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On Patent Licensing in Spatial Competition

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Abstract: We consider the issue of patent licensing in a linear city framework where firms are located at the end points of the city and compete in price. We consider three types of licensing arrangements, namely, auction, fixed fee, royalty; and focus on the optimal licensing strategy of an outsider patentee as well as an insider patentee. Contrary to the findings in the existing literature, first we show offering royalty is the best for the patentee when the patentee is an outsider for both drastic and non-drastic innovation. For insider patentee, offering no-license is the best when the innovation is drastic, while royalty is optimal when the innovation is non-drastic. We find incentive for innovation is higher for an outsider patentee compared to an insider patentee. We also show that overall increase in welfare due to innovation is independent of the fact that the patentee is outsider or insider in each of the drastic and non-drastic case.

Key words: licensing, auction, fixed fee, royalty, price competition
JEL Classification: D43, D 45, L13

Extended Abstract

We consider the issue of patent licensing in a linear city framework where firms are located at the end points of the city and compete in price. We focus on the optimal licensing strategy of an outsider patentee (independent innovator) as well as an insider patentee (incumbent innovator). In the case of outsider patentee where the patentee faces two competing firms, considers three types of licensing arrangements to offer, namely, auction, fixed fee and royalty. We show that auction and fixed fee yield equivalent payoff to the patentee, and only one of the competitors is offered with the license irrespective of the nature of innovation i.e. drastic or non-drastic. On the other hand, in the case of royalty licensing both the competing firms are offered with the license irrespective of the nature of innovation. Moreover, contrary to the findings of the existing literature on patent licensing when the patentee is an outsider, we show royalty licensing is better compared to auction or fixed fee as it always yields higher payoff to the patentee. In the case of insider patentee with a rival competitor, we find licensing by means of royalty is superior to no licensing or fixed fee licensing to the patentee when the innovation is non-drastic. When the innovation is drastic no licensing is optimal to the patentee. We also focus our attention to the much debated issue of incentive for innovation and show that in a spatial framework like this, incentive for innovation is higher for an outsider patentee compared to an insider patentee. Finally, we do some welfare analysis where show that overall increase in welfare due to innovation is independent of the fact that the patentee is outsider or insider in each of the drastic and non-drastic case.

1. Introduction

Patent licensing is a fairly common practice that takes place in almost all industries. It is a source of profit for the innovator (also called patentee) who earns rent through licensing a patent. The most common modes of patent licensing are: a royalty on per unit of output produced with the patented technology, a fixed fee that is independent of the quantity produced with the patented technology, or auction certain number of licenses i.e. offering a fixed number of licenses to the highest bidders. There is a vast literature (see Kamein (1992) for a survey on this) which studied the optimal licensing arrangement by the patentee in a wide variety of situations, and at the same time, studies are devoted to analyze various aspects of patent licensing. For example, when the patentee is an outsider as opposed to an insider, or when the competition among the rival firms or the potential licensees take place in prices or quantities, incentives for innovation of the patentee, or the type of industry structure where all these issues are considered, whether it is a single-firm industry, oligopolistic one or a competitive industry. Interestingly, to the best of our knowledge, all these studies are done in a standard framework of price and quantity competition. In this article, we introduce the study on patent licensing in a spatial framework. The fact that so far no study on patent licensing is done in spatial framework is somewhat surprising as in general, spatial competition is a major area of research in the industrial organization theory, and more specifically, in the area where firms behave strategically. Hence, to fill up this void, in this paper, we discuss some aspects of optimal patent licensing to a particular spatial framework, namely, the very well-known Hotelling's linear city model. We study the optimal licensing behavior (strategy) of an outsider patentee as well as an insider patentee in this new environment and contrast our findings with the existing results in the patent licensing literature. We find significant differences in the licensing outcomes arise due to the specific form of spatial competition we consider here. We believe this makes our study a fruitful exercise and opens up a new avenue of research in patent licensing.

We consider the issue of outsider patentee and the insider patentee in turn. When the patentee is an outsider, it faces two firms, i.e. the two potential licensees, who are engaged in a price competition *a la Bertrand*, and located at the two end points of the linear city. On the other hand, when the patentee is an insider, it is also a competitor in the product market, and we assume it competes with a rival firm in price. Here also both firms are located at the end points of the city. In each of this case, the locations of the competing firms are fixed and both firms produce a homogenous good. Consumers are uniformly distributed over the linear city, and willing to buy exactly one unit of the good. In this framework, we do our analysis of patent licensing and find the optimal strategy of the patentee in offering the license(s). Following the literature on patent licensing on the technology side, we consider two types of innovations, namely, drastic and non-drastic. We completely characterize the equilibrium licensing outcomes in each of this case, under different possible licensing arrangements of auction, fixed fee and royalty.

