Patent Policy and Licensing in Network Industries

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Abstract

Since the last decade of the twentieth century we observe a significant increase of the number of patents. This phenomenon is called the 'patent paradox'. Strategies which build up patent thickets may serve to deter entry and may be harmful to society and the purpose of protecting intellectual property is not met anymore. Network industries are inherently protected from entry. Thus, patents offer an additional instrument to sustain a firm's dominant position on a market with network externalities. This paper explains that patent thickets are detrimental to society because they deprive competitors and consumers from new technologies. Furthermore, patent policy should prevent patent thickets. Licensing agreements will affect the firms' R&D behavior and social welfare. In the discussion on one-size-fits-all patent protection the existence of network effects should be considered.

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1 Introduction

Patent policy consists of two aspects: disclosing to the public a new technology making of it a public good and granting a reward to the innovator. A patent guarantees some degree of market power which may be exploited for a limited time. This market power may be a monopoly if the patent is broad and covers a wide range of substitutive products or technologies or it may be rather limited if the patent is narrow and similar technologies or products do not infringe.

Network industries are characterized by positive externalities from the mere number of consumers of compatible or complementary products. Hence, once a firm dominates a market it has good chances to do so in subsequent periods, too. The reason is that this firm is more attractive to consumers because of its size, namely the number of customers.[1] This means that the consumers' valuation for one product of a particular firm depends on their expectation about the number of other consumers who will purchase a compatible product.

The consumers' expectations are affected by many factors. In their seminal paper on network externalities *Katz / Shapiro* (1985) regard the number of firms which offer a compatible product as primary determinant of the consumers' expectations. Certainly, various other factors will affect the expectations. Inter alia, quality of the product, timing of the product launch, and reversibility of the purchase decision may also affect the consumers' expectations. Higher quality will ceteris paribus make the product attractive to more customers and will raise the customer base.

In this paper, the firms can influence the network sizes through their R&D activities. They obtain patents which can be included into the product technology and which give the right to exclude the competitor from using this particular technology. This setting covers two aspects which are specific to patents and markets with network externalities. First, a new technology can be employed only if it results from the firms' costly research activities. Secondly, if two firms obtain patents for very similar technologies, none of the patents can be used without to infringe the patent of the competitor. These contested patents form a patent

[1] See *Economides* (1996).

thicket in the sense of *Shapiro* (2001). Such rivalry in R&D seems to be common in markets with network externalities.[2] This strategic aspect of patenting may not be socially desirable for society because firms incur costs to prevent their competitor's technology being marketed. This paper shows that such an equilibrium can occur when firms use patents to harm their competitor. Thereby they benefit indirectly from the reduced quality of their competitor's product.

The application of patent policy on a market which exhibits network externalities differs from markets without these effects. For the firms' success the consumers' expectations are crucial because the latter make their purchase decision conditional on their beliefs. Patens serve as a signal in the pre-competition stage. The firms invest in their product's quality and they care about the relative quality compared to their competitor's product. Hence, they have an incentive to choose actions that harm their competitor. *Kristiansen* (1996) analyzes the investment behavior of firms which enter successively a market which exhibits network externalities. In particular, he predicts that the first firm chooses an investment that is less risky then socially desirable and the succeeding firm chooses a project that is too risky. The reason is that the second firm may initiate the established customers to give up the existing technology. Even though *Kristiansen* identifies the firms R&D behavior as the cause of a welfare loss, he does not suggest a change in patent policy. Also in a dynamic perspective patent races occur when firms simultaneously compete for a given reward. Here there is no rivalry in the actual patents but in the benefit which results from patenting. Similar to rent seeking activities the profits of the later stage are dissipated from the perspective of the firms. Their investment is funded by the eventual profit.[3] In the present context the investment at least in part contributes to social welfare because new technology is offered to the consumers.

In the model two firms first compete for patents in a R&D stage. They accumulate a portfolio of patents which may be overlapping. If they are, they form a mutually exclusive patent thicket. The number of patents that each firm may use without to infringe its competitor's patents determines the product quality and subsequently the consumers' expectations. In the second stage the firms compete on a market with network externalities where the consumers' purchase decision is conditional on their expectation on the network sizes. We will show that the firms' supply tends to be higher if they do not build up a patent thicket. Furthermore, a patent thicket is always socially undesirable and in this situation social welfare is higher when the network externalities are low. The next section presents the model. Section 3 gives a discussion of the model and the last section concludes.

