Discussion Paper No. 12-010

Giving Away the Game?
The Impact of the Disclosure Effect on the Patenting Decision

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Non-technical Summary

Patenting is widely acknowledged as a major tool to reward innovative firms for their efforts in research and development (R&D). However, many firms decide to keep their inventions secret. Understanding a patent according to the original sense of patent law, it basically has 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 (new) knowledge by requiring the disclosure of the invention to society.

Most of the economic literature implicitly assumes that the disclosure requirement has no impact on the protective effect of a patent and consequently on the propensity to patent. Or more precisely it is assumed that the disclosure requirement is only effective after a patent's expiry. This implies that the use of the disclosed invention for subsequent innovation is strongly limited during the patent term. But this approach neglects the possibility of inventing around the precedent invention and entering the market with an improved – and oftentimes even non-infringing – product.

In this paper we take a closer look at the disclosure effect and analyze whether firms take it into account when deciding between patenting and keeping secret. Assuming that competitors may benefit from the disclosed information in different ways we want to answer the question how the extent of the disclosure effect influences an innovator's propensity to patent. To this end, we present a theoretical model and test its predictions empirically. The main theoretical and empirical result of this paper is that the disclosure effect of patenting plays a substantial role in firms' patenting decision in that a higher impact of the disclosure effect decreases the firms' propensity to patent.

This topic also has a policy dimension. If policymakers decide to implement some changes to patent law which would result in strengthening the disclosure effect of patenting, e.g. by implementing or extending a research use exemption, such actions should take into account that this could cause an increasing reluctance of firms to patent. Hence, more newly created knowledge would be kept secret. This may have further detrimental effects on the economy's overall innovativeness and future productivity.

Das Wichtigste in Kürze

Die Hauptfunktion von Patenten ist, innovative Unternehmen für ihre Forschungstätigkeit zu entlohnen. Allerdings wird beobachtet, dass Unternehmen ihre Erfindungen häufig geheim halten. Versteht man ein Patent im ursprünglichen Sinne, so hat es im Wesentlichen zwei Funktionen: Die erste ist, dass das Patent ein effektives Mittel ist, um für eine gewisse Zeit Imitationen zu unterbinden. Diese Schutzwirkung eines Patents versetzt den Erfinder in die Lage, sich die (monetären) Rückflüsse aus seiner Forschungstätigkeit anzueignen. Die zweite Funktion eines Patents ist es, durch Offenlegung der Erfindung zur Wissensdiffusion beizutragen.

Ein Großteil der Literatur nimmt implizit an, dass die Offenlegungspflicht keinen Einfluss auf den Schutzeffekt eines Patentes hat und somit auch keinen Effekt auf die Patentneigung. Oder präziser formuliert, sie nimmt an, dass die Offenlegungspflicht nur nach dem Ablauf des Patentschutzes wirksam wird. Dies impliziert, dass während der Patentlaufzeit die Nutzung von offengelegten Erfindungen für nachgelagerte Innovationen stark eingeschränkt ist. Dieser Ansatz vernachlässigt aber die Möglichkeit des "Inventing Around" und damit des Marktzutritts mit einem verbesserten Produkts, das oft sogar das Patent nicht verletzt.

In diesem Papier betrachten wir den Offenlegungseffekt näher und untersuchen, ob die Unternehmen diesen in Betracht ziehen, wenn sie sich zwischen Patentieren und Geheimhaltung entscheiden. Da Wettbewerber auf unterschiedliche Weise von der offengelegten Information profitieren können, wollen wir die Frage beantworten, wie das Ausmaß des Offenlegungseffekts die Patentneigung eines Unternehmens beeinflusst. Wir präsentieren ein theoretisches Modell und testen seine Vorhersagen empirisch. Das wesentliche Ergebnis der theoretischen und empirischen Untersuchungen ist, dass die Offenlegungspflicht eine wichtige Rolle in der Patententscheidung von Unternehmen spielt, indem ein stärkerer Einfluss des Offenlegungseffekts die Patentneigung senkt.

Dieses Thema hat auch eine politische Dimension. Sollten Entscheidungsträger Änderungen am Patentgesetz vornehmen wollen, die zu einer Stärkung des Offenlegungseffektes führen würden, z.B. durch die Einführung oder den Ausbau eines Versuchsprivilegs, sollten diese Entscheidungen berücksichtigen, dass sich dann mehr Unternehmen sich dafür entscheiden, ihre Erfindungen geheimzuhalten. Dies könnte weitere nachteilige Auswirkungen auf die Innovationskraft und künftige Produktivität einer Volkswirtschaft nach sich ziehen.

Giving Away the Game? The Impact of the Disclosure Effect on the Patenting Decision

Diana Heger[‡*] and Alexandra K. Zaby[†*]

Abstract

This article explores the propensity to patent in the light of the disclosure effect. Unlike earlier approaches concerned with the patenting decision, we take into account that a disclosure effect may decrease the merits of patenting by facilitating inventing around the patent for competitors. In our theoretical model, we find that the disclosure effect – 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: patenting decision, secrecy, disclosure requirement, patent breadth, horizontal product differentiation, circular city

JEL Classifications: L13, L24, O34

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1 Introduction

In the literature, patenting is widely acknowledged as a major tool to reward innovative firms for their efforts in research and development (R&D). However, many firms decide not to patent their inventions. Understanding a patent according to the original sense of patent law, it basically has 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 (new) knowledge by requiring the disclosure of the invention to society. We assume that the disclosure of knowledge inherent to a patent system only has an impact on the patenting decision if the disclosed information is relevant for the patentee's competitors. We aim to tackle the question how the extent of the disclosure effect influences an innovator's propensity to patent. To this end, we present a theoretical model from which we draw predictions. Those predictions are then tested empirically.

To be able to analyze the impact of the disclosure effect on the propensity to patent we need a setting in which patent protection is imperfect. Our theoretical analysis builds on a model presented in Zaby (2010). To capture imperfect patent protection, the decision to patent is introduced into a model setting with horizontally differentiated products where competitors may enter the market despite of a patent, i.e. they are able to successfully invent around the patent.[1] As the mandatorily disclosed information in a patent specification is accessible and usable for the innovator's competitors, the relevancy that this information has for their respective research activities influences the easiness of inventing around the patent.[2] The inventor

[1]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.