Earlier much has been discussed in the literature about the nature of licensing that should take place. In the standard models, in a complete information framework[1] if the patentee happens to be an outsider, it is shown that a fixed fee licensing is better than per unit royalty licensing (see Kamien and Tauman (1986), Katz and Shapiro (1986), Kamien, Oren and Tauman(1992), Kamien (1992) among others), and the reverse happen when the patentee is an insider i.e. a competitor (see Wang (1998, 2002) Wang and Yang (1999), Kamien and Tauman (2002)). In this paper, we show the existing result in the literature about the outsider patentee is not true when we consider licensing in a spatial framework of linear city. We find offering royalty licensing is always better than fixed fee or auction. Muto (1993) considered licensing policies under price competition in a standard framework, and like us assumed an external patentee who is willing to offer licensing contract when two potential licensees are competing in prices in a differentiated product market. Muto's main result was royalty is superior to other two polices, namely fixed fee and auction, when innovations are not large i.e. the innovation is non-drastic. In this framework, we find royalty is always superior to other two policies irrespective of the nature of innovation i.e. whether it is drastic or non-drastic. Another interesting feature which we note here is that in the case of outsider patentee licensing takes place even if the innovation is drastic. This is a result that has never been shown in the literature before with an outsider patentee.[2] On the other hand, as far as incentive for innovations by the patentee is concerned, in this analysis, we find that incentive for innovation is always higher when the patentee is an outsider as compared to an insider. This result is in some contrast with the result obtained in Kamien and Tauman (2002), where they show in a Cournot market structure with two firms, the incentive for innovation is higher for an insider patentee than an outsider patentee. We also find interesting welfare and policy implications. We show that overall increase in welfare due to innovation is independent of the fact that the patentee is outsider or insider in each of the drastic and non-drastic case. This

[1] For the patent licensing in an incomplete information framework, see Beggs (1992), Gallini and Wright (1990), Choi (2001), Poddar and Sinha (2002) among others.

[2] In the case of an insider patentee, similar result does exist, see Wang and Yang (1999).

also implies that given a degree of innovation, the policy on advocating an outsider or an insider patentee is neutral from the society's point of view. Although, we show consumers are better off if the innovation comes from the insider patentee.[3] The consumer surplus remains unaffected when the innovation is done by an outsider patentee.

The plan of the paper is as follows. Section 2 describes the basic framework. Section 3 considers the case of an outsider patentee. Section 4 considers the case of insider patentee. In section 5, we discuss about the incentive for innovations by the patentee. In section 6, we do some welfare analysis, and finally, we conclude in section 7.

2. The Basic Framework

Consider a linear city along the unit interval [0, 1], where firm A is located at 0 and firm B is located at 1 i.e. at the two extremes. Consumers are uniformly distributed along the interval. Each consumer buys exactly one unit of good. The utility of the consumer located at $x \in [0,1]$ is given by[4]

$$u_x = -x - p_A \quad \text{if buys from A}$$
$$= -(1-x) - p_B \quad \text{if buys from B}$$

We derive the demand for firm A and firm B by equating the utility of the person who is indifferent between buying from A or B and obtain:

$$D_A = \frac{p_B - p_A + 1}{2} \quad \text{and} \quad D_B = \frac{p_A - p_B + 1}{2}$$

Assume the existing marginal cost of production for firm A and firm B are $c_A > 0$, $c_B > 0$ respectively.

If these two firms compete in price, the equilibrium prices, demand and profits are given by:

$$p_A = \frac{2c_A + c_B}{3} + 1, \; p_B = \frac{2c_B + c_A}{3} + 1; \tag{1}$$

$$D_A = \frac{c_B - c_A + 3}{6}, \; D_B = \frac{c_A - c_B + 3}{6}; \tag{2}$$

$$\pi_A = \frac{(c_B - c_A + 3)^2}{18}, \; \pi_B = \frac{(c_A - c_B + 3)^2}{18} \tag{3}$$

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[3] Of course, as we said before, the incentive to innovate for any degree of cost reduction is always higher for the outsider patentee compared to an insider patentee.

[4] This particular formulation of the utility function in a Hotelling's linear city model is typical, see Shy (1996, 2000), Shy and Thisse (1999) among others.