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[2] See *Katz / Shapiro* ((1992), p. 55) and *Kristiansen* ((1996), p. 770).

2 The Model

In a two-stage setting, two firms first choose their effort in R&D. The interaction of both firms' level of R&D determines the technology employed in the product market competition which constitutes the second stage. As the product market exhibits network externalities the size of this market depends on the consumers' expectations about the final number of customers in this market. We will assume that the two products are not compatible. This issue is the focus of *Katz / Shapiro* (1985). Moreover, we concentrate on the firms' R&D activities. The present paper is an extension of their model where the firms compete for patents on the technology space. The number of patents available to one firm constitutes the quality of this firm's product which directly translates into the consumers' expectations about the size of the subsequent product market.

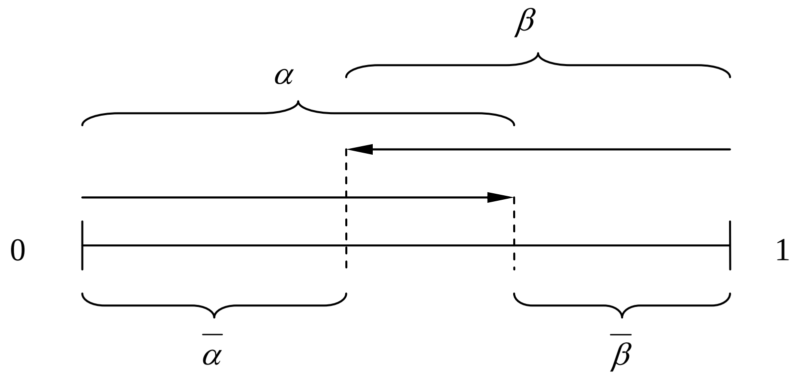
2.1 Setting

Assume that the technology space consists of a continuous number of patents on the interval $[0;1]$. Let firm i compete for α patents and firm j for β patents. We will denote the situation with $\alpha+\beta\leq 1$ as *unrestricted* whereas the firms are *restricted* in the number of patents they would like to obtain when $\alpha+\beta>1$. In the absence of licensing agreements, I will assume that the patents which are contested by both firms form a patent thicket which lies idle. Let $\overline{a}$ and $\overline{\beta}$ denote the number of patents that the firms can effectively use. Ten, the number of patents which firm i can effectively use for its product is $\overline{\alpha}=1-\beta$ and analogously $\overline{\beta}=1-\alpha$ for firm j. This is the number of patents which determines the firms' product quality. To break up the patent thicket the firms may engage in a licensing agreement. Core licensing will allow both firms to use the patents which form the patent thicket. This means that each firm may use all patents that it possesses: $\overline{\alpha}=\alpha$ and $\overline{\beta}=\beta$. Core licensing becomes only effective when the firms are restricted and some patents form a patent thicket. Full licensing allows one firm to use all patents of its competitor in addition to its own. In this case the firms contribute to a common patent pool. Figure 1 illustrates the number of patents which effectively enter the product technology when the firms are restricted in the R&D competition stage with no licensing. The locations of the firms at the limits of the technology space in the

[3] See *Scotchmer* ((2004), pp. 112-114).

figure are helpful to illustrate the calculation of $\overline{\alpha}$ and $\overline{\beta}$ although they bear no relevance for the remainder of the paper.

Fig. 1: Effective number of patents with restricted R&D competition and no licensing



The description of the setting in the following subsection starts with the behaviour of the consumers. We introduce the product competition where we adopt the notation of *Katz / Shapiro* (1985) for given number of effectively used patents. Eventually, we will present the R&D competition for different modes of licensing.

