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Conference Paper

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Beiträge zur Jahrestagung des Vereins für Socialpolitik 2020: Gender Economics

Provided in Cooperation with:

Verein für Socialpolitik / German Economic Association

Suggested Citation: Zaby, Alexandra (2020) : Safe harbors for patent infringers: sequential innovation under incomplete patent protection, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2020: Gender Economics, ZBW - Leibniz Information Centre for Economics, Kiel, Hamburg

This Version is available at:

<https://hdl.handle.net/10419/224653>

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Safe harbors for patent infringers: sequential innovation under incomplete patent protection

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this version: March 1, 2020

Abstract

From the viewpoint of an innovator a patent is a tradeoff between the right to exclude others from using the patented matter versus the requirement to disclose it. Given the sequential nature of many innovations, patent induced technology diffusion can spur technological progress. However, second innovators face the risk of being sued for infringement of the original patent. Incomplete patent protection reduces the risk of such infringement: either a narrow ‘leading breadth’ of the patent or the intentional containment of patent protection by a “research use” or “Bolar exemption” provide “safe harbors” for second innovators. This paper investigates how incomplete patent protection affects the propensity to patent of the initial inventor on the one hand and overall innovation incentives on the other hand. We find that incomplete patent protection can positively affect overall innovation incentives while maintaining the advantageousness of patent protection over secrecy. However, if second innovators face a very low risk of being punished for patent infringement, the propensity to patent decreases.

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Keywords: sequential innovation, research use exemption, patenting decision,
patent race, incomplete patent protection

JEL Classifications: O31, O24, L24, D21

1. Introduction

Europe is on the verge of establishing a Unitary Patent system.¹ The Unitary Patent will provide patent protection in all participating EU member states making the application for patent protection in every single state—which is necessary up to now—obsolete. As the Unitary Patent system is inextricably linked to the creation of a Unified Patent Court, which will have jurisdiction over Unitary Patents and “classic” European patents, the harmonization of national patent jurisdiction in Europe is inevitable. While the Agreement on a Unified Patent Court defines the rights conferred by a patent as well as the limitations to those rights, it is an open issue how the court will interpret these legal rights in the case of litigation.

From an economic perspective a patent, besides protecting intellectual property, serves the function of disclosing proprietary knowledge for the sake of technological progress. Many countries, especially in Europe, intentionally enhance such patent induced technology diffusion by restricting protection such that “acts done for experimental purposes relating to the subject-matter of the patented invention (Article 27 (b) of the Unified Patent Court Agreement)” are exempted from patent protection. Third parties are thus allowed to use patented matter as an input in their research processes. The exclusion of scientific research from patent infringement is generally referred to as the *research* or *experimental use exemption* from patent infringement. In Europe the extent of this exemption is very heterogeneous: In most European countries research *on* the patented matter is exempted (as is the case e.g. in Belgium, France, Germany, Italy, Spain, The Netherlands), whereas only in some countries the exemption extends to research *with* the patented matter (as is the case, e.g., in Belgium and Italy) (see Kupecz et al., 2015).

In the context of sequential innovation second innovators building on prior

¹The EU regulations No 1257/2012 and No 1260/2012 establishing the Unitary Patent system entered into force on 20 January 2013. They will apply starting with the date the Unified Patent Court Agreement enters into force.

patents thus face varying risks of being punished for patent infringement due to varying levels of incomplete patent protection. This paper focusses on the effects that incomplete patent protection has on the propensity to patent on the one hand, and on overall innovation incentives on the other hand. Our central finding is that incomplete patent protection can increase innovation incentives without negatively affecting the propensity to patent. However, this is only the case if exemptions from patent infringement are not too extensive.

Infringement can be of two different types: Output-infringements take place on the product market and are subject to the breadth of a patent, i.e., imitations or too closely related variations of a product. *Input-infringements* take place on the market for ideas, i.e., if second innovators use patented matter as basis or input in their research process. Depending on the extent of the implemented research use exemption, the use of patented matter can be exempted from patent protection. While this theoretical distinction is important to clarify the underlying process of patent induced knowledge diffusion, it is nearly impossible to de facto identify input-infringements. Such infringements become visible only after a second innovator either files a follow-on patent, or introduces his follow-on innovation to the market. Thus, while a research exemption comes to effect on the input side of the research process, its effect of reducing the risk of being punished for infringement materializes on the output side.

