

Patent Strength and Optimal Two-Part Tariff Licensing with a Potential Rival

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Abstract

We investigate a two-part tariff licensing contract that enables an incumbent innovator to license the technology for a new product to a potential rival, who may alternatively develop a compatible technology for an imperfectly substitutable product. We identify the optimal two-part tariff licensing contract based on the development cost incurred by the rival, the market parameter, and the substitution coefficient.

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1 Introduction

Patent licensing plays an important role in the development of technology. In particular, inward technology licensing has been used by firms as alternative sources of new product to internal R&D, see Atuahene-Gima (1992).

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Kulatilaka and Lin (2006) gives some examples of licensing of new product technology in the pharmaceutical industry. We consider licensing by a patent-holding firm to its potential rival, who may invest in the technology innovation and enter the market of the new product. We examine the class of two-part tariff contracts consisting of a fixed fee plus a linear royalty per unit of output, and identify the optimal two-part tariff contract for the patent holder. This depends on the cost of technology innovation incurred by the potential rival, the substitutability of goods, and the market parameter. We focus attention on the cost of technology innovation, which represents the strength of the patent.

The analysis of patent licensing was initiated by Arrow (1962). There are two streams of research on patent licensing. One concerns patent licensing by outsiders, and focuses on the licensing of a cost-reducing innovation by a specialist R&D firm whose sole objective is to license the patent to other firms; see Kamien (1992) for a survey. In the other strand, the R&D environment is one in which the innovator is one of the incumbent firms in the industry (see, e.g., Taylor and Silberston, 1973). The issues addressed by researchers on licensing include asymmetric cost structures of firms in a duopoly (Gallini and Winter, 1985; Marjit, 1990), the impact of the magnitude of the cost-reducing innovation (Wang, 1998, 2002; Kamien and Tauman, 2002; Martín and Saracho, 2010),¹ and the cost of technology innovation (Kulatilaka and Lin, 2006; Kitagawa et al., 2013). These authors consider licensing based on a pure fixed fee, or pure royalty licensing, and investigate the effectiveness of licensing. Based on his survey of corporate licensing in the United States, Rostoker (1984) finds that 46% of the licensing contracts use a down payment plus a running royalty, 39% use royalties alone, and 13% use a fixed fee alone. Combinations of fixed fees and royalties are most often observed in practice. There is little research on two-part tariff contracts in which the innovator is one of the incumbent producers. Two exceptions are Fauli-Oller and Sandonis (2002) and Sen and Tauman (2007),² both of whom address the impact of the magnitude of the cost-reducing innovation. Fauli-Oller and Sandonis (2002) consider the two-part tariff licensing of a cost-reducing innovation in a differentiated Bertrand and Cournot duopoly. They conclude that the optimal contract involves a positive royalty for both types of duopoly. Sen and Tauman (2007) consider the licensing of a cost-reducing innovation when the

¹A cost-reducing innovation is said to be drastic if the monopoly price under the new technology does not exceed the competitive price under the old technology; see Arrow (1962).

²For the case of outside innovators, optimal two-part tariff contracts are investigated by, e.g., Erutku and Richelle (2007), Sen and Tauman (2007), and Sen and Stamatopoulos (2009).

innovator uses a two-part tariff licensing contract in a Cournot oligopoly of general size. They analyze the case of an outside innovator as well as an incumbent innovator, obtain the optimal licensing scheme for each case, and compare the incentives of the innovators to innovate.