[2]By assuming that the information disclosed in a patent specification is accessible and usable by competing firms for own research purposes, we implicitly postulate a legislative environment where a *research use exemption* is in place. This is the case in most of the

has to balance this negative disclosure 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 disclosure effect the higher is the propensity to patent.

Subsequent to the theoretical analysis we investigate our findings empirically. The data basis is the 2005 survey of the Mannheim Innovation Panel (MIP) provided by the Centre for European Economic Research (ZEW) in Mannheim. In this year, besides the common innovation indicators the MIP also collects information on the firms' competitive environment. Using this data set our empirical model reflects the propensity to patent depending on the extent of the disclosure effect.

To our best knowledge, besides own previous work, no theoretical literature and only very sparse empirical literature exists which analyzes the impact of the disclosure effect on patenting activity. Most of the economic literature implicitly assumes that the disclosure requirement has no impact on the protective effect of a patent and consequently on the propensity to patent. Or more precisely it is assumed that the disclosure requirement is only effective after a patent's expiry. This implies that the use of the disclosed invention for subsequent innovation is strongly limited during the patent term. But this approach neglects the possibility of inventing around the precedent invention and entering the market with an improved – and oftentimes even non-infringing – product. Our work relates to several contributions which also consider that patenting has a disclosure effect In the work of Scotchmer and Green (1990) and Erkal (2005) the extent of the disclosure requirement remains fixed whereas Bhattacharya and Guriev (2006), Aoki and 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 and Spiegel (2009) focus on the influence of alternative filing procedures on

European countries; e.g. in Germany § 11 PatG defines a broad research use exemption which includes all non-commercial research and trial activities as well as the research *on* the patented subject. Research *with* the patented matter remains an infringing action. In the U.S. a research use exemption exists but its practical and legal implementation provokes uncertainty for firms relying on patented knowledge for their research activities. In the absence of a *research use exemption* the proposed model simplifies to the case where the relevancy variable (defined below) is set to unity.

the propensity to patent, Bhattacharya and Guriev (2006) analyze the choice of alternative licensing contracts and Harter (1994) due to restrictive model assumptions 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 deduction of our predictions based on the theoretical model, the data description and the empirical investigation of our theoretical findings are presented in Section 3. Section 4 concludes. Proofs can be found in Zaby (2010).

2 The Model

Assume that one of n firms engaged in an innovation race has successfully accomplished a drastic product innovation which it brings to the market after deciding whether to protect it by a patent or by secrecy. The innovator will be monopolist in the new market as long as no other firm successfully innovates. 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, denoted by the index ν, is located at $x_\nu = 0$. 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]

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

The structure of the model is as follows: on the first stage of a three-stage game the innovator decides whether to patent his innovation or to keep it secret. Denoting the strategy *patent* by ϕ and secrecy by s we can summarize these strategy choices by $\sigma_\nu^1 = \{\phi, s\}$. 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 $x_\nu = 0$, this point on the circle defines the middle of the protected product space, see Figure **??**. From there patent protection covers $\beta/2$ of the neighboring product space on either side of the innovation.

< *Insert Figure* **??** *about here.* >

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 interpreted as the barriers to entry that firms need to overcome to complete their so far unsuccessful research projects. They may consist of non-monetary costs, e.g. time, search costs for highly skilled researchers, resources dedicated to the analysis of the expected demand, or monetary investments, e.g. salaries for researchers, money spent for research equipment. By investing the fixed costs of market entry, firms can 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, $\beta < 1$.

If the information included in the patent application is relevant and thus useful for a rival firm, achieving the capability to enter the new market is easier and becomes less costly. To capture this theoretically, we assume that market entry costs decrease by patenting. Denoting market entry costs in the

[4]Contrasting this assumption patent breadth can also be interpreted as a strategic decision variable of the innovator, see Yiannaka and Fulton (2006).

case of secrecy by f_s, in the case of a patent they decrease to f_ϕ with $f_\phi = \alpha f_s$, $0 \leq \alpha \leq 1$, where α is a measure for the extent of the disclosure effect – the lower α, the higher is the disclosure effect. The difference between market entry costs with and without a patent yields the amount of mandatorily disclosed information, $\Delta f = (1-\alpha) f_s$. While it may well be that competitors very intensively profit from the disclosed information (α is low), it could also be that the opposite is the case and the information is useless (α is high).[5]
If α is set to one, the disclosure effect is absent, $f_\phi = f_s$, i.e. if the disclosed information is irrelevant for competitors, disclosure has no effect on their market entry costs.
Concerning the location of firms, we will use the well established Principle of Maximum Differentiation (see Salop (1979)): Firms will locate as far away from each other as possible to soften price competition.[6] If secrecy prevails firms will locate equidistantly with distance $1/N^s$ on the unit circle, where N^s is the number of firms operating in the market with secrecy. With a patent the non-patentee firms can no longer freely locate on the unit circle. 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, $\sigma^3_{\nu,N} = \{p\}$.

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, $\sigma^1_\nu = \{s\}$,

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

[5] This interpretation of α is related to the term "appropriability" that Kamien and Zang (2000) used for the capability of firms to appropriate the unintended R&D spillover flows from competing firms. While firms in their setting are able to endogenously determine their ability to appropriate in our model "relevancy" is a purely exogenous variable which is subject to the respective market for the innovation.

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

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

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

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.[7]
Standard computations then yield equilibrium prices,

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

and profits

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

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

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

as he does not face market entry costs.

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

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 disclosure effect in the respective market. If the non-patentee firms are able to use the disclosed information to a rather large extent (α is low), 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,

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

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

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 ($\beta \geq 1/2$).

< *Insert Figure* **??** *about here.* >

In the case that the innovator has patented, 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.[8]

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

[8]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 $j+(n^u-3)/2$.

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 $\hat{x}_{z,y}$. 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 firm 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 the disclosure effect on the propensity to patent that even if the innovator patents, 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 it might be that more firms are able to enter with patent protection than with secrecy.

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

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 $\sigma_\nu^1 = \{\phi\}$

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 more complex. In the following we will briefly outline the derivation of the critical thresholds of market entry costs f_ϕ that yield varying market structures.[9] 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 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 e.g. the subscript 4 stands for the case $N^\phi = 4$ and $\pi_{\nu,4}$ denotes the profit of the patentee in the case that 4 firms operate in the market.

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 profit(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. Recall that due to patent protection, no rival firm is able to enter in this area. 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

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

[9]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 disclosure effect on the propensity to patent, so we omit these cases here.