As indicated above, the effective numbers of patents directly translate into $x_i^e = \overline{\alpha}$ and $x_j^e = \overline{\beta}$. These are the consumers' expectations about the network size of firm i and j, respectively. This functional form is arbitrary. Eventually, we will discuss how the implications depend on the functional form. However, it catches the most important effect that consumers prefer higher quality and they know that other consumers do so too. Hence, they expect that the higher quality is purchased by a larger number of customers. Products which contain new technologies are presented to the public and to experts on fares or in magazines. This is very common inter alia for entertainment electronics, cars or PCs where also network effects prevail.[4] The experts who are familiar with the state of the art technology give a comparison and evaluation of the quality of the products to the public. Patents protect intellectual property on technologies which either reduce production costs, raise product quality, or both. Additionally, the relationship between the number of patents and the consumers' expectations reflects the idea that a higher number of patents allows to offer higher quality.

Consumers are characterized by their benefit from consuming at most one unit of good x from firm i at price p_i: $r + v(x_i^e) - p_i$. r is the direct utility from the consumption of the good x. We assume that r is uniformly distributed on the interval $]-\infty; A]$ with density one and $A > 0$. This reflects the coexistence of early adopters of new technologies and following

[4] See *Kristiansen* ((1996), p. 769).

adopters. $v(x_i^e)$ is the network externality that a consumer perceives when he expects that x_i^e customers purchase this product. We assume $v'>0$, $v'(0)=\bar{v}$, $v''<0$.

It is important to note that consumers form expectations about the size of the network that they can enter. Since we do not analyze dynamic issues of network size or the selection of equilibria we can imagine that all consumers make their purchase decisions simultaneously or, at least, without the possibility to observe the current size of the network when making the decision. Hence, each consumer has to form expectations before his purchase decision. We will only consider equilibria where the expectations are met. Certainly, actual expectations of all consumers are not met simultaneously. However, this assumption allows to extend the predictions of the model on reversible purchase decision. Consequently, in the equilibrium no consumer wishes to sell his good at a lower price to another consumer, or to purchase one good at a higher price than set by the firms.

Firms compete for patents in the first stage and eventually on the product market. The two firms choose non-cooperatively their level of R&D. We assume that there is no uncertainty. $c(\alpha)$ is the cost of controlling α patents. We assume that the Inada conditions[5] hold, namely $c'(\alpha)>0$, $c''(\alpha)>0$, $\lim_{\alpha\to 1} c(\alpha)=\infty$, $c''(0)=0$. Analogous conditions hold for β. These conditions help to avoid corner solutions which would provide no further insights. The effort translates into the effective patent portfolio according to

$$\bar{\alpha}=\begin{cases}\alpha & if \quad \alpha+\beta\le 1\\ 1-\beta & if \quad \alpha+\beta>1\end{cases}.$$

For a given price the consumers unambiguously prefer the good which belongs to the largest network. A firm can compensate for a smaller network by lowering its price. A necessary condition for both firms i and j to sell strictly positive quantities is $r+v(x_i^e)-p_i=r+v(x_j^e)-p_j$. Only consumers for which $r+v(x_i^e)-p_i>0$ holds will purchase. Note that this holds also for firm j's product because the consumers are indifferent between the two products. Then the total number of customers is determined by the mass of consumers $r\in[p_{(\cdot)}-v(x_{(\cdot)}^e);A]$ which is uniformly distributed with density one. Their number is $A-p_{(\cdot)}+v(x_{(\cdot)}^e)\equiv z$. Accordingly, the price for a good with network size $x_{(\cdot)}^e$ is $p_{(\cdot)}=A-z+v(x_{(\cdot)}^e)$. Since we assume that production costs are zero firm profits are $\pi_i=x_i\left(A-z+v(x_i^e)\right)$ and $\pi_i=x_j\left(A-z+v(x_j^e)\right)$ where $z=x_i+x_j$. The best-response functions in the product competition stage are

$$x_i = \frac{A + v(x_i^e)}{2} - \frac{1}{2} x_j \ , \quad x_j = \frac{A + v(x_j^e)}{2} - \frac{1}{2} x_i$$

and the equilibrium quantities are

$$x_i^* = \frac{A + 2v(x_i^e) - v(x_j^e)}{3} \ , \quad x_j^* = \frac{A + 2v(x_j^e) - v(x_i^e)}{3} .$$

The quantities are a function of the consumers' expectations. At the beginning of the second stage these are exogenous to the firms.

