'To sell or not to sell': Licensing versus Selling by an outside innovator

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‘To sell or not to sell’: Licensing versus Selling by an outside innovator[♦]

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Abstract

Study of patent licensing in spatial competition is relatively sparse. We study optimal licensing policies of an outside innovator in spatial framework when the potential licensees are asymmetric. We also introduce the notion of selling the property rights of innovation. We then examine the incentive of the innovator who sell the rights and compare that with conventional licensing contracts. We address this problem in linear city with two competing asymmetric firms (potential licensees). We show the optimal licensing policy is pure royalty to both firms when cost differentials between the firms are relatively small, otherwise it is fixed fee licensing to the efficient firm only. Interestingly, we show the innovator is always better-off selling innovation to one of the firms. This holds irrespective of the size of the innovation (drastic or non-drastic) and the degree of pre-innovation cost asymmetry between the firms. Social welfare is greater under selling than licensing.

Key Words: Outside innovator, Cost-reducing innovation, Patent Licensing, Patent Selling, Welfare, Linear city model

JEL Classification: D43, D45, L13.

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1. Introduction

Study of patent licensing in spatial competition is relatively sparse. Product differentiation through spatial competition is well understood in the industrial organization literature, however, the impact of licensing on technology transfer and competition in a spatial framework is less well understood. On the other hand, outside the premise of spatial competition, there is a huge literature on patent licensing, which studies various methods of licensing to the potential licensee(s) by the innovator (patentee) in the frameworks of price or quantity competition.[1] However, in any of these frameworks, the notion of *selling* the property rights of the innovation by an innovator to one of the potential licensees (who can then possibly license the new technology to its competitors, if finds profitable to do that) is rarely studied. The concept of selling the right of innovation was first introduced by Tauman and Weng (2012). In a general Cournot framework with an *outside innovator* and several symmetric potential licensees (firms), Tauman and Weng found that selling the innovation can actually be strictly better than direct licensing strategy. It is an important result because it opens the new profit opportunity to the innovator by selling the new technology instead of licensing. Also in a recent study, Lu and Poddar (2014) examined the optimal licensing scheme of an *insider patentee* under spatial competition and found that two-part tariff licensing is always optimal among all possible licensing arrangements. Between these two strands of results, we would like to fill a gap, where we study the *licensing* as well as the *selling* options of an *outsider* innovator (e.g. an independent research lab) in a *spatial* framework. We will first do a comprehensive analysis on licensing by studying various licensing arrangements, followed by exclusively selling the innovation. After the two-independent analysis, we will do a comparative analysis between licensing and selling to find the optimal strategic instrument to transfer the technology which will maximize the payoff of the outsider innovator under the spatial competition.

The second objective is the following. In most of the studies on patent licensing so far, the licensees are assumed to be symmetric (meaning identical costs for production). In reality, we more often see firms are asymmetric. Thus, in this study, we consider potential licensees to be asymmetric, and find the impact of asymmetric cost structures on the optimal mode of licensing and selling as well as its impact on post licensing competition.

[1]For a comprehensive analysis of optimal licensing schemes in a general framework see Sen and Tauman (2007).

Tauman and Weng (2012), in spite of the great significance of their result, could only show that selling is better than licensing under certain restrictions. It requires the innovation to be significant, but non-drastic and the number of potential licensees (which are all assumed to be symmetric) to be at least four or more. Moreover, for drastic innovation both the selling and direct licensing yield same payoffs to the innovator, hence no additional benefit from selling. Given the limited scope of the above finding, we were also looking for situations where the result of dominance of selling holds without much restrictions. Interestingly, we find if the problem of technology transfer is addressed in a spatial competition (*a la* Hotelling), we can get a much more robust result which shows that selling the innovation to a licensee (regardless of the recipient licensees' cost efficiency) is always strictly better than any licensing strategy irrespective of the size of the innovations (drastic or non-drastic). Moreover, only two potential licensees (recipient firms) are necessary to generate the result where the firms are also assumed to asymmetric with respect to their cost of production. Thus, in this framework, unambiguously the private incentive to innovate is maximized when the innovator opts for selling instead of licensing.