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, $\sigma_\nu^1 = \{\phi, s\}$. 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 disclosure requirement linked to a patent. The disclosure effect might lead to decreasing market entry costs. This may possibly make market entry profitable for a larger number of firms than with secrecy. Recall that we defined the reduction of market entry costs as $\Delta f = (1-\alpha)f_s$.
In the following we need to distinguish two cases: (i) the disclosure effect is so strong (i.e. α is so low) that the competitors are able to use a substantial part of the disclosed information and (ii) the disclosure effect is rather weak (i.e. α is high) due to the fact that the relevancy of the disclosed information is low. 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 $N^\phi > N^s$. 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 the strength of the disclosure effect, $\alpha < f_{N+1}/f_s$, which defines whether the disclosure effect has an impact on the market structure or not. Defining $\alpha^N \equiv f_{N+1}/f_s$ we can state that whenever $\alpha^N > \alpha \geq 0$ the disclosure effect has an impact on the propensity to patent as it enables more firms to enter the market. In case (ii) a weak disclosure effect leads to an only minor reduction of market entry costs so that $N^\phi = N^s$. Technically speaking, the disclosure effect has no impact whenever $1 \geq \alpha \geq \alpha^N$.
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.[10]

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

< Insert Figure **??** *about here. >*

Obviously the curves 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 in Figure **??**, $N^\phi = 5$ firms would enter the market with a patent while with secrecy $N^s \geq 5$ could enter in this area. Obviously, given market entry costs and patent breadth, a patent may lead to two different cases:[11]

(a) due to a dominant disclosure effect more firms are able to enter with a patent, i.e. the disclosure effect has an impact on the market structure;

(b) due to a dominant protective effect the number of firms is not changed by patenting, i.e. the disclosure effect has no impact on the market structure.

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 where $N^s = 4$. By patenting the disclosure effect reduces market entry costs to $\alpha\bar{f}_s$. In this example case the disclosure effect has an impact as by patenting we move to point A' where $N^\phi = 5$ firms are able to enter (case (a)). Keeping the strength of the disclosure effect fixed and increasing patent breadth to $\bar{\bar{\beta}}$, we are at point B where again $N^s = 4$ firms can enter with secrecy. By patenting market entry costs are reduced by the same amount as before so we move to point B'. In this case the disclosure effect has no impact as with $N^\phi = 4$ firms entering the market structure is left unaffected by patenting. Consequently, opposing the case with a low protective effect due to a low β, a strong protective effect may overcompensate the impact of the disclosure effect (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).

[11]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.

< *Insert Figure* **??** *about here.* >

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, $\pi^s_{\nu,4}(\bar{\beta}) > \pi^\phi_{\nu,5}(\bar{\beta})$. 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, $\pi^\phi_{\nu,4}(\bar{\bar{\beta}}) > \pi^s_{\nu,4}(\bar{\bar{\beta}})$.

The following Proposition summarizes our results so far.

Proposition 1 *Whenever the disclosure effect has no impact,* $1 \geq \alpha \geq \alpha^N$*, 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 disclosure effect has no impact, which leaves us to analyze the case where due to the required disclosure of the innovation and the relevancy of this information for competitors, more firms are able to enter the market with a patent, $N^\phi > N^s$ (case (a)). Again using Figure **??** 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 π^ϕ_{ν,N^ϕ} for $N^\phi > 4$ cross at least one secrecy profit function π^ϕ_{ν,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 4 firms would enter the market and with a patent 6 firms could enter due to the market entry costs reduction imposed by 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 disclosure effect has an impact, $\alpha^N > \alpha \geq 0$, 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 Proposition 1 and 2 leads us to

Corollary 1 *The propensity to patent is higher whenever the impact of the disclosure effect is weak.*

Whenever the innovator's competitors do not want to use the disclosed information due to its minor relevancy, the negative disclosure effect is mitigated and has no impact on the propensity to patent. If the disclosed information becomes more profitable for competitors the disclosure effect has a detrimental impact on the propensity to patent.

3 Empirical Investigation

Summarizing, the theoretical analysis comes to the conclusion that an innovator's decision between a patent and secrecy is mainly driven by two factors: the relevancy of the disclosed information for competitors, α, and initial market entry costs f_s. A variation of these factors may intensify the disclosure effect and may thereby lead to a decreasing propensity to patent.
Recall that it is the market-specific variation of the relevancy of the disclosed information, α, which drives the extent of the disclosure effect. The more intensively competitors benefit from the information disclosed in the patent

specification, i.e. the lower is α, the higher is the extent of the disclosure effect. This effect leads to a change in market entry costs for the patentee's rivals by the amount $\Delta f \equiv f_s - \alpha f_s$. According to Propositions 1 and 2 the propensity to patent is higher, the lower this disclosure effect is.
When looking at market entry costs in the case of a patent, the relevancy of the disclosed information α, in theoretical terms, is always linked to the height of initial market entry costs, f_s. Whenever α decreases, market entry costs in the case of a patent decrease, $\partial f_\phi / \partial \alpha > 0$. 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.
Besides the combined effect αf_s, initial market entry costs f_s itself have countervailing effects on the propensity to patent. One of these effects clearly is in line with economic intuition as it 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 our theoretical model, increasing market entry costs lead to an increase of the critical threshold for a restrictive patent, β^{res}. This leads to an increase of the minimum strength of protection which induces a higher positive protective effect of a patent. As a consequence the parameter space of patent breadth, β, where patenting potentially leads to a protective effect strong enough to overcompensate the negative effect from mandatory disclosure, becomes narrower. Through this mechanism increasing market entry costs weaken the protective effect and thereby have a negative impact on the propensity to patent. Besides this negative effect market entry costs may also positively influence the propensity to patent. This evolves from the critical threshold concerning the impact of the disclosure effect, $\alpha^N \equiv f_{N+1}/f_s$. As α^N decreases whenever initial market entry costs increase, the parameter space where the disclosure effect has no impact on the resulting market structure grows larger and thus the propensity to patent increases. 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 disclosure effect has a strong or a weak impact were excluding cases. Naturally in reality both cases prevail at the same time. In some markets the relevancy of the disclosed information may be higher than in others.
The empirical analysis proceeds with the deduction of three predictions 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 Predictions of the Theoretical Model and their Empirical Implementation

As pointed out above, the theoretical model identifies two main parameters as crucial for the propensity to patent: the relevancy of the disclosed information for 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 countervailing effects.
The theoretical model does not allow for a conclusion on which effect of market entry costs is strongest. Therefore we formulate two opposing predictions and leave it to the empirical investigation to identify the prevailing effect of market entry barriers on the propensity to patent.

