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Shigeo Muto

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On Licensing Policies in Bertrand Competition*

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Three licensing policies, the auction, the fee, and the royalty, are studied in a Bertrand-type duopoly with differentiated goods. The analysis is conducted in terms of a multistage noncooperative game involving an external patentee and two firms each producing a differentiated good in Bertrand (price) competition. A principal finding is that for a patentee the royalty may be superior to the other two policies. *Journal of Economic Literature* Classification Numbers: 026, 611, 621. © 1993 Academic Press, Inc.

1. INTRODUCTION

In licensing a patented cost-reducing process innovation, a patentee may use several different policies. Policies often observed are (1) the auction: auctioning off a limited number of licenses through a sealed bid auction; (2) the fee: offering a lump-sum licensing fee; and (3) the royalty: offering a royalty payment per unit of production. In the latter two policies, any firm that wishes can purchase a license. Implications of these policies were examined in Kamien and Tauman (1984, 1986), Kamien, Oren, and Tauman (1987), and Katz and Shapiro (1986). These studies were, however, limited to the case where goods produced by firms are homogeneous; and thus, Cournot competition in a product market was mainly supposed. Among the results, in particular, it was shown that the royalty is never optimal for a patentee. Kamien and Tauman (1986) and Kamien, Oren, and Tauman (1987) included an analysis in Bertrand competition, but

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because of the homogeneity of goods, the result was quite simple: the three policies are equivalent and all are optimal for a patentee.

The purpose of this paper is to study the patentee's optimal policy in Bertrand competition where firms' products are substitutes but not homogeneous. A principal finding is that for a patentee the royalty may be superior to the other two policies when innovations are not very large.

The remainder of the paper is organized as follows. In the next section, a differentiated duopoly model is described which we assume throughout this paper. In Section 3, Bertrand–Nash equilibria in the product market are presented. In Section 4, subgame perfect equilibria are studied in three types of games generated from the three licensing policies. In Section 5, the patentee's optimal policy is examined. The paper closes in Section 6 with brief remarks on further studies concerning licensing in a differentiated duopoly.

2. THE MODEL

Following Singh and Vives (1984), we consider the following duopoly model. There are two firms (firm 1 and firm 2) each producing a differentiated good. Denote by $x_i \geqq 0$ firm i's output level, and by $p_i \geqq 0$ its unit price where $i = 1, 2$. Consumers are identical, and the representative consumer maximizes $U(x_1, x_2) - p_1x_1 - p_2x_2$, where U is his utility function which is quadratic, strictly concave in x_1 and x_2, and symmetric with respect to x_1 and x_2:

$$U(x_1, x_2) = a(x_1 + x_2) - b((x_1)^2 + 2\theta x_1x_2 + (x_2)^2)/2.$$

Here a and b are positive, and $-1 < \theta < 1$. Firms' products are substitutes, independent, or complements according to whether $\theta > 0$, $=0$, or <0. Direct demands are then given by

$$x_i = \max\left(\frac{(1 - \theta)a - p_i + \theta p_j}{b(1 - \theta^2)}, 0\right) \qquad \text{for } i = 1, 2, i \neq j. \qquad (2.1)$$

We further suppose, for simplicity, that firms' cost functions are linear and identical: the function is given by cx, where c, $c < a$, is a constant marginal cost and x is an output level. The following analysis focuses on the case where firms engage in Bertrand (price) competition and their products are close substitutes; i.e., θ is close to 1. Other cases are briefly discussed in Section 6.

In addition to firms, there is an external patentee with a patented process innovation. For simplicity, we assume that the innovation lowers both firms' marginal costs by the same amount ε, where $0 < \varepsilon < c$. The patentee's aim is to license the patent to both or one of the firms so as to maximize his total rents. In what follows, we examine which of the following three observable licensing policies is optimal for the patentee.

