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Patent Licensing in a Mixed Oligopoly with a Foreign Firm

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Abstract

This paper investigates optimal licensing in a mixed oligopoly with a foreign firm. It is the first to compare licensing by means of a fixed fee and by means of a royalty when the innovator is a public firm. In contrast to a private oligopoly, we show that license via a fixed fee is superior to license via a royalty for the innovator.

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1. Introduction

Despite the fact that many innovations originate in the public sector, the theoretical literature overwhelmingly studies patent licensing by private sector firms. While the literature examines the optimal licensing arrangement in a wide variety of situations (see Kamien 1992 for an early review), the most basic choice remains that of adopting either a fixed fee independent of the quantity produced or a royalty per unit of output produced. This paper presents the first examination of this choice in a mixed oligopoly with a public innovator and reaches conclusions that would not be anticipated by the research to date.

The choice of a fixed fee or a royalty traditionally turns on whether or not the patentee is an insider producing in the industry in which the innovation applies. The early literature makes clear that if the patentee is an outsider, rents from the fixed fee exceed that from the royalty (Kamien and Tauman 1986; Katz and Shapiro 1986; Kamien et al. 1992). The fixed fee allows capturing additional rent as it does not increase the marginal cost of production thereby reducing the quantity of the output demanded. On the other hand, when the patentee is an insider producing in the market, rents from the royalty exceed that from the fixed fee (Wang 1998, Kamien and Tauman 2002), because the royalty provides both licensing revenue and a competitive advantage in production. The superiority of the royalty for an insider has proven robust. It remains in a Bertrand differentiated product framework (Wang and Yang 1999 and Wang 2002), remains in a Hotelling "locate then price" model (Poddar and Sinha 2004) and remains in a model with leadership (Filippini 2005). [1] Yet, with notable exceptions discussed below, the logic of optimal licensing has not been widely applied to the growing literature on mixed oligopoly.

The present paper investigates the case in which the innovator is a welfare-maximizing public patentee. We demonstrate that it is always optimal for a public patentee to license to reduce total production cost in society despite the fact that additional profits earned by the foreign firm will flow out of the country. In addition, it is shown that licensing by a fixed fee is superior to licensing by a royalty for the public innovator.

Beyond helping to determine the relative weight of conflicting theoretical incentives, practical examples suggest the need for this examination. The paper's focus on a public firm that licenses technology to foreign firms is illustrated by several Chinese examples. Thus, Sinopec, one of the major state-owned petroleum companies in China, earned RMB 1.48 billion in 2008 from licensing its technology, including licenses to foreign firms in Cuba (Wang 2009). In the iron and steel industry, the state-owned enterprise, Baosteel, licenses its slag processing technology to JSW Steel in India and POSCO in South Korea (Chen 2007). Such practical evidences motivate our examination of the optimal licensing in mixed oligopoly.

In what follows, the next section sets up the model and presents results of a duopoly. The third section extends the model for an N-firm oligopoly. Section four provides concluding remarks.

2. Model Setting

We consider a duopoly in which firm 0 is a public firm maximizing social welfare and firm 1 is a private, profit-maximizing firm. The firms face a common demand function $p = a - Q$ where reservation price $a > 0$ and $Q = q_0 + q_1$. Following the tradition from the mixed oligopoly literature, we assume quadratic production cost, $C_i = k_i q_i + q_i^2$ (Lu and Poddar 2006 for an example). The cost-reducing innovation developed by firm 0 can lower the unit marginal production cost by the amount of ε, i.e. $C_i = (k_i - \varepsilon)q_i + q_i^2$, where ε and k_i are less than a. The profit function of firm i is: $\prod_i = pq_i - C_i, i = 0,1$. The foreign firm's profit is shifted out from the domestic country and thus not counted in the domestic social welfare, but the licensing revenue contributes to social welfare. The resulting social welfare, the sum of consumer surplus, public firm's profit and licensing revenue, is the public firm's objective function: $W = \int_0^Q p(t)dt - \sum_{i=0}^{1} C_i - \Pi_1 + F$ or $W = \int_0^Q p(t)dt - \sum_{i=0}^{1} C_i - \Pi_1 + R$, where F is the licensing revenue by a fixed fee and R is the licensing revenue by a royalty.