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

Prediction 2 *The propensity to patent* ***increases*** *when market entry costs increase.*

Note that the above Predictions propose that the weakening effect of market entry costs on the protective effect may even overcompensate the combined effect αf_s, which captures the impact of the disclosure effect on the propensity to patent. On the one hand, whenever the relevancy parameter is low, the negative effect of the required disclosure is mitigated as the revealed information is nearly useless for the innovator's competitors. In this case, due to their respective competitive environment, competitors are not able to use the disclosed information, i.e. if the innovator chooses to patent, their market entry costs are only slightly reduced. This low impact of the disclosure effect obviously has a positive effect on the propensity to patent. On the other hand, whenever the relevancy parameter is high, patenting has a strong negative effect, as the mandatorily disclosed information has a high relevancy for competitors' innovation activities, i.e. market entry costs are strongly reduced so that market entry becomes profitable for more firms. Summarizing we can state that a decreasing relevancy of the information disclosed by patenting has a positive effect on the propensity to patent. This gives us the third prediction.

Prediction 3 *Whenever the impact of the disclosure effect decreases, the propensity to patent increases.*

We translate these theoretical results into the following empirical equation:

$$P = \beta_0 + \beta_1 MEC + \beta_2 REL + \beta_3 REL * MEC + Controls + \epsilon,$$

where P denotes the patenting decision, MEC are the initial costs of market entry, and REL reflects the relevancy of the disclosed information for the patentee's competitors.
To capture the disclosure effect in empirical terms we include the combined effect $REL * MEC$, as the theoretical model proposes that this reflects the impact of the disclosure effect on the propensity to patent.
In the previous section we extensively discussed that we expect the single effect of MEC to be ambiguous: as initial market entry costs rise, the barriers to entry increase so that the usefulness of a patent diminishes, resulting in a decrease of the propensity to patent. However, the interaction term with relevancy, $REL * MEC$, which reflects the impact of the disclosure effect, should reveal a negative effect on patenting.

3.2 Sample and Variable Definition

The basis for our empirical analysis is the Mannheim Innovation Panel (MIP) of the year 2005 consisting of about 5,000 surveyed German firms. The MIP is an annual survey which is conducted by the Centre for European Economic Research (ZEW) Mannheim on behalf of the German Federal Ministry of Education and Research. The aim of the survey is to provide a tool to investigate the innovation activities of German manufacturing and service firms. Regularly – currently every two years – the MIP is the German contribution to the Community Innovation Survey (CIS). In the year 2005, the survey contained additional questions concerning the firms' perception of their competitive situation with respect to competitive factors like price or quality as well as the perceived competitive situation regarding 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 innovative firms by implementing the binding constraint that the sample firms have recently introduced either a product or a process innovation. Furthermore, we reduce the sample to firms which indicate that their innovation activities resulted

in the establishment of new markets.[12] Hence, considering all theoretical assumptions our empirical investigation is based on a sample of 799 firms.
In the restricted data set we have about 45% of firms indicating that they applied for a patent to protect their intellectual property in the considered time period of the years 2002 to 2004. To capture the relevancy of the disclosed information for competitors, REL, we use a proxy reflecting the easiness of substitutability of own products by products of competitors in the main product market. The survey respondents could rate the extent of this characteristic of the product market choosing between "completely applies", "mainly applies", "hardly applies" and "does not apply". Whenever firms indicate that the easiness of substitutability completely or mainly applies, the proxy REL has unit value. Descriptive statistics reveal that nearly 70% of firms find that their competitive environment is characterized by easy to substitute products.
A further crucial parameter of the theoretical model are market entry costs which are not straightforward to implement empirically. Recall that the theoretical interpretation of these barriers to entry is very broad as it includes the monetary as well as the non-monetary investments necessary to accomplish a successful entry into the envisioned market. As we aim at the pioneer's decision to patent, it is his assessment of the barriers to entry his competitors face, which is relevant. Translating this into empirical terms we refer to a firm's perception on whether its market position is threatened by the entry of new rivals, *threat of entry (TOE)* as one possible proxy for initial market entry costs, MEC. The question of whether the competitive environment in the main product market is characterized by a high threat of the market position by the market entry of new competitors could be answered by one of the following categories: "completely applies", "mainly applies", "hardly applies" and "does not apply". We define this proxy to take unit value whenever a firm perceives its market position as hardly or weakly threatened by the market entry of competitors, indicating that initial market entry costs are high. This is found relevant by almost 90% of the sampled firms.
As the threat of entry is only a rough approximation for market entry costs and may well reflect other effects, we want to substantiate our results alternatively using the actual entry of new competitors. Therefore, we take

[12] To answer the question about their innovation activities' results the firms could evaluate the evaluate the extent of establishing a new market by ticking "high", "medium", "low" or "not relevant". We kept all firms which have chosen "high" or "medium". Other (non-exclusive) results of innovation activities are "increase of market share", "quality improvement", "production flexibility", "increased capacity" etc.

into account the number of *newly founded firms (NEW)* in a respondent's respective industry. This measure has been calculated by using the ZEW Enterprise Panel where all active German firms are listed. Data collection is carried out by Creditreform, Germany's largest credit rating agency. The ZEW Enterprise Panel contains reliable information on the firms' number of employees, sales and industry affiliation. Newly established firms in a specific sector are identified by counting all firms assigned to a specific 3-digit-NACE code. The advantage of this measure is that the information is objective as opposed to the MIP where information relies on the perception of the firms which may be biased. Furthermore, the ZEW Enterprise Panel has a longitudinal dimension so that we are able to lag the number of newly established firms to avoid endogeneity problems. We use the logarithm of the number of firms in the year 2001.