We analyze the effect of incomplete patent protection in a patent race setting with sequential innovation. Ex-ante asymmetric firms compete in achieving a follow-up innovation: one “leader” owns the initial innovation which gives him a technological headstart, implying a higher probability of winning the second race. “Followers”, can freely enter the race for the follow-up innovation. Before this race starts, the leader decides whether to patent the initial innovation or to keep it secret. With a patent the leader earns positive profits until a follow-up innovation replaces his product. However, this comes at the cost of (partially) disclosing his proprietary knowledge, what reduces his headstart. With secrecy, market entry with the innovation would result in the immediate market entry of rivals due to reverse engineering, driving profits to zero. However, secrecy

preserves his technological headstart for the second race. Followers' probability to win the race depends on own R&D investments, the leader's headstart, and on the threat of being punished for patent infringement. This threat is determined by two policy parameters: the probability of detection and prosecution of an infringement, and the extent of the punitive fine.

In two related papers, Nagaoka and Aoki (2006, 2007), building on Scotchmer (2004) analyze the effect of a research use exemption on the R&D activities of firms, whereas the patenting decision itself is not considered. They find that a research exemption spurs technological progress. Moschini and Yerokhin (2008) study the effect of a research use exemption in the context of a quality ladder model where they compare a scenario with a research use exemption with one where a research use exemption does not exist. They find that firms *ex ante* always prefer full patent protection, i.e., the absence of a research use exemption. From a welfare perspective the advantageousness of either scenario depends on innovation costs. Our analysis differs from Moschini and Yerokhin (2008) in four central aspects. Firstly, we include the initial patenting decision of the first innovator, what allows us to investigate the effect of a research use exemption on the propensity to patent. Secondly, we assume that competitors—due to the existence of unintentional knowledge spillovers—can participate in the race for the follow-up innovation even if a research use exemption does not exist. Thirdly, instead of comparing two contrary scenarios, we include varying extents of a research use exemption. Lastly, we do not restrict our analysis to two firms, but allow for free entry into the race for the follow-up innovation.

Thumm (2003) provides the only empirical survey which explicitly includes an investigation of the research use exemption. For the Swiss biotechnology sector, he finds that participants consider the introduction of a broad research use exemption as relatively beneficial. Two main reasons drive this positive assessment: a broad research use exemption increases the access to genetic inventions, and it promotes the dissemination of technology.

Most of the economic literature on patents disregards the disclosure effect of a patent, implicitly assuming that a research use exemption does not exist

and that competitors—to avoid patent infringement—refrain from using patented knowledge as an input to their research. Our work relates to several contributions which also consider that patenting has a disclosure effect, but disregard the effects of a research use exemption (see e.g. Scotchmer and Green (1990), Bhattacharya and Guriev (2006), Aoki and Spiegel (2009)). Our model setting is related to that presented in Erkal (2005) and Denicolò (2000). Both analyze the welfare aspects of alternative patent regimes in a setting of two consecutive R&D races.

The analysis proceeds as follows. In the following Section 2 we lay out the legal differences regarding the implementation of a RUE in Europe and the U. S. and relate them to our theoretical set up. Section 3 introduces the theoretical model, beginning with the analysis of the R&D race in Section 3.1 and proceeding with the analysis of the patenting decision in Section 3.2. Section 4 concludes. All proofs can be found in the Appendix.

2. Legal implementation and theoretical approach

From the viewpoint of follow-on inventors a broad research use exemption grants legal certainty regarding the use of patented knowledge, meaning that the threat of punishment for patent infringement is low. A narrow research use exemption contrarily leads to legal uncertainty and thus to a high threat of punishment. Most countries have implemented a research use exemption, its extent, however, depends on the respective juridical system. A central difference is whether a research exemption is implemented in common law jurisdiction, or whether it is part of a country’s statutory law. Two major representatives of the alternative regimes are the U.S. and Germany. In the U.S. a specific statutory exemption was introduced in 1984 by the Patent Term Restoration and Drug Price Competition Act (Hatch-Waxman Act) by implementing 35 U.S.C. § 271 (e). As it was introduced after the *Roche v. Bolar* decision (See 733 F.2d 858, 865 (Fed. Cir. 1984).) this exemption is commonly referred to as the Bolar exemption. This exemption allows generic drug companies to conduct research on and test

