Patent Novelty and Patent Life

Patrick F.E. Beschorner*

(preliminary)

January 14, 2005

Abstract

Patent breadth and length have been discussed extensively in literature. In this paper I analyze the optimal degree of novelty of patent protection. In the context of subsequent innovations each innovation builds on the previous. The degree of novelty which is necessary for a non-infringing patent is crucial for the firms' incentive to innovate. One of the findings is that the privately optimal degree of novelty is lesser than socially desirable. Furthermore, patent life has to be extended to sustain the optimal degree of novelty. This unveils an analogous trade-off between patent length and the degree of novelty as it is known from patent breadth.

JEL: D43, L15, O31
key words: innovation, patent policy, firm strategy

*Centre for European Economic Research, P.O.Box 10 34 43, D-68161 Mannheim, Germany, Tel.: +49-(0)621-1235-175, beschorner@zew.de

Extended Abstract: The optimal degree of novelty in the patent system

In this paper I analyze the optimal degree of novelty of patent protection. The patent system consists of granting the right to exploit a new technology to its inventor in exchange for disclosing the technology to society. The design of the patent system consists of managing the (intertemporal) trade-off between the profit of the inventor and the participation of consumers in the new technology.

Temporary market power and monopoly profits are the driving forces of innovation and the patent system allocates the property rights on technology. The scope of patent protection is defined by its length, breadth and the degree of novelty.

Patent length and breadth have been explored extensively beginning with the controversial debate between Gilbert and Shapiro (1990) and Klemperer (1990). In the tradition of this discussion patents are directly linked to products provided to the market. This allows to infer that a broad patent only allows for highly differentiated products and a higher firm profit. Then a short patent life suffices to cover the research costs. Conversely, a narrow patent allows for imitation and providing similar products by competitors. Both articles give clear conditions when one of the two patent designs is favorable in the sense of social surplus.

This discussion does not cover sequential innovations with stepwise quality improvements. Scotchmer (2005) tackles the question on how innovative a patent has to be to not infringe existing patents while rival firms have the same chance to realize a subsequent improvement. For an exogenously given social value of an innovation she considers overlapping innovations where the new technology relies on licensing of the prior patent. Furthermore, she addresses the issue of stepwise non-infringing sequential innovations which is an application of patent races. In a more detailed analysis Scotchmer (2005)

and O'Donoghue et al. (1998) combine the issues of sequential innovation with two aspects of patent breadth: protection against imitation and new improved products.

Although the literature on the design of patent protection has become very extensive, to my knowledge straightforward results as the trade-off between length and breadth in Gilbert and Shapiro (1990) and Klemperer (1990) have not yet been inferred about the optimal degree of novelty of a patent.

I use a simple model of vertical product differentiation in the framework of Gilbert and Shapiro (1990) and Klemperer (1990) to obtain comparable results to theirs. In my model the social value of an innovation is endogenous as the latter depends on the degree of novelty and the consumers' responses to a new product. Moreover, the setting catches the public good property of technological knowledge when it is disclosed in a patent.

The first result is that the firms' incentive to innovate is lesser than the social value of an innovation. Both, the expenditures for R&D and the novelty of an innovation are covered by this result. This is in line with the established results on the replacement effect (See Tirole 1988, Ch. 10.). There exists a trade-off between firm profit a the wideness of an innovative step and this result allows for policy implications about the design of the patent scope.

A second result will cover the trade-off between patent life and the degree of novelty. A deviation from the firm's optimum degree of novelty will result in a reduced flow of firm profit which must be compensated by a longer patent life.

An extension of the model which includes the public good property of a patent (the disclosure of the technology) unveils an additional trade-off between the increased social value of a patent and the private incentive for R&D expenditures. Here, the model will suggest that low requirements on novelty promotes diffusion of research tools which are applicable to several industries. This adds a new insight to the aspect of research spillovers which is in line with previous results.

