Strategic Licensing of Product Innovations

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May 2007

Abstract

Obtaining a patent provides the patentee with the ability to offer a potential entrant a license to operate within the patent that has been claimed. This paper shows that the patentee always has an incentive to provide a license if the patentee is unable to use patent breadth to deter entry (if the patentee can deter entry, it is optimal for the patentee to do so). Licensing a new product to a competitor has two benefits for the patentee. First, licensing creates an incentive for the entrant to select the product location that maximizes the joint profits of both it and the patentee, rather than just its own profits. Second, the patent breadth decision determines the default profits for both the patentee and the entrant, which in turn affects the manner in which the benefits of the cooperative R&D are shared between the two parties. Generally the patentee has an incentive to choose a smaller patent breadth when licensing is possible than it would choose where licensing not possible. The smaller patent breadth is optimal because it lowers the probability of the patent being found invalid, which in turn lowers the default profits for the entrant (i.e., the profits earned in the absence of a license).

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, OR, July 29-August 1, 2007

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1 Introduction

Firms that develop and patent new technologies often make these new technologies available to competitors through licensing agreements. An example from the agricultural biotechnology area illustrates the situation. Monsanto developed and patented the YieldGard Corn Borer and YieldGard Corn Rootworm technologies that provide protection from two serious corn pests. While both of these products are sold by Monsanto; Monsanto has also licensed them to Pioneer, which has incorporated this technology into its hybrids (Pioneer 2005a). Pioneer provides experimental data to show that the yields of its hybrids exceeds that of its competitor (Pioneer 2005b).

Numerous strategic reasons have been suggested for why firms might license a new technology to a competitor. Gallini (1984) shows that an incumbent monopoly may license a technology to a entrant, since allowing her into the market reduces her incentive to undertake R&D that could make her an even stronger competitor. In a similar vein, Rockett (1990) develops a model in which licensing is used as a way of selecting weak competitors; the presence of these competitors then keeps stronger competitors out of the market when the patent expires. In both of these instances, the incumbent, knowing that he cannot deter entry, uses the license to position the entrant so that his profits are maximized.

The purpose of this paper is to examine an additional strategic reason for the licensing of a technology to a competitor. In a similar vein to Gallini (1984) and Rockett (1990), the paper examines the incumbent's ability to optimally position an entrant in the market – in this case, however, the positioning is with regards to product quality. Specifically, if entry cannot be deterred, the incumbent can use the awarding of a license to induce the entrant to invest in the product quality that maximizes joint profits. Since holding a patent to the technology is critical in allowing the incumbent to optimally position the entrant, the patent – by providing the incumbent with property rights to his technology – allows a more efficient outcome to be obtained (see Gallini and Winter (1985) for a similar conclusion).

The patent, however, has other effects. Because the incumbent is able to maximize his share of the profits through the optimal selection of patent breadth, the patent also has distributional impacts. More specifically, although the entrant always benefits from licensing in the sense that at the optimal patent breadth that is chosen when licensing occurs, the entrant's profits with the license are greater than those that would be earned if the license were not offered. However, if licensing was not available (e.g., the legal system did not support it), then the patent breadth chosen by the patentee would be different. It is possible that at this patent breadth the entrant may be better off than what she would be if licensing were possible. Thus, licensing has both efficiency and distributional impacts for the industry in which the patentee and entrant operate.

The situation examined in this paper is that of a vertically differentiated product market in which the incumbent has a patent over the product it has developed. This paper shows that, if entry cannot be deterred, the incumbent has an incentive to license this product to a competitor, even when the competitor uses this license to develop a superior product. In the absence of a license, the entrant – which must undertake costly R&D to position itself in the market – has to choose a quality location so that it best responds to the patent breadth chosen by the incumbent. In doing so, the entrant either over invests or under invests in R&D. This outcome occurs because, although both firms benefit from an increase in product differentiation (see, for example, Lane (1980), Motta (1993), and Shaked and Sutton (1982)), the entrant chooses her R&D activity to maximize only her own profits. By licensing the product, the incumbent is able to induce the incumbent to choose a location that maximizes the profits of both firms. Moreover, patent breadth is chosen to maximize the size of the profits that accrue to the patentee.

