How to license a public licensor's technology to an asymmetric duopoly

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Abstract

We consider the issue of optimal licensing from the viewpoint of an external public licensor maximizing social welfare. Our principal findings are as follows. Fee licensing is always at least as good as royalty licensing for the public licensor. For small innovations, there exists a subgame perfect equilibrium outcome in which the public licensor licenses his patented technology to only an efficient (low-cost) firm maximizing its profit.

Keywords: public licensor, asymmetric duopoly, fee license, royalty license

JEL Classification Codes: C45, L32

1. Introduction

We consider an asymmetric duopoly market in which a public licensor, who maximizes social welfare, licenses his patented technology to firms under two licensing policies: fee and royalty. The purpose of this paper is to investigate which licensing policy a public licensor would choose and to whom the patented technology would be given.

Since the seminal papers of Kamien and Tauman (1984, 1986), many subsequent studies focused on an external patent holder maximizing his own profit, and mainly examined the optimal licensing policies that maximize his revenue. Erutku and Richelle (2007) provided

the optimal non-linear contract that specifies a fixed lump-sum fee and a royalty rate. Sen and Tauman (2007) found the optimal combination of licensing schemes in which the amount of the fee is determined by auction and a royalty rate is determined by the patent holder. Giebe and Wolfstetter (2008) proposed an auction mechanism that is more profitable for the patent holder than standard licensing policies such as fee and royalty.

In practice, however, there are state-owned research laboratories that maximize social welfare. Although many examples of such public patent holders exist (e.g., the National Institute of Advanced Industrial Science and Technology and RIKEN in Japan), little attention has been paid to this case. Based on the literature, we construct a basic model in which an external public patent holder licenses his (patented) cost-reducing technology to duopolistic firms having an asymmetric cost structure. Applying the subgame perfect equilibrium to this model, we analyze and compare the outcomes under two licensing policies.

Our principal findings are as follows. (I) Fee licensing is at least as good as royalty licensing for the public licensor. (II) Under the fee policy, for small innovations, there exists a subgame perfect equilibrium outcome in which the public licensor licenses his patented technology to only an efficient (low-cost) firm, but he never licenses to only an inefficient (high-cost) firm.

2. The model

We consider an asymmetric duopoly market producing a homogeneous product. Let $N = \{1,2\}$ be the set of private firms, which maximize their profits. The market price is determined by $p(q_1, q_2) = \max\{0, a - q_1 - q_2\}$, where a is a constant maximum price of the product and q_i is firm i's production level. Firm 1 produces at the constant unit cost c_L and firm 2 produces at the constant unit cost c_H. Throughout this paper, we assume that $0 < c_L < c_H < \infty$, i.e., firm 1 is the more efficient firm in the market.

An external licensor, who has no production facilities, is a state-owned public firm; thus, he intends to maximize social welfare. This public licensor has a patented technology that can reduce any licensee's unit cost of production by the amount of ε, where $0 < \varepsilon < c_L$. Consider the situation in which the public licensor can license his patented technology to firms by a policy of either a (limp-sum) fee or a (per-unit) royalty. The fee policy means that the licensee pays a lump-sum fee $f\ (\geq 0)$ for licensing the patented technology. On the other hand, under the royalty policy, the licensee pays at a uniform royalty rate r, where $0 \leq r \leq \varepsilon$, per unit of production. For notational ease, let $c_k^\delta \equiv c_k - \delta$ for $k = L, H$.

The game is organized as follows: At the first stage, the public licensor announces the

amount of the fee (or royalty rate) to all firms in the market.[1] At the second stage, each firm simultaneously and independently decides whether to buy the license. At the third stage, firms compete *à la* Cournot (i.e., in quantities) in the market, knowing which firms hold the license. Our solution concept is the subgame perfect equilibrium (SPE). In the following sections, this game is analyzed backwardly.

Suppose that firm i has an unspecified constant unit cost c_i of production. Then, firm i's (gross) profit is $(p(q_1, q_2) - c_i)q_i$. Let $q_i(c_1, c_2)$ and $\pi_i(c_1, c_2)$ denote the Cournot equilibrium quantity and (gross) profit of firm i at the third stage. Throughout this paper, we assume that $a - 2c_H + c_L > 0$. Under this assumption, both firms produce positive output levels in the Cournot equilibrium at the third stage when no firm is licensed (i.e., $q_1(c_L, c_H) > 0$ and $q_2(c_L, c_H) > 0$).

