firms, say y and z. From the viewpoint of firm y the indifferent consumer will be denoted by $\hat{x}_{y,z}$, from the viewpoint of its neighbor z it will be denoted by

[7] For this firm we need to distinguish two cases that depend on the number of non-patentee firms n

- if n is even, which we will denote by n^e, then the firm furthest away from the patentee is firm $i + (n^e/2 - 1)$ and its neighborhood is non-uniform: to the left firm $i + (n^e/2 - 2)$, to the right firm $j + (n^e/2 - 1)$
- if n is uneven, n^u, then the firm furthest away is firm $i + (n^u - 1)/2$ and its neighborhood is uniform: to the left firm $i + (n^u - 3)/2$, to the right firm $j + (n^u - 3)/2$.

$\hat{x}_{z,y}$. By standard computations the location of the indifferent consumer can be found by equating the respective utilities a consumer realizes by buying from either of its neighboring firms.

Given the indifferent consumer the demand and the price reaction functions of the respective firms types can be derived. For an extensive elaboration on this see *Zaby* (2010).

2.2 Market Entry

The analysis of the market entry decisions again needs to distinguish the cases (i) the innovator has not patented and (ii) the innovator has patented. It is crucial for our analysis of the impact of a statutory research use exemption on the propensity to patent that even if the innovator patents, his competitors have the possibility to enter the market by inventing around the patent. As market entry costs decrease subject to the strength of the disclosure effect, i.e. the appropriation capability of competitors, it might be that more firms are able to enter with patent protection than with secrecy.

(i) the innovator has not patented $\sigma_\rho^1 = \{s\}$

Whenever the innovator decides to keep his discovery secret the analysis of the market entry decisions of his rivals corresponds to the well known Salop result: the number of firms entering the market can be derived by solving the zero-profit condition $\pi_n^s = 0$ of a representative firm for n. Using (2) we get

$$(n^s)^0 = (1/f_s)^{1/3} - 1. \tag{5}$$

(ii) the innovator has patented $\sigma_\rho^1 = \{\phi\}$

If we turn to case (ii) and assume that the innovator has patented his innovation on the first stage of the game, we can no longer pin down the market entry decisions in one zero-profit condition. Due to the asymmetric neighborhoods of firms the analysis of market entry becomes somewhat more complex. In the following we will derive the critical thresholds of market entry costs f_ϕ that yield market structures varying from $N^\phi = 4$ to $N^\phi \to \infty$.[8] As the patentee always operates in the market himself the total number of firms consists of him and the number of entering firms. In the case that the innovator

[8]The analysis of the cases $N^\phi < 4$ can be found in *Zaby* (2010). They reveal some special issues which are not essential for the qualitative results concerning the impact of the research use exemption on the propensity to patent, so we omit these cases here.

has patented we denote the entering rival firms by n^ϕ so that $N^\phi = n^\phi + 1$. To ease notation we simply use the respective number of firms operating in the market as subscript, so the subscript 4 stands for the case $N^\phi = 4$ and so on.

For a sufficient definition of the number of entering competitors an upper and a lower bound for market entry costs have to be defined. We denote the upper bound of a market structure with N firms as f_N. This means that for market entry costs $f_N \geq f$ at least N firms are able to enter. The exact number can be defined by additionally defining a lower boundary assuring that no more than N firms can enter. We refer to this critical threshold as f_{N+1}. Obviously the potential entrant(s) with the lowest profits is (are) decisive for this threshold. Whenever profits decrease due to higher market entry costs his (their) profit(s) will be the first to become negative. Following economic intuition the firm(s) with the lowest profits(s) must be the firm(s) located at the furthest distance to the patentee. This is due to the following fact: The border firms i and j are able to set the highest prices of all non-patentee firms, as they face a relatively large mass of consumers situated between themselves and the patentee. This positive price effect of patent protection is passed on to every other neighbor, but it gets weaker the further away from the patentee a firm is located.
Whenever the number of entering firms, n^ϕ, is even, all rivals have a semi-symmetric partner and thus the profits of the two firms located at the greatest distance to the patentee define the lower bound of market entry costs. Whenever the number of entering firms is uneven, the firm located furthest away from the patentee has no semi-symmetric partner and thus the lower bound of market entry costs is given by its profits.
Given both boundaries for market entry costs the number of entering firms in general is sufficiently defined by

$$f_N \geq f > f_{N+1} \,. \tag{6}$$

The derivation of the critical boundaries is in detail described in *Zaby* (2010).