The paper extends the work by Green and Scotchmer (1995) who examine licensing with sequential product development. The model developed in this paper, however, differs from their paper in that licensing involves the incumbent providing a competitor with a technology. In this way the paper is similar to Gallini (1984), Gallini and Winter (1985), Katz and Shapiro (1985), Rockett (1990), and Poddar and Sinha (2004); however, rather than considering process innovations, this paper considers product innovation in a market where the products are vertically differentiated.

This paper contrasts with Green and Scotchmer (1995) in that patent breadth is a strategic variable for the incumbent firm and patents may be found invalid in the court case that occurs after the patent has been infringed.

2 The Model

2.1 Model Assumptions

This paper builds on the work of Yiannaka and Fulton (2006) who, in the context of a vertically differentiated product market, examine the patent breadth decision by an innovator when licensing does not occur. In this paper, the patent breadth decision is followed by a decision to license the technology that has been developed. The agents in the game are an incumbent innovator who has invented a patentable drastic product innovation and a potential entrant who decides on whether to enter the incumbent's market and, if entry occurs, where to locate in a vertically differentiated product space.

If entry occurs, the two firms compete against each other in prices, where the intensity of competition depends on the product quality location q_e chosen by the entrant, which in turn depends on whether the product has been licensed to the entrant. If the product has been licensed, the entrant locates at the jointly-optimal location, while if the product has not been licensed, the entrant chooses a product quality that maximizes her own profits. Since the costs of relocation make a change in product location prohibitive, the entrant does not alter her location once it has been chosen. This implies that only the *ex ante* licensing case is examined (see Green and Scotchmer (1995) and Gallini and Winter (1985) for models with *ex post* licensing).

The incumbent and the entrant, if she enters, operate in a vertically differentiated product market. Both players are risk neutral and maximize profits. All decisions are determined in a sequential game of complete information. It is assumed that the regulator (e.g., Patent Office) always grants the patent as claimed; thus, the regulator is not explicitly modeled. The incumbent's investment decision that led to the development of a new product is treated as exogenous to the game.

Since the incumbent has already incurred the development costs associated with the product quality that he wants to patent, his R&D costs are sunk. The entrant, however, must develop a higher quality product if she wishes to enter. To do so, she incurs R&D costs $F_e(q_e)$; q_e can be interpreted as the the quality difference between the incumbent's and the entrant's product. It is assumed that $F_e'(q_e) > 0$, $F_e''(q_e) \geqslant 0$ and $F_e(0) = 0$. The R&D costs are assumed sunk once they are incurred.

The patent breadth claimed and granted to the incumbent's product is denoted by b ($b \in (0, 1]$), which defines the region in product space that the patent protects. When the entrant locates at a distance $q_e < b$ the patent is infringed and, in the absence of a license, the incumbent invokes an infringement trial. It is assumed that the filing of an infringement lawsuit by the incumbent is always met with a counterclaim by the accused infringer that the patent is invalid. The costs incurred during the infringement trial/validity attack by the incumbent and the entrant are denoted by C_p and C_e, respectively, and are sunk. These costs are assumed to be independent of the breadth of protection and of the entrant's location.

Patent validity is directly linked to patent breadth. In general, the broader is the patent protection, the harder it is to show novelty, nonobviousness and enablement (Miller and Davis 1990). Thus, the broader is patent protection, the harder it is to establish validity. In addition, evidence from the literature shows that courts tend to uphold narrow patents and invalidate broad ones (Waterson 1990, Cornish 1989, Merges and Nelson 1990). To capture these observations, the probability $\mu(b)$ that the patent will be found to be valid, or equivalently that infringement will be found, is assumed to be inversely related to patent breadth.[1] Thus, $\mu'(b) < 0$; it is further assumed that $\mu'' \geqslant 0$.

[1]The patent system being modeled is assumed to be that of the fencepost type, in which patent claims define an exact border of protection. Under the fencepost system, infringement will always be found when an entrant locates within the incumbents claims, unless the entrant proves that the patent is invalid (Cornish 1989). The implication of assuming a fencepost patent system is that the probability that infringement will be found is equal to the probability that the validity of the patent will be upheld.