patented compounds for clinical trials before the end of the patent term. Since the clinical trial phase usually takes several years, a denial of the exemption would lead to a de facto prolongation of the patent term and may assure the patent holder with an expanded monopoly period beyond the patent term. This allows generic drug producers to enter the market at the time of the compound patent's expiry. For all other fields, the research use exemption is part of common law jurisdiction where the definition of its extent depends on the courts and may differ from case to case. This naturally creates uncertainty for the firms using patented knowledge as input in their research activities.

In Germany § 11 PatG defines one of the broadest research use exemptions. This exemption 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.² Furthermore, § 11 PatG was extended by the Supreme Court's decisions "Clinical Trials I" and "Clinical Trials II" which exempted the research use of patented compounds for equivalency tests, the provision of information and data for the admission procedures etc. This corresponds to the Bolar exemption in the U.S.

The research use exemption legalizes the usage of the information disclosed through patenting. How severely this disclosure hurts an innovator is however not specified by the research use exemption itself, but is subject to innovation- and industry-specific characteristics.³ Further, the implemented research use exemption affects firm behavior through varying reliability. Firms using patented knowledge as input in their research face the risk of being sued for damages due to this behavior. The use of patented knowledge by rival firms may constitute a patent infringement which will be detected and prosecuted by an exogenously given probability, $1 - p$. In the case of prosecution, a firm has to pay a fine to the first innovator.

²Consequently, the use of research tools is not exempted as they are used in the research process as tool and not as knowledge input (see e.g. Holzapfel (2004)).

³For a discussion of these heterogeneous costs of disclosure see Heger and Zaby (2013).

The threat of punishment is thus driven by two parameters: (i) the legal certainty p that an input-infringement will not be prosecuted, and (ii) the extent of the prosecution fine.

The decision to patent is additionally influenced by the degree to which it spurs technology diffusion, that is, how good the patent system fulfills its aim to increase diffusion through compulsory information disclosure.

3. Model

Propose a research environment where ex-ante asymmetric firms have free entry into a R&D race. One of the firms, the *leader* ℓ , already owns an invention which gives him a technological headstart such that he has a higher probability of winning the race (i.e. a higher hazard rate) than the other firms, *followers* f . Before the R&D race starts the leader decides how to protect his invention: Only if he patents it, he can earn a positive flow of profits until a follow-up innovation replaces his product (we assume production at zero marginal cost). If he relies on secrecy, reverse engineering leads to the immediate entry of rival firms driving profits to zero. Hence, with secrecy the innovator cannot realize positive profits from selling the first innovation. As generally assumed in innovation race models, the value of the (follow-up) invention is exogenous and commonly known, while its timing follows a Poisson discovery process (Loury (1979); Lee and Wilde (1980)). Once, before the beginning of the race every participant i decides how much to invest. His R&D investment on the one hand increases his probability of success, on the other hand it creates one-time lump-sum costs of height cx_i where c is the per-unit R&D cost and x_i denotes the chosen R&D effort level (see Loury (1979)). The common social and private discount rate is given by r . Thus the time structure of the model is as follows: 1. inventor's patenting decision concerning the first innovation, 2. all firms' R&D investment decisions and 3. the R&D race starts.

The linear hazard functions $h_i(x_i)$ depend on the chosen intellectual property protection strategy of the leader ℓ , and on the implemented research use exemp-

tion. While the leader's hazard function is $h_\ell(x_\ell) = x_\ell$ his rivals by assumption have a lower probability of winning the race, $h_f(x_f) = (1 - \alpha\gamma)x_f$, where $0 < \gamma < 1$, defines the extent of the leader's headstart and $0 < \alpha \leq 1$, captures patent induced technology diffusion. Thus, the hazard functions of the leader and his rivals equalize, the lower the technological headstart of the leader, or the higher technology diffusion is.