3. The Case of Outsider Patentee

Let's assume pre-innovation marginal costs of the existing firms are $c_A = c_B = c$. An outsider patentee (independent innovator) comes up with a cost reducing innovation, which could lower the marginal cost by $\varepsilon > 0$. We say that the innovation is drastic if one firm buys the license while the other firm does not then the unlicensed firm is unable to compete anymore and goes out of business. For example, if firm A buys the license and firm B does not, then because of competitive disadvantage D_B becomes 0, and as a result firm A serves the whole market i.e. D_A becomes 1. This is the case when the innovation is drastic. Whereas in case of non-drastic innovation, in spite of cost disadvantage, D_B still remains positive after firm A becomes the only license holder. Now, using the equilibrium demand (from (1)), the above is same as saying as long as $0 < \varepsilon < 3$, the innovation is non-drastic and when $\varepsilon \geq 3$, the innovation is drastic.

3.1 The Licensing Game

The outsider patentee has got three licensing policies to offer: auction, fixed fee, and royalty. We consider a three stage game where in the first stage the patentee decides on a licensing policy among the above three policies and announces the number of license to be offered In the second stage the firms simultaneously and independently decides whether to accept or reject the offer in case of fee and royalty policy, or they simultaneously bid for license in case of auction. And in the third stage the firms compete in price in the market depending on the availability of the technology inherited from the second stage of the licensing game. We focus on the subgame perfect equilibrium of the game. We first consider the policy of auction.

3.1.1 Auction Policy

In case of auction in the first stage the outside patentee decides whether to auction one or two licenses. In case of selling two licenses the patentee has to fix the minimum price for the bids. We will analyze two cases i.e. non-drastic and drastic innovation in turn.

3.1.1.1 *Non Drastic Case* $(0 < \varepsilon < 3)$

(i) First, consider the case of one license being auctioned. Then in the second stage the two firms bid and the highest bidder is awarded the license. In case of a tie, the patentee chooses the licensee at random. In this auction we can calculate the bid any firm will be willing to make for the license. In case of success a firm will produce with that technology and the rival firm produces with the old technology in the third stage of the game. As a result, the licensee (L) and the non licensee (NL) get the payoff

$\pi_L = \frac{(3+\varepsilon)^2}{18}$ and $\pi_{NL} = \frac{(3-\varepsilon)^2}{18}$ (use equation 3 in section 2to derive these expressions)

Thus, a firm would always be willing to bid the difference between these two payoffs and one of the firms will be awarded the license at random. Thus, auctioning one license, the outsider patentee receives $\frac{2}{3}\varepsilon$.

(ii) Now suppose instead of one license the outside patentee decides to issue two licenses in auction. Then the patentee has to fix a minimum bid and any firm bidding higher than that amount would be awarded the license. In case of both firms being awarded the license the output market competition will have two firms with the same technological capability and thus the payoff to the each firm will be $\frac{1}{2}$. In case a firm does not bid higher than the minimum bid, but its rival bids higher than the minimum bid then the payoff to the non licensee is $\pi_{NL} = \frac{(3-\varepsilon)^2}{18}$. Thus, a non licensee would always bid for the technology if the minimum bid is not greater than $\frac{1}{2} - \frac{(3-\varepsilon)^2}{18}$. Thus, with this minimum bidding price, both firms will bid and receive the license and therefore the patentee would receive the pay off $1 - \frac{(3-\varepsilon)^2}{9}$.

Lemma 1

By comparing the payoffs from auctioning of one and two licenses, we find that auctioning off one license is strictly better than the auctioning off two licenses when the innovation is non-drastic.

3.1.1.2 ***Drastic Case*** $(\varepsilon \geq 3)$

(i) If one firm is offered the technology in auction then any firm would bid $(\varepsilon - 1)$ as the unsuccessful firm will go out of business and earn zero profit. The market will be served by the successful firm under monopoly and the optimal price charged by the firm is $(c-1)$. Thus, by auctioning one license when the technology is drastic the patentee receives the payoff $(\varepsilon - 1)$.

(ii) Suppose the patentee decides to offer two licenses under auction. Then the minimum bidding price has to be such that both firm prefers to bid than no bidding. Note that once both licenses are granted then in the third stage of the game both firms will earn a profit $\frac{1}{2}$ each. And a firm gets zero if it does not bid for the technology. Thus each firm would be willing to pay at the most $\frac{1}{2}$. Thus by offering two licenses under auction the patentee receives $\frac{1}{2}+\frac{1}{2}=1$

Lemma 2

By comparing the payoffs from auctioning of one and two licenses we find that auctioning off one license is strictly better than the auctioning off two licenses when the innovation is drastic.