Our approach is new in that we focus on two-part tariff licensing by an incumbent innovator who competes with a potential rival who may self-develop the technology. First, unlike most researchers in the literature, we assume that the incumbent innovator has a technology for a new good that can be licensed to a potential rival, who has the option of self-developing a compatible technology to produce an imperfect substitute for the new good without patent infringement. The main feature of our model is the cost of technology development. That is, we obtain results based on two types of scenario for the development cost. When the potential rival does not have a license, it can enter the market by investing in technology development. However, if the development cost is high, such entry is not profitable for the rival. We call this cost scenario the high development cost scenario. The scenario in which this is not the case is termed the low development cost scenario. The cost of technology development represents the strength of the patent because a strong patent implies that the cost of developing a compatible technology without patent infringement is high for the potential rival.³ Second, we investigate the class of two-part tariff licensing contracts, which includes the two special cases of pure royalty and pure fixed-fee licensing. Thus, the optimal two-part tariff licensing contract analyzed in this paper weakly dominates the two special cases investigated by Kitagawa et al. (2013).

Our main findings can be summarized as follows. The technology of the patent holder is licensed except for the case of homogeneous goods with a high development cost. When the patent is weak, the incumbent offers a pure royalty contract. The optimal two-part tariff involves a positive royalty rate, except when the two products do not compete, in which case, pure fixed-fee licensing prevails. These findings are consistent with the analysis of Fauli-Oller and Sandonis (2002) for the case of a cost-reducing innovation. Furthermore, the optimal royalty rate and the optimal fixed fee are nondecreasing in the development cost. This is because a strong patent gives the patent holder an edge.

³Thus, the high development cost scenario and the low development cost scenario roughly reflect the cases of drastic and nondrastic innovation, respectively, identified by Arrow (1962).

2 The model

Suppose that the incumbent (firm 1) with a technology for a new product uses two-part tariff licensing to license its own technology to a potential rival (firm 2), who may alternatively self-develop the technology for an imperfectly substitutable product.

Under the two-part tariff contract, firm 2 pays a lump sum of $\varphi \geq 0$, which is independent of the level of production, and a royalty rate of $r \geq 0$ per unit of production. Hereafter, we denote such a two-part tariff contract by (r, φ) . In period 0, firm 1 decides whether to offer licensing to firm 2. If firm 1 does not offer licensing to firm 2, firm 2 has two options in period 1. Firm 2 may stay out of the market or enter the market by self-developing the technology. If firm 2 invests in its own technology development, it incurs a cost of $J > 0$ ⁴, and the development succeeds without patent infringement. If firm 1 offers licensing, firm 2 may accept or reject this offer in period 1. In the latter case, firm 2 may refrain from competition or may enter the market by self-developing the technology. We assume that firm 2 accepts the offer if firm 2 is indifferent between accepting and rejecting the offer. We also assume that firm 2 enters the market if firm 2 is indifferent between entering and not entering. For analytical convenience, we further assume that firm 1 does not offer a contract if firm 1 is indifferent between offering and not offering one.

In period 2, if firm 2 enters the market, both firms engage in Cournot competition. Otherwise, firm 1 monopolizes the market. Even if the two firms have identical technology, the products of the two firms may be differentiated. Firm i 's product demand q_i , $i = 1, 2$, is given by the inverse demand function $P_i = \theta - q_i - aq_j$, $i, j = 1, 2$, $j \neq i$, where P_i is the price of firm i 's product. We call the parameters $\theta > 0$ and $a \in [0, 1]$ the market parameter and the substitution coefficient, respectively. If firm 2 accepts firm 1's offer (r, φ) , then firm 1 charges firm 2 a licensing fee of $r q_2 + \varphi$.

3 Analysis

Let $\Pi_i^N(j)$ be firm i 's profit under the “no license” policy in scenario j , where $j \in \{\ell, h\}$ denotes “low” and “high”, respectively. Let $\hat{J} \equiv \frac{\theta^2}{(a+2)^2}$. Lemma 1 below shows that when no license is offered, firm 2 enters the market if and only if the development cost J is less than or equal to \hat{J} . Hereafter, $J > (\leq) \hat{J}$ characterizes the high (low) development cost scenario. Moreover,

⁴When $J = 0$, our model is reduced to the standard Cournot duopoly.

we say that the patent is strong (weak) in the high (low) development cost scenario.