Whenever the inventor *patents*, potentially two types of infringement could occur: (i) an *output-infringement* may take place on the product market, such that a rival firm markets a follow-up product which incorporates some features of the patented innovation or (ii) an *input-infringement* could occur. As discussed earlier an input-infringement becomes visible only after the second innovator either patents or markets his innovation. Given the lack of a legal research exemption, the mere use of patented knowledge as research input by rival firms constitutes such an (input-)infringement. This means that whenever the first innovation is patented and a follower wins the R&D race, he faces the risk of being punished for an infringement of the initial patent. We disregard strategic considerations of the followers whether it is worthwhile to infringe or not but assume that they (knowingly or unknowingly) always infringe. This behavior will be detected and prosecuted with the exogenously given probability $1 - p$. The probability of not being prosecuted for the use of patented knowledge, p , can thus be interpreted as the probability for a suing firm to succeed, what reflects the strength of patents in a legal system. In the case of prosecution the infringer has to pay a fraction $0 < s \leq 1$ of his profits as a fine to the initial innovator. In the extreme case of $s = 1$ all profits have to be transferred to the technology leader.

To summarize, we distinguish two potential intellectual property protection strategies of the leader:

- (a) Secrecy –
 - (pro) the inventor maintains his technological headstart,
 - (con) whenever a rival firm wins the R&D race the first inventor earns null,

(con) due to reverse engineering the leader receives no profits from the initial innovation

(b) Patent –

(pro) the innovator earns a positive profit flow from the first innovation;

(pro) a threat of punishment for follow-on inventors yields positive profits even if the second race is lost⁴

(con) the inventor loses part of his technological headstart due to patent induced technology disclosure.

3.1. R&D race

The leader's expected profit function at the beginning of the R&D race generally is given by

$$\begin{aligned}\Pi_\ell &= \int_0^\infty e^{-(h_\ell + \sum_f h_f + r)t} \left[h_\ell v_w + \sum_f h_f v_l + v_1 \right] dt - cx_\ell \\ &= \frac{h_\ell v_w + \sum_f h_f v_l + v_1}{h_\ell + \sum_f h_f + r} - cx_\ell\end{aligned}\tag{1}$$

where $\sum_f h_f$ represents the aggregate hazard functions of the followers, v_w is the profit if the leader wins the race, v_l his profit if the race is lost and v_1 are the (potential) profit flows from the first innovation. We assume throughout that the follow-on innovation is drastic, i.e., an infinite flow of profits from the first invention, $\int_0^\infty e^{-rt} v_1$ is lower than the one per period profit from winning the second race, $v_1/r < v_w$.

⁴We deliberately narrow down the incentive to patent by disregarding the merits of licensing payments. If we would include dependent follow-on inventions (see Footnote ??), patenting would be more profitable as the patentee would additionally collect licensing income. We disregard this as possible input-infringements would never be prosecuted, because they are already compensated for by paying the licensing fee.

(a) *no patent*

In the case that the leader refrains from patenting and chooses secrecy to protect his innovation the hazard functions of the followers are given by $h_f^s(x_f^s) = (1 - \gamma)x_f^s$ and for the leader we have $h_\ell(x_\ell) = x_\ell$. Further, the leader receives neither profits from the initial innovation ($v_1 = 0$) nor when he loses the race ($v_l = 0$). Inserting these parameter values in equation (1) the expected payoff function of the leader is given by

$$\Pi_\ell^s = \frac{x_\ell^s v_w}{x_\ell^s + (1 - \gamma)X_f^s + r} - cx_\ell^s, \quad (2)$$

where $X_f^s \equiv \sum_f x_f^s$ represents the aggregate investment of f rival firms participating in the R&D race.

The innovator maximizes Π_ℓ^s with respect to x_ℓ^s . His first order condition yields

$$\frac{v_w}{c_2} [(1 - \gamma)X_f^s + r] = [x_\ell^s + (1 - \gamma)X_f^s + r]^2. \quad (3)$$

The expected profit of a generic rival firm in the R&D race is given by

$$\Pi_f^s = \frac{(1 - \gamma)x_f^s v_w}{x_\ell^s + (1 - \gamma)X_f^s + r} + cx_f^s. \quad (4)$$

Concerning the followers, due to free entry into the race we can set $\Pi_f^s = 0$.⁵ Inserting the leader's first order condition (3) in the zero-profit condition we calculate the aggregate investment of the f participating rival firms as

$$X_f^{s*} = (1 - \gamma) \frac{v_w}{c} - \frac{r}{(1 - \gamma)}. \quad (5)$$

In line with economic intuition the followers' aggregate investment decreases when the headstart of the innovator, γ , increases.⁶ Given this aggregate investment we can easily derive the innovator's investment decision in the R&D race. Inserting X_f^{s*} in equation (3) yields

$$x_\ell^{s*} = \gamma(1 - \gamma) \frac{v_w}{c}. \quad (6)$$

⁵Denicolò (2000) and Erkal (2005) use this modeling approach in a setting of two consecutive R&D races.