(1) The auction policy: one license is auctioned off through a sealed bid auction; the higher bidder gets the license at his bid price; and ties are resolved by a random choice. As discussed in Kamien, Oren, and Tauman (1987), when two licenses are auctioned, a limit on the minimum bid must be set; and thus, auctioning two licenses is equivalent to the fee policy below. Hence throughout this paper the auction policy means auctioning only one license.

(2) The fee policy: a flat lump-sum license fee α is offered at which any firm that wishes can purchase a license.

(3) The royalty policy: a flat royalty payment r, $0 < r \leqq \varepsilon$, per unit of production is offered at which any firm can purchase a license.

For each of the three licensing policies, interactions between the patentee and firms are characterized by a multistage noncooperative game, which is played as follows. When the auction policy is adopted by the patentee, firms simultaneously and independently determine how much to bid, and then a licensee is determined. Then, commonly knowing which firm holds a license, firms engage in a market competition with their cost functions inherited from the licensing stage: they simultaneously and independently determine their price levels. We denote this game by G^{A}. In the case of the fee (or the royalty) policy, the patentee first announces a fee α (or a royalty payment r), and then firms simultaneously and independently decide whether to purchase a license. Then, knowing who holds a license, firms engage in a market competition. We denote this game by G^{F} (or G^{R}). It should be noted that a licensee's marginal cost is $c - \varepsilon$ in the auction and the fee policy, while it is $c - \varepsilon + r$ in the royalty policy. A nonlicensee's marginal cost is c, the same as the preinnovation level. The patentee's payoff is his total rents, and firms' payoffs are their profits net of license expenses.

In analyzing the games described above, we adopt the subgame perfect equilibrium (in pure strategies) from Selten (1975). The subgame perfect equilibrium can be found in a backward manner. We thus first study Bertrand–Nash equilibria in the product market.

3. Equilibrium Outcomes in the Product Market

Bertrand–Nash equilibria of the above-described duopoly market were already studied in Singh and Vives (1984, pp. 548–549), and thus we only present the results. In the following, the Bertrand–Nash equilibrium price, and the corresponding output level and profit of firm i are denoted by p_i, x_i, and π_i, respectively. Further, the symbol δ, $0 \leqq \delta < c$, stands for ε in the auction and in the fee policy, and for $\varepsilon - r$ in the royalty policy.

The Bertrand–Nash equilibrium is given as follows.

(BN1) Both firms hold a license:

$$p_1 = p_2 = \frac{(1 - \theta)(a - c + \delta)}{2 - \theta} + c - \delta, \qquad x_1 = x_2 = (p_1 - c + \delta)/(1 - \theta^2)b,$$

$$\pi_1 = \pi_2 = (p_1 - c + \delta)^2/(1 - \theta^2)b.$$

(BN2) Neither firm holds a license:

$$p_1 = p_2 = \frac{(1 - \theta)(a - c)}{2 - \theta} + c, \qquad x_1 = x_2 = (p_1 - c)/(1 - \theta^2)b,$$

$$\pi_1 = \pi_2 = (p_1 - c)^2/(1 - \theta^2)b.$$

(BN3) Only one firm holds a license: let firm i and firm j be a licensee and a nonlicensee, respectively.

(i) $0 \leqq \delta < ((1 - \theta)(2 + \theta)/\theta)(a - c)$:

$$p_i = \frac{(1 - \theta)(2 + \theta)(a - c) + (2 - \theta^2)\delta}{4 - \theta^2} + c - \delta,$$

$$p_j = \frac{(1 - \theta)(2 + \theta)(a - c) - \theta\,\delta}{4 - \theta^2} + c,$$

$$x_i = (p_i - c + \delta)/(1 - \theta^2)b, \qquad x_j = (p_j - c)/(1 - \theta^2)b,$$

$$\pi_i = (p_i - c + \delta)^2/(1 - \theta^2)b, \qquad \text{and} \qquad \pi_j = (p_j - c)^2/(1 - \theta^2)b.$$