Consider the subgame that starts after firm 1 chooses not to license in period 0. If firm 2 stays out of the market, firm 1 monopolizes the market and maximizes its payoff $\Pi_1 = (\theta - q_1)q_1$ by choosing optimal output of $q_1^* = \theta/2$. The payoffs of the firms are given by $(\Pi_1, \Pi_2) = (\frac{1}{4}\theta^2, 0)$. If firm 2 enters the market, the two firms engage in Cournot competition, and have payoff functions of $\Pi_1 = (\theta - q_1 - aq_2)q_1$ and $\Pi_2 = (\theta - q_2 - aq_1)q_2$. The equilibrium outputs are $q_1^* = q_2^* = \frac{\theta}{a+2}$ with payoffs of $(\frac{\theta^2}{(a+2)^2}, \frac{\theta^2}{(a+2)^2} - J)$. Thus, we obtain the following lemma.

Lemma 1 *Consider the subgame that starts after firm 1 chooses not to license. If $J > \hat{J}$, firm 2 stays out of the market and firm 1 monopolizes the market, which results in payoffs of $(\Pi_1^N(h), \Pi_2^N(h)) \equiv (\frac{1}{4}\theta^2, 0)$. If $J \leq \hat{J}$, firm 2 enters the market, and the payoffs are $(\Pi_1^N(\ell), \Pi_2^N(\ell)) \equiv (\frac{\theta^2}{(a+2)^2}, \frac{\theta^2}{(a+2)^2} - J)$.*

We next examine the subgame that starts after firm 1 chooses to offer a two-part tariff contract (r, φ) . If the royalty rate is too high, firm 2 does not produce output after it accepts the offer. The next lemma shows that the condition that corresponds to this case is

$$r > \hat{r} \equiv \frac{-a+2}{2}\theta.$$

Lemma 2 *Consider the subgame that starts after firm 1 offers the contract (r, φ) and firm 2 accepts it. The payoffs from this subgame are*

$$(\Pi_1, \Pi_2) = \begin{cases} (\pi_1^*(r, \varphi), \pi_2^*(r, \varphi)) & \text{if } r \leq \hat{r}, \\ (\frac{1}{4}\theta^2 + \varphi, -\varphi) & \text{if } r > \hat{r}, \end{cases}$$

where

$$\pi_1^*(r, \varphi) = \frac{(3a^2 - 8)r^2 + (a^3 - 4a^2 + 8)\theta r + (a - 2)^2\theta^2}{(a^2 - 4)^2} + \varphi, \quad (1)$$

$$\pi_2^*(r, \varphi) = \frac{(2r + (a - 2)\theta)^2}{(a^2 - 4)^2} - \varphi. \quad (2)$$

Proof. In this subgame, the Cournot competition is represented by $\max_{q_1 \geq 0} \pi_1 = (\theta - q_1 - aq_2)q_1 + rq_2 + \varphi$ and $\max_{q_2 \geq 0} \pi_2 = (\theta - q_2 - aq_1 - r)q_2 - \varphi$. The first-order

conditions imply that when the royalty rate is low (high), i.e., $r \leq \hat{r}$ ($r > \hat{r}$), a duopoly (a monopoly) emerges with

$$(q_1^*, q_2^*) = \begin{cases} \left(\frac{\theta}{a+2} + \frac{ar}{-a^2+4}, \frac{\theta}{a+2} - \frac{2r}{-a^2+4} \right) & \text{if } r \leq \hat{r}, \\ \left(\frac{\theta}{2}, 0 \right) & \text{if } r > \hat{r}. \end{cases}$$

The lemma then follows from simple calculation. ■

3.1 The high development cost scenario

Under the high development cost scenario ($J > \hat{J}$), we obtain the following result.