⁶To narrow down the complexity of our analysis we only consider cases where leader and followers participate in the R&D race, i.e. $x_\ell > 0$ and $X_f > 0$.

Simple comparative statics show that an increase of headstart γ leads to an increase of the optimum investment level of the innovator, if and only if his headstart is sufficiently small, i.e. $\gamma < 1/2$. If his headstart is high, $\gamma \geq 1/2$, the relatively lower hazard rates of the participating rivals give him the opportunity to lower his R&D expenses without significantly decreasing his probability to win the innovation race.

Inserting the aggregate investment X_f^{s*} and the innovator's individual investment x_ℓ^{s*} into equation (2) yields the expected profit of the innovator given that he has not patented,

$$\Pi_\ell^{s*} = \gamma^2 v_w. \quad (7)$$

With secrecy, the inventor's expected profit is increasing in his technological headstart γ .

(b) patent

In the case that the first inventor chooses to patent, the followers are able to use the information disclosed in the patent specification as input in their own research. By patenting the hazard functions of the followers thus increase to $h_f^I(x_f^I) = (1 - \alpha\gamma)x_f^I$. The profit of the leader in case that he loses the race, v_ℓ^p , depends on the threat of punishment, i.e. on the probability that the winner's input-infringement is detected and prosecuted, $1 - p$, and on the height of the fine the leader then receives, sv_w . Whenever a successful follower is not prosecuted, what happens with probability p , the leader receives null, whereas whenever he is prosecuted the leader receives part of the winner's profits, sv_w as compensation fine. the profit of the leader if he loses the second race is thus given by $v_\ell^p = p \cdot 0 + (1 - p)sv_w$.

Thus the leader's expected profit with a patent is given by

$$\Pi_\ell^\phi = \frac{x_\ell^\phi v_w + (1 - \alpha\gamma)X_f^\phi((1 - p)sv_w) + v_1}{x_\ell^\phi p + (1 - \alpha\gamma)X_f^I + r} - cx_\ell^\phi. \quad (8)$$

If a rival firm wins the R&D race, with risk $1 - p$ it will be prosecuted for patent infringement. In this case the successful rival has to pay a fine sv_w

to the early innovator to reimburse him for his losses. With probability p an infringement is not detected or it is found to be legal as it falls under the research use exemption. In this case the follower receives monopoly profits from selling the second innovation. The expected profit of a generic follower firm given the first innovation is patented thus amounts to

$$\Pi_f^\phi = \frac{(1 - \alpha\gamma)x_f^\phi[pv_w + (1 - p)(1 - s)v_w]}{x_\ell^\phi + (1 - \alpha\gamma)X_f^\phi + r} - cx_f^\phi.$$

Defining $\sigma \equiv 1 - (1 - p)s$ and $\beta \equiv (1 - \alpha\gamma)$ this payoff function simplifies to

$$\Pi_f^\phi = \frac{\beta x_f^\phi \sigma v_w}{x_\ell^\phi + \beta X_f^\phi + r} - cx_f^\phi, \quad (9)$$

where σ captures the *threat of punishment* and β the extent of technology diffusion. If at the same time the probability to be prosecuted for a patent infringement and the fine in the case of prosecution, s , are small, the threat of punishment is small. This is the case when parameter σ is high. With a high probability of prosecution $(1 - p)$ and a high fine s the threat of punishment is high. This case is reflected by a small value of the parameter σ . While the threat of prosecution can be influenced by policy measures, the parameter β reflecting technology diffusion can only be influenced indirectly. Taking the level of the technological headstart of a leader as given, a high parameter β results from a high level of technology diffusion whereas a low value of β reflects low technology diffusion.