From a different angle, in an empirical study of patent licensing, Rostoker (1983) finds that licensing by royalty alone are used in 39% of the cases, a fixed fee is used in 13%, and both instruments together i.e. a two-part tariff is used in 46% of the cases. Earlier, Taylor and Silberston (1973) found similar percentages among different licensing policies in their study. More recently, Macho-Stadler et. al (1996) find, using Spanish data, that 59% of the contracts have only royalty payments, 28% have fixed fee payments, and 13% include both fixed and royalty fees (i.e. two-part tariff). From these empirical studies, we also find the dominance of pure royalty contract to a certain extent. Given this, we are interested to see why that is the case or under what scenarios of patent licensing royalty is more prevalent. In our patent licensing analysis, we do find the dominance of pure royalty licensing among other licensing arrangements.

We end our study by doing some welfare analysis to see which mode of technology transfer between selling and licensing generates higher welfare and its comparison to pre-licensing/pre-selling scenario. We find that selling unambiguously leads to greater social welfare vis-à-vis licensing for all kinds of innovations, drastic or non-drastic.

The analytical framework we employ here is the Hotelling's linear city model.

Specifically, we assume that there is a non-producing outside innovator (research lab) who has a new cost reducing technology and there are two competing firms in the product market, namely, the two potential licensees. The firms are asymmetric in terms of the initial costs of production, hence one firm could be more efficient than the other.[2] Throughout our analysis, we keep the locations of the firms fixed at the two extremes of the linear city. We assume linear transportation costs of the consumers.[3] One of the implications of extreme location of firms is that the consumers view the products as maximally differentiated and the extent of product differentiation is given.

The innovator can choose to license its innovation to a single firm or both the firms in the first stage. Once the offer is made, in the second stage, the firms decide whether to accept or reject the licensing contract. Then in the third stage the firms compete in prices. We will deal with all possible licensing scenarios, namely, upfront fixed fee licensing, auctioning of one or two licenses, per unit royalty licensing, and two-part tariff licensing. For the selling game, the innovator decides to sell its innovation to one of the two firms. Since the innovator is ultimately interested in maximizing the value of the patent (which maximizes its payoff as well), we compare whether it is profitable to the innovator, to license or sell the innovation or both the modes of technology transfer are necessary depending on the environment.

Our main findings are as follows. We first characterize the equilibrium licensing outcomes under all forms of licensing arrangements mentioned above. When fixed fee licensing is considered, we find that the innovator will always license its innovation to only one firm viz. the efficient firm. In the case of auction, where the innovator has the choice of auctioning one or two licenses, we find that the innovator will always auction one license and the efficient firm will win the auction. However, fixed fee licensing gives higher payoff than auction to the innovator. In the case of royalty licensing, the innovator would always license the technology to both the firms rather than a single firm. In the case of two-part tariff licensing, the innovator will always license to both firms as well, and interestingly we also see that the optimal two-part tariff contract is in fact a pure royalty licensing (i.e. fixed fee part is zero). Thus, we do get a dominance of pure royalty licensing in this scenario, which also largely explains the licensing

[2] Note that the case of symmetric competing firms as potential licensees which is more often studied in the literature for patent licensing will be a special case of our analysis.

[3] It is well known that in the linear city model with linear transportation costs equilibrium in location choice might not exist. It exists if the firms are sufficiently far apart and in this paper we assume the firms to be at the extremes of the city. Thus existence related issues do not arise.

patterns found empirically as discussed before.

Comparing the payoffs of the outside innovator from all the licensing arrangements, we find that optimal licensing contract is pure royalty contracts to both firms when the pre-innovation cost differentials between the firms are relatively small, i.e. firms are close competitors; otherwise fixed fee licensing to the efficient firm only can be optimal i.e. when market is less competitive. Thus, we find initial cost asymmetric matters so far as the optimal mode of licensing is concerned which also explains the observed difference in licensing policies in reality. In this environment, we also show that the gain in welfare is always positive from licensing the new technology compared to pre-innovation or no licensing scenario.

On the other hand, when we consider selling the property rights of the innovation, we find that the outside innovator will sell the right to any one of the firms (who then further licenses to the other firm), and the payoff to the innovator from selling *strictly* dominates all the payoffs from optimal licensing arrangements. The result is true irrespective of the size of the innovations (drastic or non-drastic) and the degree of pre-innovation cost asymmetries between the competing firms. We also show social welfare is greater under selling than licensing.