2.2 The Game

The licensing game consists of four stages. In the first stage, the patentee applies for a patent, claiming a patent breadth, b, which is granted by the Patent Office. In the second stage of the game, a potential entrant observes the breadth of protection granted to the patentee and chooses whether to enter the market. If the entrant does not enter she earns zero profits, while the patentee earns monopoly profits in the fourth stage of the game. If the entrant enters, she does so by licensing the technology from the patentee for a licensing fee L; this fee is determined by a bargain between the patentee and the entrant. In the third stage of the game, the entrant chooses the quality q_e^L of her product. In the fourth stage of the game the patentee and the entrant compete in prices.

If a licensing agreement is reached between the patentee and the entrant, the license fee is determined by a bargain over the profits they obtain when the entrant chooses quality q_e^L. The threat points in this bargaining game are the profits earned by the two players if an *ex ante* agreement cannot be reached (*ex post* licensing, where a bargain can be reached if the patent has been infringed and found to be valid, is not examined because the costs of product relocation are assumed to be prohibitive). If the absence of a licensing agreement, the entrant observes the patent breadth chosen by the patentee and chooses q_e to maximize profits.

If the entrant chooses a quality greater than or equal to the patent breadth claimed by the patentee (i.e., $q_e \geqslant b$), then no infringement occurs, and she and the patentee compete in prices and earn profits Π_e^{NI} and Π_p^{NI}, respectively. If the entrant locates inside the patent breadth claimed by the patentee (i.e., $q_e < b$), the patent is infringed and a trial occurs in which the validity of the patent is examined. With probability $\mu(b)$, the patent is found to be valid (i.e., infringement is found), the entrant is not allowed to market her product and the patentee operates as a monopolist in the final stage of the game. With probability 1-$\mu(b)$ the patent is found to be invalid and the entrant and the patentee compete in prices. The payoffs for the patentee and the entrant when the entrant chooses $q_e < b$ are $E\{\Pi_p^I\}$ and $E\{\Pi_e^I\}$, respectively.

The solution to this game is found by backward induction. The fourth stage of the game in which the patentee and the entrant – when applicable – compete in prices is examined first, followed by the third stage in which the entrant makes her entry decision and chooses her product location, and the second stage in which the licensing fee L is determined. The first stage in which the patentee makes his decision regarding patent breadth is examined last.

3 Analytical Solution of the Game

3.1 Stage 4 – The Pricing Decisions

In the fourth stage of the game, two cases must be considered – the case where the entrant has entered and the case where she has not. Considering the last case first, in the absence of entry, the incumbent charges the monopoly price and earns monopoly profits Π_p^M, while the entrant earns zero profits.

If entry occurs, the patentee and the entrant compete in prices. The resulting profits are given by $\pi_p(q_e)$ and $\pi_e(q_e)$, respectively, with $\pi_p' > 0$ and $\pi_e' > 0$. Since q_e is the difference in product quality between the incumbent and the entrant, profits for both firms are assumed to be increasing in the degree of product differentiation. This assumption captures the situation where greater product differentiation relaxes price competition in the pricing stage and consequently generates greater profits (Lane 1980, Motta 1993, Shaked and Sutton 1982). This well-established result plays an important role in the bargaining game undertaken at the licensing stage. It is further assumed that $\pi_p'' \leqslant 0$ and $\pi_e'' \leqslant 0$.

3.2 Stage 3 – The Location Decision

The location decision is only relevant if the entrant has entered the market. Assuming entry has occurred, the entrant's location decision depends on whether licensing has occured or not. If licensing has occurred, the entrant chooses product quality location q_e^L to maximize the joint profits of the incumbent and the entrant, where

$$q_e^L = \arg\max_{q_e}\{\pi_p(q_e) + \pi_e(q_e) - F_e(q_e)\} \tag{1}$$

Thus, q_e^L solves:

$$\pi_p'(q_e^L) + \pi_e'(q_e^L) = F'(q_e^L) \tag{2}$$

If licensing has not occurred, then the entrant has two choices – she can enter and not infringe the patent or she can enter and infringe the patent. If she does not infringe the patent, the entrant chooses $q_e^{NI} = b$, providing $b > q_e^*$, where q_e^*

$$q_e^* = \arg\max_{q_e}\{\pi_e(q_e) - F_e(q_e)\} \tag{3}$$

Thus, q_e^* solves:

$$\pi_e'(q_e^*) = F'(q_e^*) \tag{4}$$

Result 1 *For $b > q_e^*$, the profits of the entrant in the non-infringement case $\Pi_e^{NI}(b) = \pi_e(b) - F_e(b)$ are decreasing in patent breadth – i.e., $\frac{\partial \Pi_e^{NI}(b)}{\partial b} < 0$.*