The game consists of two stages. In stage one, firm 0 innovates and decides whether to retain the cost advantage (not license), to license to firm 1 by means of a single fixed fee or to license to firm 1 by means of a per unit royalty. If firm 0 licenses, firm 1 shares a low production cost. In stage two, firms choose quantities given their costs of production and the licensing arrangement. At issue will be whether licensing takes place and, if so, in what form. The equilibrium is solved by backward induction to arrive at the subgame Nash perfect equilibrium.

We start our analysis by considering unspecified k_i and results of this model will serve as a reference for deriving equilibria for the alternative licensing models. The Cournot game on quantity generates best response functions of both firms:

$$\begin{aligned} q_0 &= (a - k_0)/3 \\ q_1 &= (a - k_1 - q_0)/4 \end{aligned} \tag{1}$$

Solving best response functions simultaneously generate equilibrium quantities:

$$\begin{aligned} q_0 &= (a - k_0)/3 \\ q_1 &= (2a + k_0 - 3k_1)/12 \end{aligned} \tag{2}$$

2.1. Retain the innovation and do not license

When public firm does not license its technology to the foreign firm, $k_0 = k - \varepsilon$, $k_1 = k$. The new equilibrium becomes:

$$\begin{aligned} q_0^{NL} &= (a - k + \varepsilon)/3 \\ q_1^{NL} &= (2a - 2k - \varepsilon)/12 \\ \Pi_1^{NL} &= (2k - 2a + \varepsilon)^2/72 \\ W^{NL} &= [52\left(a - k + \varepsilon\right)^2 - 3\varepsilon\left(\varepsilon + 4a - 4k\right)]/288 \end{aligned} \tag{3}$$

2.2. Licensing by a fixed fee

When the public firm licenses its innovation to the foreign firm by fixed-fee F, we have $k_1 = k_0 = k - \varepsilon$. Thus, the equilibrium becomes

$$\begin{aligned} q_0^F &= (a - k + \varepsilon)/3 \\ q_1^F &= (a - k + \varepsilon)/6 \\ \Pi_1^F &= (a - k + \varepsilon)^2/18 \end{aligned} \tag{4}$$

To maximize F, the public firm chooses the amount that makes the foreign firm indifferent between licensing and not licensing, that is $F = \Pi_1^F - \Pi_1^{NL} = \varepsilon(4a - 4k + \varepsilon)/24$. And thus, the welfare with fixed fee revenue is $W^F = [13\left(a - k + \varepsilon\right)^2 + 3\varepsilon\left(\varepsilon + 4a - 4k\right)]/72$.

Proposition 1. In a mixed duopoly with a foreign private firm, the pubic innovator generates higher social welfare from licensing by fixed fee than not licensing.
Proof: $W^F - W^{NL} > 0$. (See details in Appendix)

The foreign firm contributes to welfare by increasing consumer surplus, but it shifts profit out of domestic country, which reduces welfare. Licensing reduces the foreign firm's cost and enhances its output level increasing consumer surplus ($CS^F > CS^{NL}$). Whether welfare increases or decreases depends on balance of these two opposite forces. On one hand, the output of the public firm remains unchanged between pre- and post-licensing but the foreign firm produces more with the cost-reducing technology. Therefore, the oligopolistic market is associated with lower dead weight loss after licensing, resulting in higher global welfare. On the other hand, fixed fee licensing requires the profit shifted out of the domestic country by the foreign to remain unchanged. As a consequence, licensing by fixed fee improves domestic welfare and thus it is optimal for the pubic innovator to license by a fixed fee.

2.3. Licensing by a royalty

When public firm licenses its technology to foreign firm by royalty, new equilibrium with a given royalty rate r is

$$\begin{aligned} q_0^R &= (a-k+\varepsilon)/3 \\ q_1^R &= (2a-2k-3r+2\varepsilon)/12 \\ W + rq_1 &= [26(a+\varepsilon-k)-21r][2(a+\varepsilon-k)+3r]/288 \end{aligned} \tag{5}$$

where $0 \le r \le \varepsilon$. Maximizing welfare with respect to r, the first order condition generates $r = 2(a-k+\varepsilon)/7$ but $r \le \varepsilon$ (that foreign firm will accept the license). Therefore, we have

$$r = \begin{cases} \varepsilon & \text{if} \quad 0 \le \varepsilon \le 2(a-k)/5 \\ 2(a-k+\varepsilon)/7 & \text{if} \quad 2(a-k)/5 \le \varepsilon \end{cases} \tag{6}$$