(ii) $((1 - \theta)(2 + \theta)/\theta)(a - c) \leqq \delta < ((2 - \theta)/\theta)(a - c)$:

$$p_i = \frac{(1 - \theta)}{\theta}(a - c) + c, \qquad p_j = c, \qquad x_i = \frac{a - c}{\theta b}, \qquad x_j = 0,$$

$$\pi_i = (p_i - c + \delta)x_i, \qquad \text{and} \qquad \pi_j = 0;$$

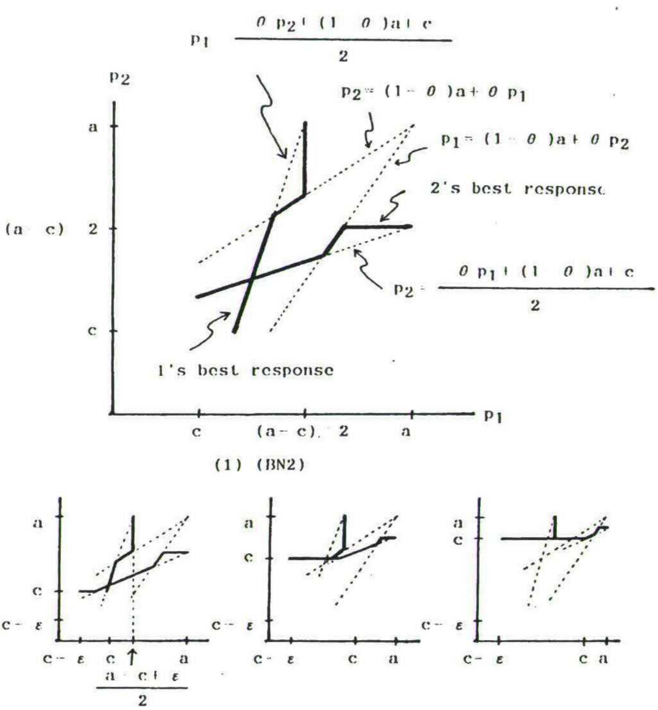
hence a nonlicensee is expelled from the market, but a licensee may not charge a monopoly price.

(iii) $((2 - \theta)/\theta)(a - c) \leqq \delta$:

$$p_i = \frac{a - c + \delta}{2} + c - \delta, \qquad p_j = c, \qquad x_i = (p_i - c + \delta)/b, \qquad x_j = 0,$$

$$\pi_i = (p_i - c + \delta)^2/b, \qquad \text{and} \qquad \pi_j = 0;$$

hence a licensee monopolizes the market.



(1) (BN2)

(2) (BN3)(i) (3) (BN3)(ii) (4) (BN3)(iii)

FIG. 3.1. An illustration of best responses.

For better understanding of the equilibria above, firms' best responses in price space are illustrated in Fig. 3.1. Note that the equalities $p_i = (1-\theta)a + \theta p_j$ and $p_i = (\theta p_j + (1-\theta)a + c)/2$ come from the nonnegativity condition on x_i in (2.1) and the first order condition in maximizing i's profit $(p_i - c)x_i$, respectively. When θ is close to 1, the case (i) of (BN3) is negligible, and thus we consider only the cases (ii) and (iii) in what follows.

We hereafter use $W(2, \delta)$, $W(1, \delta)$, and $L(1, \delta)$ to denote the firms' equilibrium profits: $W(s, \delta)$, $s = 1, 2$, is the equilibrium profit of each licensee when there are s licensees, while $L(1, \delta)$ is the equilibrium profit of a nonlicensee when his rival holds a license. In case neither firm holds a license, we denote by $L(0)$ each firm's equilibrium profit. If $\delta = 0$, all of these four values are equal.

Since a licensee may monopolize the market when $((2-\theta)/\theta)(a-c) \leqq \delta$, we call an innovation with $\varepsilon \geqq ((2-\theta)/\theta)(a-c)$ "drastic":

note that as $\theta \to 1$, $((2 - \theta)/\theta)(a - c) \to a - c$. Refer to Kamien and Tauman (1986, p. 475).