If the patentee sets $b \leqslant q_e^*$, then the entrant can enter and choose her optimal location q_e^* without infringing the patent. If $b > q_e^*$, then the entrant must choose $q_e^{NI} = b$ so as not to infringe the patent. Since q_e^* maximizes the entrant's profits, the profits from non-infringement, $\Pi_e^{NI}(b)$, decline as b increases.$\square$

Consider now the case where the entrant infringes the patent. The entrant observes patent breadth b and chooses $q_e^I(b)$ where

$$q_e^I = \arg\max_{q_e}\{E\{\Pi_e^I\} = [1 - \mu(b)]\pi_e(q_e) - F_e(q_e) - C_e\} \tag{5}$$

Thus, q_e^I solves:

$$[1 - \mu(b)]\pi_e'(q_e^I) = F'(q_e^I) \tag{6}$$

Result 2 *If the entrant infringes the patent, she always chooses a quality location that is less than her optimal location – i.e., $q_e^I < q_e^*$.*

Given the properties of π_e and F_e, the presence of the term $[1 - \mu(b)]$ in equation 6 means that $q_e^I < q_e^*$ (compare equations 4 and 6).$\square$

Result 3 *The profit earned by the entrant under infringement* $E\{\Pi_e^I(b)\} = [1-\mu(b)]\pi_e(q_e^I) - F_e(q_e^I) - C_e$ *is increasing in patent breadth – i.e.,* $\frac{E\{\partial\Pi_e^I(b)\}}{\partial b} > 0$.

Totally differentiating equation 6 with respect to b and q_e gives $\frac{dq_e^I}{db} = \frac{\mu'\pi_e'}{(1-\mu)\pi_e''-F_e''} > 0$, since $(1-\mu)\pi_e'' - F_e'' < 0$ by the second-order conditions. This implies that $\frac{dE\{\Pi_e^I(b)\}}{db} = \pi_e'\frac{dq_e^I}{db} > 0.\square$