2.3 The Patenting Decision

On the first stage of the three-stage game the innovator decides whether to patent his innovation or to keep it secret, $\sigma_\rho^1 = \{\phi, s\}$. His patenting decision is driven by two opposing effects. On the one hand a patent protects part of the market, β, from the entrance of rival firms. We refer to this as the *protective effect* of patenting. On the other hand the patentee faces the consequences from the research use exemption: the disclosure requirement linked to a patent in combination with the competitors' capability to appropriate the disclosed information leads to decreasing market entry costs. We call this the *disclosure effect* of patenting and it may possibly make market entry profitable for a larger number of firms than with secrecy. Given a market specific level of appropriability, α, we define the reduction of market entry costs as $f_\phi \equiv \alpha f_s$, with $0 \leq \alpha \leq 1$. Note that the higher the capability to appropriate the disclosed information, the lower the parameter α.

In the following we need to distinguish two cases: (i) the appropriability is so high (i.e. α is so low) that the competitors are able to use a substantial part of the disclosed information and (ii) the capability to appropriate the information disclosed by patenting is low (i.e. α is high) so that the disclosure effect is rather small. In case (i) the strong disclosure effect leads to a major reduction of market entry costs and thus enables more firms to enter the market whenever the initial innovation is patented so that $N^\phi > N^s$. Obviously the statutory research use exemption from patent infringement has an impact on the propensity to patent in this case. Technically speaking, the number of firms which are able to enter increases whenever market entry costs decrease below the critical threshold f_{N+1}, see Equation (6). Thus more firms will be able to enter due to patenting whenever $f_\phi = \alpha f_s < f_{N+1}$. Rearranging we get a critical condition for appropriability, $\alpha < f_{N+1}/f_s$. Defining $\alpha^N \equiv f_{N+1}/f_s$ we can then state that whenever $\alpha^N > \alpha \geq 0$ the research use exemption has an impact on the propensity to patent. In case (ii) a low level of appropriability leads to an only minor reduction of market entry costs so that $N^\phi = N^s$. Technically speaking, the research use exemption has no impact whenever $1 \geq \alpha \geq \alpha^N$.

The following figure illustrates the critical thresholds of market entry costs for alternative levels of patent breadth, β, where the solid lines depict the critical thresholds for the case that the innovator chooses secrecy and the dashed lines depict the critical thresholds for the case that the innovator patents.[9]

[9]Note that to maintain clarity we omitted $f_{s,\,N^s}$ for $N^s > 6$. These curves would be located below $f_{s,\,6}$.

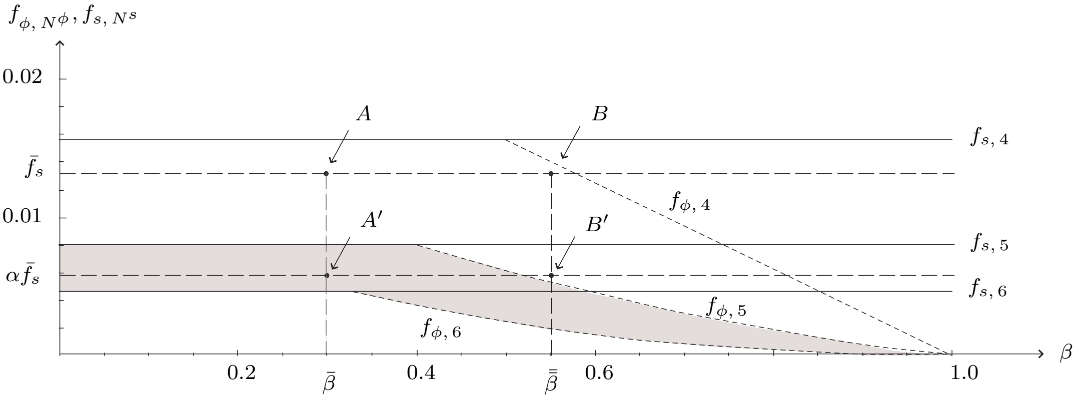


Figure 3: Critical thresholds of market entry costs

Obviously f_{ϕ,N^ϕ} and f_{s,N^s} are equal up to the point where patent protection becomes restrictive, $\beta \geq 2/N^s$. All combinations of f and β that lie between two curves f_N and f_{N+1} lead to a situation where N firms enter the market. Thus in the shaded area $N^\phi = 5$ firms would enter the market with a patent while with secrecy $N^s \geq 5$ could enter in this area. Figure 3 shows that given market entry costs and patent breadth, a patent may lead to two different cases:[10]

(a) due to a dominant disclosure effect more firms are able to enter with a patent,

(b) due to a dominant protective effect the number of firms is not changed by patenting.