Concerning the Bertrand–Nash equilibria above, we present the following simple observations which will be useful in the following discussion. They are easily obtained through straightforward calculation; and thus, the proofs are omitted.

First, the following properties of equilibrium prices and profits are well known in Bertrand competition with homogeneous goods:

(1) if firms' marginal costs are identical, the equilibrium price is equal to the marginal cost, and their profits are zero; and

(2) if marginal costs are different, the firm with a lower cost can drive out the rival by setting its price at the rival's marginal cost or the monopoly price.

By letting $\theta \to 1$ in the equilibria above, this well-known fact follows.

Observation 3.1. As $\theta \to 1$, the following hold.

(1) In the cases (BN1), (BN2): $p_1 = p_2 \to c - \delta$ (resp. c), $x_1 + x_2 \to (a - c + \delta)/b$ (resp. $(a - c)/b$) in (BN1) (resp. in (BN2)), and $W(2, \delta)$, $L(0) \to 0$.

(2) In the case (BN3): in (ii) $p_i \to c$, $x_i \to (a - c)/b$, and $W(1, \delta) \to \delta(a - c)/b$; in (iii) p_i, x_i, and $W(1, \delta)$ are constant regardless of values of θ; and in both cases $L(1, \delta) = 0$. The case (i) disappears when $\theta \to 1$.

When goods are close substitutes but not homogeneous, the following is easily obtained from the Bertrand–Nash equilibria above.

Observation 3.2. If θ is close to 1, the following hold.

(1) In the cases (BN1), (BN2): $p_1 = p_2 > c - \delta$ (resp. $> c$) and $x_1 + x_2 < (a - c + \delta)/b$ (resp. $< (a - c)/b$) in (BN1) (resp. in (BN2)).

(2) In the case (BN3) (ii): $p_i < c$ and $x_i > (a - c)/b$.

Thus even if firms' marginal costs are identical, the equilibrium price is above the marginal cost and thus the firms can gain positive profits; the equilibrium total output level is lower than that in the homogeneous goods case. Further the firm with a lower marginal cost must set its price below the rival's cost in order to drive him out. These facts properly reflect the nonhomogeneity of products.

With respect to the equilibrium profits, the following is observed.

Observation 3.3: If θ is close to 1, the following inequalities hold for each fixed δ, $0 < \delta < c$.[1]

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[1] The inequalities (1) and (2) still hold when $\theta > 0$ (goods are substitutes). When $\theta < 0$ (goods are complements), inequalities $W(2, \delta) > W(1, \delta) > L(1, \delta) > L(0) > 0$ and $W(2, \delta) - L(1, \delta) > W(1, \delta) - L(0)$ hold. Thus each firm is better off when the rival acquires a license (the former), and the payoff to obtaining a license increases when the rival holds one. A type of agglomeration effect mentioned in Katz and Shapiro (1986) in a different setting emerges (the latter).

(1) $W(1, \delta) > W(2, \delta) > L(0) > L(1, \delta) \geqq 0$;
(2) $W(1, \delta) - L(0) > W(2, \delta) - L(1, \delta)$.
Further the equality $L(1, \delta) = 0$ holds in (ii), (iii) of (BN3).

The inequality (1) shows that each firm is worse off when the rival acquires a license; and (2) shows that each firm finds a license less valuable when its rival holds one. Similar relations appeared in Kamien and Tauman (1984) in their analysis of licensing in a Cournot oligopoly with homogeneous goods. Since $W(2, \delta)$, $L(1, \delta)$ and $L(0)$ are all close or equal to 0 (Observation 3.1), we have the stronger inequality $W(1, \delta) - L(0) > 2(W(2, \delta) - L(1, \delta))$ which will be utilized in analyzing the fee policy in the next section.