Theorem 3 *Under the high development cost scenario, the equilibrium path is as follows. When $0 \leq a < 1$, firm 1 offers (r^*, φ_h^*) and firm 2 accepts it, where*

$$r^* \equiv \frac{a(a-2)^2}{2(-3a^2+4)}\theta, \quad \varphi_h^* \equiv \frac{4(a-1)^2}{(3a^2-4)^2}\theta^2, \quad (3)$$

and the payoffs are

$$(\pi_1^*(r^*, \varphi_h^*), \pi_2^*(r^*, \varphi_h^*)) = \left(\frac{a^2 - 8a + 8}{4(-3a^2 + 4)}\theta^2, 0 \right). \quad (4)$$

When $a = 1$, firm 1 offers no contract, which results in payoffs of $(\Pi_1^N(h), \Pi_2^N(h))$.

Proof. Because the patent is strong ($J > \hat{J}$), firm 2 does not enter the market, having rejected the offer. We first identify the set of contracts that firm 2 accepts. Lemma 2 shows that, for $r \leq \hat{r}$, firm 2 accepts the offer (r, φ) if and only if $\pi_2^*(r, \varphi) \geq \Pi_2^N(h) = 0$, or equivalently,

$$\varphi \leq \frac{(2r + (a-2)\theta)^2}{(a^2 - 4)^2}. \quad (5)$$

For $r > \hat{r}$, firm 2 accepts the offer (r, φ) if and only if $-\varphi \geq \Pi_2^N(h) = 0$, or equivalently,

$$\varphi = 0. \quad (6)$$

In this case, because firm 2 produces nothing, firm 1 has a monopoly. We next consider the equilibrium contract. Consider the set of contracts (r, φ) with $r \leq \hat{r}$. Equations (1) and (5) imply that the best contract (r, φ) in this set satisfies

$$\varphi = \varphi_h(r) \equiv \frac{(2r + (a-2)\theta)^2}{(a^2 - 4)^2} \geq 0. \quad (7)$$

Thus, substituting (7) into (1) yields a payoff for firm 1 of

$$\pi_1^*(r, \varphi_h(r)) = \frac{(3a^2 - 4)r^2 + a(a - 2)^2\theta r + 2(a - 2)^2\theta^2}{(a^2 - 4)^2}. \quad (8)$$

This equation is quadratic in r and is maximized at $r = r^*$ in (3), which implies a payoff of $\pi_1^*(r^*, \varphi_h(r^*)) = \frac{a^2 - 8a + 8}{4(-3a^2 + 4)}\theta^2$. Simple calculation reveals that $0 \leq r^* \leq \hat{r}$. Thus, $(r^*, \varphi_h(r^*))$ is the best offer in the set of acceptable contracts with $r \leq \hat{r}$. Next, we consider the set of contracts (r, φ) with $r > \hat{r}$. If $r > \hat{r}$, then from Lemmas 1, 2, and (6), firm 1's payoff is

$$\Pi_1 = \begin{cases} \frac{1}{4}\theta^2 & \text{if } \varphi > 0, \text{ so that firm 2 rejects the contract,} \\ \frac{1}{4}\theta^2 + \varphi = \frac{1}{4}\theta^2 & \text{if } \varphi = 0, \text{ so that firm 2 accepts the nil contract.} \end{cases}$$

Thus, $r > \hat{r}$ implies that firm 1's payoff is $\frac{1}{4}\theta^2$. Combining these results yields

$$\Pi_1 = \max \left\{ \frac{1}{4}\theta^2, \pi_1^*(r^*, \varphi_h(r^*)) \right\}.$$

It can be verified that $\pi_1^*(r^*, \varphi_h(r^*)) \geq \frac{1}{4}\theta^2$ with equality only if $a = 1$. Hence, $a < 1$ implies that firm 1 offers (r^*, φ_h^*) and firm 2 accepts it, where $\varphi_h^* \equiv \varphi_h(r^*)$. If $a = 1$, firm 1 offers no contract. ■

From equation (3), the royalty rate is increasing and the fixed fee is decreasing in the substitution coefficient a . This implies that charging a royalty is effective for the patent holder in a highly competitive market.