Take for example the case where patent breadth is rather low, $\bar{\beta}$, and thus the protective effect is only moderate. Given market entry costs, $\bar{f}_s$, we are at point A with $N^s = 4$. By patenting market entry costs are reduced to $\alpha\bar{f}_s$. In this example case, market entry costs change substantially as by patenting we move to point A' where $N^\phi = 5$ firms are able to enter (case (a)). Keeping the level of appropriablity fixed and increasing patent breadth to $\bar{\bar{\beta}}$, we come to point B where again $N^s = 4$ firms can enter with secrecy. With a patent market entry costs are again reduced by the same amount as before and we move to point B', where $N^\phi = 4$ firms are able to enter. Consequently, opposing the case with a low protective effect due to a low

[10] In fact, a third case where due to a dominant protective effect less firms enter with a patent may prevail, see *Zaby* (2010) for details.

β, a strong protective effect may overcompensate the impact of the research use exemption so that the number of firms operating in the market is left unaffected by a patent (case (b)).
To find out whether the innovator will choose to patent or to keep his innovation secret in the cases considered above, we need to compare the respective profits he can realize given the alternative combinations of market entry costs and patent breadth. In the following figure the profits of the innovator subject to f and β are plotted for the cases that he chooses a patent (dashed lines) or secrecy (solid lines).

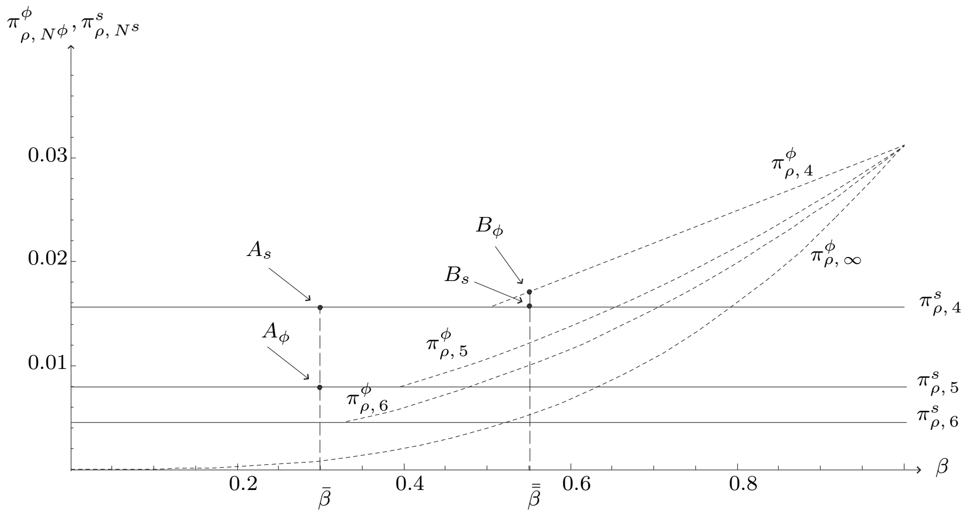


Figure 4: Alternative profits of the innovator with a patent/secrecy

Let us start with the analysis of case (a) where more firms are able to enter due to a patent. In our example case with moderate patent breadth, $\bar{\beta}$, we need to compare the profits A_s and A_ϕ. Obviously the innovator is better off with secrecy in this case, as then he realizes higher profits, $\pi^{s}_{\rho,4}(\bar{\beta}) > \pi^{\phi}_{\rho,5}(\bar{\beta})$. Things change in case (b) where we assumed a higher patent breadth, $\bar{\bar{\beta}}$. Here we have $N^s = N^\phi = 4$. Comparing the profits at points B_ϕ and B_s shows that in this case the innovator is better off with a patent, as this yields higher profits, $\pi^{\phi}_{\rho,4}(\bar{\bar{\beta}}) > \pi^{\phi}_{\rho,4}(\bar{\bar{\beta}})$.