We consider only equilibria where the consumers' expectations are fulfilled. Otherwise, the firms would still make the same profit in the present setting. However, the demand behaviour relies on the consumers' anticipating of their benefit from consuming the network good. As we assume that all agents in the world form rational expectations and the setting of the model is common knowledge, the willingness to pay of the consumers would not be as given if they knew for sure that they would be deceived in the second stage systematically. Eventually, we will discuss the importance of this assumption.

When the expectations are consistent with firm behavior $x_{(\cdot)} = x_{(\cdot)}^e$ then the second stage firm profit simplifies to $\pi_{(\cdot)} = (x_{(\cdot)}^*)^2$. This completes the second stage where the firms take the consumers' expectations as given. We can now turn to the firms' patenting behavior in the first stage which determines the expectations in the second.

Inserting $x_{(\cdot)}^e$ into the profit function yields

$$\pi_i = \left[\frac{A}{3} + \frac{2}{3} v(\overline{\alpha}) - \frac{1}{3} v(\overline{\beta}) \right]^2 - c(\alpha) \text{ and } \pi_j = \left[\frac{A}{3} + \frac{2}{3} v(\overline{\beta}) - \frac{1}{3} v(\overline{\alpha}) \right]^2 - c(\beta) .$$

The Nash-equilibrium of this game is a pair (α^*, β^*) for which $\alpha^* = \arg\max_\alpha \pi_i$ and $\beta^* = \arg\max_\beta \pi_j$ hold simultaneously.

2.2 Equilibrium

In this section we will derive the properties of the equilibrium. There are two cases to be considered. In the equilibrium either the firms are restricted in the use of their patents, $\alpha + \beta > 1$, or they are not, $\alpha + \beta \leq 1$. We will start with the latter case.

2.2.1 Unrestricted equilibrium

In the unrestricted equilibrium the firms' R&D effort directly transforms into the number of patents. There is no patent thicket from contested technology areas.

[5] See *Inada* ((1963), pp. 119-127).

$$\pi_i = \left[\frac{A}{3} + \frac{2}{3}v(\alpha) - \frac{1}{3}v(\beta)\right]^2 - c(\alpha) \text{ and } \pi_j = \left[\frac{A}{3} + \frac{2}{3}v(\beta) - \frac{1}{3}v(\alpha)\right]^2 - c(\beta)$$

are the relevant profit functions. In the equilibrium the best-response functions of both firms cross each other. Firm i's best-response function is

$$\frac{4}{9}\left[A + 2v(\alpha) - v(\beta)\right]v'(\alpha) - c'(\alpha) = 0.$$ [6]

This function implicitly defines the best-response function $\alpha(\beta)$. An equilibrium (α^*, β^*) is unique and stable if it exists. It is sufficient to show that $\alpha(\beta)$ crosses $\beta(\alpha)$, firm j's best-response function, from above. In the first step we show that the reaction functions are downward sloping in the relevant range. The second step exemplifies that $\tilde{\beta} > \hat{\beta}$ for $\alpha(\tilde{\beta}) = 0$ and $\hat{\beta} = \beta(0)$.

Total differentiation of the implicit best-response function of firm i yields

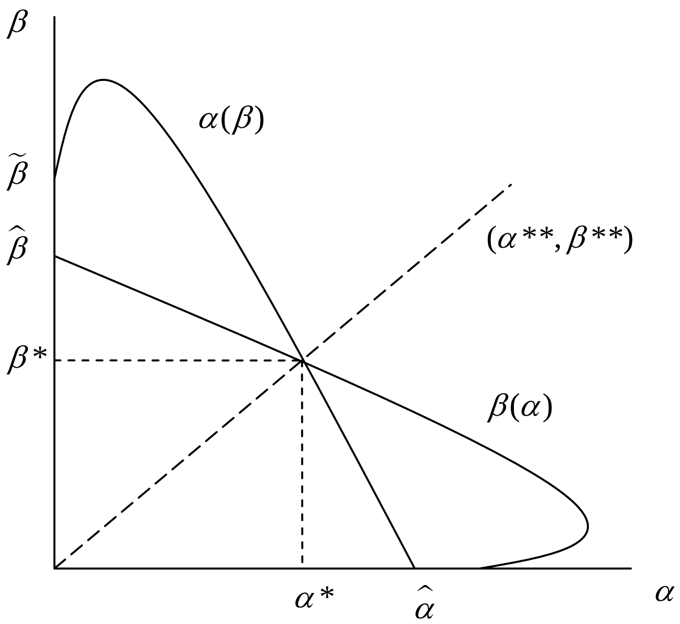
$$\frac{d\beta}{d\alpha} = \frac{\frac{4}{9}\left[2v'(\alpha)v'(\beta) + \left[A + 2v(\alpha) - v(\beta)\right]v''(\alpha)\right] - c''(\alpha)}{\frac{4}{9}v'(\beta)v'(\alpha)}.$$