3.2 The low development cost scenario

In this subsection, we analyze the low development cost scenario, characterized by $(J \leq \hat{J})$. Recall that, under the low development cost scenario, if firm 2 does not accept a contract, it self-develops the technology and obtains a payoff of $\Pi_2^N(\ell) = \frac{\theta^2}{(a+2)^2} - J$. We consider two cases: (i) $J < \hat{J}$; and (ii) $J = \hat{J}$.

Consider Case (i). If firm 2 self-develops the technology, its payoff is $\Pi_2^N(\ell) > 0$. Consider a contract (r, φ) with $r > \hat{r}$. If firm 2 accepts this contract, according to Lemma 2, its payoff cannot exceed zero. This implies that firm 2 does not accept the contract and instead invests in the technology to enter the market. Then, firm 1's payoff is $\Pi_1^N(\ell) = \frac{\theta^2}{(a+2)^2}$. Next consider a contract with $r \leq \hat{r}$. Firm 2 accepts (r, φ) if and only if $\pi_2^*(r, \varphi) \geq \Pi_2^N(\ell)$ (see (2)) or, equivalently,

$$\varphi \leq \varphi_\ell(r) \equiv \frac{4r(r + (a - 2)\theta)}{(a^2 - 4)^2} + J. \quad (9)$$

Thus, firm 1's payoff from offering (r, φ) is

$$\Pi_1(r, \varphi) = \begin{cases} \pi_1^*(r, \varphi) & \text{if (9) and } r \leq \hat{r} \text{ hold (if firm 2 accepts the offer),} \\ \frac{\theta^2}{(a+2)^2} & \text{otherwise (if firm 2 rejects the offer).} \end{cases} \quad (10)$$

Because contract $(0, J)$ satisfies (9), $\pi_1^*(0, J) = \frac{\theta^2}{(a+2)^2} + J$ and $J > 0$, in order to maximize $\Pi_1(r, \varphi)$, it is sufficient to consider only the first case in (10). From (1), for (r, φ) to maximize $\pi_1^*(r, \varphi)$ subject to the constraints (9) and $r \leq \hat{r}$ in (10), it must be the case that $\varphi = \varphi_\ell(r)$ and $\varphi_\ell(r) \geq 0$. It is apparent that $\varphi_\ell(r) \geq 0$ if and only if

$$r \leq \tilde{r} \equiv \frac{-a+2}{2} \left(\theta - \sqrt{\theta^2 - (a+2)^2 J} \right). \quad (11)$$

Note that $0 < \tilde{r} < \hat{r}$. Hence, firm 1's payoff can be written as

$$\Pi_1 = \max_{0 \leq r \leq \tilde{r}} \pi_1^*(r, \varphi_\ell(r)), \quad (12)$$

where

$$\pi_1^*(r, \varphi_\ell(r)) = \frac{(3a^2 - 4)r^2 + a(a-2)^2\theta r + (a-2)^2\theta^2}{(a^2 - 4)^2} + J. \quad (13)$$

Because equation (13) is identical to (8) apart from the constant term, it follows that $\pi_1^*(r, \varphi_\ell(r))$ is maximized at $r^* \geq 0$ in (3). This implies that (12) is maximized either at r^* or at the corner solution \tilde{r} . Let $M(J) \equiv \tilde{r} - r^*$. Then, $M(J) \geq 0$ if and only if

$$J \geq \tilde{J} \equiv \frac{a(a-2)(5a^2 + 2a - 8)\theta^2}{(a+2)^2(3a^2 - 4)^2}. \quad (14)$$

Calculations then reveal that

$$\tilde{J} \leq \hat{J}. \quad (15)$$

Firm 1's profit, Π_1 in (12), is either $\pi_1^*(r^*, \varphi_\ell(r^*))$ or $\pi_1^*(\tilde{r}, \varphi_\ell(\tilde{r}))$ depending on whether $J \geq \tilde{J}$ or $J < \tilde{J}$, where $\varphi_\ell(\tilde{r}) = 0$.