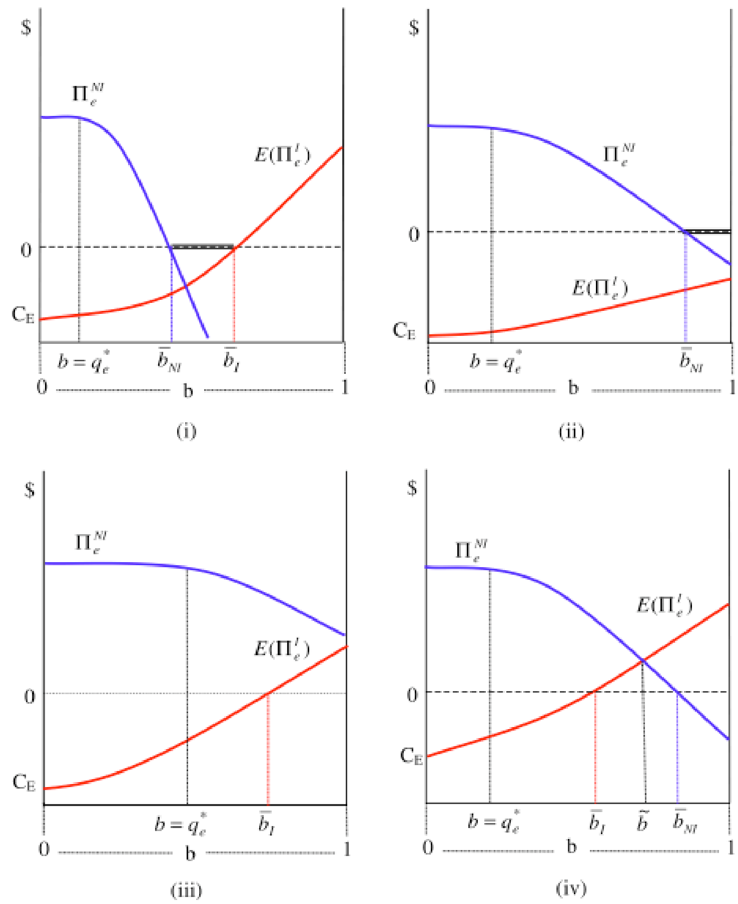

Figure 1: Entrant's Profits Under Infringement, No Infringement and No Entry

Figure 1 shows the shape of the Π_e^{NI} and the $E\{\Pi_e^I\}$ curves and the four possible cases that can arise depending on the underlying parameter values.[2] Panels (i) and (ii) illustrate cases where there is a range of patent breadth values over which the entrant's profits from both entry without infringement and entry with infringement are negative. In such cases, the entrant would not find it

[2]Yiannaka and Fulton (2006) provide details on the various parameter values that determine which of the cases exist.

optimal to enter – she earns higher profits (namely zero) by remaining out of the market – if the patentee were to choose patent breadth within that range.

Panel (iii) shows the case where the entrant always finds it profitable to select entry and non-infringement over the other two options, regardless of the patent breadth chosen by the patentee. Panel (iv) shows the case where the entrant's choice to infringe the patent depends on the patent breadth chosen by the patentee. Specifically, for $b \leqslant \tilde{b}$, the entrant will find it optimal to choose non-infringement, while if $b > \tilde{b}$ the entrant will find it optimal to choose infringement.

Thus, the four cases illustrated in figure 1 map onto three different scenarios – entry deterrence, entry and no infringement, and entry and infringement/no infringement. As will be seen, the particular scenario that presents will have different implications for the patentee.

3.3 Stage 2 – The Licensing Decision

As in the third stage, two scenarios have to be considered – the scenario where the entrant enters and the scenario where she does not. The latter case is easily examined – if the entrant does not enter, then the patentee operates as a monopoly and does not have to license the technology.

If the entrant does enter and a license is provided, the patentee and the entrant bargain over a lump sum license fee L that divides the bargaining surplus $[\Pi^* - (D_p + D_e)]$, where $\Pi^* = \pi_p + \pi_e - F_e$ are total profits earned by the players. Recall that Π^* is determined by the entrant's choice of q_e^L in stage 3 (see equations 1 and 2).

The profits Π_p^* earned by the patentee under the bargain can be expressed as:

$$\Pi_p^* = D_p + \phi(\Pi^* - D_p - D_e) \tag{7}$$

while the profits obtained by the entrant are:

$$\Pi_e^* = D_e + (1 - \phi)(\Pi^* - D_p - D_e) \tag{8}$$

The parameter ϕ represents the bargaining power of the patentee, while $1 - \phi$ is the bargaining power of the entrant (Binmore, Rubinstein, and Wolinsky (1986)). The terms $D_p(b)$ and $D_e(b)$ are the threat points for the patentee and entrant, respectively, and are functions of the patent breadth

b chosen by the patentee in the first stage. Note that the patentee's profits in equation 7 can be rewritten as:

$$\Pi_p^* = \phi\Pi^* + (1-\phi)D_p - \phi D_e \tag{9}$$

3.4 Stage 1 – The Patent Breadth Decision

With knowledge of how the bargaining and pricing stages will unfold, the patentee makes a decision in stage 1 regarding the patent breadth he will claim. Formally, the problem facing the patentee is to choose patent breadth b to maximize profits Π_p^*:

$$\max_b \Pi_p^* = \phi\Pi^* + (1-\phi)D_p(b) - \phi D_e(b) \tag{10}$$

Since Π^* is fixed (it is determined by the choice of q_e^L), the patentee's problem is effectively one of choosing patent breadth to maximize the weighted difference between the threat points. Assuming that $q_e^L < \tilde{b}$, the patentee solves:

$$\max_b \Delta D = (1-\phi)D_p(b) - \phi D_e(b) \tag{11}$$

The threat points, $D_p(b)$ and $D_e(b)$, represent the profits that the patentee and entrant, respectively, would earn if a licensing agreement could not be reached. The threat points for the entrant were determined in the location decision stage (stage 3) and depend on whether the entrant infringes the patent or not.