1 Introduction

The patent system grants temporary market power to reward innovators. This entails a welfare loss because the price of goods to which a patent is essential is higher than it would be on a competitive market. The magnitude of the loss is determined by the scope of patent protection. This is defined by its breadth, its length, and by the degree of novelty. The latter specifies the extent of protection against improvements. van Dijk (1996) uses the term of 'patent height'.

The occurrence of the welfare loss is restricted to the lifetime of the patent. This is often denoted by patent length. Breadth affects the range of similar products available to consumers. Klemperer (1990) identifies two kinds of social costs connected to patent breadth. A wide patent protection allows for higher prices which deter consumers from the entire product range. A narrow patent protection allows competitors to offer similar products. Consumers may switch to a less preferred product variants if the price difference is important enough. Refraining or deviating from the most preferred choice cause a welfare loss. These arguments are borrowed from the discussion on horizontal product differentiation. Conversely, patent height refers to a technological advance which allows for a quality improvement. When products differ such that consumers unanimously have the same preference ordering the goods are vertically differentiated.

The owner of a patent prefers a long and broad patent protection because it prevents that similar products are marketed. Likewise, a high degree of novelty keeps competitors from introducing a new product. Since the scope of patent protection determines the extent of the market power of the patentee, a short and narrow patent reduces the welfare loss. However, to ensure a sufficient incentive to innovate a certain reward is necessary which can be attained by finding an optimal combination of length, breadth and height. In this paper I tackle the tradeoff between patent length and patent height.

I will employ the same basic framework as Gilbert and Shapiro (1990) and Klemperer (1990) did for the tradeoff between patent breadth and length to obtain comparable results.

The two seminal articles by Gilbert and Shapiro (1990) and Klemperer (1990) have analyzed the trade-off between patent breadth and patent length. In the tradition of this discussion patents are directly linked to products provided to the market. This allows to infer that a broad patent only allows for highly differentiated products and a higher firm profit. Then a short patent life suffices to cover the research cots. Conversely, a narrow patent allows for imitation and providing similar products by competitors. Both articles give clear conditions when one of the two patent designs is favorable in the sense of social surplus. Gilbert and Shapiro (1990) interpret the patent breadth as the ability of the patentee to raise price. Klemperer (1990) presumes that a patent protects from competitors introducing similar products. If the latter 'patent around' their products will be highly differentiated which allow for monopoly profit for the patentee.

The literature on innovation includes some articles on patent height but to my knowledge none of them focuses on the tradeoff between the degree of novelty and patent length. In the context of cumulative patents Chang (1995) discusses the distribution of the surplus between basic inventions and subsequent innovations which build upon the first. He finds out that protection for basic inventions should be rather broad, even if the patent has little stand-alone value. In a setting with a sequence of innovations where firms repeatedly supersede each other O'Donoghue (1998) considers subsequent innovations as a rise on a quality ladder. A quality gap between an established technology and the subsequent innovation is the patent height. In his model the innovation process is stochastic and he distinguishes the situation where a social planner can control the expenditure for innovation and the minimum patent requirement - which is the patent height - and the situation where he can only control for the patent height. O'Donoghue concludes that patent height should be greater when the design of the patent policy covers the degree of novelty only.

In a welfare analysis Horowitz and Lai (1996) discuss how patent length affects the rate of innovation, which is supposed to be the objective of patent law, and consumer surplus. Patent length reduces the frequency of innovation but increases the size of innovation. The timing in their model is discrete when innovations along a product quality ladder can take place. I will adopt from their setting that the cost of imitation is zero after the expiration of the patent protection. However, instead of the consumer surplus I will compare the private and the social incentives to innovate which are represented by the firm profit and the social welfare respectively.