1.1 Literature Review

There is vast literature on patent licensing which have discussed the nature of licensing that should take place between the patentee and the licensees. In a general competitive environment under complete information, if the patentee is an outside innovator, it has been generally shown that fixed fee licensing is optimal (see Katz and Shapiro (1986), Kamien and Tauman (1986), Kamien et al., (1992), Stamatopolous and Tauman (2009)) whereas per-unit royalty contract is optimal when the patentee is an insider (Wang (1998), (2002), Wang and Yang (2004), Kamien and Tauman (2002))[4]. In this paper of outside innovator, we get a differentand new set of results on optimal licensing contracts which depend on the cost asymmetries of the licensees.[5]We show pure royalty contracts to both firms or fixed fee licensing to the efficient firm can be optimal under spatial competition with an outside innovator.[6]

[4] See also Sen (2005) to note the restriction when the number of licensees must be an integer.

[5] In one of the earlier studies on technology transfer under insider patentee, Marjit (1990) provided the extent of cost asymmetry where fixed fee licensing can take place from the efficient firm to the less efficient firm.

[6]In a pioneering work of patent licensing in spatial framework, Poddar and Sinha (2004) analyzed the case of outsider patentee with two incumbent potential licensees and derived licensing policy. However, the licensees are assumed to be symmetric in the analysis.

Sen and Tauman (2007) provide a comprehensive analysis for general licensing schemes and its impact on the market structure and the diffusion of a cost reducing innovation in a Cournot oligopoly industry. Regarding patent licensing by an outside innovator, Muto (1993) using a standard product differentiation framework and price competition showed that only royalty licensing is optimal (compared to auction and fixed fee). In a different work, Fauli-Ollerand Sandonis (2002) developed a licensing game in differentiated product market with an insider patentee and found that two-part tariff licensing is optimal both under price and quantity competition. Mukherjee and Balasubramanian (2001) in a horizontal differentiation framework considered technology transfer in a Cournot duopoly market and found optimality of two-part tariff licensing with an insider patentee. Recently, Bagchi and Mukherjee (2014) examined the impact of product differentiation on optimal licensing schemes by an outsider patentee. They showed that royalty licensing is optimal for a certain range of product differentiation irrespective of quantity and price competition.

The rest of the paper is organized as follows. In section 2, we lay out the model. The main analysis on the licensing game is analyzed in detail in section 3. We take up the welfare analysis in section 4. Section 5 concludes.

2. The Linear City Model

Consider two firms, firm A and firm B located in a linear city with unit interval $[0,1]$. Firm A is located at 0 whereas firm B is located at 1 that is at the two extremes of the linear city. Both firms produce homogenous goods with constant marginal cost of production and compete in prices. We assume that consumers are uniformly distributed over$[0,1]$. Each consumer purchases exactly one unit of the good either from firm A or firm B. The transportation cost per unit of distance is t.Therefore the utility function of a consumer located at x is given by:

$$U = v - p_A - tx \qquad \text{if buys from firm A}$$

$$= v - p_B - (1-x)t \qquad \text{if buys from firm B}$$

We assume that the market is fully covered. The demand functions for firm A and firm B can be calculated as:

$$Q_A = \frac{1}{2} + \frac{p_B - p_A}{2t} \qquad \text{if } p_B - p_A \in (-t.t)$$

$$= 0 \qquad \text{if } p_B - p_A \leq -t$$

$$= 1 \qquad \text{if } p_B - p_A \geq t$$

and $Q_B = 1 - Q_A$

There is a non-producing outside innovator (a research lab) which has a cost reducing innovation. The innovation helps reduce the per-unit marginal costs of the licensee firm(s) by ϵ. ϵ is also known as the size of the innovation. The innovator has the option of licensing the innovation to a single firm or both firms. Alternatively, it can sell the innovation to any single firm. We will consider different forms of licensing viz. fixed fee licensing, auction policy, royalty licensing, and two-part tariff licensing. We will examine both non-drastic and drastic innovations. An innovation is drastic innovation when the size of the cost reducing innovation is sufficiently high such that the firm not getting the license goes out of the market and the licensee becomes the monopoly.[7]

The timing of the game is given as follows:

Stage 1: The outside innovator decides to license its innovation (to either one or both firms) or to sell the innovation (to any one firm).

1a: The licensing game –One or two licensing contracts are offered. In case of offering one license if first firm rejects, the offer goes to the second firm.