Here, we summarize the outcome under auction policy.

Proposition 1

Under auction policy, the outside patentee always offers one license irrespective of the amount of cost reduction. In case of non-drastic innovation the patentee receives $\frac{2}{3}\varepsilon$ *and in case of drastic innovation it receives* $(\varepsilon - 1)$.

3.1.2 Fixed Fee Policy

In the first stage of our licensing game the patentee announces whether it wants to offer one or two licenses and the corresponding fees. In the second stage firms decides whether to accept or not, and in the third stage they compete in price.

3.1.2.1 ***Non Drastic Case*** $(0 < \varepsilon < 3)$

(i) Suppose the outside patentee decides to issue one license. Then the most the patentee can charge as fixed fee is $\frac{2}{3}\varepsilon$. The argument is same as in the auction case 3.1.1.1 (i).

(ii) In case the patentee decides to issue two licenses then the amount it can charge to each party is what is the minimum bid fixed in case of auctioning two licenses, which is $\frac{1}{2}-\frac{(3-\varepsilon)^2}{18}$. Therefore the patentee would receive the payoff $1-\frac{(3-\varepsilon)^2}{9}$.

3.1.2.2 ***Drastic Case*** $(\varepsilon \geq 3)$

(i) Suppose the outside patentee decides to issue one license. Then the most the patentee can charge as fixed fee is $\varepsilon - 1$. Same argument as in auction in 3.1.1.2 (i).

(ii) In case the patentee decides to issue two licenses then the amount it can charge to each party is $\frac{1}{2}$. Therefore, the patentee would receive the payoff of 1. See 3.1.1.2 (ii).

Proposition 2

In the case of fixed fee, the outsider patentee would always offer one license irrespective of the amount of cost reduction and the patentee receives the same amount as in the auction case. Thus, we show that fixed fee policy and auction policy are equivalent

3.1.3. Royalty Policy

In case of royalty policy the patentee charges a payment scheme based on the per unit output production.

3.1.3.1 ***Non Drastic Case*** $(0 < \varepsilon < 3)$

(i) Suppose the patentee decides to offer one license under royalty (r) per unit of output. Due to the competition of the licensee and non licensee rival firms in the third stage of the licensing game the patentee would receive the royalty revenue equal to $r\left(\frac{\varepsilon - r + 3}{6}\right)$. This expression is maximized with the choice $\varepsilon = r$ when $\varepsilon \leq 3$, i.e., if the technology is non-drastic. Thus by licensing to one firm under royalty the patentee receives $\frac{1}{2}\varepsilon$.

(ii) Suppose the patentee offers two licenses with a royalty rate r per unit of output. When both the firms have the technology under royalty scheme their effective marginal cost of production would be $(c-\varepsilon+r)$. When both the firms have the same cost of production then each firm produces output equal $\frac{1}{2}$. Thus, the payoff to the patentee would be $\frac{1}{2}r + \frac{1}{2}r = r$ Now, given the natural restriction that the royalty payment cannot exceed the amount of cost reduction ε we find that the payoff to the patentee is maximized when $r = \varepsilon$, and thus the total royalty revenue becomes ε.

Lemma 3

By comparing the payoffs under royalty licensing, we find that licensing to two firms is better than licensing to one firm when the innovation is non-drastic.

3.1.3.2 *Drastic Case* ($\varepsilon \geq 3$)

(i) In case of drastic technology if the patentee offers to license one firm there are two situations to consider. First, the royalty is such that the licensee firm is a monopoly in the market and the second case is licensee competes with the non licensee and both operate in the market. The non licensee would remain out of the market if royalty rate $r \leq \varepsilon - 3$. Thus, the patentee can at the most get $\varepsilon - 3$ by charging the royalty optimally so that the non-licensee is driven out of the market due to the cost advantages of the licensee even after royalty payment. On the other hand if $r > \varepsilon - 3$ then the non-licensee would be able to compete in the market. In this situation the patentee receives $r\left(\frac{\varepsilon - r + 3}{6}\right)$. This unconstrained maximization yields $r = \left(\frac{\varepsilon + 3}{2}\right)$. Since the optimal $r = \left(\frac{\varepsilon + 3}{2}\right)$ has to be greater than ε-3 (i.e., the condition under which both firms operate in the market) we have the condition ε<9. However, when $\varepsilon \geq 9$ then to have the non licensee operating in the market the royalty rate must be high such that $r > \varepsilon - 3$ and as a result the patentee gets $r\left(\frac{\varepsilon - r + 3}{6}\right)$. So the maximum attainable payoff for the patentee is $\frac{(\varepsilon + 3)^2}{24}$ when $3 \leq \varepsilon < 9$. However for $\varepsilon > 9$ the maximum attainable payoff to the patentee is at the most $(\varepsilon - 3)$ in the limit. Now comparing the payoff under different royalty rate and the subsequent market outcome in terms whether one firm or two firms operate in the market we find the following outcome. For $3 \leq \varepsilon < 9$, the optimal royalty rate is $r = \left(\frac{\varepsilon + 3}{2}\right)$ and both firm operates in the market and the patentee receives $\frac{(\varepsilon+3)^2}{24}$. On the other hand for $\varepsilon \geq 9$ then it is optimal for the patentee to charge $r = \varepsilon - 3$ and the whole market is served by the licensee only.