The following Proposition summarizes our results so far.

Proposition 1 *Whenever the impact of the research use exemption is very low,* $1 \geq \alpha \geq \alpha^N$, *so that* $N^s \geq N^\phi$, *the innovator's protection decision depends solely on the protective effect of a patent. If* *(i)* $\beta \leq 2/N^s$ *the protective effect is low and the innovator always prefers secrecy*

(ii) $\beta > 2/N^s$ *the protective effect is high and the innovator always prefers to patent.*

The above Proposition covers the situation where the impact of a research use exemption is very low which leaves us to analyze the case where due to the required disclosure of the innovation and the capability of competitors to appropriate and use this information, more firms are able to enter the market with a patent, $N^{\phi} > N^s$ (case (a)). Again using Figure 4 it is easy to see that if the disclosure effect is so substantial that the number of firms in the market increases by patenting, it is nevertheless subject to patent breadth whether the innovator is better off with a patent.
Obviously the patent profit functions $\pi^{\phi}_{\rho, N^{\phi}}$ for $N^{\phi} > 4$ cross at least one secrecy profit function π^{ϕ}_{ρ, N^s} with $N^{\phi} > N^s$. We will refer to the intersection point as $\hat{\beta}_{N^s, N^{\phi}}$. As the patent profit functions are increasing in patent breadth, the innovator will prefer secrecy for relatively low values of patent breadth, $\beta \leq \hat{\beta}_{N^s, N^{\phi}}$, and he will prefer to patent for relatively high values of patent breadth, $\beta > \hat{\beta}_{N^s, N^{\phi}}$. Take for example the situation where with secrecy four firms would enter the market and with a patent six firms could enter due to the market entry costs reduction of the disclosure requirement. The relevant intersection point in this case is $\hat{\beta}_{4, 6}$. Whenever patent breadth is lower than $\hat{\beta}_{4, 6}$ the protective effect of the patent is too weak to overcompensate the negative disclosure effect and the innovator will prefer secrecy as this yields higher profits. If patent breadth exceeds the critical threshold, the protective effect overcompensates the disclosure effect and the innovator is better off with a patent. Generalizing these results we come to our next Proposition.

Proposition 2 *Whenever the impact of the research use exemption is sufficiently high,* $\alpha^N > \alpha \geq 0$*, so that* $N^{\phi} > N^s$*, the innovator will*

(i) prefer secrecy for all $\beta \leq \hat{\beta}_{N^s, N^{\phi}}$*,*

(ii) prefer to patent if and only if patent breadth exceeds a critical threshold $\beta > \hat{\beta}_{N^s, N^{\phi}}$*.*

A comparison of the critical thresholds for patenting in the theoretically alternative cases of a high and a low impact of a research use exemption leads us to

Corollary 1 *The propensity to patent is higher whenever the impact of a research use exemption is weak.*

The above Corollary is easily proved as $2/N^s < \hat{\beta}_{N^s, N^\phi}$.

Whenever the innovator's competitors have a very low capability of appropriating the information disclosed by patenting, the negative disclosure effect is mitigated and the existence of a statutory research use exemption has no impact on the propensity to patent. If the capability to appropriate information is high, the disclosed information becomes more profitable for competitors and the research use exemption in this case has an impact on the propensity to patent: Due to a strong disclosure effect the propensity to patent decreases.

Note that the introduction of a statutory research use exemption would have the same effects as moving from a scenario where the research use exemption has a weak impact on the propensity to patent to a scenario where it has a strong impact. This enables us to relate the finding stated in the above Corollary to the ongoing discussion of implementing a statutory research use exemption in several countries. Although the implementation of a research use exemption may spur technological progress by simplifying the research of follow-on inventors (see e.g. *Nagaoka*, *Aoki* (2007) for an economic analysis that comes to this conclusion), at the same time it may lead to a substantial decrease of the propensity to patent. Therefore it could be that the overall effect of introducing a research use exemption yields a negative effect on technological progress.