1b: The selling game – Selling contract is offered to one of the firms. If one firm rejects the selling contract it goes to the other firm.

Stage 2: The firm(s) (potential licensees) accepts or rejects the offer following 1a or 1b.

Stage 3: The firms compete in prices and products are sold to consumers.

[7]Following the definition of Arrow (1962) on drastic and non-drastic innovation.

2.1. Absence of Outside Innovator – No Licensing or Selling

First we examine the case where the outside innovator is not in the scenario and two asymmetric firms A and B are competing in the market with old production technology. Let's denote the constant marginal costs of production of firms A and B by c_A and $c_B$respectively and define $\delta = c_B - c_A$. To fix ideas suppose $\delta = c_B - c_A > 0$, i.e. firm A is the efficient firm[8].We assume that $\delta \leq 3t$ so that the less efficient firm's equilibrium quantity is positive before the innovation takes place. Therefore, the no-licensing/no-selling equilibrium prices, demands and profits can be given as:

$$p_A = \frac{1}{3}(3t + 2c_A + c_B) = c_A + \frac{1}{3}(3t + \delta) \tag{1}$$

$$p_B = \frac{1}{3}(3t + c_A + 2c_B) = c_B + \frac{1}{3}(3t - \delta) \tag{2}$$

$$Q_A = \frac{1}{6t}(3t - c_A + c_B) = \frac{1}{6t}(3t + \delta) \tag{3}$$

$$Q_B = \frac{1}{6t}(3t + c_A - c_B) = \frac{1}{6t}(3t - \delta) \tag{4}$$

$$\pi_A = \frac{1}{18t}(3t - c_A + c_B)^2 = \frac{1}{18t}(3t + \delta)^2 \tag{5}$$

$$\pi_B = \frac{1}{18t}(3t + c_A - c_B)^2 = \frac{1}{18t}(3t - \delta)^2 \tag{6}$$

3. Presence of Outside Innovator – The Licensing Game

If the outside innovator licenses to firm A (the efficient firm), and if $\epsilon > 3t - \delta$, then firm A becomes monopoly (B goes out of the market). On the other hand, if the outside innovator licenses to firm B (the inefficient firm), then firm B becomes monopoly (and firm A goes out of the market) only when $\epsilon > 3t + \delta$. Recall that for licensing game, we have defined when one license is offered by the innovator if first firm rejects, the offer goes to the second firm. So when $\epsilon > 3t - \delta$ but $\epsilon < 3t + \delta$ then if firm A rejects and B gets, firm B doesn't become a monopoly since the size of the innovation is not sufficient to drive firm A out of the market. Hence in our context, an innovation is drastic only when $\epsilon > 3t + \delta$, otherwise it is non-drastic.

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[8]Results and intuitions go through even if we assume $\delta = c_A - c_B > 0$. i.e. firm A is the inefficient firm.

Now we consider different forms of licensing one by one. Suppose the outside innovator is licensing the innovation to firm A. We start with fixed fee licensing.

3.1 Fixed Fee Licensing:

3.1.1: Fixed fee licensing to one firm:

Non-Drastic Case (i) ($\epsilon < 3t - \delta$)*:*

Consider the case where the innovator licenses its innovation to firm A by charging a fixed fee. The post licensing marginal cost of firm A will be $c_A - \epsilon$ and that of firm B will be c_B. In this situation the equilibrium prices, demands and profits can be given as:

$$P_A^F = c_A - \epsilon + \frac{1}{3}(3t + \delta + \epsilon) \tag{7}$$

$$P_B^F = c_B + \frac{1}{3}(3t - \delta - \epsilon) \tag{8}$$

$$Q_A^F = \frac{1}{6t}(3t + \delta + \epsilon) \tag{9}$$

$$Q_B^F = \frac{1}{6t}(3t - \delta - \epsilon) \tag{10}$$

$$\pi_A^F = \frac{1}{18t}(3t + \delta + \epsilon)^2 - F_A \tag{11}$$

$$\pi_B^F = \frac{1}{18t}(3t - \delta - \epsilon)^2 \tag{12}$$

If firm A accepts the licensing contract, it's payoff will be $\frac{1}{18t}(3t + \delta + \epsilon)^2 - F_A$. If firm A rejects then firm B gets the license and in this situation firm A's payoff can be calculated as $\frac{1}{18t}(3t + \delta - \epsilon)^2$. Therefore, firm A will accept if $\frac{1}{18t}(3t + \delta + \epsilon)^2 - F_A \geq \frac{1}{18t}(3t + \delta - \epsilon)^2$. Therefore, the outside innovator can optimally charge $F_A^* = \frac{1}{18t}(3t + \delta + \epsilon)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2 = \frac{2\epsilon(3t+\delta)}{9t} = R_F^*$ which is the revenue of the outside innovator.