3. Fee licensing

We first define social welfare to analyze the outcomes under the fee policy. Social welfare is basically defined as the sum of the licensing revenue, firms' profits, and consumers' utility measured in monetary units. Suppose that the unit costs of firms 1 and 2 are c_1 and c_2, respectively. Then, in the Cournot equilibrium, social welfare in fee licensing is given as

$$SW_f(c_1, c_2) = \pi_1(c_1, c_2) + \pi_2(c_1, c_2) + CS(c_1, c_2), \tag{1}$$

where $CS(c_1, c_2) = (q_1(c_1, c_2) + q_2(c_1, c_2))^2/2$ is called consumer surplus.[2] Under the fee policy, the public licensor decides the amount of the fee so as to maximize this social welfare.

Under the assumption that $a - 2c_H + c_L > 0$, in the Cournot equilibrium at the third stage, both firms supply the products to the market in the cases where no firm is licensed and where both firms are licensed. When no firm is licensed, the Cournot equilibrium output and gross profit of the two firms are $q_1(c_L, c_H) = (a - 2c_L + c_H)/3 > 0$, $q_2(c_L, c_H) = (a - 2c_H + c_L)/3 > 0$, $\pi_1(c_L, c_H) = [q_1(c_L, c_H)]^2$ and $\pi_2(c_L, c_H) = [q_2(c_L, c_H)]^2$. When both firms are licensed, the firms' Cournot equilibrium outputs and gross profits are $q_1(c_L^\varepsilon, c_H^\varepsilon) = (a - 2c_L + c_H + \varepsilon)/3$, $q_2(c_L^\varepsilon, c_H^\varepsilon) = (a - 2c_H + c_L + \varepsilon)/3$, $\pi_1(c_L^\varepsilon, c_H^\varepsilon) = [q_1(c_L^\varepsilon, c_H^\varepsilon)]^2$, and $\pi_2(c_L^\varepsilon, c_H^\varepsilon) = [q_2(c_L^\varepsilon, c_H^\varepsilon)]^2$. Then, for the two cases, the social welfare in fee licensing is given as

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[1] In agreement with the literature referred in this study, it is assumed that the licensor publicly announces a licensing payment to all potential licensees. Even if the public licensor can select which firms he offers the license to, we would obtain the same results.
[2] In fee licensing, the equilibrium quantities $q_1(c_1, c_2)$ and $q_2(c_1, c_2)$ do not depend on the amount of the fee f, so the sum of gross profits $\pi_1(c_1, c_2) + \pi_2(c_1, c_2)$ is constant. Thus, social welfare in fee licensing does not depend on f, because f cancels out in (1).

$$SW_f(c_L, c_H) = \frac{1}{9}\left[4a(a - c_L - c_H) - 7c_L c_H + \frac{11((c_L)^2 + (c_H)^2)}{2}\right],$$

and

$$SW_f(c_L^\varepsilon, c_H^\varepsilon) = \frac{1}{9}\left[4(a + \varepsilon)(a - c_L - c_H + \varepsilon) - 7c_L c_H + \frac{11((c_L)^2 + (c_H)^2)}{2}\right]. \quad (2)$$

Comparing these equations, we have

$$SW_f(c_L^\varepsilon, c_H^\varepsilon) - SW_f(c_L, c_H) = \frac{4}{9}(2a - c_L - c_H + \varepsilon)\varepsilon > 0. \quad (3)$$

Thus, licensing to both firms is always better than licensing to neither firm for the public licensor.

In order to analyze the equilibrium outcomes in the case where only one firm is licensed, we need to consider three innovation levels, which depend on the magnitude of ε. We say that an innovation is non-drastic if $\varepsilon < a - 2c_H + c_L$, semi-drastic if $a - 2c_H + c_L \leq \varepsilon < a - 2c_L + c_H$, and drastic if $a - 2c_L + c_H \leq \varepsilon$. In the case of non-drastic innovations, even though only one firm is licensed, the other firm always supplies the product in the Cournot equilibrium. For a semi-drastic innovation, firm 2 using the old technology is driven out of the market when only firm 1 uses the new technology, but firm 1 operates in the market even if only firm 2 is licensed. If the innovation is drastic, a firm using the new technology always drives a firm using old technology out of the market in the Cournot equilibrium. We derive the equilibrium strategy of the public licensor for each innovation level.