3 Empirical Investigation

Summarizing, the theoretical analysis comes to the conclusion that when a statutory research use exemption is in place, an innovator's decision between a patent and secrecy is mainly driven by two factors: the appropriation capability of competitors, α, and initial market entry costs f_s. A variation of these factors may intensify the impact of the research use exemption and may thereby lead to a decreasing propensity to patent.
The first of these factors, appropriability, drives the impact of the research use exemption, i.e. the strength of the disclosure effect. The effect of this parameter in theoretical terms is linked to the height of initial market entry costs, f_s. Whenever α decreases, i.e. appropriability increases, market entry costs with a patent, $f_\phi = \alpha f_s$, decrease. This in turn leads to an increasing number of firms that are able to enter the market despite a patent. This negative effect of patenting then leads to a decreasing propensity to patent.

The second factor, market entry costs, has countervailing effects on the propensity to patent. Additionally to the combined effect with the capability to appropriate the mandatorily disclosed information, αf_s, two sole effects exist. Concerning the combined effect, increasing market entry costs lead to a situation where less firms are able to enter in the case that the innovator patents so that the propensity to patent increases.
Next we turn to the sole effects of market entry costs on the propensity to patent. Interestingly one of the sole effects mitigates the negative disclosure effect of a patent while the other weakens its protective effect. The latter effect stems from the fact that increasing market entry costs form a natural barrier to entry, so that patenting, i.e. establishing own, costly entry barriers, becomes obsolete. In terms of the theoretical model, increasing market entry costs lead to an increase of the critical threshold for a restrictive patent, β^{res}. This means that the minimum strength of protection which would induce a positive protective effect for the innovator increases. As a consequence the parameter space of patent breadth, β, where patenting potentially leads to a protective effect which can overcompensate the possible negative effect from mandatory disclosure, becomes narrower. Through this mechanism increasing market entry costs weaken the protective effect and thereby have a negative effect on the propensity to patent. Besides this weakening impact on the protective effect, increasing market entry costs also mitigate the disclosure effect. This indirect effect evolves from the critical threshold concerning appropriability, α^N. As α^N decreases whenever market entry costs increase, the parameter space where the research use exemption has no impact grows larger and thus, as the disclosure effect is mitigated, the propensity to patent increases.
From the theoretical model it is obvious that market entry costs define the number of firms operating in the market, $N(f)$, $\partial N(f)/\partial f < 0$. For this reason, the above effects can be easily reformulated on the basis of the number of competitors operating in the market. This characteristic of the theoretical model will serve us as a plausability check in the empirical analysis.
Before we proceed with the empirical investigation it should be noted that a basic difference between the theoretical and the empirical analysis is the fact that in the theoretical model the cases where either the research use exemption has a strong or a weak impact were excluding cases. Naturally in reality both cases prevail at the same time. Given that a statutory research use exemption exists in a country, in some markets the capability to appropriate information may be higher than in others. Due to this firms face differing impacts of the research use exemption depending on the capability to appropriate disclosed information in their respective market.
The empirical analysis proceeds with the deduction of three hypotheses from

the theoretical model in Section 3.1. Subsequently we will turn to the definition of our data sample and the implementation of the variables in Section 3.2 before we turn to our empirical results in Section 3.3.

3.1 Hypotheses and their Empirical Implementation

As pointed out above, the theoretical model identifies two main parameters as crucial for the propensity to patent: the appropriation capability of competitors, α, and initial market entry costs f_s. In the above summary the influence of increasing market entry costs on the propensity to patent was divided into two sole effects and a combined effect with the appropriation capability, αf_s. These effects influence the propensity to patent in opposing directions. Our first hypothesis is concerned with the sole effects of market entry costs.

Although the theoretical model reveals the complex mechanisms of the effects that increasing market entry costs induce, it does not allow for a conclusion on which of the effects of increasing market entry costs is strongest: The combined effect αf_s inducing a positive effect on the propensity to patent, the mitigating impact on the disclosure effect inducing a positive effect on the propensity to patent or the weakening impact on the protective effect inducing a negative effect on the propensity to patent. Nevertheless, to formulate an adequate hypothesis we need to determine a possible scenario. Economic intuition leads us to the conclusion that an innovator will never patent if patenting does not induce any positive protective effect. At the same time the existence of a disclosure effect does not per se exclude patenting as a profitable strategy. Thus, we propose that the weakening effect of market entry costs on the protective effect is decisive for the overall effect. This leads to the following Hypothesis.