This function is upward sloping for small values of α and downward sloping for large values of α. In particular for $\alpha = 0$ and $\frac{d\beta}{d\alpha} = \frac{4}{9}\left[A - v(\beta)\right]\bar{v} = 0$ and this is equivalent to $A = v(\beta)$. This means that firm i chooses not to file any patent if j sets β such that $A = v(\beta)$. Since the function is concave with $v' = \bar{v} > 0$ and $v'' < 0$ and A is exogenous, the corresponding value of $\tilde{\beta}$ may become arbitrarily high.

The second step is to show that $\hat{\beta} < \tilde{\beta}$. Because of the symmetry of the two firms we will still refer to $\alpha(\beta)$. For $\beta = 0$ the best-response function simplifies to $\frac{4}{9}\left[A + 2v(\alpha)\right] = \frac{c'(\alpha)}{v'(\alpha)} \equiv g(\alpha)$. The left hand side increases as $v(\beta)$ vanishes. Because of $g' > 0$ and $g'' > 0$ and $\lim_{\alpha \to 1} g(\alpha) = \infty$ there exists $\hat{\alpha} \in]0;1[$ such that $\hat{\alpha} = \hat{\beta} < \tilde{\beta}$. Hence, there exists a unique symmetric and stable equilibrium (α^*, β^*) which is illustrated in Figure 2. Note that this unrestricted equilibrium holds only if $\alpha^* + \beta^* \leq 1$. Otherwise there is no unrestricted equilibrium.

[6] In the following we omit the functions for firm *j* which are symmetric.

Fig. 2: Best-response functions in the unrestricted equilibrium



In the context of an unrestricted equilibrium $\alpha + \beta \leq 1$ only full licensing is sensible. Core licensing would have no effect because there are no contested patents. It is straightforward to show that a full licensing agreement reduces the incentive to innovate. If a non-restricted equilibrium emerges in the absence of a licensing agreement then the firms innovate more than they would have done with a full licensing agreement.

In the full licensing scenario, both firms can use $\alpha + \beta$ patents. The profit is $\left(\frac{A + v(\alpha + \beta)}{3}\right)^2 - c(\alpha)$ and the first order condition is $\frac{2}{9} v'(\alpha + \beta)\left(A + v(\alpha + \beta)\right) = c'(\alpha)$. From the assumptions on the cost function we know that a lower marginal revenue implies a lower investment in R&D and α. Because of the symmetry of the firms in the equilibrium $\alpha = \beta$ holds and the first order conditions for the two scenarios (full and no licensing) simplify to

$$\frac{2}{9} v'(2\alpha)\left[A + v(2\alpha)\right] = c'(\alpha) \text{ and } \frac{4}{9} v'(\alpha)\left[A + v(\alpha)\right] = c'(\alpha),$$

respectively. Because of the convexity of $v(\cdot)$ marginal revenue with full licensing is always lower (for $A > 0$) then without. This proves that full licensing reduces the incentive for patenting.

The intuition of this effect is that the full licensing agreement turns patents into a public good and this reduces the individual incentive to contribute. There are two effects of innovation on the firm profit. The first is that the size of the market increases in the number of patents. The second is that an additional patent makes a firm more competitive relative to its competitor from which it attracts consumers.

Yet we have established that each firm will have fewer patents under a full licensing agreement. It is straightforward to show that the total number of patents $\alpha+\beta$ which one firm may use is lager under full licensing than without licensing. The marginal revenue in the left first order condition is at least than half of the marginal revenue in the right first order condition because of the convexity of $v'(\cdot)$. Then α in the left marginal cost is more than half of α in the right marginal cost. This establishes that the consumers benefit from a higher quality and a larger network when the firms engage in a full licensing agreement.