Again, due to free entry into the race, we set $\Pi_f^I = 0$ and insert the leader's first order condition to derive the aggregate investment of followers as

$$X_f^{\phi*} = \frac{c(v_1 - rv_w) + \sigma^2 \beta^2 v_w^2}{cv_w \sigma \beta}. \quad (10)$$

Given $X_f^{\phi*}$ the leader's optimal investment in the R&D race yields

$$x_\ell^{\phi*} = \frac{(1 - \beta)\sigma \beta v_w}{c} - \frac{v_1 - (1 - \sigma)rv_w}{\sigma v_w}. \quad (11)$$

$$\Pi_\ell^{I*} = \frac{\sigma[(1 - \sigma) + \sigma(1 - \beta)^2]v_w^2 + c(v_1 - (1 - \sigma)rv_w)}{\sigma v_w}. \quad (12)$$

Obviously the leader's profit decreases as the level of technology diffusion increases ($\frac{\partial \Pi_\ell^{\phi*}}{\partial \beta} < 0$), whereas, due to $v_1/r < v_w$, the expected profit decreases in the threat of punishment ($\frac{\partial \Pi_\ell^{\phi*}}{\partial \sigma} > 0$). (check)

Our focal interest are the effects of (i) the threat of punishment and (ii) technology diffusion on R&D investments.

(i) *The threat of punishment.* We set off analyzing separately the investment levels of the leader and the followers, before turning to the effect on aggregate investment. to be done

Lemma 1. *If the first innovation is patented, decreasing the threat of punishment increases aggregate R&D investments.*

(ii) *technology diffusion.* From the viewpoint of the inventor, technology diffusion, α , constitutes a crucial factor for the profitability of a patent as it increases the hazard rate of followers, $h_f(x_f) = (1 - \alpha\gamma)x_f$. As discussed earlier, policy attempts can only indirectly influence this measure because it is by large subject to innovation and industry-specific characteristics. The effect of patent induced technology diffusion on the leader's investment is summarized in the following lemma.

Lemma 2. *If the first innovation is patented*

- (i) *technology diffusion decreases inventor's R&D investments whenever his headstart is small, $\gamma \leq \frac{1}{2\alpha}$,*
- (ii) *technology diffusion increases the inventor's R&D investments whenever his headstart is large, $\gamma > \frac{1}{2\alpha}$.*

With a small headstart (i), hazard rates of the inventor and his competitors are quite similar at the beginning of the second race. As technology diffusion increases, this is even more the case so that R&D investments only have a weak impact on increasing the probability of winning the race. Given a large headstart (ii), the threat of losing the lead through technology diffusion is rather high. A high level of diffusion now has a strong impact as it aligns the hazard rates of

the leader and his rivals, so the leader attempts to increase his probability of winning the race by higher investments in R&D.

Effect on followers' investments to be done

Lemma 3. *If the first invention is patented, increasing technology diffusion increases aggregate R&D investments.*

Summarizing these findings, we state

Proposition 1. *If the first innovation is patented, aggregate R&D investments are highest, whenever the threat of punishment is low and technology diffusion is high.*

While this is obviously a desirable effect of a policy measure increasing legal reliability (such as the RUE which intends to reduce the threat of punishment), the possible backside may be that the propensity to patent decreases because increasing technology spillovers and decreasing the threat of punishment—positive effects from the viewpoint of the followers—are negative effects from the viewpoint of a leading firm.

3.2. The Patenting Decision

Clearly, before the race begins, the early innovator will choose the protection strategy which yields the highest expected profits. Thus, we compare his expected profits in the cases (a) the basic innovation is kept secret and (b) the basic innovation is patented, given the leader's optimum investment decision and the aggregate investment level of the rivals participating in the R&D race. Analytically this boils down to a comparison of the functions $\Pi_\ell^{\phi*}$ and Π_ℓ^{s*} . The critical condition for patenting to be more profitable than secrecy, $\Pi_\ell^{\phi*} - \Pi_\ell^{s*} \geq 0$, depends on the threat of punishment, σ , and the extent of technology diffusion, α , see Figure 1. In the shaded area of the figure, the leader's expected profit from secrecy is higher than with a patent, meaning that he prefers to keep the first innovation secret. In the white area of Figure 1 the leader expects a higher payoff from securing his intellectual property with a patent.