4. SUBGAME PERFECT EQUILIBRIA UNDER THE THREE POLICIES

4.1. *The Auction Policy: The Game* G^{A}

Let b_i ($i = 1, 2$) be a bid submitted by firm i and let H^{A} be a payoff to the patentee. Since $W(1, \varepsilon) > L(1, \varepsilon)$ for all $\varepsilon > 0$ (Observation 3.3), the subgame perfect equilibrium gives the unique pair of bids $b_1^* = b_2^* = W(1, \varepsilon) - L(1, \varepsilon)$; and the corresponding patentee's payoff is $H^{\mathrm{A}*} = W(1, \varepsilon) - L(1, \varepsilon)$, where and hereafter the symbol * is used to denote subgame perfect equilibrium strategies and the corresponding patentee's payoff. Hence, firms bid the same amount $W(1, \varepsilon) - L(1, \varepsilon)$: only one of them gets a license by a random choice.

4.2. *The Fee Policy: The Game* G^{F}

Let α be a fee determined by the patentee. Denote by d_i (= B or N) a decision by firm i, $i = 1, 2$: d_i = B (or N) implies that firm i buys (or does not buy) a license. The remark on Observation 3.3(2) shows that the relation $W(1, \varepsilon) - L(0) > 2(W(2, \varepsilon) - L(1, \varepsilon))$ holds; hence, the patentee gains more profit by selling a license to only one firm at the fee $W(1, \varepsilon) - L(0)$ than by selling it to both firms at the fee $W(2, \varepsilon) - L(1, \varepsilon)$. Thus the subgame perfect equilibrium of the game G^{F} gives $\alpha^* = W(1, \varepsilon) - L(0)$, (d_1^*, d_2^*) = (B, N) or (N, B); and the corresponding patentee's payoff is $H^{\mathrm{F}*} = W(1, \varepsilon) - L(0)$.

4.3. *The Royalty Policy: The Game* G^{R}

Let r be a royalty payment determined by the patentee. As in the fee policy case, let d_i (= B or N) denote a decision by firm i, $i = 1, 2$. Observation 3.3 shows that the relations $W(2, \varepsilon - r) > L(1, \varepsilon - r)$ and $W(1, \varepsilon - r) > L(0)$ hold as long as $r < \varepsilon$. Therefore the pair (B, B) is the unique equilibrium with respect to firm's decisions under the royalty payment r with $r < \varepsilon$. Thus the patentee gains $2rx$, where x stands for the equilibrium output level of each firm when both firms hold a license; namely, $x = x_1 = x_2 = (a - c + \varepsilon - r)/(1 + \theta)(2 - \theta)b$. Recall the case (BN1) in Section 3. Therefore, noting that the equation $W(2, \varepsilon - r) = W(1, \varepsilon - r) = L(1, \varepsilon - r) = L(0)$ holds when $r = \varepsilon$, we obtain that the subgame perfect equilibrium of G^R gives the following:

(1) $0 < \varepsilon < a - c$:

$r^* = \varepsilon, (d_1^*, d_2^*) = (B, B)$; and the corresponding patentee's payoff is $H^{R*} = 2\varepsilon (a - c)/(1 + \theta)(2 - \theta)b$.

(2) $a - c \leqq \varepsilon$:

$r^* = (a - c + \varepsilon)/2, (d_1^*, d_2^*) = (B, B)$; and the corresponding patentee's payoff is $H^{R*} = 2((a - c + \varepsilon)/2))((a - c + \varepsilon)/2(1 + \theta)(2 - \theta)b)$.

5. THE PATENTEE'S OPTIMAL POLICY

We now examine the optimal policy of the patentee. Since goods are close substitutes, we essentially have two cases to be examined: $((1 - \theta)(2 + \theta)/\theta)(a - c) \leqq \varepsilon < a - c$ and $((2 - \theta)/\theta)(a - c) \leqq \varepsilon$. Recall the three cases of (BN3) in the description of Bertrand–Nash equilibria (Section 3) and the two cases in the description of subgame perfect equilibria in the game G^R (Section 4), and note that $(1 - \theta)(2 + \theta)/\theta \to 0$, $(2 - \theta)/\theta \to 1$ as $\theta \to 1$.