Non-Drastic Case (ii) ($3t - \delta < \epsilon < 3t + \delta$)*:*

Under this scenario, if firm A accepts the contract, it becomes monopoly and its payoff becomes $(\epsilon + \delta - t) - F_A$. Firm A's no-acceptance payoff is $\frac{1}{18t}(3t + \delta - \epsilon)^2$ given firm B gets the license. Therefore, firm A will accept the license iff $F_A \leq (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta - \epsilon)^2$ and therefore $R_F^* = (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta - \epsilon)^2$when $3t - \delta < \epsilon < 3t + \delta$.

Drastic Case ($\epsilon > 3t + \delta$):

Here if firm A accepts the contract, its monopoly profit will be $\pi_A^F = (\epsilon + \delta - t) - F_A$. But if firm A rejects then firm B gets the license and becomes a monopoly. Therefore, firm A's no-acceptance payoff goes to zero. Therefore, in this case firm A will accept the contract iff $F_A \leq (\epsilon + \delta - t)$. Therefore, the revenue of the outside innovator will be $R_F^* = (\epsilon + \delta - t)$.

It is also evident from the profit expressions of firm A and B that under both drastic and non-drastic innovations the outside innovator is better-off licensing it to the efficient firm i.e. firm A. Later we will also see the above result is robust to all licensing schemes.

3.1.2. Fixed Fee Licensing to both Firms:

Now consider the case when the outside innovator is licensing its innovation to both firms A and B by charging a fixed fee. In this situation the relevant variables are given below:

$$p_A = c_A - \epsilon + \frac{1}{3}(3t + \delta) \tag{13}$$

$$p_B = c_B - \epsilon + \frac{1}{3}(3t - \delta) \tag{14}$$

$$Q_A = \frac{1}{6t}(3t + \delta) \tag{15}$$

$$Q_B = \frac{1}{6t}(3t - \delta) \tag{16}$$

$$\pi_A = \frac{1}{18t}(3t + \delta)^2 - F_A \tag{17}$$

$$\pi_B = \frac{1}{18t}(3t - \delta)^2 - F_B \tag{18}$$

Non-Drastic Case (i) ($\epsilon < 3t - \delta$):

If both firms accept the contracts, then firm A's payoff is $\frac{1}{18t}(3t + \delta)^2 - F_A$. If firm A rejects then given that firm B gets the contract, firm A's no-acceptance payoff will be $\frac{1}{18t}(3t+\delta-\epsilon)^2$. Therefore, the outside innovator can charge $\frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2 > 0$ from firm A. Now take firm B. If both firms accept then firm B's payoff is $\frac{1}{18t}(3t-\delta)^2 - F_B$. If firm B rejects then given that firm A gets the license, firm B's payoff will be $\frac{1}{18t}(3t-\delta-\epsilon)^2$. Therefore, the innovator can optimally charge $\frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 > 0$ from firm B. Adding these two one can get the outside innovators total revenue as $Rev^*_{FixedBoth} = \frac{\epsilon(6t-\epsilon)}{9t} > 0$.

Non-Drastic Case (ii) ($3t-\delta<\epsilon<3t+\delta$):

Under this scenario, we know if firm A accepts and B does not then firm A becomes monopoly, however, the reverse is not true. Hence, the innovator can extract $\frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2$ from firm A and $\frac{1}{18t}(3t-\delta)^2$ from firm B. Therefore $Rev^*_{FixedBoth} = \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2 + \frac{1}{18t}(3t-\delta)^2$.

Drastic Case ($\epsilon > 3t+\delta$):

Here, the outside innovator can optimally extract $\frac{1}{18t}(3t+\delta)^2$ from firm A and $\frac{1}{18t}(3t-\delta)^2$ from firm B (respective monopoly profits from each firm) and its optimum revenue will be $Rev^*_{FixedBoth} = \frac{1}{18t}(3t+\delta)^2 + \frac{1}{18t}(3t-\delta)^2$.