If the entrant were to find it optimal to not infringe the patent, then her threat point is:

$$D_e^{NI}(b) = \Pi_e^{NI}(b) = \pi_e(b) - F_e(b) \tag{12}$$

If the entrant were to find it optimal to infringe the patent, then her threat point is:

$$D_e^I(b) = E\{\Pi_e^I(b)\} = [1-\mu(b)]\pi_e(q_e^I(b)) - F_e(q_e^I(b)) - C_e \tag{13}$$

The threat points for the patentee also depend on whether the entrant infringes the patent or not. If the entrant were to find it optimal to not infringe the patent, then the patentee's threat point is:

$$D_p^{NI}(b) = \Pi_p^{NI}(b) = \pi_p(b) \tag{14}$$

If the entrant were to find it optimal to infringe the patent, then the patentee's threat point is:

$$D_p^I(b) = E\{\Pi_p^{NI}(b)\} = \mu(b)\Pi_p^M + [1-\mu(b)]\pi_p(q_p^I(b)) - C_p \tag{15}$$

In choosing the patent breadth, the patentee must determine which one of the three scenarios he is in. Recall that the three scenarios are:

1. Entry Deterrence – If there exists a patent breadth that generates negative profits for the entrant regardless of whether she infringes the patent or not, then the patentee can deter entry by choosing a patent breadth b within the range where the entrant's profits are negative. This scenario is presented in panels (i) and (ii) of figure 1.

2. Entry and No Infringement – This scenario is presented in panel (iii) of figure 1. Under this scenario, the entrant will always find it optimal to enter without infringing the patent, regardless of the patent breadth that has been chosen.

3. Entry and Inducement of Infringement/Non Infringement – This scenario is presented in panel (iv) of figure 1. If there exists a patent breadth $\tilde{b}$ where the profits from infringement and non-infringement are equal and positive, then entry by the entrant cannot be deterred regardless of the patent breadth chosen. The entrant will not infringe the patent if $b \leqslant \tilde{b}$ and will infringe the patent if $b > \tilde{b}$.

Each of these three scenarios will be examined in turn.

3.4.1 Entry Deterrence

If the patentee can deter entry, then the optimal strategy is to do so and to operate as a monopolist and earn monopoly profits Π_p^M. Assuming that the monopoly profits Π_p^M always exceed those generated under a duopoly, the patentee never has an incentive to allow entry if it can otherwise be avoided.

3.4.2 Entry and No Infringement

Proposition 1 *If, in the absence of a license, the entrant always finds it optimal to enter without infringing the patent, regardless of the patent breadth that has been chosen, then the patentee's* *optimal patent breadth is the maximum patent breadth, i.e.,* $b = 1$.

Substituting in the expressions for $D_p^{NI}(b)$ and $D_e^{NI})$ gives $\Delta D^{NI} = (1-\phi)\pi_p(b) - \phi[\pi_e(b) - F_e(b)]$. Taking the derivative with respect to b gives:

$$\frac{\partial \Delta D^{NI}}{\partial b} = (1-\phi)\pi_p'(b) - \phi[\pi_e'(b) - F_e'(b)] > 0 \tag{16}$$

Since $\pi_p'(b) > 0$ by assumption and $\pi_e'(b) - F_e'(b) < 0$ for $b > q_e^*$ (see result 1), ΔD^{NI} is increasing in b for $b > q_e^*$. Thus, choosing the maximum patent breadth gives the patentee maximum profits.□

Corollary 1 *If, in the absence of a license, the entrant always finds it optimal to enter without infringing the patent, regardless of the patent breadth that has been chosen, then the introduction of a license eliminates the over investment that would otherwise have occurred.*

In the absence of a license, the patentee chooses the maximum breadth ($b = 1$) and the entrant responds by choosing $q_e = 1$ to avoid infringing the patent. However, with a license, the entrant enters and chooses q_e^L. The choice of location q_e^L generates the maximum joint profits for the two firms and eliminates the excess investment that would otherwise have occurred.□

3.4.3 Entry and Inducement of Infringement/Non Infringement

In this scenario there exists a patent breadth $\tilde{b} > q_e^*$ where the entrant's profits from infringement and non-infringement are equal and positive in the absence of a license. The entrant will not infringe the patent if $b \leqslant \tilde{b}$ and will infringe the patent if $b > \tilde{b}$.