For non-drastic innovations ($\varepsilon < a - 2c_H + c_L$), when only firm 1 is licensed, the two firms' outputs and gross profits in the Cournot equilibrium are $q_1(c_L^\varepsilon, c_H) = (a - 2c_L + c_H + 2\varepsilon)/3$, $q_2(c_L^\varepsilon, c_H) = (a - 2c_H + c_L - \varepsilon)/3$, $\pi_1(c_L^\varepsilon, c_H) = [q_1(c_L^\varepsilon, c_H)]^2$, and $\pi_2(c_L^\varepsilon, c_H) = [q_2(c_L^\varepsilon, c_H)]^2$, and so social welfare in fee licensing is given as

$$SW_f(c_L^\varepsilon, c_H) = \frac{1}{9}\left[4a(a - c_L - c_H + \varepsilon) - 7(c_L - \varepsilon)c_H + \frac{11((c_L - \varepsilon)^2 + (c_H)^2)}{2}\right]. \quad (4)$$

If only firm 2 is licensed, the Cournot equilibrium outputs and gross profits are $q_1(c_L, c_H^\varepsilon) = (a - 2c_L + c_H - \varepsilon)/3$, $q_2(c_L, c_H^\varepsilon) = (a - 2c_H + c_L + 2\varepsilon)/3$, $\pi_1(c_L, c_H^\varepsilon) = [q_1(c_L, c_H^\varepsilon)]^2$, and $\pi_2(c_L, c_H^\varepsilon) = [q_2(c_L, c_H^\varepsilon)]^2$. Then, social welfare in fee licensing is

$$SW_f(c_L, c_H^\varepsilon) = \frac{1}{9}\left[4a(a - c_L - c_H + \varepsilon) - 7c_L(c_H - \varepsilon) + \frac{11((c_L)^2 + (c_H - \varepsilon)^2)}{2}\right]. \quad (5)$$

Comparing (4) with (5), we have

$$SW_f(c_L^\varepsilon, c_H) - SW_f(c_L, c_H^\varepsilon) = 2\varepsilon(c_H - c_L) > 0. \quad (6)$$

Together, (3) and (6) imply that the public licensor prefers licensing his patented

technology to either both firms or only firm 1. From (2) and (4),

$$SW_f(c_L^\varepsilon, c_H) - SW_f(c_L^\varepsilon, c_H^\varepsilon) = \frac{\varepsilon}{9}\left(\frac{3}{2}\varepsilon - 4a - 7c_L + 11c_H\right),$$

which implies that $SW_f(c_L^\varepsilon, c_H) \geq SW_f(c_L^\varepsilon, c_H^\varepsilon)$ if $\varepsilon \geq (8a + 14c_L - 22c_H)/3$. The equation $a - 2c_H + c_L - \varepsilon = 0$ intersects the equation $8a + 14c_L - 22c_H - 3\varepsilon = 0$ at $(c_L, c_H) = (a - 8\varepsilon/3, a - 11\varepsilon/6)$. Under the assumption that $\varepsilon < c_L$, if $0 < \varepsilon < 3a/11$, then there exists a case where licensing to only firm 1 is better than licensing to both firms for the public licensor for non-drastic innovations. (See Figure 1)