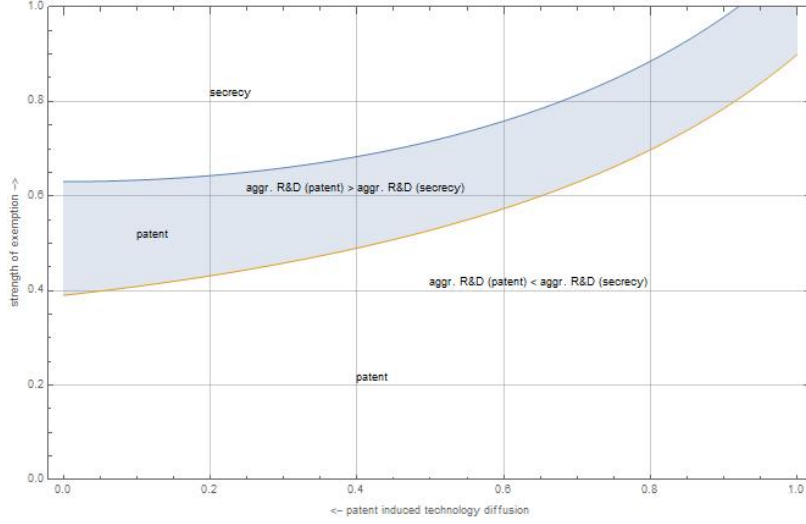


Figure 1: The propensity to patent ($v_1 = 0.1$, $v_w = 3$, $r = 0.1$, $\gamma = 0.6$, $c = 5$)

In the lower left area of Figure 1 the threat of punishment and technology diffusion are both high. The inventor is better off patenting his initial innovation to secure profit flows and to insure himself against losing the second race through the prospect of eventual punishment payments. When the probability for the latter decreases, while technological diffusion remains high (upper left area), the dominance of the patenting strategy vanishes as now—depending on the threat of punishment—secrecy might be more profitable as this protection strategy prevents the high spillovers created by patenting. If technology diffusion and the threat of punishment are both low (upper right area), patenting may be the dominant strategy.

Overall, when summarizing the effect of moving from a high to a low threat of punishment, we can state

Proposition 2. *Decreasing the threat of punishment decreases the propensity to patent if patent induced technology diffusion is sufficiently severe.*

Thus, as mentioned before, the positive effect of a low threat of punishment on

overall R&D investments is opposed by a negative effect on the propensity to patent.

In the Appendix we derive a critical level for the risk of punishment, σ_1 , which is decisive for the patenting decision, see Figure 1. Whenever the risk of punishment is below this critical value, $\sigma > \sigma_1$, the innovator chooses secrecy.

The intention of a research use exemption is to spur technological progress, i.e., to impose a positive effect on overall innovation incentives. To investigate this effect we compare overall innovation incentives in case of a patent with those in case of secrecy. Comparing equations X and Y yields another critical level for the risk of punishment, σ_2 . Whenever the risk of punishment is below this critical value, $\sigma > \sigma_2$, aggregate R&D investments are higher with a patent than with secrecy. In the appendix we show that $\sigma_1 > \sigma_2$, i.e., for an intermediate risk of punishment the innovator chooses a patent and overall innovation investments are higher in this case as compared to secrecy. In Figure 1 this situation is marked by the shaded area.

This gives us our final proposition

Proposition 3. *With an intermediate threat of punishment the leader chooses to patent and aggregate R&D investments are higher than in case of secrecy.*

4. Concluding Remarks

A patent consists of two countervailing effects: a protective and a disclosure effect. Many scholars assume that the disclosure effect of a patent becomes effective after a patent expires while during the patent term, the patented invention is protected from the use of third parties. However, one specific use of a patented matter is often – either implicitly or explicitly – exempted from infringement, namely the research on patent matter. For example, if a patent is the starting point for a competitor’s research process this action does not constitute an infringement. The goal of such a research use exemption is to foster technological progress.

The implementation of a research use exemption depends on a country’s juridical system. For illustration, we chose two countries with differing implementations: In Germany, a country with a statutory research exemption, the extent of the exemption is certain, whereas in the U.S., a country with a common law exemption, the applicability of the exemption is uncertain.