Next, we consider Case (ii). The argument is similar to Case (i). When $J = \hat{J}$, it follows that $\Pi_2^N(\ell) = 0$. Note that $\Pi_1^N(\ell) = \frac{\theta^2}{(a+2)^2}$. Consider a contract with $r > \hat{r}$. From Lemma 2, the only contract accepted by firm 2 is $(r, 0)$, which is a contract with payoffs of $(\frac{\theta^2}{4}, 0)$. Note that $\frac{\theta^2}{4} \geq \Pi_1^N(\ell) = \frac{\theta^2}{(a+2)^2}$ with equality only if $a = 0$. Thus, if $a > 0$, firm 1's best offer based on a royalty rate above \hat{r} is $(r, 0)$, with any $r > \hat{r}$, which has a payoff of $\frac{\theta^2}{4}$. If

$a = 0$, firm 1 does not offer any (r, φ) with $r > \hat{r}$. Now consider a contract with $r \leq \hat{r}$. As in Case (i), firm 1's payoff can be written as (12), with $\pi_1^*(r, \varphi_\ell(r))$ given by (13), where J is replaced by \hat{J} . It follows from (15) that $M(\hat{J}) \geq 0$. Thus, $\pi_1^*(r, \varphi_\ell(r))$ is maximized at r^* . Given $J = \hat{J}$, calculations reveal that $\pi_1^*(r^*, \varphi_\ell(r^*)) > \frac{\theta^2}{(a+2)^2}$ for all $a \in [0, 1]$. Hence, with $r \leq \hat{r}$, firm 1's best strategy is to offer contract $(r^*, \varphi_\ell(r^*))$ with payoff $\pi_1^*(r^*, \varphi_\ell(r^*))$. We now compare the two cases, $r > \hat{r}$ and $r \leq \hat{r}$. Note that $\pi_1^*(r^*, \varphi_\ell(r^*)) \geq \frac{\theta^2}{4}$ with equality only if $a = 1$. In addition, if $a = 1$, then $\tilde{J} = \hat{J}$ and $r^* = \hat{r} = \frac{\theta}{2}$. Thus, we conclude that, if $0 \leq a < 1$, the contract $(r^*, \varphi_\ell(r^*))$ is chosen, whereas if $a = 1$, the contract $(r, 0)$ with $r \geq \hat{r} = \frac{\theta}{2}$ is chosen.

Summarizing the above argument, we can state the following theorem.

Theorem 4 *Consider the low development cost scenario $J \leq \hat{J}$. The equilibrium path is as follows.*

- a) If $J \geq \tilde{J}$ (see (14)) and $a < 1$, firm 1 offers (r^*, φ_ℓ^*) , where r^* is given by (3) and

$$\varphi_\ell^* \equiv \varphi_\ell(r^*) = J - \frac{a(a-2)(5a^2+2a-8)}{(a+2)^2(3a^2-4)^2}\theta^2, \quad (16)$$

which firm 2 accepts, and which yields payoffs of

$$(\pi_1^*(r^*, \varphi_\ell^*), \pi_2^*(r^*, \varphi_\ell^*)) = \left(\frac{a^4-4a^3-8a^2+16}{4(a+2)^2(-3a^2+4)}\theta^2 + J, \frac{\theta^2}{(a+2)^2} - J \right). \quad (17)$$

If $J \geq \tilde{J}$ and $a = 1$, firm 1 offers contract $(r, 0)$ with $r \geq \frac{\theta}{2}$, which firm 2 accepts, and which generates payoffs of $(\frac{\theta^2}{4}, 0)$.