We next need to consider whether only the specific firm(s) to which the public licensor hopes to transfer his patented technology buys the license in equilibrium at the second stage, by announcing an appropriate licensing fee at the first stage. Let f denote the amount of the fee. If $\pi_1(c_L^\varepsilon, c_H^\varepsilon) - f \geq \pi_1(c_L, c_H^\varepsilon)$ and $\pi_2(c_L^\varepsilon, c_H^\varepsilon) - f \geq \pi_2(c_L^\varepsilon, c_H)$, both firms buy the license in equilibrium at the second stage. Thus, the public licensor can sell the license to both firms by setting a fee f such that $0 \leq f \leq \min\{\pi_1(c_L^\varepsilon, c_H^\varepsilon) - \pi_1(c_L, c_H^\varepsilon), \pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H)\}$. If $\pi_1(c_L^\varepsilon, c_H) - f \geq \pi_1(c_L, c_H)$ and $\pi_2(c_L^\varepsilon, c_H) \geq \pi_2(c_L^\varepsilon, c_H^\varepsilon) - f$, only firm 1 buys the license in equilibrium at the second stage; thus, when the public licensor announces a fee f such that $\pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H) \leq f \leq \pi_1(c_L^\varepsilon, c_H) - \pi_1(c_L, c_H)$, only firm 1 buys the license. For non-drastic innovations, we can easily show that $0 < \pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H) < \min\{\pi_1(c_L^\varepsilon, c_H^\varepsilon) - \pi_1(c_L, c_H^\varepsilon), \pi_2(c_L, c_H^\varepsilon) - \pi_2(c_L, c_H)\} < \pi_1(c_L^\varepsilon, c_H) - \pi_1(c_L, c_H)$. Therefore, it is always feasible for the public licensor to license his patented technology to the intended specific firm(s) by setting an appropriate licensing fee at the first stage. Then, we have the following lemma.

Lemma 1: *For non-drastic innovations, if $0 < \varepsilon < 3a/11$, then there exists a cost profile (c_L, c_H) where fee licensing to only firm 1 is realized as an SPE. Under this condition, the public licensor transfers his patented technology to only firm 1 if $(8a + 14c_L - 22c_H)/3 \leq \varepsilon < a - 2c_H + c_L$. Otherwise, the patented technology diffuses to both firms.*

This result indicates that, under the fee policy, licensing to only the efficient firm is socially optimal when the difference between the two firms' (ex ante) costs c_L and c_H of production is large.

There are two possible effects on social welfare, according to which firm(s) is licensed. Licensing to both firms has the positive effect on social welfare that both firms compete fiercely (*competition effect*), whereas licensing to only one firm (in our study, the efficient firm) has the effect that the production shifts from the inefficient firm to the efficient firm (*production substitution effect*). If the difference between the firms' costs is small, the former effect dominates the latter one, while if the difference is large, the latter outweighs the former.

The public licensor decides to which firms to license his patent according to which effect is stronger.

In the case of semi-drastic innovations ($a - 2c_H + c_L \leq \varepsilon < a - 2c_L + c_H$), when only firm 2 is licensed, the Cournot equilibrium outcome at the third stage is the same as in the case of non-drastic innovations. Comparing (2) with (5), because $\varepsilon < a - 2c_L + c_H$, we have

$$SW_f(c_L^\varepsilon, c_H^\varepsilon) - SW_f(c_L, c_H^\varepsilon) = \frac{\varepsilon}{9}\left(4a - 11c_L + 7c_H - \frac{3}{2}\varepsilon\right) > \frac{\varepsilon}{9}\left(\frac{5}{2}a - 8c_L + \frac{11}{2}c_H\right) > 0.$$

Hence, as in the case of non-drastic innovations, the public licensor prefers licensing his patented technology to either both firms or only firm 1. On the other hand, firm 2 is driven out of the market if the public licensor licenses his patented technology to only firm 1. Thus, when only firm 1 is licensed, the Cournot equilibrium outputs and gross profits are $q_1(c_L^\varepsilon, c_H) = (a - c_L + \varepsilon)/2$, $q_2(c_L^\varepsilon, c_H) = 0, \pi_1(c_L^\varepsilon, c_H) = [q_1(c_L^\varepsilon, c_H)]^2$, and $\pi_2(c_L^\varepsilon, c_H) = 0$, and the social welfare in fee licensing is therefore

$$SW_f(c_L^\varepsilon, c_H) = \frac{3}{8}(a - c_L + \varepsilon)^2. \tag{7}$$

Then, for semi-drastic innovations,

$$SW_f(c_L^\varepsilon, c_H) - SW_f(c_L^\varepsilon, c_H^\varepsilon) = -\frac{1}{72}(5a + 17c_L - 22c_H + 5\varepsilon)(a - 2c_H + c_L + \varepsilon).$$

Because $a - 2c_H + c_L + \varepsilon > \varepsilon > 0$ by our assumption, $SW_f(c_L^\varepsilon, c_H) \geq SW_f(c_L^\varepsilon, c_H^\varepsilon)$ if $\varepsilon \leq -a - (17c_L - 22c_H)/5$. The equation $5a + 17c_L - 22c_H + 5\varepsilon = 0$ intersects the equations $a - 2c_H + c_L = 0$ and $a - 2c_H + c_L - \varepsilon = 0$ at $(c_L, c_H) = (a - 5\varepsilon/6, a - 5\varepsilon/12)$ and $(c_L, c_H) = (a - 8\varepsilon/3, a - 11\varepsilon/6)$, respectively. Because $\varepsilon < c_L$ and $a - \varepsilon/3 < a - 5\varepsilon/6$, there exist cases where the public licensor prefers licensing to only firm 1 if $0 < \varepsilon < 6a/11$ for semi-drastic innovations. (See Figure 1.)