In the present model the patent height is directly linked to the expenditures in contrast to O'Donoghue (1998). Is is a sensible assumption that patent height and the expenditures are positively correlated. Certainly, investments in innovation are risky. However, I focus on the private and the social incentive for innovation an I will abstract away from the effects of uncertainty. These have been analyzed in Takalo (1998). In his setting an innovator invests in R&D. After uncertain success is realized, he decides whether to patent or to keep the innovation secret. After having observed the innovator's decision, an imitator can decide to imitate the product and to enter the market. One result of this model is that patent length and patent breadth are strategic substitutes when spillovers are small and they are strategic complements when spillovers are large. van Dijk (1996) analyzes the effects of patent height on the interaction between one innovating firm and one imitating firm. The exogenously patent height determines the incentives of the imitator either to improve upon the existing basic patent or to imitate the incumbent firm. van Dijk finds out that a patent holder can lose with medium patent heights whereas a low patent height is equivalent to no patent protection and high protection is preferable to the patentee.

As the effects of patent height on imitation behavior have been discussed in previous papers, I will fucus on the tradeoff between patent height and patent length. This adds the dimension of the degree of novelty to the discussion from Gilbert and Shapiro (1990) and Klemperer (1990) which concentrate on patent length and breadth. Thereby I distinguish the private and the social incentive when choosing the optimal patent height. The reward will be taken as exogenous and has to be attained through the instruments of pricing and novelty. This makes the demand and the profit endogenous. The degree of novelty is equivalent to a rise on a quality ladder. This means that there is no uncertainty related to investments in innovation. A new insight to the discussion by Gilbert and Shapiro and Klemperer is that there is a unique strictly positive patent length which maximizes social welfare. This length balances the effects of a sufficiently high reward and a innovative step which is wide enough to provide consumer surplus.

The plan of the paper is as follows. Section 2 presents the model which starts with the demand behavior. Then the objectives of a private firm and a social planner are derived. Section 3 discusses the model and gives some extensions. The last section concludes.

2 The Efficient Degree of Novelty

The degree of novelty of an invention affects the demand behavior of consumers. Hence, the flow of profit and of social welfare are endogenous. In the model, two instruments, the degree of novelty δ and the length of a patent T, must be chosen. There are two benchmark cases. In the first, a monopoly firm maximizes profit where the two instruments are unrestricted. In the second δ and T are chosen to achieve the maximum social welfare. In this section, I will present the consumer behavior and derive the firm profit and the social welfare. This allows to derive the optimal degree of novelty in the benchmark cases and the related conditions for optimal patent policy. I adopt the notation of Gilbert and Shapiro (1990).

For deriving the demand behavior I assume a model of vertically differentiated products where the product of the innovating firm is preferred by the consumers. A continuum of consumers differ in a utility index m which is uniformly distributed on the interval $[0; 1]$. $U = m \cdot \theta - p$ is the flow of utility of a consumer who purchases a product of quality θ at the price p. The unit demand is defined by all consumers with $m \geq p/\theta$. Assume that the quality θ is produced by a competitive industry at zero marginal cost and is offered for price zero. An innovating firm can increase the quality by an amount δ which is the degree of novelty. Consumers purchase the high-quality product if $m \cdot (\theta + \delta) - p \geq m \cdot \theta$.

For a monopolist with convex innovation costs δ^2 the value of a patent for a quality improvement δ is

$$V = \int_0^T \left(1 - \frac{p}{\delta}\right) p \ e^{-rt} dt - \delta^2 = \left(1 - \frac{p}{\delta}\right) p \frac{1 - e^{-rT}}{r} - \delta^2 \qquad (1)$$

where r is the interest rate for a period of unit length and T is the lifetime of the patent grant. After the period of length T the new technology is publicly available and the quality $\theta + \delta$ is offered a the competitive price $p = 0$. Maximizing the private value of the patent yields

$$p^m = \frac{1}{16} \frac{1 - e^{-rT}}{r} \quad \text{and} \quad \delta^m = \frac{1}{8} \frac{1 - e^{-rT}}{r}.$$

This completes the first benchmark case.