- b) If $J < \tilde{J}$, firm 1 offers a pure royalty contract $(\tilde{r}, 0)$ with \tilde{r} in (11), which firm 2 accepts, and which generates payoffs of $(\pi_1^*(\tilde{r}, 0), \pi_2^*(\tilde{r}, 0))$, where

$$\begin{aligned} \pi_1^*(\tilde{r}, 0) &= \frac{-3a^2+8}{4}J + \frac{(a^2+a-1)\theta^2 - (a^2+a-2)\theta\sqrt{\theta^2 - (a+2)^2J}}{(a+2)^2}, \\ \pi_2^*(\tilde{r}, 0) &= \frac{\theta^2}{(a+2)^2} - J. \end{aligned}$$

3.3 Discussion

In this subsection, we summarize the results in Theorems 3 and 4, and discuss their implications. The optimal licensing contract that emerges for various parameters is identified in Figure 1.

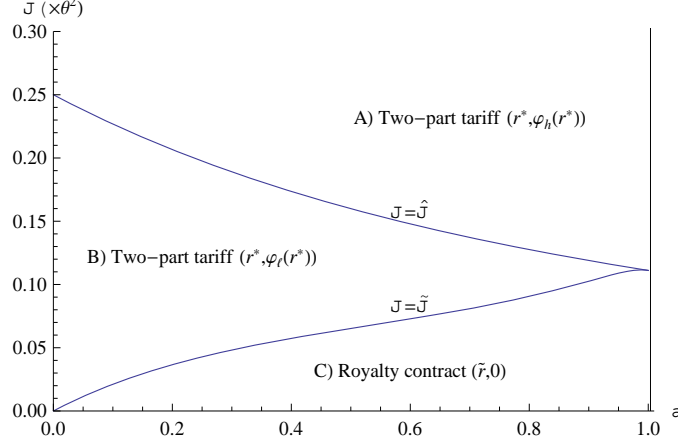


Figure 1: Optimal licensing method vs. the development cost J and the substitution coefficient a

For the high development cost scenario (region A in Fig. 1), the patent holder maximizes the joint profit with respect to the royalty rate and extracts all the surplus from the rival firm through the fixed fee, see Theorem 3. If instead the patent holder were to extract the surplus through a higher royalty rate then it would result in too little output from a joint profit maximization perspective. The patent holder offers a contract that is accepted if and only if the products are not perfect substitutes because 1) when the products are the same, entry by the rival firm does not increase the industry's potential profit, and 2) the patent holder is not threatened by the rival's entry. When the products are the same, the rival firm's product need not be in the market for the patent holder to maximize the surplus extracted from consumers. However, when the rival firm's product is an imperfect substitute, having the rival firm in the market increases the surplus that can be extracted from consumers. For the high development cost scenario, the patent holder's profit is decreasing in the substitution coefficient, see (4). This is because maximal consumer surplus is smaller when product variety is less. If consumers have less surplus then there is less surplus to extract and less profit to be earned.

For the low development cost scenario, the patent holder must work with the constraint that the rival firm will enter on its own if it is not offered a sufficiently lucrative contract. This constraint has the implication that the fixed fee may be zero. The patent holder maximizes the joint profit and extracts as much surplus as possible from the rival firm subject to the

constraint that the rival firm earns as much profit as it could without a license. Unless the development cost is very low (region B in Fig. 1), the patent holder sets the royalty rate as in the high development cost scenario and charges a positive fixed fee. However, when the development cost is sufficiently low (region C in Fig. 1), this constraint is strict and the nonnegativity constraint of the fixed fee is binding.

Both the royalty rate and the fixed fee are nondecreasing in the development cost, see (3), (11) and (16). This reflects the fact that a strong patent gives the patent holder an edge. Numerical methods confirm that the fixed fee is decreasing in the substitution coefficient, see Fig. 1 in the online Appendix⁵. The royalty rate is increasing in the substitution coefficient if the development cost is sufficiently high for the fixed fee to be positive (regions A and B), see (3). This is because the royalty rate is set to maximize the joint profit. When the development cost is low (region C), the effect of the substitution coefficient on the royalty rate is ambiguous, see Fig. 2 in the online Appendix. This is because, in a small market in which there is little product variety, the patent holder prefers a less competitive rival that can nevertheless earn sufficient profit.

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