The analysis above provided an understanding of the shape of the ΔD^{NI} function. Substituting in the expressions for $D_p^I(b)$ and $D_e^I(b)$ gives the expression for ΔD^I:

$$\Delta D^I = (1-\phi)[\mu\Pi_p^M + (1-\mu)\pi_p(q_e^I) - C_p] - \phi[(1-\mu)\pi_e(q_e^I) - F_e(q_e^I) - C_e] \tag{17}$$

Taking the derivative with respect to b gives:

$$\frac{\partial \Delta D^I}{\partial b} = \mu' \left[(\Pi_p^M - \pi_p) - \phi(\Pi_p^M - \pi_p - \pi_e)\right] + (1-\phi)(1-\mu)\pi_p' q_e' \tag{18}$$

Proposition 2 *If, in the absence of a license, there is a patent breadth $\tilde{b} > q_e^*$ where the entrant's profits from infringement and non-infringement are equal and positive, then the patentee's optimal patent breadth will be either $b = \tilde{b}$ or $b = \tilde{b} + \epsilon$ when the patentee has all the bargaining power – i.e., when $\phi = 1$.*

The first expression on the right-hand side of equation 18 is negative, while the second expression vanishes when $\phi = 1$. Thus, when the patentee induces the entrant to infringe the patent in the absence of a license, the patentee's profits from licensing fall with an increase in b. Since the patentee's profits from inducing non-infringment in the absence of a license rise with an increase in b up until $b = \tilde{b}$ (see proposition 1), the patentee's optimal choice of patent breadth b is to either choose $b = \tilde{b}$ to induce non-infringement or choose $b = \tilde{b} + \epsilon$ to induce infringement.□

This result indicates that the patentee will never choose the maximum patent breadth when he is able to induce the patentee to either infringe or not infringe the patent in the absence of a license. The reasoning is straightforward. With all the bargaining power, the patentee's profits are maximized when the entrant's profits are minimized. Patent breadth $\tilde{b}$ minimizes the entrant's profits while ensuring that the entrant does not infringe the patent. If the patent breadth is increased beyond $\tilde{b}$, then the entrant is induced to infringe the patent. Since increasing b beyond $\tilde{b}$ leads to an increase in the entrant's profits (see result 3), the patentee finds it optimal to choose either $b = \tilde{b}$ or $b = \tilde{b} + \epsilon$ depending on which provides the greater return.

The results are less clear cut when $\phi < 1$, since the first term in equation 18 is negative while the second term is positive – note that this holds even if $\phi = 0$. Assuming that the second derivatives μ'', π'' and $\frac{\partial^2 q_e^I}{\partial b^2}$ are relatively small,

$$\frac{\partial^2 \Delta D^I}{\partial b^2} \approx -\mu' \left[2(1-\phi)\pi_p' - \phi\pi_e'\right] q_e' \tag{19}$$

Proposition 3 *If $\phi < 1$, then the optimal patent breadth is either $b = \tilde{b}$, $b = \tilde{b} + \epsilon$, or $b = 1$ – i.e., the patentee does not find it optimal to locate in the interior of the area between $\tilde{b}$ and one.*

With $\phi = 1$, the ΔD^I function is convex and monotonically decreasing, since $\frac{\partial^2 \Delta D^I}{\partial b^2} \approx \mu' \ \pi_e' q_e' < 0$

(recall also the result in proposition 2). At the other extreme, with $\phi = 0$, the ΔD^I function is concave, since $\frac{\partial^2 \Delta D^I}{\partial b^2} \approx -2\mu' \ \pi_p' q_e' > 0$ (recall that the first term in equation 18 is negative while the second term is positive). Assuming continuity between these two extremes and noting that $\frac{\partial\left(\frac{\partial^2 \Delta D^I}{\partial b^2}\right)}{\partial \phi} \approx \mu' q_e' \left[2\pi_p' + \pi_e'\right] < 0$, the implication is that for a range of ϕ values, the ΔD^I function reaches a minimum at $b = \breve{b}$. If $\breve{b} \leqslant \tilde{b}$, then the optimal patent breadth is either $b = \tilde{b}$ or $b = 1$. If $\breve{b} \geqslant 1$, then the optimal patent breadth is either $b = \tilde{b}$ or $b = \tilde{b} + \epsilon$. Finally, if $\tilde{b} < \breve{b} < 1$, then the optimal patent breadth may be either $b = \tilde{b}$, $b = \tilde{b} + \epsilon$, or $b = 1$.□