(ii) Now offering the drastic technology to both firms under royalty the patentee can expect to get $r.1$. This payoff is maximized when $r = \varepsilon$. Thus, ε is the optimal payoff when the drastic technology is given to both firms under royalty licensing. Now by comparing the payoff from licensing to one firm and two firms we find that the technology is given to both firms at a royalty rate ε. One interesting point to note here is that even in the case of drastic innovation both firms will be licensed at a royalty rate equal to the amount of cost reduction. This feature is something which was never shown before in the literature with an outsider patentee case.

Thus, we summarize the royalty policy of the outside patentee.

Lemma 4

By comparing the payoffs under royalty licensing, we find that licensing to two firms is better than licensing to one firm when the innovation is drastic.

Here, we summarize the outcome under the royalty policy.

Proposition 3

Under royalty policy, the patentee always offers two licenses as opposed to one irrespective of the amount of cost reduction and in both drastic and non-drastic innovation the patentee receives ε.

Now by comparing the outcomes depicted in Propositions 1, 2, and 3we find that if the patentee opts for royalty, both in drastic as well as non-drastic case it receives ε, whereas in either of other two licensing modes (auction and fixed fee) its gets $\frac{2}{3}\varepsilon$ for non-drastic innovation and $(\varepsilon - 1)$ for drastic innovation. Thus, we have the main result of this section.

Proposition 4

(i) *In the case of outsider patentee, it is always better for the patentee to license out the technology to both firms in the market using a royalty contract as compared to either auction or fixed fee.*

(ii) *Two firms get licensed under royalty, where as one firm gets licensed in auction or fixed fee.*

Here it is important to note that in optimal royalty licensing, under *drastic innovation*, both firms are licensed by the patentee. This is a result that has never been shown in the literature before with an outsider patentee.

4. The Case of Insider Patentee

Let's assume pre-innovation marginal costs of the firms are $c_A = c_B = c$. Firm A comes up with a cost reducing innovation, which lowers its marginal cost by $\varepsilon > 0$, so that post-innovation $c_A = c - \varepsilon$ and $c_B = c$.

4.1 No Licensing

When firm A does not license its technology to firm B and both firms compete, then we have the following.

4.1.1 *Non Drastic Case* $(0 < \varepsilon < 3)$

$$D_A = \frac{3+\varepsilon}{6} \text{ and } D_B = \frac{3-\varepsilon}{6} ;$$

$$\pi_A = \frac{(3+\varepsilon)^2}{18} \text{ and } \pi_B = \frac{(3-\varepsilon)^2}{18} \tag{4}$$

4.1.2 *Drastic Case* $(\varepsilon \geq 3)$

$D_A = 1$ and $D_B = 0$;

$p_A = c - 1$

$$\pi_A = (\varepsilon - 1) \text{ and } \pi_B = 0 \tag{5}$$

Note that under drastic case: $\pi_A \geq 2$.

4.2 The Licensing Game

A licensing game consists of three stages. In the first stage, the patent holding firm A sets a fixed licensing fee or a royalty rate.[5] In the second stage, the other firm B decides whether to accept or reject the offer from firm A. In the last stage, both firms compete in prices. Firm A sets fixed fee or royalty rate in order to maximize the sum of the profit from its own production and the licensing revenue.

4.2.1 Fixed Fee Licensing

First consider licensing by means of a fixed fee only. Under the fixed fee licensing, firm A licenses its cost reducing technology to firm B at a fixed fee F (say), which is invariant of the quantity firm B produces using the new technology. The maximum license fee firm A can charge firm B, is what will make firm B indifferent between having the license and not having the license of the new technology. In case the licensing occurs, both firms will produce at the same marginal cost of $(c-\varepsilon)$.