Thus, the equilibrium welfare becomes:

$$W^R = \begin{cases} (26a-26k+5\varepsilon)(2a-2k+5\varepsilon)/288 & \text{if} \quad 0 \le \varepsilon \le 2(a-k)/5 \\ 25(a-k+\varepsilon)^2/126 & \text{if} \quad 2(a-k)/5 \le \varepsilon \end{cases} \tag{7}$$

Proposition 2. In a mixed duopoly with a foreign private firm, the pubic innovator generates higher social welfare from licensing by royalty than not licensing, but less than licensing by fixed fee.
Proof: If $0 \le \varepsilon \le 2(a-k)/5$, $W^R - W^{NL} > 0$ and $W^R - W^F < 0$. If $2(a-k)/5 \le \varepsilon$, $W^R - W^{NL} > 0$ and $W^R - W^F < 0$.

The intuition follows the previous proposition. The fixed fee extracts the maximum amount of profit from foreign firm, leaving its profit identical to that without licensing. Yet, the royalty leaves the foreign firm with higher profit. Moreover, the consumer surplus under fixed fee licensing is larger than that under royalty licensing ($CS^F > CS^R$). In consequence, licensing by a fixed fee is superior for the public innovator.

Corollary 1. In a mixed duopoly with a foreign private firm, the public innovator will license by a fixed fee.

The corollary follows directly from propositions 1 and 2 and summarizes the subgame perfect equilibrium. The finding that it is optimal for the public innovator to license by a fixed fee differs from the case without a public firm (Wang 1998).

3. The N-firm Case

Studies show that the number of licensees plays a crucial role on the optimality comparison for fixed fee versus royalty (Sen 2005). In this section, we explore the case in which the public innovator faces decision to license to N identical foreign private firms or not, if so, whether it is optimal to license by a fixed fee or by a royalty. The cost-reducing innovation developed by firm 0 can lower the unit marginal production cost by the amount of ε, i.e $C_i = (k_i - \varepsilon)q_i + q_i^2$, where $k_i = k,\ i = 1, 2 ... n$. The profit function of firm i is: $\Pi_i = pq_i - C_i, i = 0, 1 ... n$. The resulting social welfare function becomes: $W = \int_0^Q p(t)\,dt - \sum_{i=0}^{n} C_i - \sum_{i=1}^{n} \Pi_i + F$ or $W = \int_0^Q p(t)\,dt - \sum_{i=0}^{n} C_i - \sum_{i=1}^{n} \Pi_i + R$. The maximization of profit and welfare again generates the equilibrium for each case. We summarize the critical comparison in a proposition analogous to Corollary 1.

Proposition 3. In a mixed oligopoly with a foreign firm, the public innovator will license by a fixed fee.
Proof: See Appendix.

The results remain robust to the move from duopoly to the N-firm oligopoly. The public innovator would charge a positive licensing fee which adds to domestic welfare. By a fixed fee, the public innovator extracts the entire incremental profit from foreign firms and leaves them indifferent between licensing and not licensing. By royalty licensing, however, the public innovator has to share some profit with foreign firms.[2] Similarly, the consumer surplus under fixed fee licensing is larger than that under royalty licensing ($CS^F > CS^R$). As a consequence, the fixed fee is superior to the royalty for the public innovator when the private firms are foreign.

4. Conclusion

This paper compares licensing by a fixed fee versus licensing by a royalty for a welfare-maximizing public innovator. In contrast to the literature on an inside private patentee, the optimal choice is licensing by fixed fee. There remain a variety of directions for further research. First, the addition of domestic firms that compete in the single market may well alter the optimal licensing method and the policy conclusions. Second, the innovator may be able to license its technology only to some firms and allowing for an optimal number of licenses stands as another future research addition. Third, it would be interesting to examine the influence of partial privatization. Again, the optimal licensing method and policy conclusions are likely to change with such an examination.