The second benchmark case shows

Proposition 1 *The socially desirable length of a patent is zero and the optimal degree of novelty is always higher than δ^m.*

The social value of an innovation with magnitude δ is

$$W = \int_0^T \Bigg(\underbrace{\int_0^{p/\delta} m \cdot \theta \ dm}_{(i)} + \underbrace{\int_{p/\delta}^{\infty} m(\theta + \delta) \ dm}_{(ii)} \Bigg) e^{-rt} dt$$

$$+\underbrace{\int_T^{\infty}\Big(\int_0^1 m(\theta+\delta)\ dm\Big)\, e^{-rt}\ dt}_{(ii)} - \delta^2.$$

It consists of (i) the benefit of the consumers with $m \leq p/\delta$ from the low-quality product during the lifetime of the patent, (ii) of the benefit from the high quality product of the customers with a utility index $m \geq p/\delta$ during the lifetime of the patent and serving all customers after this time, and of the costs of the innovation. This collapses to

$$\frac{\theta+\delta}{2r} - \frac{p^2}{\delta}\frac{1-e^{-rT}}{r} - \delta^2.$$

The social welfare is strictly decreasing in T. A profit maximizing firm always chooses $p = \delta/2$ and from the first order condition with respect to δ follows immediately

$$\delta^s = \frac{1}{4r} - \frac{1-e^{-rT}}{8r}. \tag{2}$$

Hence, it is socially desirable to have a minimum lifetime of the patent $T \to 0$ and the optimal degree of novelty is

$$\delta^s_{T\to 0} = \frac{1}{4r} > \frac{1-e^{-rT}}{8r} = \delta^m.$$

The price becomes irrelevant. □

The optimal innovation has a higher degree of novelty $\delta^s > \delta^m$ and it is immediately publicly available. This result is not surprising since the public good property of knowledge suggests that it should be publicly available as long as there is no rivalry. In the optimum the marginal cost of incremental novelty of the innovation must be equal to the marginal benefit of higher quality to all consumers who purchase the product. The social marginal benefit includes the consumers' benefit in addition to the firm profit. $\delta^s > \delta^m$ is an immediate consequence from the convexity of the costs of innovation. Any deviation from δ^m reduces the profit and prescribing a minimum degree of novelty δ^s for a patent may effect a negative profit.

The purpose of the patent system relies on the ability to innovate which is exclusive to firms. The two benchmark cases show that the firms' incentives to innovate differ from the social welfare. A higher degree of novelty and a minimum patent length $\delta^s_{T\to 0}$ are socially desirable.

Patent protection excludes some consumers from the high quality good because its price exceeds the marginal cost during the patent life. When a patent is granted for a period T then δ^s indicates that the optimal degree of novelty is inferior to $\delta^s_{T\to 0}$. The preclusion of some customers during early times of an innovation reduces the aggregate benefits of the innovation. Hence, they can carry less of the marginal costs of the innovation which means a lower degree of novelty. In consequence δ^s approaches δ^m and this raises the firm profit. Analogously, a higher interest rate gives less weight to the period beyond the patent lifetime where all customers have access to the higher quality. Given a strictly positive patent lifetime, longer patent protection and higher interest rates raise the firm profit because the optimum degree of novelty decreases. According to

Corollary 1 *For $T > 0$ the socially optimal degree of novelty δ^s yields a nonnegative profit when $r \cdot T \geq \ln 3$.*

Inserting $p = \delta/2$ and (2) into (1) yields

$$\frac{1}{4}\delta\frac{1-e^{-rT}}{r} - \delta^2 \geq 0$$

and

$$\frac{1}{4}\left(\frac{1}{4r} - \frac{1-e^{-rT}}{8r}\right)\frac{1-e^{-rT}}{r} - \left(\frac{1}{4r} - \frac{1-e^{-rT}}{r}\right)^2 \geq 0$$

respectively. Replacing $\mathcal{E} = 1 - e^{-rT}$ simplifies to

$$\frac{8}{3}\mathcal{E} - \mathcal{E}^2 - \frac{4}{3} = -\Big(\mathcal{E}+2\Big)\left(\mathcal{E} - \frac{2}{3}\right) \geq 0$$

$$\Leftrightarrow \quad \frac{2}{3} \leq 1 - e^{-rT} \leq 2.$$

As $r, T \geq 0$ the right inequality always holds. The left inequality transforms to $\ln 3 \leq r \cdot T$ which proves the corollary. $\square$