4.2.1.1 *Non Drastic Case* $(0<\varepsilon<3)$

If licensing takes place, each firms' profit, $\pi_A=\pi_B=\frac{1}{2}$

Therefore, $F=\frac{1}{2}-\frac{(3-\varepsilon)^2}{18}$ (using (3))

Hence, total profit of firm A under fixed fee licensing is;

$$\pi_A^F=\frac{1}{2}+F=1-\frac{(3-\varepsilon)^2}{18} \tag{6}$$

4.2.1.2 *Drastic Case* $(\varepsilon\geq 3)$

$F=\frac{1}{2}-0=\frac{1}{2}$ (using (4))

Hence, total profit of firm A under fixed fee licensing is;

$$\pi_A^F=\frac{1}{2}+\frac{1}{2}=1 \tag{7}$$

Now comparing (4) and (6) as well as (5) and (7) we get the following.

[5] The case of auction does not arise here since there is just one firm to license.

Proposition 5

Both under non-drastic and drastic innovation, offering no license to the rival is better for the patentee than offering a fixed fee licensing.

This result is interesting because in the situation where the patentee is also a competitor in the product market, and the competition takes place in price, there will be no fixed fee licensing. This happens exactly because of the nature of price competition. When the patentee offers a fixed fee license to the rival, both the patentee and the licensee compete on equal footing, and the price competition results a low profit to both firms. As a result, the patentee cannot charge a high fixed fee from its rival because the difference between the competing profit and the reservation payoff becomes small. On the other hand, if the patentee does not license the rival, it can hold a significant cost advantage when it shares the market with rival in the non-drastic case, which enables the patentee to get a significantly higher profit. On the other hand, in the case of drastic innovation the patentee actually serves the whole market just as a monopoly and naturally gets a high profit. Thus offering no license is better than offering a fixed fee licensing when the patentee competes with the rival in price. This is in contrast with a similar situation when the competition takes place in quantities where under certain parametric configuration fixed fee licensing is actually better than no licensing (see Wang, 1998).

4.2.2 Royalty Licensing

Under a royalty licensing, firm A licenses its new technology to firm B at a royalty rate r (say), and the amount of total royalty firm B pays will depend on the quantity firm B produces using the new technology. In this case, firm A's marginal cost of production is $(c-\varepsilon)$ and firm B's marginal cost of production becomes $(c-\varepsilon+r)$ if firm B buys the license. Note that the maximum royalty that firm A can charge is ε (i.e. $0<r\leq\varepsilon$).

Now, if firm B buys the license at a royalty rate r then $D_B=\frac{3-r}{6}$ (using (2))

Note that for $D_B\geq 0$, we must have $r\leq 3$

Firm A's profit from competing is: $\pi_A=\frac{(3+r)^2}{18}$

4.2.2.1 ***Non Drastic Case*** $(0 < \varepsilon < 3)$

Firm A's total profit under royalty licensing is:

$$\pi_A^R = \frac{(3+r)^2}{18} + r\left(\frac{3-r}{6}\right), \text{ which is maximum when } r = \varepsilon(<3).$$

Hence, $$\pi_A^R = \frac{(3+\varepsilon)^2}{18} + \varepsilon\left(\frac{3-\varepsilon}{6}\right) \quad (8)$$

4.2.2.2 ***Drastic Case*** $(\varepsilon \geq 3)$

Firm A' total profit under royalty licensing is:

$$\pi_A^R = \frac{(3+r)^2}{18} + r\left(\frac{3-r}{6}\right)$$

Unconstrained maximization of the above expression with respect to r, gives $r^* = 3.75$

Note that π_A^R is a concave function in r and it is increasing for $r < 3.75$.

Also recall that $D_B \geq 0$, when $r \leq 3$. Hence (constrained) optimal r^* in the drastic case is 3.

Thus, $$\pi_A^R = \frac{(3+3)^2}{18} + 3.0 = 2 \quad (9)$$

Now comparing (4) and (8) as well as (5) and (9) we have the following.

Proposition 6

Offering royalty licensing is superior to offering no license for the patentee when the innovation is non-drastic, while offering no license is superior to royalty when the innovation is drastic.