For semi-drastic innovations, it can also be shown that $0 < \pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H) < \min\{\pi_1(c_L^\varepsilon, c_H^\varepsilon) - \pi_1(c_L, c_H^\varepsilon), \pi_1(c_L^\varepsilon, c_H) - \pi_1(c_L, c_H), \pi_2(c_L, c_H^\varepsilon) - \pi_2(c_L, c_H)\}$. As discussed in the case of non-drastic innovations, both firms buy the license at the second stage when the public licensor sets a fee f such that $0 \leq f \leq \pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H)$, and only firm 1 buys it at the second stage when the public licensor sets a fee f such that $\pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H) \leq f \leq \pi_1(c_L^\varepsilon, c_H) - \pi_1(c_L, c_H)$. Hence, the following lemma holds.

Lemma 2: *For semi-drastic innovations, if $0 < \varepsilon < 6a/11$, then there exists a cost profile (c_L, c_H) such that fee licensing to only firm 1 is realized as an SPE. Under this condition, the public licensor transfers his patented technology to only firm 1 if $a - 2c_H + c_L \leq \varepsilon \leq -(5a + 17c_L - 22c_H)/5$. Otherwise, the patented technology diffuses to both firms.*

If the innovation is drastic ($a - 2c_L + c_H \leq \varepsilon$), a firm using the old technology is driven out of the market in the Cournot equilibrium when its rival firm has access to the new technology. In the case where only firm 2 is licensed, firms' outputs and gross profits in the Cournot equilibrium are $q_1(c_L, c_H^\varepsilon) = 0$, $q_2(c_L, c_H^\varepsilon) = (a - c_H + \varepsilon)/2$, $\pi_1(c_L, c_H^\varepsilon) = 0$, and $\pi_2(c_L, c_H^\varepsilon) = [q_2(c_L, c_H^\varepsilon)]^2$. Thus, the social welfare in fee licensing is

$$SW_f(c_L, c_H^\varepsilon) = \frac{3}{8}(a - c_H + \varepsilon)^2. \tag{8}$$

When only firm 1 is licensed, the equilibrium outcome is the same as in the case of semi-drastic innovations. By (7) and (8), $SW_f(c_L^\varepsilon, c_H) > SW_f(c_L, c_H^\varepsilon)$ because $c_H > c_L$. Comparing (2) with (7), we have

$$SW_f(c_L^\varepsilon, c_H) - SW_f(c_L^\varepsilon, c_H^\varepsilon) = -\frac{1}{72}(a + c_L - 2c_H + \varepsilon)(5a + 17c_L - 22c_H + 5\varepsilon)$$

$$\leq -\frac{1}{72}(a + c_L - 2c_H + \varepsilon)[7(a + c_L - 2c_H) + 3(a - c_H)] < 0,$$

because $0 < a - 2c_L + c_H \leq \varepsilon$ and $0 < a + c_L - 2c_H$. In the case of drastic innovations, we can also show that $0 < \pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H)$; thus, both firms buy the license at the second stage when the public licensor sets a fee f such that $0 \leq f \leq \pi_2(c_L^\varepsilon, c_H^\varepsilon) - \pi_2(c_L^\varepsilon, c_H)$. Then, the following lemma holds.

Lemma 3: *For drastic innovations, in every SPE, the public licensor licenses his patented technology to both firms.*

Lemmas 1, 2, and 3 jointly imply the main proposition in this section. We can confirm this result from Figure 1.