< Insert Table 1 about here. >

As described in Section 3.1 we include the combined effect of the impact of the disclosure effect and market entry costs, $REL * MEC$. Since market entry costs are captured in two alternative ways (*low threat of entry* and *newly founded firms*) we alternatively use the interaction terms $REL * TOE$ and $REL * NEW$, which reflect the market entry costs if the relevancy of the disclosed information for the competitors is high.
Furthermore, we control for several factors that may influence the decision to patent. To reflect the influence of the number of competitors the patentee faces, we use a categorical variable provided by the MIP displaying the ranges of the number of competitors as perceived by a firm.[13] We 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. Firm size is represented by the lagged number of *employees* in the year 2002, *human capital* by the lagged share of employees holding a university degree. In order to capture whether the main market is characterized by specific market entry barriers, we control for (lagged) *capital intensity* defined as tangible assets per employee. Furthermore, as R&D is viewed as a crucial input for potentially patentable innovation activities we control for

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

(lagged) *R&D intensity* defined as expenditures for in-house R&D activities per sales.[14] 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. Demand conditions on the product market may also influence firms' IP protection strategy. Firms could choose the extent of the share of sales generated by the three most important customers between "100 %", "50 to 99 %", "20 to 49 %" and "below 20 %". Hence, *Customer 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, i.e. the local, regional and national markets, serves as reference category in the regression. Thus it is not contained in the variable *EU*. 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*.

3.3 Empirical Results

To test the influence of a varying impact of the disclosure effect, which the theoretical model identified as the combined effect of the relevancy of the disclosed information for competitors and initial market entry costs, on the propensity to patent we estimate a probit model and calculate marginal effects evaluated at the sample means. The marginal effect of the interaction term is calculated according to Ai and Norton (2003). Results are presented in Table 2.

< Insert Table 2 about here. >

First, we look at the results for the market entry costs. As described in Section 3.2 we reflect market entry costs using two alternative variables: the *threat of entry* and the number of *newly founded firms*.[15] To begin with we

[14] Note that while capital intensity is taken from the year 2002 due to the lack of adequate data we could only use R&D expenditures of the year 2003.

[15] Another measure to capture the market entry costs is the minimum efficient scale. This measure could be calculated a the mean of industry sales (industry sales divided by the number of firms in an industry) at the 3-digit NACE level taken form the statistics

focus on the threat of entry. As pointed out earlier the theoretical model proposes countervailing effects of market entry costs on the propensity to patent. The empirical estimation now allows us to draw a conclusion about which of the effects is strongest. Since we find a positively significant total effect, the mitigating impact of initial market entry costs on the disclosure effect obviously overcompensates the other negative effects. Thus, by reducing the critical threshold, α^N, and thereby increasing the parameter space in which the disclosure effect has no impact on the resulting market structure, increasing market entry costs lead to a rising propensity to patent. This points to the fact that actually market entry costs do not form a sufficiently strong natural barrier to entry so that even with high market entry costs patenting does not become obsolete. This finding is in line with Prediction 2. Concerning the combined effect of market entry costs and the relevancy of the disclosed information for the competitors, $REL * TOE$, we find a negative marginal effect. The interpretation is 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 $f_\phi \equiv \alpha f_s$. Recall from above that the disclosed information amounts to $\Delta f = f_s - \alpha f_s$. Hence, in industries with a low α, the combination with increasing market entry costs, f_s, increases the change in market entry costs, Δf, so that firms' propensity to patent decreases.
We now turn to the number of *newly founded firms* as an approximation for the market entry costs. We find that the positive total effects turns insignificant which means that the countervailing effect (see Prediction 1 and 2) of market entry costs neutralize each other. However, the interaction effect, $REL * NEW$, still displays a negative effect. The marginal effect of the interaction term shows that in the case when the disclosure effect has an impact an increasing number of newly established firms reduces the propensity to patent. At first glance this result contradicts the previous finding: The negative effect indicates that, in a situation where the disclosure effect has an impact, a high number of newly established firms would decrease the propensity to patent. However, the variable *newly founded firms* displays the number of new firms which entered the market *before* the decision to patent takes place. Hence, the formation of new firms is not only an indicator for market entry costs but also a measure for an increasing number of firms

of the German Monopoly Commission. The caveat of this measure is that it reduces our sample heavily (the number of observations would halve) as this information is only available for manufacturing.

in a market. Here we face a critical friction between our theoretical model and the empirical implementation: While in theory the innovation opens up a new market which is subject only to the *future* entry of competitors, in reality a clear definition of the market for an innovative product is nearly impossible. De facto a potential patentee faces established firms including firms that were newly founded in this industry (our proxy variable NEW). These incumbents may be offering related products that compete with the innovation although it is "new to the market". Hence, a possible explanation for the negative interaction term $REL * NEW$ is that not only the potential entrants profit from the disclosed information but also these incumbent firms. Our variable NEW - which was intended as a proxy for market entry costs - additionally reflects the number of firms operating in the market for the innovative product. Obviously, whenever the number of these incumbent firms is high more firms are able to access and use the information disclosed by patenting and consequently the disclosure effect grows stronger. Given that the relevancy of the disclosed information is high (REL=1), only a patent of sufficient strength can overcompensate this negative disclosure effect in a way that the strategy *patent* becomes preferable compared to the alternative *secrecy*. Thus, when the relevancy of the disclosed information is high an increase of the number of incumbent firms leads to a decreasing propensity to patent.[16]

Concerning our control variables we find that larger firms, firms with an increasing percentage of highly qualified employees, firms with an increasing 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 have filed a patent but not where they filed it, there may be two explanations for this finding. On the one hand it may be that these firms file patents at their domestic patent office (i.e. the German or European Patent Office) in order to secure their domestic markets from the entry of foreign competitors. On the other hand, it may be that these firms file their patents in their main competitors' countries in order to secure their market entry. Both effects may exist at the same time. This reasoning does not contradict the non-significant effect of a main competitors' base in the

[16]Note that the effect that the disclosure effect is stronger due to the existence of incumbent firms which also profit from the disclosed information is not explicitly included in the theoretical model.

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.
Moreover, we conduct several robustness checks. First, we include the (lagged) Herfindahl indices at the 3-digit NACE level taken from the statistics of the German Monopoly Commission to reflect the competitive environment. This measure replaces the firms' perception about the number of competitors in their relevant market. The advantage of the Herfindahl indices is that they do not rely on subjective information. A caveat is that the industry classification may be too broadly defined so that it may not adequately reflect the firms' relevant markets. Second, we additionally include a measure for an industry's profitability since this may drive the threat as well as the actual entry of competitors. This variable is constructed by (lagged) growth of industry sales. As before the information is taken from the statistics of the German Monopoly Commission. The main problem with the data of the German Monopoly Commission is that it only observes manufacturing. By using this data we substantially reduce our sample. The respective tables can be found in the Appendix. The previously described results remain the same.