Hypothesis 1 *The propensity to patent decreases when market entry costs increase.*

Note that the above Hypothesis proposes that the weakening effect of market entry costs on the protective effect even overcompensates the combined effect of market entry costs and the capability to appropriate the mandatorily disclosed information. This combined effect, αf_s, captures the impact of the research use exemption on the propensity to patent as it reflects to what extent market entry costs are reduced by the disclosure effect of patenting. Whenever the capability to appropriate is low (α is high), the negative effect of the required disclosure is mitigated as the revealed information is nearly useless for the innovator's competitors. Due to their respective prevailing competitive environment they are not able to appropriate and use the disclosed information, i.e. by patenting market entry costs of the innovator's competitors are only slightly reduced. This low impact of the research use exemption obviously has a positive effect on the propensity to patent. Whenever the capability to appropriate is high (α is low), patenting has a strong negative effect as the mandatorily disclosed information can be very well appropriated by competitors, i.e. market entry costs are strongly reduced making market entry profitable for more firms. Summarizing the mechanisms induced by this combined effect we can state that a decreasing capability to appropriate - by weakening the impact of the research use exemption - has a positive effect on the propensity to patent. This gives us the second hypothesis.

Hypothesis 2 *Whenever the impact of the research use exemption decreases, i.e. the negative disclosure effect becomes weaker, the propensity to patent increases.*

As stated earlier we will use the theoretically imposed interdependence of market entry costs and the number of firms operating in a market as a plausability check for our empirical estimation. Due to this interrelation it must be that when we look at the number of firms instead of market entry costs, the mechanism described in Hypothesis 2 can be reformulated as stated in the following hypothesis.

Hypothesis 3 *Whenever the capability to appropriate information is high, an increasing number of firms leads to a decreasing propensity to patent.*

Hypotheses 2 and 3 show the two sides of the same coin.

We translate these theoretical results into the following empirical equation:

$$P = \beta_0 + \beta_1 N^s * AP + \beta_2 f_s + \beta_3 f_s * AP + \beta_4 N^s + \beta_5 AP + Controls + \epsilon,$$

where P denotes the patenting decision, N^s the number of firms operating in the market (initial market structure), AP reflects the capability to appropriate disclosed information and f_s are the cost of market entry with secrecy. To capture the interrelations between appropriability and market entry costs as well as between appropriability and the number of firms, we include the interaction terms $N^s * AP$ and $f_s * AP$.
In the previous section we extensively discussed that we expect the single effect of f_s to be negative: as market entry costs with secrecy rise, the barrier to entry increases so that the usefulness of a patent diminishes, resulting in a decrease of the propensity to patent. However, the interaction term

with appropriability, $f_s * AP$, which reflects the effect of market entry costs accounting for a high impact of the research use exemption, should have a positive effect on patenting.

3.2 Sample and Variable Definition

The basis for our empirical analysis is data from 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 on behalf of the Federal Ministry of Education and Research. 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 to the Community Innovation Survey (CIS). Our empirical investigation is based on 831 firms.

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

A central assumption to our theoretical analysis is that the successful inventor commercializes his invention immediately, thereby opening a new market. To implement this in empirical terms, we restrict our data to firms which indicate that their innovation activities resulted in the establishment of new markets. Further we only include innovating firms.

In the restricted data set we have 45% of firms indicating that they applied for a patent in the considered time period. To capture the ability to appropriate information, AP, we use a variable reflecting the easiness of substitutability as a proxy. Descriptive statistics reveal that nearly 70% of firms find that their competitive environment is characterized by easy to substitute products. Two crucial interdependent parameter of the theoretical model are market entry costs and the number of firms operating in a market. Neither is straightforward to implement empirically. To find a measure for the number of firms we use a categorical variable provided my the MIP displaying the ranges of the number of competitors as perceived by a firm.[11] We thus use a dummy variable *large number of firms* which indicates that a respondent firm has more than 15 competitors. In our data set this is the case for 16% of all firms.

In default of a corresponding measure for market entry costs in MIP 2005,

[11] The ranges are defined as follows: *no competitors*, *1 to 5 competitors*, *6 to 15 competitors* and *more than 15 competitors*.

we refer to a firm's perception on whether it's market position is threatened by the entry of new rivals as a proxy for initial market entry costs, f_s. We argument that whenever a firm perceives its market position as strongly threatened by market entry, initial market entry costs are low. This is found relevant by 10% of firms.