While the research use exemption is our central example, the presented model captures a wider range of possible infringements and focusses on the effect that the threat of detection and prosecution of an infringement has on R&D investments and on the decision to patent itself. Our central finding is that weak patent strength, reflected in a low threat of punishment for patent infringers, leads technology leaders to refrain from patenting. If patent induced technology diffusion is low, this negative influence becomes weaker.

A patent system aiming at spurring technology diffusion through functioning patent disclosure should thus also guarantee strong protective rights to patentees meaning that the threat of punishment for patent infringers is high.

To capture these varying extents of the research use exemption, we propose a model of cumulative innovation in a patent race setting and distinguish two different regimes: a *probabilistic* RUE regime where the legal certainty, that the RUE will not be challenged in court, varies and a *dependable* RUE regime where legal certainty is given. This paper addresses the question whether the RUE has an impact on the overall technological progress and on the patenting decision of leading firms.

For the model, we assume ex-ante asymmetric firms. The leader holds an invention which gives him a higher probability to win the race, i.e. a technological headstart.

The research use exemption only plays a role when the leader decides to patent his invention. Hence, the two regimes of probabilistic vs. dependable exemption are compared to the situation in which the leader decides to keep his invention secret.

Regarding the impact of the RUE on technological progress, we find that the

aggregate R&D investments are highest if legal certainty as well as technological diffusion are high. With respect to the exemption's influence on the leader's propensity to patent, we find a negative effect, i.e. the stronger the exemption, the more attractive secrecy becomes. Thus strengthening the RUE has countervailing effects: On the one hand it increases overall R&D investments, but on the other hand it decreases the propensity to patent.

An analysis of the net effect of a RUE is not possible within the scope of this simple model, nevertheless we feel that we contribute important insights concerning the differing effects of a research use exemption.

Appendix

Proof of Lemma 1

Calculating $\frac{\partial \sum x}{\partial \sigma} > 0$ yields

$$\sigma^2 > \frac{(1 - \beta)(v_1 - rv_w)c}{(2 - \beta)\beta^2 v_w^2}. \quad (13)$$

Calculating $\frac{\partial X_f^{\phi*}}{\partial \sigma} > 0$ yields

$$\sigma^2 > \frac{(v_1 - rv_w)c}{\beta^2 v_w^2}. \quad (14)$$

Due to $\frac{1-\beta}{2-\beta} < 1$ condition (13) is obviously less restrictive than condition (14).

Proof of Lemma 2

Calculating $\frac{\partial x_l^{\phi*}}{\partial \alpha} = \frac{\gamma(1-2\alpha\gamma)\sigma v_w}{c} \gtrless 0$ the crucial condition is given by

$$\frac{1}{2\alpha} \gtrless \gamma. \quad (15)$$

Consequently, for high γ $\frac{\partial x_l^{\phi*}}{\partial \alpha} < 0$ holds while for low gamma $\frac{\partial x_l^{\phi*}}{\partial \alpha} > 0$ is fulfilled.

Proof of Lemma 3

We have $\frac{\partial \sum x}{\partial \alpha} = \frac{\gamma(-2\alpha\gamma(1-\alpha\gamma)^2\sigma^2v_w^2+c(v_1-rv_w))}{c(1-\alpha\gamma)^2\sigma v_w}$. Consequently $\frac{\partial \sum x}{\partial \alpha} \gtrless 0$ whenever

$$\frac{c(v_1 - rv_w)}{2\alpha\gamma(1 - \alpha\gamma)^2v_w^2} \gtrless \sigma^2 \quad (16)$$

Thus, for a low threat of punishment we have $\frac{\partial \sum x}{\partial \alpha} < 0$ while for a high threat of punishment $\frac{\partial \sum x}{\partial \alpha} > 0$ holds.

Proof of Proposition 2

Solving $\Pi_\ell^\phi - \Pi_\ell^s > 0$ for α yields

$$\alpha > \alpha^{\text{crit}} \equiv \frac{\sqrt{-c(v_1 - rv_w(1 - \sigma)) + v_w^2\sigma(-1 + \gamma^2 + \sigma)}}{\gamma v_w \sigma}. \quad (17)$$

It is easy to show that α^{crit} is increasing in σ .

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