< *Insert Table 3 about here.* >

Finally, the theoretical model assumes that the innovator only has one innovation and firms are balancing between patenting and keeping an invention secret. In reality, firms often conduct several research projects at the same time and choose different protection mechanisms for each invention. Furthermore, firms can rely on a wider range of means to protect their intellectual property, e.g. trademarks, copyright. In contrast to the theoretical assumptions the MIP observes at the firm instead of the innovation level. Hence, the respondents are supposed to answer for the whole company which means that the IP protection strategy may take both forms, patenting and secrecy.

< *Insert Table 4 about here.* >

In order to better reflect this, we further estimate bivariate probits for all of the before mentioned estimation models. The results are displayed in Table 4 in the Appendix. With respect to our variables of interest we can state that the results remain the same for the patenting equation. Secrecy is not affected by the market entry costs or the impact of the disclosure effect. Two effects may be responsible for this result: First, as long as no formal protection mechanism is chosen firms rely per definition on secrecy to protect their IP. Second, firms are not asked to reveal their protection strategy with respect to the innovative product or process they launched (which is one binding constraint for our sample definition). Looking at Figure **??** we can see the effects of the interaction term $REL * NEW$ in the bivariate probit: The impact of the number of newly established firms affects the propensity to patent positively if the disclosure effect has no impact (= 0), whereas there is only a slightly negative effect if the disclosure effect (= 1) has an impact. Turning to the propensity to keep secret market entry costs seem to have a slightly positive impact if the disclosure effect has an impact, i.e. an increasing number of newly founded firms combined with a strong disclosure effect favors firms' decision to keep inventions secret. This robustness check further strengthens our previous results regarding the effect of the disclosure effect and market entry costs on the propensity to patent.

< Insert Figure **??** *about here. >*

Regarding the control variables we find a similar pattern for patenting and secrecy: larger firms, firms with a higher share of qualified employees, firms located in Western Germany and firms having R&D cooperations tend to increase the propensity for both protection mechanisms. Those similarities can be explained by the pattern of IP protection in the sample: More than 36% of the firms state that they use both patenting and secrecy, one third only uses alternative protection mechanisms like trademarks and copyrights and only 30% use either patenting or secrecy. Hence, the results may be driven by the substantial overlap of the patenting and secrecy strategy. Firms with a higher R&D intensity show a positive significant effect with respect to their propensity to patent whereas there is no effect on the propensity to keep the invention secret. Regarding the regional dimension of the firms' relevant market, we find different effects for secrecy and patenting: as before, a propensity to patent responds positively if the firm predominantly operates in market outside the EU and Germany whereas the propensity to keep secret is positively affected by the fact that the firm operates on the EU level compared to the German level.

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 the relevancy of the disclosed information for the patentee's competitors. 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 disclosure effect could be substantiated as a decrease of initial market entry costs. Our main theoretical results are: Either the influence of the disclosure effect 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 disclosure effect is strong so that the number of firms increases if the innovator patents. Whenever the disclosure effect has no 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 disclosure effect has an impact, we find that the propensity to patent decreases.

The empirical investigation of our three predictions derived from the theoretical model supports our theoretical findings. The existence of a disclosure effect has a substantial impact on the propensity to patent. Whenever the negative effect of patenting gains weight due to a high relevancy of the disclosed information for competitors, the propensity to patent decreases. In empirical terms we capture this by including an interaction term consisting of a measure for the impact of the disclosure effect and the market entry costs. Regarding the overall effect of market entry costs we reject our hypothesis that the prevailing effect of increasing market entry costs on the propensity to patent is negative which would be in line with economic intuition. The results regarding the threat of entry supports the theoretically derived countervailing effect that increasing market entry costs mitigate the disclosure effect. Hence when the natural barriers to market entry increase, it does not become obsolete to establish own, costly entry barriers and thus the propensity to patent increases.

The main theoretical and empirical result of this paper is that the disclosure effect of patenting plays a substantial in a firm's patenting decision. Although the disclosure effect is oftentimes neglected particularly in the empirical literature this paper shows that firms are balancing the protective and disclosure effect of patenting and only decide to patent if the protective effect overcompensates the disclosure effect.

This finding also has a policy dimension. If policymakers decide to implement some changes to patent law which would result in strengthening the disclosure effect of patenting, e.g. by implementing or extending a research use exemption, such actions should take into account that this could cause an increasing reluctance of firms to patent. Hence, more newly created knowledge would be kept secret. Whether this may have further detrimental effects on the economy's overall innovativeness and future productivity is subject to further research.

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5 Figures

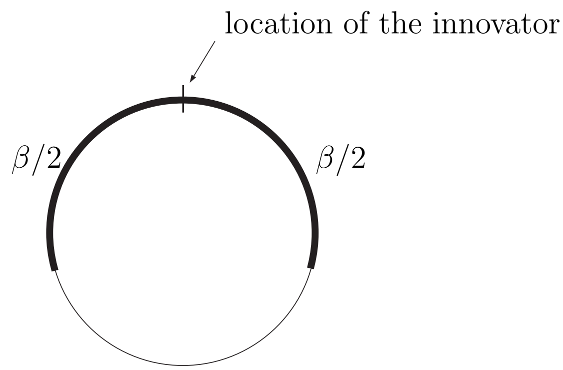
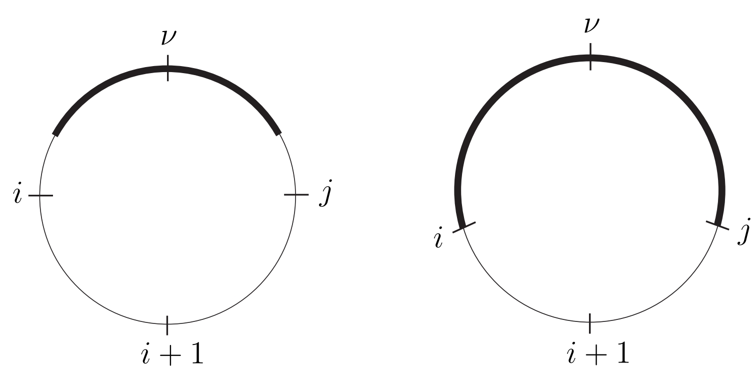