Table 1: Descriptive Statistics

	Mean	**Std. Dev.**	**Min**	**Max**
patent	0.442	0.497	0	1
market entry costs	0.105	0.306	0	1
large number of firms	0.158	0.365	0	1
appropriability	0.687	0.464	0	1
*MEC * appro.*	0.084	0.278	0	1
*firms * appro.*	0.120	0.326	0	1
log(employees)	4.305	1.673	0	9.077
human capital	0.243	0.255	0.000	1.000
R&D intensity	0.065	0.273	0.000	6.427
capital intensity	0.109	0.272	0.000	4.554
EU	0.584	0.493	0	1
non_EU	0.409	0.492	0	1
customer power	0.300	0.458	0	1
cooperation	0.368	0.483	0	1
east	0.321	0.467	0	1

As described above we include the interaction terms *firms * appro.* and *MEC * appro.* Descriptive statistics show that the first, which captures the change in the number of firms whenever appropriability is high, is relevant for 12% of all firms while the latter, which reflects the perceived market entry costs if appropriability is high, is relevant for 8% of firms.

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

3.3 Empirical Results

To test the influence of a varying impact of a research use exemption on the propensity to patent we estimate a probit model and calculate marginal effects evaluated at the sample means. The marginal effects of the interaction terms are calculated according to *Cornelißen*, *Sonderhof* (2009). Results are presented in Table 2.

According to our first Hypothesis a decrease of market entry costs should result in a higher probability to patent, i.e. if a high threat of entry is perceived, the propensity to patent should increase. As we calculate marginal effects, the negatively significant effect of market entry costs reveals that the partial effect of market entry costs is negative. This confirms Hypothesis 1 so that we have empirical evidence supporting our initial supposition that the weakening effect of market entry costs on the protective effect of a patent overcompensates all other effects. This points to the fact that actually market entry costs as a natural barrier to entry form sufficient protection to make patenting obsolete.

Concerning the combined effect of market entry costs and the capability to appropriate disclosed information, we find a positive marginal effect of the interaction term $MEC * appro$. This confirms our second Hypothesis. The interpretation is quite straightforward. Recall from the theoretical model how αf_s drives the negative effect of patenting, i.e. the loss of information. With secrecy, market entry costs are given by f_s, by patenting they are reduced to $f_\phi \equiv \alpha f_s$. Thus the disclosed information amounts to $\Delta f = f_s - \alpha f_s$.

[12] Note that while capital intensity is taken from the year 2002 due to the lack of adequate data we could not use a lagged instrument variable for R&D expenditures. We try to mitigate the resulting problem of endogeneity by instead using the normed variable R&D activities per sales.

For the empirical analysis we divided the effects imposed by market entry costs into single effects and the combined effect. Hypothesis 2 focusses on the latter effect, so right now we are concerned with the interpretation of the last term, αf_s. The higher αf_s, the lower is the loss of information. Given that appropriability is high, i.e. the research use exemption has a strong impact, increasing market entry costs lead to a lower loss of information and thus the effect on the propensity to patent is positive. In this case market entry costs serve as a mitigation for the impact of the research use exemption. Empirical evidence supports this theoretical finding that a decreasing impact of the research use exemption leads to an increasing propensity to patent.

Concerning our last hypothesis, which serves us as a plausability check for the preceding hypothesis, we find that the interaction term $firms * appro.$ has a negatively significant effect. As market entry costs and the number of firms operating in a market are negatively interrelated, i.e. the higher market entry costs are, the less firms are able to enter the market, the effects of an increase of either parameter should reveal the opposite effect. As the interaction term $MEC * appro.$ revealed a positive effect, we expected the interaction term $firms * appro.$ to reveal a negative effect. Hypothesis 3 is thus confirmed.