Hence an optimal patent system has to include a participation constraint for the firms. For the sake of simplicity, I assume that firms innovate if the patent grants a nonnegative profit $V^m \geq 0$. It is straightforward to show

Proposition 2 *There is an optimal patent length $T^* \in (0, \infty)$ and the firms' participation constraint is binding, $V^m = 0$.*

In the proof I will first show that the participation constraint is binding. This allows to simplify the maximization problem for the social welfare which has a single peak at $T = T^*$.

Since the firm profit V^m is an increasing function of the patent length T and the social welfare is strictly decreasing in T the optimal patent length will be set where the firm profit is zero, $V^m = 0$. This es equivalent to $\delta = 1/4 \cdot (1 - e^{-rT})/r \equiv \delta_0$. This implicit function indicates the patent length T and the degree of novelty δ_0 where the maximum profit of a price-setting firm is zero.

With δ_0 and $p^m = \delta/2$ the optimization problem

$$\max_{T,\delta} \quad W \qquad \text{s.t.} \quad V^m = 0$$

immediately simplifies to finding a length T which maximizes

$$\frac{4r\theta - e^{-2rT} + e^{-rT}}{8r^2} \equiv \mathcal{X}(T).$$

Obviously, $\mathcal{X}(0) = \lim_{T\to\infty} \mathcal{X}(T) = \theta/2r > 0$.

$$\frac{\partial \mathcal{X}(T)}{\partial T} = \frac{2e^{-2rT}r - e^{-rT}r}{8r^2} \quad \begin{cases} > 0 & \text{for} \quad T < \frac{1}{r}\ln(1/2) \equiv T^* \\ = 0 & \text{for} \quad T = T^* \\ < 0 & \text{for} \quad T < T^* \end{cases}$$

completes the proof. $\square$

3 Discussion and Extensions of the Model

The two benchmark cases show that the interest of a firm diverges from that of the social planner. For a firm an innovation is an instrument to increase its profit. An innovation which entails a quality advance will make the product of its inventor more attractive. This raises the demand for this product which allows for higher profit. Conversely, once the innovative technology has been invented, it would be socially desirable to disclose it. This would make the achievement available to all consumers. Proposition 1 includes this case with zero patent lifetime. From the literature we know that both benchmark cases are impossible. Patents do not perfectly protect from imitation or other forms of infringement.[1] This reduces the firms' incentive to innovate because they cannot fully appropriate the revenues from their invention. From the perspective of the social planner the first best solution where a new technology is immediately disclosed, will destroy the incentive of firms to file patents and for R&D expenditures. They may recur on secrecy as an imperfect and uncertain instrument to protect their intellectual property.

The effectiveness of secrecy to protect intellectual property strongly depends on the technical specifics of the invention. Relying solely on this instrument would assign arbitrary rewards to the inventor. They would not be directly related to the consumers' valuation of the product or the possibility to imitate it. A patent system may help to circumvent this flaw. Its design includes the length and the breadth, as extensively discussed by Gilbert and Shapiro (1990) and Klemperer (1990), and the height of the protection and its objective is to promote technological progess.[2] In these two articles the rewards which at least cover the R&D expenditures are exogenous and the design of the patent system is the subject matter of the analysis. The optimal design is a combination of patent length and breadth which minimizes the distortions from the market power of the patentee.

[1] See van Dijk (1996) and Takalo (1998).