Figure 1: Patent breadth



(a) non-restrictive patent (b) restrictive patent

Figure 2: Firms' locations with a patent, $N^{\phi} = 4$

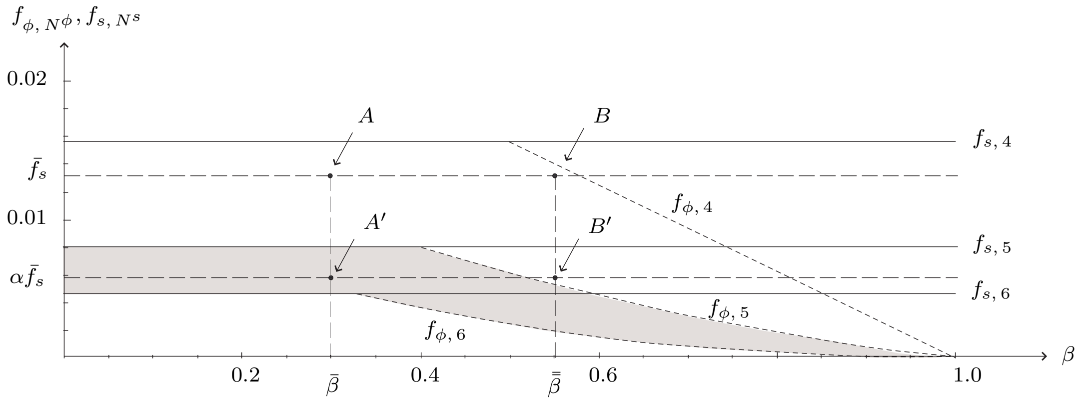


Figure 3: Critical thresholds of market entry costs

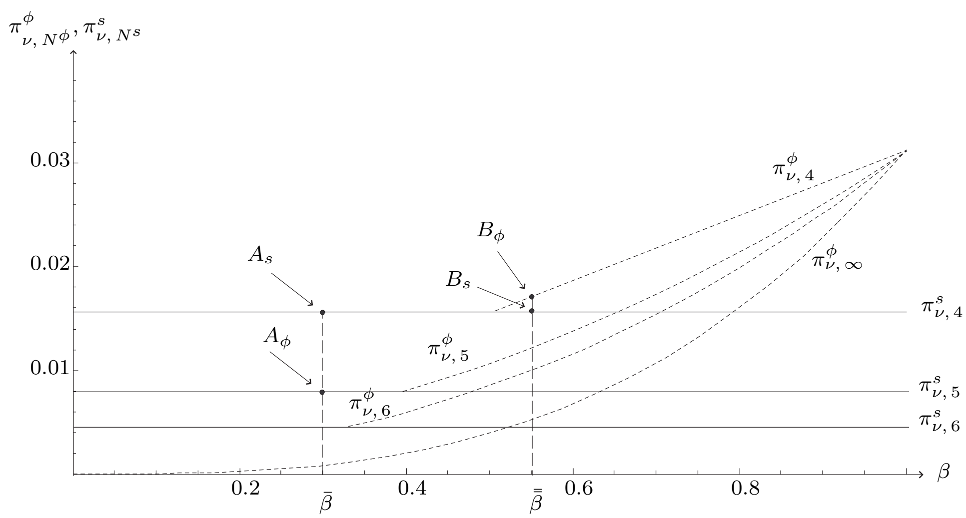
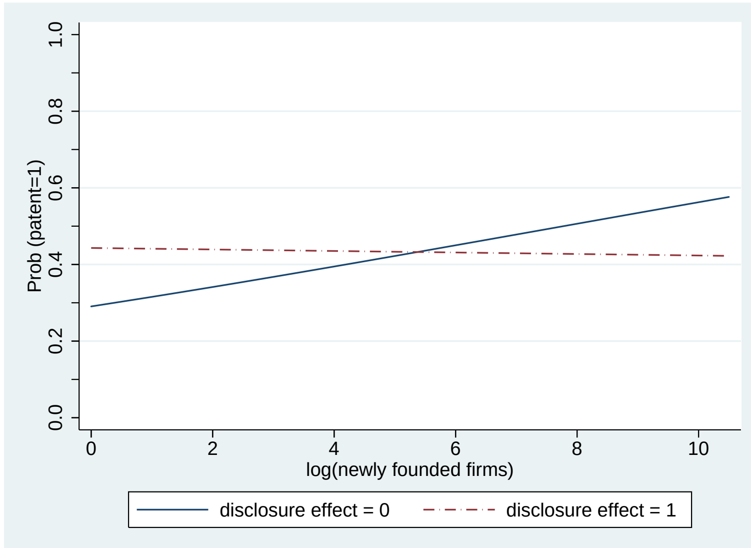
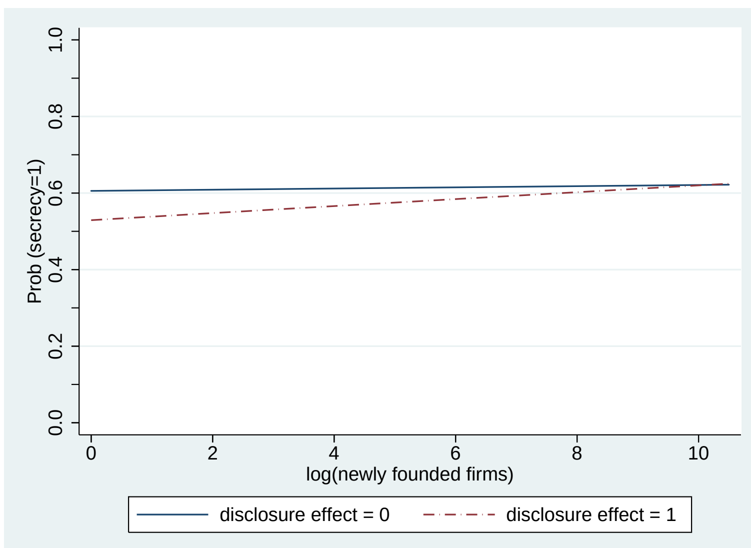


Figure 4: Alternative profits of the innovator with a patent/secrecy



(a) patenting



(b) secrecy

Figure 5: Interaction of disclosure effect and number of newly founded firms

Note: Average predictions. Source: MIP 2005, author's calculations.