2.2.2 Restricted equilibrium

By assumption, the technology space is an interval of length one. This means that the firms' patents cannot cover more technology than unity when $\alpha+\beta>1$. Consequently, there must be some overlapping patents which we define as a patent thicket. Such patents prevent that firms can use them without infringing. In turn, the competitor cannot use his patent either. Once the technology space is entirely covered by the active firms, any additional patent cannot be employed in the production process, but it serves to block patents of the competitor. This effect is known as Raising Rivals' Costs.[7]

The profit function of firm i is

$$\pi_i=\left[\frac{A}{3}+\frac{2}{3}v(1-\beta)-\frac{1}{3}v(1-\alpha)\right]^2-c(\alpha).$$

Again, we see that the number of firm j's patents harms firm i. The best-response function is implicitly defined by the first order condition

$$\frac{2}{9}\left[A+2v(1-\beta)-v(1-\alpha)\right]v'(1-\alpha)=c'(\alpha).$$

This condition also defines the optimal number of patents α for firm i given the number of patents β of firm j. In this condition the marginal revenue is concave due to the assumptions on $v(\cdot)$ and the marginal costs are convex. Hence, the optimum is a maximum. However, this condition does not guarantee that the maximum lies in the interval $\alpha\in[1/2;1]$. The same arithmetics hold for firm j because the best-response functions are symmetric.

In this context, core licensing would allow both firms to use all patents which form the patent thicket. Certainly, once a patent thicket has been built up, it is beneficial to introduce a

[7] See *Scheffman / Salop* ((1983), pp. 267-271).

licensing agreement. However, the anticipation or the existence of such an agreement affects the firms' incentive to innovate.

In the context of the restricted equilibrium $\alpha+\beta>1$ the first order conditions without and with core licensing are

$$\frac{2}{9}v'(1-\alpha)\left[A+2v(1-\beta)-v(1-\alpha)\right]=c'(\alpha) \quad \text{and} \quad \frac{4}{9}v'(\alpha)\left[A+2v(\alpha)-v(\beta)\right]=c'(\alpha),$$

respectively. Compared to the situation without licensing, we can show that core licensing has a positive effect on the total number of patents when the marginal valuation $v'(\cdot)$ of an additional is high and that the number of patents is lower otherwise.

Proof: For (nearly) constant marginal valuation $v'(\cdot)$ of an additional patent, the marginal revenue in the first order condition is higher when there is core licensing. For given (α,β), 4/9>2/9 and the term in squared brackets is higher while all other terms are equal. The only term on the LHS which may decrease when α grows is $v'(\cdot)$. For the marginal revenue to drop in consequence of a core licensing agreement, $v'(\cdot)$ must decrease and $v'(1-\alpha)>>v'(\alpha)$ (because of $\alpha>1/2>1-\alpha$) in order to imply a lower marginal revenue in the second first order condition.

2.2.3 Comparison of the equilibria

So far we have presented two scenarios. Unrestricted and restricted equilibria may occur and we have not yet stated when one of the two scenarios occurs. This section will present some statements on the existence and the uniqueness of equilibria and we will infer the welfare properties of the two scenarios.

In both scenarios the effective number of patents which enter the technology used in the industry cannot exceed unity. We can show that multiple equilibria cannot emerge for given cost functions $c(\cdot)$ and private valuation functions $v(\cdot)$.

$$\frac{4}{9}\left[A+2v(\alpha)-v(\beta)\right]v'(\alpha)=c'(\alpha) \quad \text{and}$$

$$\frac{2}{9}\left[A+2v(1-\beta)-v(1-\alpha)\right]v'(1-\alpha)=c'(\alpha)$$

are the two first order conditions for the unrestricted and the restricted scenario, respectively. For theoretical considerations assume that two symmetric equilibria may occur with identical numbers of effective patents while one equilibrium is restricted whereas the other is not: $\overline{\alpha}=\overline{\beta}=\alpha=\beta=1-\alpha=1-\beta$. Then the first order conditions simplify to

$$\frac{4}{9}\left[A+v\right]v'=c' \quad \text{and} \quad \frac{2}{9}\left[A+v\right]v'=c'.$$

This is equivalent to $c'_{unrestricted}=2c'_{restricted}$. This equation cannot hold for strictly increasing marginal cost functions. Similarly, we can show

Proposition 1: Given the properties of $v(\cdot)$ and $c(\cdot)$, multiple symmetric equilibria will never arise.