Since $L(0) > L(1, \varepsilon) = 0$ in these two cases (Observation 3.3), we have $H^{A*} = W(1, \varepsilon) - L(1, \varepsilon) > W(1, \varepsilon) - L(0) = H^{F*}$; and thus for the patentee the auction is superior to the fee.

We next compare the auction with the royalty. First consider the case of $((1 - \theta)(2 + \theta)/\theta)(a - c) \leqq \varepsilon < a - c$; i.e., the case of nondrastic innovations. The patentee's profits in these two policies are given by

$$H^{A*} = (-(1 - \theta)(a - c)/\theta + \varepsilon)((a - c)/\theta b) \qquad \text{(the auction),}$$

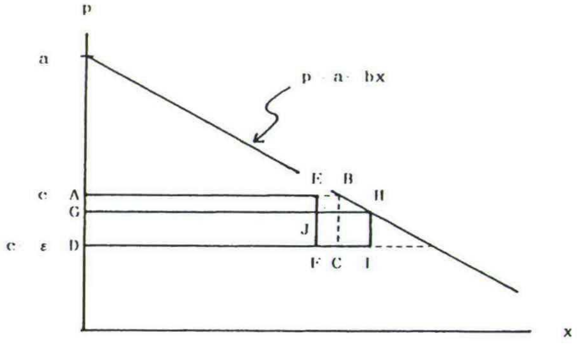
and (5.1)

$$H^{R*} = 2\varepsilon\,((a - c)/(1 + \theta)(2 - \theta)b) \qquad \text{(the royalty).}$$

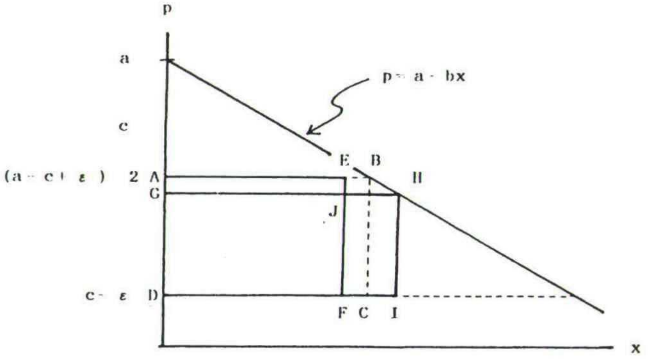
Recall Section 4.1 and the case (BN3) (ii) in Section 3 for the auction, and the case (1) in Section 4.3 for the royalty. Thus we obtain through straightforward calculation that

$$H^{R*} \geqq H^{A*} \text{ if and only if } \varepsilon \leqq \frac{(1 + \theta)(2 - \theta)}{\theta(2 + \theta)}(a - c).$$

Hence the royalty is optimal when $\varepsilon < ((1 + \theta)(2 - \theta)/\theta(2 + \theta))(a - c)$. Note that $(1 + \theta)(2 - \theta)/\theta(2 + \theta) \to 2/3$ as $\theta \to 1$.



(1) A nondrastic innovation



(2) A drastic innovation

FIG. 5.1. Comparison of the patentee's profits: The royalty vs. the auction.

Why the royalty is superior to the auction for small ε may be explained in the following manner. Consider first the homogeneous goods case. Letting $\theta \rightarrow 1$ in (5.1), the patentee's profits are given by $\varepsilon\,(a - c)/b$ in either of the two policies. See Fig. 5.1(1): the rectangle ABCD depicts this profit. Thus the two policies are equivalent for the patentee. We here note, recalling Observation 3.1, that ABCD is equal to ε times the equilibrium total output level of firms with identical marginal costs c; and also equal to the equilibrium profit of a licensee, a firm with a marginal cost $c - \varepsilon$, when he sets a price at the rival's marginal cost c to drive him out. It should be noted further that in the homogeneous goods case the fee policy gives the patentee the same profit as the royalty since $L(0) \rightarrow 0 = L(1, \varepsilon)$

as $\theta \rightarrow 1$ (Observation 3.1). Therefore the three policies are equivalent as claimed in Kamien and Tauman (1986).