6 Tables

Table 1: Descriptive Statistics

	Mean	**Std. Dev.**	**Min**	**Max**
patent	0.437	0.497	0	1
secrecy	0.593	0.492	0	1
low threat of entry	0.897	0.303	0	1
log(newly founded firms)	6.012	1.856	0.000	10.467
relevancy	0.687	0.464	0	1
large number of firms	0.158	0.365	0	1
log(employees)	4.304	1.680	0	9.077
human capital	0.244	0.257	0.000	1.000
R&D intensity	0.065	0.274	0.000	6.427
capital intensity	0.110	0.277	0.000	4.554
EU	0.582	0.494	0	1
non_EU	0.409	0.492	0	1
customer power	0.302	0.459	0	1
cooperation	0.370	0.483	0	1
east	0.318	0.466	0	1
No. of observation		799		

Table 2: Results of the Patenting Decision Estimation

	Marginal Effect (Standard Error)	**Marginal Effect (Standard Error)**
relevancy	0.012 (0.048)	-0.020 (0.048)
low threat of entry	0.174** (0.075)	
*REL * TOE*	-0.434*** (0.162)	
log(newly founded firms)		0.012 (0.013)
*REL * NEW*		-0.041** (0.019)
large number of firms	-0.083 (0.064)	-0.100 (0.064)
log(employees)	0.113*** (0.016)	0.118*** (0.016)
human capital	0.252** (0.125)	0.243* (0.125)
R&D intensity	1.452*** (0.305)	1.404*** (0.294)
capital intensity	-0.191* (0.112)	-0.211* (0.123)
EU	0.061 (0.052)	0.075 (0.054)
non_EU	0.102** (0.050)	0.096* (0.051)
customer power	-0.058 (0.049)	-0.052 (0.049)
cooperation	0.244*** (0.045)	0.243*** (0.045)
east	-0.107** (0.050)	-0.098** (0.049)
industry dummies	*included*	*included*
Log likelihood	-359.86	-361.27
McFadden's adjusted R^2	0.343	0.340
$\chi^2(all)$	264.61***	263.56***
$\chi^2(ind)$	44.53 ***	46.95***
Number of observations	799	799

*** (**, *) 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 that of the interaction term is obtained according to Ai and 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.

Table 3: Results of the Patenting Decision Estimation

	Marg. Eff. (**Std. Err.**)	**Marg. Eff.** (**Std. Err.**)	**Marg. Eff.** (**Std. Err.**)	**Marg. Eff.** (**Std. Err.**)
relevancy	0.032 (0.065)	0.033 (0.065)	0.001 (0.063)	-0.000 (0.063)
low threat of entry	0.179* (0.106)	0.182* (0.107)		
*REL * TOE*	-0.522** (0.239)	-0.526** (0.240)		
log(newly founded firms)			-0.019 (0.021)	-0.018 (0.021)
*REL * NEW*			-0.079*** (0.023)	-0.081*** (0.023)
profitability		-0.200 (0.493)		-0.189 (0.502)
Herfindahl	-0.001*** (0.001)	-0.001 (0.001)	-0.001** (0.001)	-0.001** (0.001)
log(employees)	0.168*** (0.023)	0.168*** (0.023)	0.173*** (0.023)	0.173*** (0.023)
human capital	0.053 (0.193)	0.057 (0.196)	0.044 (0.187)	0.048 (0.188)
R&D intensity	2.643*** (0.613)	2.642*** (0.613)	2.711*** (0.588)	2.709*** (0.588)
capital intensity	0.032 (0.172)	0.035 (0.173)	-0.081 (0.183)	-0.078 (0.184)
EU	0.026 (0.071)	0.026 (0.071)	0.037 (0.071)	0.037 (0.071)
non_EU	0.098 (0.064)	0.100 (0.064)	0.090 (0.064)	0.092 (0.064)
customer power	-0.032 (0.066)	-0.034 (0.066)	-0.025 (0.067)	-0.027 (0.067)
cooperation	0.224*** (0.059)	0.224*** (0.059)	0.222*** (0.059)	0.222*** (0.059)
east	-0.067 (0.061)	-0.064 (0.061)	-0.061 (0.062)	-0.060 (0.062)
industry dummies	*included*	*included*	*included*	*included*
Log likelihood	-229.78	-229.71	-229.80	-229.73
McFadden's adjusted R^2	0.320	0.320	0.320	0.320
$\chi^2(all)$	149.92***	150.95***	156.89***	158.58***
$\chi^2(ind)$	22.11***	22.20***	21.96***	22.07***
Number of observations	488	488	488	488

*** (**, *) 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 that of the interaction term is obtained according to Ai and 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.

Table 4: Bivariate probit: patenting vs. secrecy

	Patenting	Secrecy	Patenting	Secrecy
	Marg. Eff.	**Marg. Eff.**	**Marg. Eff.**	**Marg. Eff.**
	(Std. Err.)	**(Std. Err.)**	**(Std. Err.)**	**(Std. Err.)**
relevancy	0.004 (0.048)	-0.045 (0.043)	-0.029 (0,047)	-0.039 (0.043)
low threat of entry	0.178** (0.076)	-0.017 (0.067)		
log(newly founded firms)			0.011 (0.012)	0.008 (0.012)
large number of firms	-0.075 (0.064)	-0.075 (0.053)	-0.093 (0.065)	-0.077 (0.052)
log(employees)	0.110*** (0.015)	0.081*** (0.014)	0.115*** (0.016)	0.081*** (0.014)
human capital	0.240* (0.125)	0.479*** (0.105)	0.228* (0.125)	0.474*** (0.105)
R&D intensity	1.435*** (0.300)	0.328 (0.211)	1.387*** (0.289)	0.339 (0.215)
capital intensity	-0.209* (0.120)	-0.209* (0.112)	-0.236* (0.132)	-0.191* (0.104)
EU	0.064 (0.053)	0.156*** (0.059)	0.082 (0.053)	0.156*** (0.049)
non_EU	0.110** (0.050)	-0.014 (0.049)	0.102** (0.050)	-0.013 (0.049)
customer power	-0.054 (0.048)	0.017 (0.044)	-0.047 (0.049)	0.017 (0.044)
cooperation	0.241*** (0.046)	0.194*** (0.042)	0.241*** (0.046)	0.196*** (0.042)
east	-0.118** (0.049)	-0.086** (0.042)	-0.109** (0.049)	-0.085 (0.043)
industry dummies	*included*	*included*	*included*	*included*
Log likelihood	-765.20		-767.77	
ρ	0.460***		0.454***	
$\chi^2(all)$	369.95***		368.54***	
$\chi^2(ind)$	59.72***		61.98	
Number of observations	799		799	

*** (**, *) indicate significance of 1 % (5 %, 10 %) respectively.
This table depicts marginal effects of a bivariate probit estimation regarding the determinants of the decision to patent and to keep secret. Marginal effects are calculated at the sample means. 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.