Assume that
$$\frac{4}{9}\left[A+v(\alpha^{u})\right]v'(\alpha^{u})=c'(\alpha^{u}) \quad \text{and}$$
$$\frac{2}{9}\left[A+v(1-\alpha^{r})\right]v'(1-\alpha^{r})=c'(\alpha^{r})$$

are the first order conditions in the equilibrium when the firms are symmetric $\alpha=\beta$ and where (u) r denotes the (un)restricted equilibrium. Because of $c'(\alpha^{r})>c'(\alpha^{u})$ due to $\alpha^{r}>\alpha^{u}$ it follows $\frac{2}{9}\left[A+v(1-\alpha^{r})\right]v'(1-\alpha^{r})>\frac{4}{9}\left[A+v(\alpha^{u})\right]v'(\alpha^{u})$ (*). $v(1-\alpha^{r})>v(\alpha^{u})$ is equivalent to $\alpha^{u}<1-\alpha^{r}$ and $v'(1-\alpha^{r})>v'(\alpha^{u})$ is equivalent to $\alpha^{u}>1-\alpha^{r}$. Any solution where $v'(1-\alpha^{r})<v'(\alpha^{u})$ or $v(1-\alpha^{r})<v(\alpha^{u})$ cannot meet (*) because $\alpha=\frac{1}{2}$ cannot be a solution and $\alpha\to 1$ would contradict the first order condition.

The idea of the non-existence of multiple equilibria is that not continuous for $\alpha=\frac{1}{2}$. For $\alpha<\frac{1}{2}$ the marginal revenue consist of a demand raising effect due to increased quality and an advantage gain over the competitor. For $\alpha>\frac{1}{2}$ only the relative advantage is relevant while an additional patent even reduces overall demand because the additional patent is blocked. Since the marginal cost function is monotonically and continuously increasing while the marginal revenue function is monotonically but non-continuously decreasing there is at most one equilibrium, possibly none.

3 Discussion

We have analyzed the market performance on a market with network externalities when firms can influence the consumers' expectations on the network size. The instrument we focused on is the R&D activities of the competing firms. The model has shown that two types of equilibria can emerge. Either the firms have distinct patents where each firm can fully use its patents, or the firms have patents on overlapping ranges of technologies. In the latter case, they form a patent thicket with knowledge that lies idle. The only purpose of the patents which form the thicket is to block the competitors' patents and thus to lower his quality and consequently his network size.

In the paper we concentrate on symmetric equilibria. The reason is that we have made symmetric assumptions on the firms. More assumptions would be necessary to explain how an asymmetric equilibrium can emerge and, in particular, how the firms choose their asymmetric roles. Also the timing of entry is symmetric. In the model we have analyzed simultaneous entry. The setting fits the situation where firms introduce new products that contain different technologies. Examples are very common in entertainment electronics like video recorders[8], audio recording, GSM frequencies, or automobiles. Firms announce new technological developments and the consumers may form expectations about the quality and the features of the new products. Often firms actually enter the market simultaneously.

We have presented two types of equilibria but we have no precise prediction on which of the two types of equilibria will emerge. This heavily depends on the cost function and the utility function. We have not specified a particular functional form because no insight is gained from interpreting the outcome of an arbitrary function. Moreover, there are manifold specifications of network externalities as presented by Economides (1996) while we have made no particular assumptions on the type of network externalities. This level of generality inhibits precise predictions on the type(s) of equilibria that may emerge. At least we have shown that no multiple equilibria can emerge.

The consumers' expectations about the number of patents which directly translates into product quality are a restrictive assumption of the model. However, product quality seems to cover a wide range of specifics of a good that consumers take into consideration when they assess their private valuation for a particular good. Again, the network size which is entirely determined by the number of patents is a technical assumption which would make obsolete the interpretation of any functional form for the cost function or the network externality. Another assumption on the consumers' expectations is that we concentrate on fulfilled equilibria. This implies that in equilibrium neither an additional customer is willing to purchase one unit, nor a present customer is willing to sell his unit. Thus, the analysis covers situations where consumers have to make their purchase decisions without observing the decision of other consumers. If consumers can revise their purchase decision the scenario displays one possible equilibrium but it does not predict how it is achieved.