Now suppose θ decreases from 1. In the royalty both firms pay the royalty payment ε, and thus their net marginal costs are c. Observation 3.2 shows that their total equilibrium output level is less than that in the homogeneous goods case: the latter is the line segment AB. Thus the patentee's profit is depicted by, say AEFD. In the auction, Observation 3.2 shows that the equilibrium price is less than c and thus the patentee's profit is given by, say GHID. Therefore the difference of these profits is given by the difference of the areas of AEJG and JHIF. As easily seen, the former dominates the latter if ε is small. Thus the royalty is superior to the auction for small innovations.

In the case of $((2 - \theta)/\theta)(a - c) \leqq \varepsilon$, i.e., the case of drastic innovations, the equilibrium royalty payment is $r = (a - c + \varepsilon)/2$, and thus the patentee's profit is depicted by ABCD in Fig. 5.1(2) when $\theta \rightarrow 1$. In the auction, the patentee exploits the licensee's monopoly profit, and thus the patentee's profit is also given by ABCD. In this case, JHIF dominates AEJG since ε is quite large. Thus the auction is superior to the royalty. One may explicitly show this fact through straightforward calculation using the patentee's profits H^{A*} and H^{R*} in this case.

In concluding this section, we contrast the results above, in particular the optimality of the royalty policy in the nondrastic innovation case, with the outcome in Cournot competition: the auction is superior to the royalty if goods are homogeneous (Kamien and Tauman, 1986). When goods are homogeneous and both firms have the same marginal cost c, the Cournot equilibrium total output level is $2(a - c)/3b$, and the corresponding price is $c + (a - c)/3$. Thus, in the royalty policy, the patentee can gain the profit depicted by AEFD in Fig. 5.2. In Bertrand competition, however, the patentee's profit in the royalty policy is given by ABCD; recall Fig. 5.1(1). The latter is greater, and essentially this fact induces different outcomes in Cournot and Bertrand competition. Put differently, the patentee's profit in the royalty policy depends on the equilibrium total output level, and this amount is significantly greater in Bertrand competition.

6. CONCLUDING REMARKS

We have shown that, in licensing a cost-reducing innovation to firms engaging in Bertrand competition, a patentee may gain more profit by adopting the royalty policy than from the other two policies, the auction and the fee. This fact has never appeared in the literature on licensing. Thus we might claim that our analysis first provides a prediction on the use of royalties which we often observe empirically.

Our analysis has been limited to patentee's profits in Bertrand competition with close substitutes. One may carry out the analysis in a similar

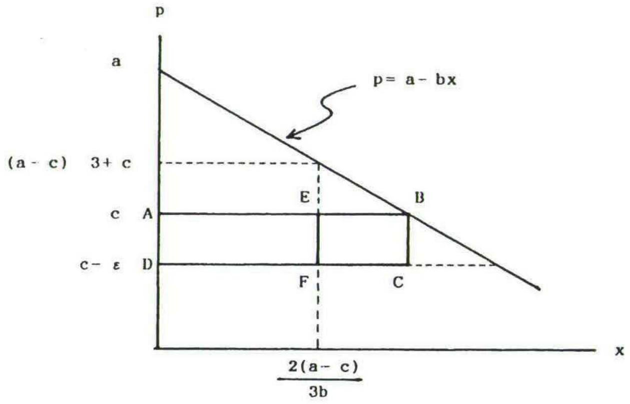


FIG. 5.2. Comparison of the patentee's profits in the royalty policy: Bertrand vs. Cournot.

manner even if these restrictions are removed. The following is a rough summary of further outcomes. For details, see Muto (1988).

In Bertrand competition, if goods are not close substitutes, the royalty is still optimal for a patentee for small innovations, but for large innovations the fee is optimal. In Counot competition, if goods are close substitutes, the fee and the auction are optimal according to whether innovations are small or large; and if otherwise, the fee is optimal. For consumers and firms, the fee and the royalty are most favorable, respectively, in both Bertrand and in Cournot competition.

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