Concerning our control variables we find that larger firms, firms with an increasing percentage of highly qualified employees, firms with an augmenting R&D intensity and firms with R&D cooperations have a higher propensity to patent. Contrasting this, firms located in the Eastern part of Germany have a lower probability to patent. Finally, firms mainly competing with enterprizes outside Europe have a higher propensity to patent. As we can only observe that firms file a patent but not where they filed a patent, there may be two explanations for this finding. First, they file patents at their domestic patent office (i.e. the German or European Patent Office) in order to secure their domestic markets with respect to foreign entrants. Second, firms may file their patent in their main competitors' countries in order to secure their own market entry. For example, if an innovative German firm tries to enter the US market, without a patent portfolio it may have huge difficulties in establishing its business because it will most probably be sued by US firms in the same field. Both effects may exist at the same time. This reasoning does not contradict the non-significant effect of a main competitors' base in the EU. The EU tries to establish a harmonization of the member countries' patent laws which is not yet accomplished but is already in progress. As a result, there is de facto no difference between the German and the European product market with respect to patent protection.

Table 2: Results of the Patenting Decision Estimation

	Marginal Effect	**Standard Error**
appropriability	0.002	0.044
market entry costs	-0.142**	0.062
large number of firms	-0.056	0.058
*MEC * appro.*	0.305***	0.106
*firms * appro.*	-0.329**	0.143
log(employees)	0.112***	0.017
human capital	0.246**	0.109
R&D intensity	1.405***	0.303
capital intensity	-0.185	0.147
EU	0.070	0.049
non_EU	0.082*	0.048
customer power	-0.059	0.044
cooperation	0.234***	0.044
east	-0.105**	0.043
industry dummies	*included*	
Log likelihood	-372.83	
McFadden's adjusted R^2	0.346	
$\chi^2(all)$	395.00***	
$\chi^2(ind)$	62.59***	
Number of observations	831	

*** (**, *) 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 *Cornelißen*, *Sonderhof* (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.

4 Concluding Remarks

Our aim was to provide a framework in which the decision of an innovator between a patent and secrecy could be analyzed in the light of a varying impact of a statutory research use exemption from patent infringement. Although a statutory research use exemption from patent infringement is in place for all firms located in a respective country, we argument that the impact of the research use exemption may vary subject to the capability of firms to actually appropriate and use the information disclosed in a patent application. To capture the positive and negative effects of patenting we introduced the strategic protection decision of an innovator into a model of horizontally differentiated products. As here market entry costs are decisive for the number of firms which are able to enter, the impact of the research use exemption could be substantiated as a decrease of the initial market entry costs. Whenever the innovator patents, asymmetry is introduced in the circular market, so that it becomes crucial in which neighborhood a firm is situated. Our main theoretical results are driven by the impact of the research use exemption: Either the influence of the research use exemption is weak so that if the innovator patents the number of firms able to enter the market is left unchanged or the impact of the research use exemption is strong so that the number of firms increases if the innovator patents. Whenever the research use exemption has a weak impact, the patenting decision is solely driven by the protective effect – the broader a patent is, the higher is the innovator's propensity to patent. Other than this, whenever the research use exemption has a strong impact, we find that the propensity to patent decreases. Although we are not able to investigate the issue of introducing a statutory research exemption in empirical terms due to the lack of data, we can nevertheless state that based on the theoretical model we come to the conclusion that the introduction of a research use exemption might lead to a substantial decrease of the propensity to patent.

The empirical investigation of three hypotheses derived from the theoretical model support our theoretical findings. The existence of a statutory research use exemption from patent infringement has a substantial impact on the propensity to patent. Whenever the negative effect of patenting gains weight due to a high capability of competitors to appropriate disclosed information the existence of a research use exemption decreases the propensity to patent. In empirical terms we captured this by including an interaction term consisting of a measure for the impact of the research use exemption and market entry costs. With a high impact of the research use exemption increasing market entry costs increase the propensity to patent. Regarding the overall effect of market entry costs we could confirm our hypothesis that the prevailing effect of increasing market entry costs on the propensity to patent is negative. This result is in line with economic intuition – when the natural barriers to market entry increase, it becomes obsolete to establish own, costly entry barriers and thus the propensity to patent decreases. Finally, we can add to the discussion whether a research use exemption is worthwhile to introduce. *Nagaoka*, *Aoki* (2007) find that the establishment of a research use exemption may spur the research of follow-on inventors and hence contribute to the technological progress. We show that a research use exemption deters the propensity to patent and as a consequence may impede technological progress. Which effect prevails is decisive for answering the question whether a research use exemption should be implemented and is subject to further research.

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