In the case of non-drastic innovation royalty licensing turns out to be optimal since by charging an appropriate per unit royalty, the patentee can hold its cost advantage when it competes and at the same time collects the extra revenue coming from royalty. Whereas in the case of drastic innovation, the revenue from royalty part goes to zero, because the optimal royalty rate becomes so high, the rival chooses to produce nothing. In this case, the patentee can do better by offering no license at all.

5. Incentive for Innovation

Now we focus our attention to one of the much debated issue in innovation and licensing literature, namely the incentive for innovation. In particular, we are interested to compare the incentive for innovation in two cases depending whether the innovator is an insider or an outsider. Note that the incentive for innovation is what an agent expects as a gain in payoff from undertaking innovation.

First in the case of insider innovator, the incentive for non-drastic innovation is given by the difference between its payoff under innovation and selling the license license with the pre-innovation payoff under old technology, which is given by $\frac{(3+\varepsilon)^2}{18}+\varepsilon\left(\frac{3-\varepsilon}{6}\right)-\frac{1}{2}$. While the incentive for drastic innovation is given by $(\varepsilon-1)-\frac{1}{2}$. Recall that in the drastic case, the innovator does not license.

On the other hand, an outsider patentee always receives a payoff of ε from the innovation followed by licensing, irrespective of the fact the innovation is drastic or non drastic.

Hence, comparing the two payoffs in these two cases we find the following.

Proposition 7

Irrespective of the nature of innovation, the incentive for innovation is always higher when the patentee is an outsider as opposed to an insider.

This is an interesting feature of our analysis. It is clear from Kamien and Tauman (2002) that in Cournot market structure with the number of firm being 2 the incentive for innovation is higher for an incumbent innovator than an outsider innovator. In the present context, we get the opposite result.

6. Welfare Analysis

In this section, we highlight the welfare implications of an innovation depending on whether the innovation is brought about by an insider patentee or an outsider patentee. First consider the case of outsider patentee. In the case of outsider patentee we have seen that the optimal licensing policy is to offer a royalty to both firms with the optimal royalty being the amount of cost reduction. It is easy to see from the price equation (1) that the price of the product remains the same as in pre-innovation stage for any innovation under the optimal royalty contract As a result the consumers are not benefited by the innovation. From equation (3) we also find that the profit of the two firms operating in the market remains the same as they were getting prior to the innovation. Thus the entire surplus is appropriated by the outsider patentee and it receives the payoff ε, which is the amount of cost reduction. Thus we have the following proposition.

Proposition 8

When the patentee is an outsider, both the consumer surplus and producer surplus remains unaffected i.e. they remain the same in pre-innovation and post innovation stage. The whole gain due to the technology innovation accrues to the patentee and the amount of surplus generated in the market is ε for any degree of cost reduction ε.

Now, let us consider the case of insider patentee. Note that the price prevailing in the market prior to the innovation is $p = c + 1$ (from (1)) and the profit of each firm is $\frac{1}{2}$ (from (3)). Now there are two cases to consider depending on the magnitude of innovation.

Consider the case of non-drastic innovation first, i.e. when $(0 < \varepsilon < 3)$. We have seen that in this non-drastic case the incumbent patentee would offer the license to its rival under royalty and therefore it would receive the total payoff (from (8)) $\frac{(3+\varepsilon)^2}{18} + \varepsilon\left(\frac{3-\varepsilon}{6}\right)$ and the profit of the licensee would be $\frac{(3-\varepsilon)^2}{18}$. Prices charged by the incumbent innovator and the licensee are given by $\left(c+1-\frac{2\varepsilon}{3}\right)$ and $\left(c+1-\frac{\varepsilon}{3}\right)$ respectively.

Lemma 5

The change in consumer surplus and producer surplus after innovation and licensing are given by $\frac{\varepsilon}{2}\left(1+\frac{\varepsilon}{9}\right) > 0$ *and* $\frac{\varepsilon}{2}\left(1-\frac{\varepsilon}{9}\right) > 0$ *respectively when the innovation is non-drastic.*

Proof: See appendix.

Hence, change in total welfare is given by $\varepsilon > 0$.

On the other hand, in case of drastic innovation (i.e. when $\varepsilon \geq 3$), the insider patentee would not offer any license and would charge a price $(c-1)$ and receive a payoff of $(\varepsilon - 1)$.

Lemma 6

The change in consumer surplus and producer surplus after innovation are given by 2 *and* $(\varepsilon - 2)$ *respectively when the innovation is drastic.*

Proof: See appendix.

Hence, change in total welfare is given by $\varepsilon > 0$.