Proposition 1: *Under the fee policy, if $0 < \varepsilon < 6a/11$, then there exists a cost profile (c_L, c_H) where fee licensing to only firm 1 is realized as an SPE.*

Figure 1. The region where only firm 1 is licensed in the SPE outcomes under the fee policy
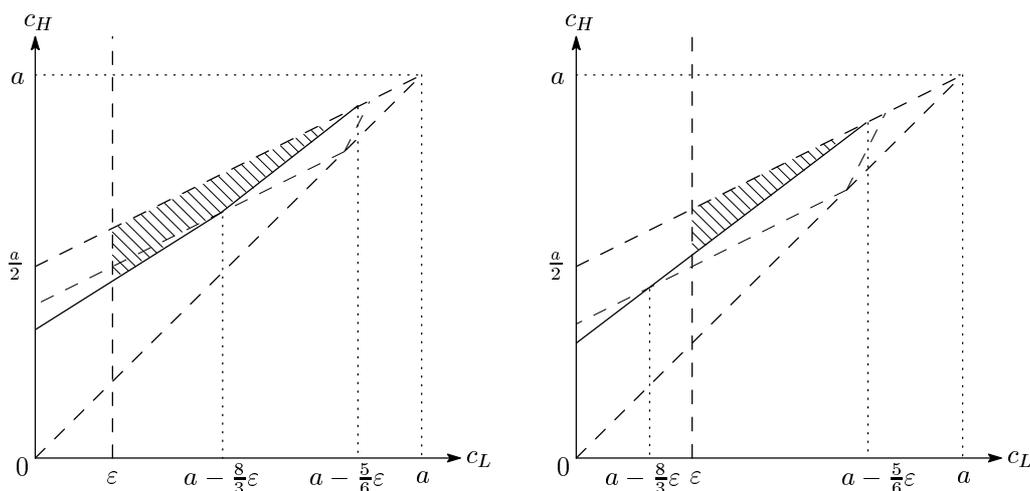
Note: Shaded area: The region where only firm 1 is licensed. Left figure: $0 < \varepsilon < 3a/11$. Right figure: $3a/11 \leq \varepsilon < 6a/11$.

4. Royalty licensing

Under the royalty policy, both firms accept the offer at the second stage in royalty licensing (because $r \leq \varepsilon$, $c_L - \varepsilon + r \leq c_L$ and $c_H - \varepsilon + r \leq c_H$), and thereby the patented technology always diffuses to both firms. Then, in the Cournot equilibrium, social welfare in royalty licensing is given as

$$SW_r(r) = \pi_1(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) + \pi_2(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) + CS(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) + r(q_1(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) + q_2(c_L^{\varepsilon-r}, c_H^{\varepsilon-r})),$$

where $CS(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) = (q_1(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) + q_2(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}))^2/2$.

Under the assumption that $a + c_L - 2c_H > 0$, when both firms are licensed at a royalty rate r, they supply the products to the market in the Cournot equilibrium. Their Cournot equilibrium outputs and profits are then $q_1(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) = (a - 2c_L + c_H + \varepsilon - r)/3$, $q_2(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) = (a + c_L - 2c_H + \varepsilon - r)/3$, $\pi_1(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) = [q_1(c_L^{\varepsilon-r}, c_H^{\varepsilon-r})]^2$, and $\pi_2(c_L^{\varepsilon-r}, c_H^{\varepsilon-r}) = [q_2(c_L^{\varepsilon-r}, c_H^{\varepsilon-r})]^2$. Thus, social welfare in royalty licensing is

$$SW_r(r) = \frac{1}{9}\left[-2r^2 - (2(a + \varepsilon) - c_L - c_H)r + 4(a + \varepsilon)(a + \varepsilon - c_L - c_H) \right.$$

$$\left. - 7c_H c_L + \frac{11((c_L)^2 + (c_H)^2)}{2} \right] \tag{9}$$

Maximizing this function with respect to r subject to the constraint that $0 \leq r \leq \varepsilon$, we have the solution $r^* = 0$. Thus, the following proposition holds.

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Proposition 2: *In the SPE outcome in royalty licensing, the public licensor always licenses his patented technology to both firms at the royalty rate $r = 0$.*

Finally, we compare the outcomes under the two licensing policies. Comparing (2) and (9) with $r = 0$, we have $SW_f(c_L^\varepsilon, c_H^\varepsilon) = SW_r(0)$. There exist, however, outcomes where licensing to only firm 1 is socially preferred under the fee policy. Therefore, we have the following proposition.