[2] See Horowitz and Lai (1996, p. 786).

In the present model the tradeoff exists between patent length and height. The most important difference between height and breadth is that patents do not restrict consumers in their decision to consume similar products. Moreover, patent height affects the quality which is available and vertical differentiation is more costly than imitation of an existing patent.[3] The assumption of convex costs seems plausible since the pace of technological progress cannot be chosen arbitrarily. Enforcing a higher pace is increasingly costly. If the innovation is to be carried out by private firms they have to be sufficiently rewarded to not withdraw from the market. Hence, the first best degree of novelty $\delta^s_{t\to 0}$ is not attainable when the costs of innovation have to be borne by private firms. In consequence, the social planner has to grant a patent to the innovator at least temporarily. δ^s indicates the optimal degree of novelty for an arbitrary lifetime T according to (2). This is a decreasing function of T because a longer lifetime precludes some customers for a longer time from the higher quality. Then, less consumer surplus is generated which can only cover reduced costs of innovation.

It is important to note that the calculation of the optimal patent height is independent from the firm profit. Introducing a nonnegative profit as a condition for a feasible degree of novelty restricts the range of admissible combinations of δ and T. Corollary 1 states that patent heights which correspond lifetimes for which $r \cdot T \geq \ln 3$ holds are permissible. The interest rate determines the relative weight of the surpluses during and after the patent lifetime. A high interest rate means that the time after the patent expiration date becomes less important. The condition shows that with increasing r the restriction becomes less severe for T. The social planner can set a shorter patent lifetime which in turn implies a higher innovative step according to (2). Note that the two situations cannot be compared by their level of utility or welfare. The interest rate depends inter alia on the consumers' preferences and such a comparison would be inter-personnel.

[3]See van Dijk (1996, p. 152).

The second proposition gives a unique and interior solution for the optimal patent length. From (2) the same holds for the optimal degree of novelty. In contrast to the two models with analogous setting by Gilbert and Shapiro (1990) and Klemperer (1990) the optimum cannot be neither an infinitely short nor a long patent lifetime. The former would not be possible because of the participation constraint of the firm. The latter would preclude some customers for a too long time from the higher quality. Analogously, the optimal patent height cannot attain the limit values $\delta \in (1/8r; 1/4r)$ which are determined by (2). The intuition is that a high degree of novelty would be costly and the firm would ask a high price which would exclude many customers. Granting a patent for a small innovative step would reach a wider range of customers but their valuation and, hence, the surplus would be small.

The contribution of a single innovation to social welfare consists of a higher quality which is consumed by a fraction of the consumers during the lifetime of the patent and by all consumers thereafter. One limitation of the present model is that an innovation is a singular event. Hence the tradeoff between patent length and height does not cover the possibility that a second innovation is introduced - may be even during the patent lifetime of the initial innovation. As soon as one firm has a patent the underlying technology is disclosed to all competitors and constitutes a new starting point for further research. The incentive of the patentee to innovate is less important than that of the competitors because of the replacement effect. However, if the number of competitors is sufficiently large, a subsequent innovation by a competitor becomes more probable. As long as the novelty requirement is met, a new patent can be granted during the lifetime of the first. Consequently, this would reduce the profit of the first patentee. Ex ante this reduces the incentive to innovate. Per se no statement about the overall pace of technological progress is possible.

One extension of the model addresses the question how the conditions for the optimal patent height vary if the market power during the patent lifetime is uncertain. This will definitively reduce the expected revenue of a patentee. Such an effect is not uncommon in the context of patents since not only technological progress but also a limited protection from imitation may cause this effect. Then the participation constraint has to account for a possible turn down of the revenue during the patent lifetime. This extension of the model will analyze the effects of a more rigorous participation constraint $V^m \geq \overline{V} > 0$ on the tradeoff between patent height and length and also on Proposition 2.