Proposition 9

In the case of insider patentee the consumer surplus as well as producer surplus (i.e. total industry profit) are higher compared to the pre-innovation stage for any magnitude of cost reducing innovation (drastic or non-drastic) although the licensee's profit declines in the post innovation period. Moreover, due to innovation (drastic or non-drastic), the total increase in society's welfare is ε.[6]

Now comparing proposition 8 and 9, we get the following important result.

Proposition 10

Total surplus generated due to innovation i.e. the positive change in welfare from pre-innovation stage to post innovation stage is always the same (which is ε *here, the amount of cost reduction) irrespective of the fact the patentee is an outsider or an insider in each of the drastic and non-drastic case.*

We find this result is really striking and very robust. This allows the policy recommendations very simple and straight forward. Given a degree of innovation, the policy on advocating an outsider or an insider patentee is neutral. From society's point of view this does not make any difference whatsoever.[7] Although, the consumers are better off if the innovation comes from

[6] Note that in the non-drastic case $0 < \varepsilon < 3$ and in the drastic case $\varepsilon \geq 3$.

[7] Of course, as we show before, the incentive to innovate for any degree of cost reduction is always higher for the outsider patentee as compared to insider patentee.

the insider patentee. The consumer surplus does not change from the pre-innovation stage when the innovation is done by an outsider patentee.

7. Conclusion

In this paper, we focus on the optimal licensing strategy of an outsider patentee as well as an insider patentee in a spatial competition. In the case of outsider patentee, we show that auction and fixed fee yield equivalent payoff to the patentee, and only one of the competitors is offered with the license irrespective of the nature of innovation i.e. drastic or non-drastic. On the other hand, in the case of royalty licensing both the competing firms are offered with the license irrespective of the nature of innovation. Moreover, royalty licensing turns out to be better compared to auction or fixed fee as it always yields higher payoff to the patentee. In the case of outsider patentee, we also find the interesting result that the licensing takes place even if the innovation is drastic. We believe this a new result in the literature. In the case of insider patentee with a rival competitor, we find licensing by means of royalty is superior to no licensing or fixed fee licensing to the patentee when the innovation is non-drastic. When the innovation is drastic no licensing is optimal to the patentee. We also focus our attention to the issue of incentive for innovation and show that in a spatial framework like this, irrespective of the nature of innovation i.e. drastic or non-drastic, incentive for innovation is always higher for an outsider patentee compared to an insider patentee. Our welfare analysis shows that total (positive) change in welfare due to innovation is independent of the fact that the patentee is outsider or insider in each of the drastic and non-drastic case. Although, we find consumers are better off if the innovation comes from an insider patentee as opposed to an outsider patentee.

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Appendix :

Non-Drastic Case:

The pre-innovation price is given by $p = c+1$, and the post-innovation price for patentee and the licensee are given by $p^P = c+1-\frac{2\varepsilon}{3}$ and $p^L = c+1-\frac{\varepsilon}{3}$ (using (1)).

Since the prices of the of the patentee and the licensee are different, the position of the marginal consumer who is indifferent between going to either of the firm is given by $\frac{1}{2}\left(1+\frac{\varepsilon}{3}\right)$. We work out the total change in consumer surplus in the following way. First we divide the unit interval in the following three regions: $\left[0,\frac{1}{2}\right],\left[\frac{1}{2},\frac{1}{2}\left(1+\frac{\varepsilon}{3}\right)\right],\left[\frac{1}{2}\left(1+\frac{\varepsilon}{3}\right),1\right]$.

To derive the change in CS in each interval we multiply reduction in price (due to innovation) with the length of the interval. Recall consumers are uniformly distributed over the unit interval.

Total change in CS = $\frac{\varepsilon}{2}\left(1+\frac{\varepsilon}{9}\right)$

Total change in PS = $\frac{(3+\varepsilon)^2}{18}+\varepsilon\left(\frac{3-\varepsilon}{6}\right)+\frac{(3-\varepsilon)^2}{18}-1 = \frac{\varepsilon}{2}\left(1-\frac{\varepsilon}{9}\right)$.

Hence, change in total welfare = change in CS + change in PS = ε

Drastic Case:

The pre-innovation price is given by $p = c+1$, and the post-innovation price for the patentee is given by $p = (c-1)$.

Thus, total change in CS = 2

The pre-innovation profit of each firm is given by $\frac{1}{2}$, and the post-innovation profit for the patentee is $(\varepsilon - 1)$

Total change in PS = $(\varepsilon - 2)$.

Hence, change in total welfare = change in CS + change in PS = ε