Proposition 3: *Fee licensing is at least as good as royalty licensing for the public licensor.*

5. Comparisons with the pure licensor

Wang and Yang (2004) considered an external pure licensor who maximizes his own profit for the same asymmetric duopoly market as in this paper. Throughout this section, to compare our results with those of pure licensor's case by Wang and Yang (2004), we focus only on the case of non-drastic innovations (i.e., $\varepsilon < a + c_L - 2c_H$).

Under the fee policy, the pure licensor licenses his patented technology to both firms if $a + 4c_L - 5c_H < \varepsilon$. Otherwise, he licenses it to only firm 1. Furthermore, if $0 < \varepsilon < 3a/16$, then there exists a case in which licensing at the royalty rate of $r = \varepsilon$ is preferred to fee licensing for the pure licensor. On the other hand, we have shown that if $3a/11 \le \varepsilon$, the public licensor always licenses his patented technology to both firms by means of a fee.

Regardless of the magnitude of ε, if the difference between the two firms' unit costs is small, both the pure and the public licensors license their patented technology to both firms under the fee policy; thus, optimal behavior of the pure licensor maximizes social welfare. Further, when $\varepsilon < 3a/11$, fee licensing to only firm 1 is better for both licensors if the difference is large. Thus, in this case as well, the outcome derived from the pure licensor's behavior is socially optimal. Under the condition that $3a/11 \le \varepsilon$, however, if the difference is large, the socially optimal outcome does not coincide with the one derived from the pure licensor's optimal behavior. See Figure 2.

Figure 2. The region in which our SPE outcomes coincide with those in Wang and Yang (2004)
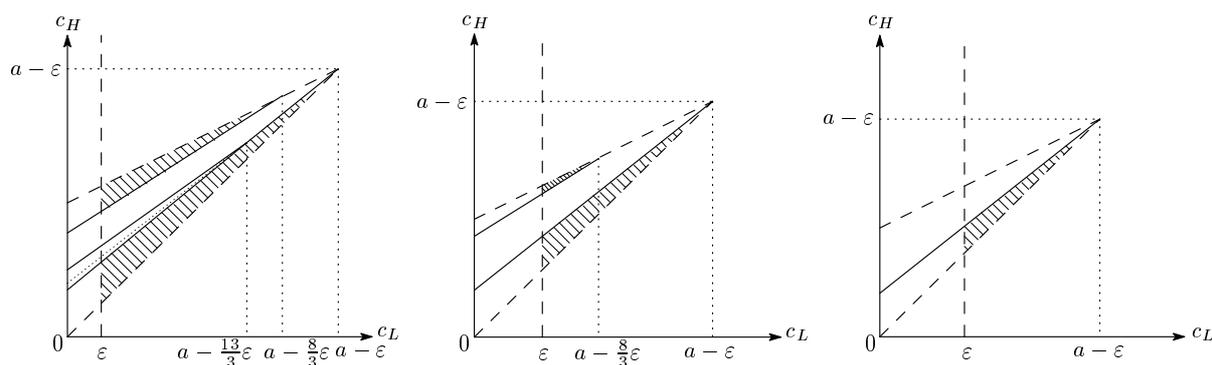
Note: Shaded area: The coinciding region. Left figure: $0 < \varepsilon < 3a/16$. Middle figure: $3a/16 \leq \varepsilon < 3a/11$. Right figure: $3a/11 \leq \varepsilon$.

6. Conclusion

We consider the optimal licensing problem from the viewpoint of the public licensor maximizing social welfare. We show that fee licensing is always at least as good as royalty licensing for the public licensor. It is also shown that, for small innovations, there exists a subgame perfect equilibrium outcome in which the public licensor licenses his patented technology to only an efficient (low-cost) firm maximizing its profit. There are two opposing effects, which are the competition effect and the production substitution effect, behind our results. The public licensor transfers to only the efficient firm if and only if the production substitution effect is stronger than the competition effect.

We briefly mention the case of oligopoly. In the licensing literature, duopoly is sometimes a special case that cannot be generalized to more than two firms. Considering the case of oligopoly with the public licensor, the results largely depend on the assumption made on the cost functions and the magnitude of the innovation. One approach to this problem is to assume that there are two types of firms: n efficient firms and m inefficient firms. We conjecture that if n is close to m, our main result holds. The case where the difference between n and m is large remains as future work.

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