The second extension is devoted to the effect that a patent may not be directly linked to a product. Moreover, it can offer access to a new technology which can be utilized in various industries. In the context of the present model an innovation would create more surplus because it affects several markets. If the inventor cannot appropriate the entire benefit from his invention, may be because it includes markets on which he is not active, this may distort the incentive for further innovations. Then the socially desirable effort to innovate will even more diverge from the private incentive as in the absence of positive externalities.

4 Conclusion

This article has shown that, under a basic setting which is apt to cover various dimensions of patent policy, there exist a unique patent length and height which constitute the optimal patent design. Together with the established results from literature this finding suggests a moderate use of patent length as a policy instrument because both, an infinitely long and a short patent protection cannot be socially desirable.

Unfortunately, an evaluation of the current patent policy offers no unambiguous implication because the actual degree of novelty may be to high or too low. In particular, each evaluation must be industry-specific because such are the cost parameters. However, a comparison of two industries which significantly differ in both, their innovation costs and in the possible revenue to an innovating firm, allows to predict that low costs and high revenues will shift the tradeoff towards a higher degree of novelty and a shorter patent lifetime. This will overall increase the pace of technological progress. This result is in line with the intuition that a market with a strong underlying demand can carry more innovative activities.

The minimum revenue of the innovating firm in the participation constraint affects the magnitude and the effects of the deadweight loss due to the market power. Firm profit has to be covered by consumers in the form of delayed or restricted access to higher quality.

The present analysis focuses on a single firm in a stationary environment. van Dijk (1996) reports that when a second firm which can introduce a subsequent innovation the incumbent firm may benefit from a high degree of novelty and is harmed by an intermediate degree. This means that in the context of strategic interaction between two firms, the firm profit does not necessarily have a unique maximum and also that the tradeoff between patent length and height no longer necessarily holds.

The introduction of competition as well as an unstable environment may jeopardize the implications from the model. The first extension will cover an analysis of the effects on social welfare when the revenue to the innovating firm has to be raised as to keep the expected profit constant.

Analogously to Gilbert and Shapiro (1990) or Klemperer (1990) the lacking third dimension of patent policy may veil some insights. Here, the breadth of a patent and the proneness of a technology to imitation have been neglected. These effects represent externalities which drive a wedge between social welfare and firm profit. Similarly, the private incentive to innovate and, in consequence, the pace of technological progress is affected by revolving innovations which may cut off the flow of profit before the patent lifetime expires. This constitutes a further limitation which narrows the policy-relevance of the present model.

References

Chang, Howard F. (1995), Patent scope, antitrust policy, and cumulative innovation, in: RAND Journal of Economics 26, 1, 34-57.

Gilbert, Richard and Carl Shapiro (1990), Optimal patent length and breadth, in: RAND Journal of Economics 21, 1, 106-112.

Horowitz, Andrew W. and Edwin L.-C. Lai (1996), Patent length and the rate of innovation, in: International Economic Review 37, 4, 785-801.

Klemperer, Paul (1990), How broad should the scope of patent protection be?, in: RAND Journal of Economics 21, 1, 113-130.

O'Donoghue, Ted (1998), A patentability requirement for sequential innovation, in: RAND Journal of Economics 28, 4, 654-679.

O'Donoghue, Ted, Suzanne Scotchmer, and Jacques-Francois Thisse (1998), Patent breadth, patent life, and the pace of technological progress, in: Journal of Economics & Management Strategy 7, 1-32.

Scotchmer, Suzanne (2005), Standing on the Shoulders of Giants: Protecting Cumulative Innovators (review article), Ch. 5 of Innovation and Incentives, forthcoming MIT Press January 2005.

Takalo, Tuomas (1998), Innovation and Imitation under Imperfect Patent Protection, in: Journal of Economics 67, 3, 229-241.

Tirole, Jean (1988), The theory of industrial organization, MIT Press.

van Dijk, Theon (1996), Patent Height and Competition in Product Improvements, in: The Journal of Industrial Economics 44, 151-167.