Lemma 1 *A patentee will choose the same patent breadth in the absence of licensing as he will with licensing when the entrant has all the bargaining power ($\phi = 0$).*

When the entrant has all the bargaining power in the licensing negotiations, the patentee chooses the patent breadth that maximizes his default value $D_p(b)$ – i.e., since the entrant gets all the bargaining surplus, the patentee only receives his default value. Maximization of the default value is, of course, the objective of the patentee in the absence of licensing.□

Proposition 4 *As the patentee's bargaining power increases, the patent breadth chosen when licensing occurs is more likely, all else equal, to be less than the patent breadth chosen when licensing does not occur (e.g., because of a lack of legal system).*

Following lemma 1, the patentee's choice of patent breadth in the case of no licensing can be found by observing the case where $\phi = 0$. As shown in proposition 3, the optimal patent breadth may be $b = 1$ in such a situation. As ϕ rises, the ΔD_p^{NI} function becomes increasingly concave (recall that $\frac{\partial\left(\frac{\partial^2 \Delta D^I}{\partial b^2}\right)}{\partial \phi} \approx \mu' q_e' \left[2\pi_p' + \pi_e'\right] < 0$). Thus, the ΔD_p^I function is more likely to be monotonically downward sloping over the range from $\tilde{b}$ to one, thus making the optimal patent breadth choice in the presence of licensing more likely to be either $b = \tilde{b}$ or $b = \tilde{b} + \epsilon$.□

The patentee has an incentive to choose a smaller patent breadth when licensing occurs because of the impact of patent breadth on the entrant's default values. In the case where the patentee induces the entrant to infringe, greater patent breadth results in greater profits for the entrant, since higher patent breadth increases the probability of the patent being found invalid (see result 3). Higher default entrant profits enable the entrant to obtain a greater value from the bargain and result in the patentee receiving correspondingly less. Since the profits earned by the patentee in the absence of a license are convex in b, increased patent breadth can result in greater default patentee profits under some circumstances (for details on these circumstances, see Yiannaka and Fulton (2006)). However, as the bargaining power of the patentee increases, the default profits of the patentee matter less and the default profits of the entrant matter more in the determination of the optimal patent breadth. Thus, the patentee generally has an incentive to choose a smaller patent breadth when licensing occurs.

4 Concluding Remarks

Obtaining a patent provides the patentee with the ability to offer a potential entrant a license to operate within the patent that has been claimed. This paper shows that the patentee always has an incentive to provide a license if the patentee is unable to use patent breadth to deter entry (if the patentee can deter entry, it is optimal for him to do so). Licensing a new product to a competitor has two benefits for the patentee. First, licensing creates an incentive for the entrant to select the product location that maximizes the joint profits of both it and the patentee, rather than just its own profits. Thus, licensing allows the cooperative R&D outcome to be achieved and to create an efficiency improvement.

Second, the patent breadth decision determines the default profits for both the patentee and the entrant, which in turn affects the manner in which the benefits of the cooperative R&D are shared between the two parties. Generally the patentee has an incentive to choose a smaller patent breadth when licensing is possible than it would choose were licensing not possible. The smaller patent breadth is optimal because it lowers the probability of the patent being found invalid, which in turn lowers the default profits for the entrant (i.e., the profits earned in the absence of a license).

The entrant always benefits from licensing in the sense that at the optimal patent breadth that is chosen when licensing occurs, the profits earned by the entrant with the license are less than those that would be earned if the license were not offered. However, if licensing was not available (e.g., because of a lack of a legal system to enforce the agreement), then the patent breadth chosen by the patentee would be different. It is possible that at this patent breadth the entrant may be better off than what it would be if licensing were possible. Thus, licensing has both efficiency and distributional impacts for the industry in which the patentee and entrant operate.

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