The firms' patenting strategies may involve blocking patents. In the present setting this results in patent thickets. This means that consumers do not benefit from a certain number

[8] See *Ohashi* (2003, 2003a).

of patents. Ideally, the firms would form a patent pool with licenses which mutually grant the right to use the patents which are said to infringe each other. This would benefit all involved parties. The consumers would gain access to enhanced quality and the firms would benefit from larger networks which result from a higher quality. However, if the firms know ex ante that they form a patent pool where each firm contributes patents this would alter the firms' incentives to innovate. They would privately bear the R&D costs while both parties benefit. Moreover, strengthening the competitor's position affects negatively the own competitiveness. An assessment of patent policy in the present context suggests that policy should facilitate patent pools once patent thickets have emerged. This is certainly correct in a static inspection of a particular constellation. In contrast, a policy which would systematically introduce patent pools as soon as thickets have emerged is not sensible because it would not be incentive compatible from an inter-temporal perspective. Once a firm has disclosed a new technology in a patent any competitor could build a patent thicket around the initial patent and benefit from the inventor's idea. A further dynamic aspect is that firms may adapt their R&D strategies. This concerns several dimensions of R&D projects like their probability of failure, their length and their size, none of which are covered by the simple model presented here. In the context of repeated interaction, even without an explicit licensing agreement, firms may start to use the competitor's patents without the fear of being sued for infringement. Ex post Licensing is certainly beneficial to both firms. Then an implicit agreement is welfare enhancing. The anticipation of such a behavior may induce the firms to invest in blocking patents to ensure that they may participate in such an agreement eventually.

We have shown that an equilibrium is unique if it exists. However, it is possible that there is no pure strategy equilibrium where marginal cost equals marginal revenue in the relevant range. For the discontinuity of the marginal revenue in the model Dasgupta and Maskin (1986) give conditions for and the properties of a mixed strategy equilibrium. Since the model is highly stylized it is not appropriate to interpret firms' behavior as a mixed strategy. In the model we have assumed that every additional patent when the (fixed) technology space is covered would form a patent thicket. Actually, R&D projects are risky and their outcome is uncertain. Firms cannot precisely control for having non-overlapping technological fields in which they are active. It may happen that patent thickets emerge while the technology space is not yet covered.

In the context of network externalities it is difficult for an entrant to compete against an incumbent firm which has already built up a considerable network size. A patent policy which grants an exclusive right to use a technology would give additional protection to an incumbent firm. Entry would then be made even more difficult. Furthermore, if an incumbent firm files selective patents on concurrent technologies, it is not necessary to cover the entire range of technology like in the model. Moreover some single patents would be sufficient to deter entry. Thus, network externalities are an inherent protection for a network good. Patenting is necessary only if the incumbent cannot control for compatibility with the competitors' products. In contrast, patenting allows an incumbent to reinforce his position even more because the entry of a superior technology is impeded by both, the network externality and the selective blocking of patents.

4 Conclusion

Patent policy is an established incentive mechanism to encourage technological progress. In the context of network externalities blocking patents becomes an even more attractive strategy than without the externality. This reduces social welfare because the entry of a superior technology is even more likely to be deterred. Ex post and ex ante licensing, both is welfare improving but they affect the choice of R&D projects and intensity of firms. This suggests that patent policy should prevent blocking patents in the context of network externalities. However, this issue has to be embedded in the discussion on one-size-fits-all patenting because network externalities are only one peculiarity which can occur on markets.

The current mode of patent policy grants uniformly protection of an invention. This handling covers at least three dimensions of protection: patent length, patent breadth and the degree of novelty of an invention. The application of these instruments allows for a more effective prevention of patent thickets. Granting patents which cannot be used in products without infringing similar patents builds up patent thickets when the patents belong to different firms. Here, the evaluation of patent applications by the administration can help to circumvent detrimental patent thickets.

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