Appendix

Proof for Proposition 1: $W^F - W^{NL} = 5\varepsilon(4a - 4k + \varepsilon)/96 > 0$

$$CS^F - CS^{NL} = \varepsilon(4a - 4k + 3\varepsilon)/32 > 0$$

Proof for Proposition 2:

$$W^R - W^{NL} = \begin{cases} \varepsilon(2a - 2k - \varepsilon)/12 > 0 & \text{if} \quad 0 \le \varepsilon \le 2(a-k)/5 \\ (12(a-k)^2 + 19\varepsilon^2 - 13k\varepsilon + 52a\varepsilon)/672 > 0 & \text{if} \quad 2(a-k)/5 \le \varepsilon \end{cases}$$

$$W^R - W^F = \begin{cases} -\frac{1}{96}\varepsilon(4a - 4k + 13\varepsilon) < 0 & \text{if} \quad 0 \le \varepsilon \le 2(a-k)/5 \\ (3a^2 - 4\varepsilon^2 + 3k^2 + 22k\varepsilon - 6ak - 22a\varepsilon)/168 < 0 & \text{if} \quad 2(a-k)/5 \le \varepsilon \end{cases}$$

$$CS^R - CS^F = \begin{cases} -\varepsilon(4a - 4k + 3\varepsilon)/32 < 0 & \text{if} \quad 0 \le \varepsilon \le 2(a-k)/5 \\ -13(a - k + \varepsilon)^2/392 < 0 & \text{if} \quad 2(a-k)/5 \le \varepsilon \end{cases}$$

Proof for Proposition 3:

The equilibrium quantities with unspecified k_i for oligopoly become:

$q_0 = \frac{a - k_0}{3}, q_i = \frac{2a + k_0 - 3k_i}{3(n+3)}$, analogous to equation (2). Similarly, we have the equilibrium fixed fee revenue: $F = \Pi_i^F - \Pi_i^{NL} = \frac{2\varepsilon(4a + \varepsilon - 4k)}{3(n+3)^2}$. Under royalty licensing, the public innovator adopts optimal royalty rate $r = \begin{cases} \varepsilon & \text{if} \quad 0 \le \varepsilon \le \frac{2(a-k)}{n+4} \\ \frac{(2a - 2k + 2\varepsilon)}{n+6} & \text{if} \quad \varepsilon \ge \frac{2(a-k)}{n+4} \end{cases}$. Thus, we have:

When $0 \le \varepsilon \le \frac{2(a-k)}{n+4}$,

$W^R - W^{NL} = \frac{n\varepsilon(2a - 2k - \varepsilon)}{3(n+3)} > 0,\ W^R - W^F = -\frac{n\varepsilon(4a - 4k + 10\varepsilon + 3n\varepsilon)}{6(n+3)^2} < 0$ and

$CS^R - CS^F = -\frac{n\varepsilon[(2n+2)(a-k) + (n+2)\varepsilon]}{2(n+3)^2} < 0$.

When $\frac{2(a-k)}{n+4} < \varepsilon \le k$, $W^R - W^{NL} = \frac{n\{4(a-k)[\varepsilon(n^2 + 6n + 6) + 3(3-k)] + \varepsilon^2(n^2 + 6n + 12)\}}{6(n+3)^2(n+6)}$, which is monotonically increasing with respect to ε in the interval. We have its minimum value $W^R - W^{NL}|_{\varepsilon = \frac{2(a-k)}{n+4}} = \frac{4n(a-k)^2}{3(n+4)^2} > 0$, and thus $W^R - W^{NL} > 0$.

Similarly, we have $W^R - W^F = \frac{2n\{(a-k)[3(a-k) - 18\varepsilon - 4n\varepsilon] - \varepsilon^2(n+3)\}}{3(n+3)^2(n+6)}$, which is monotonically decreasing with respect to ε in the interval. We have its maximum value $W^R - W^F|_{\varepsilon = \frac{2(a-k)}{n+4}} = -\frac{2n(5n+18)(a-k)^2}{3(n+3)^2(n+4)^2} < 0$, and thus $W^R - W^F < 0$. On consumer surplus, $CS^R - CS^F = -\frac{2n(n^2 + 6n + 6)(a - k + \varepsilon)^2}{(n+3)^2(n+6)^2} < 0$.

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[1] One exception is Heywood and Ye (2011), in which the innovator prefers a fixed fee to a royalty in a model of spatial price discrimination when reduced willingness to pay by consumers limits the competitive location advantage.

[2] As the number of foreign firms increases, the public innovator charges a lower royalty rate unless it is binding, $\partial r / \partial n < 0$ and $\lim_{n \to \infty} r = 0$.