Comparing the payoffs of the innovator for one and two firms licensing, we get that

Proposition 1: *Under fixed fee licensing the innovator will always license its innovation to only one firm viz. the efficient firm.*

The intuition of the above result can be given as follows: the efficient firm's gain from the new technology vis-à-vis no acceptance is higher compared to the inefficient firm and therefore the outside innovator will optimally offer the license to the efficient firm. Also when the innovation is licensed to both the firms then costs of both the firms get reduced. So the gain of one firm vis-a-vis the other falls since both are reaping the benefit of the cost reducing technology now. This competition effect drives down gain of both the firms and thus the outside innovator will be able to extract less from both the firms since the monopoly profit of the efficient firm exceeds the sum of payoffs of both the competing firms. Therefore, in equilibrium we get that the innovator will be able to extract more when it licenses the innovation to only one firm and specifically the efficient firm.

3.2. Auction Policy:

3.2.1. Auction Policy - Only one license offered:

Non-Drastic Case (i) ($\epsilon < 3t - \delta$):

Suppose the innovator wants to license its innovation to only one firm through an auction and the highest bidder will get it by paying his bid, i.e. a first price auction. If firm A wins the license its payoff will be $\frac{1}{18t}(3t+\delta+\epsilon)^2$ and if firm A loses the license (and firm B wins it) its payoff will be $\frac{1}{18t}(3t+\delta-\epsilon)^2$. Therefore, firm A will be willing a bid a maximum amount up to $\frac{1}{18t}(3t+\delta+\epsilon)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2 = \frac{2\epsilon(3t+\delta)}{9t}$. On the other hand, if firm B wins the auction it will receive $\frac{1}{18t}(3t-\delta+\epsilon)^2$ whereas if it loses the auction (and firm A wins) firm B's payoff will be $\frac{1}{18t}(3t-\delta-\epsilon)^2$. Thus firm B will be willing to bid a maximum $\frac{1}{18t}(3t-\delta+\epsilon)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 = \frac{2\epsilon(3t-\delta)}{9t}$. Note that the inefficient firm B's bid is always less than efficient firm A's bid. Thus under complete information, firm A can always ensure that it wins the auction by bidding slightly higher than the maximum possible bid of firm B, i.e. $b_A^* = \frac{2\epsilon(3t-\delta)}{9t} + k$ where $k > 0$ and small. The outside innovator's payoff will be $\frac{2\epsilon(3t-\delta)}{9t} + k$.

Non-Drastic Case (ii) ($3t - \delta < \epsilon < 3t + \delta$):

Firm A's net gain from winning the auction is $(\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta-\epsilon)^2$ whereas firm B's net gain will be $(\epsilon-\delta-t)$. One can easily show that $(\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta-\epsilon)^2 > (\epsilon - \delta - t)$for $\forall\, \epsilon \in [3t-\delta, 3t+\delta)$. Therefore, firm A will again win the auction by biding $b_A^* = (\epsilon-\delta-t) + k$.

Drastic Case ($\epsilon > 3t + \delta$):

Firm A's payoff from winning the auction is $(\epsilon + \delta - t)$ whereas firm B's payoff from winning is $(\epsilon - \delta - t)$. The losing payoff for both the firms is zero. Firm A therefore, can again win the auction by bidding $b_A^* = (\epsilon - \delta - t) + k,\ k > 0$ which will be innovator's revenue in this situation as well.[9]

Therefore, we can state our next result:

Lemma 1: *When only one license is auctioned then the efficient firm will always win the auction irrespective of whether be the size of the innovation i.e. drastic or non-drastic.*

3.2.2: Auction Policy - Two licenses offered:

Suppose the innovator offers two licenses to both the firms subject to a minimum floor bid of the bidders (i.e. firms)[10]. Both the bidders pay their respective bids.

Non-Drastic Case (i) ($\epsilon < 3t - \delta$):

If firm A gets the license and both firms get the license its payoff will be $\frac{1}{18t}(3t+\delta)^2$ and if firm A doesn't get the license (and firm B gets it) its payoff will be $\frac{1}{18t}(3t+\delta-\epsilon)^2$. Therefore, firm A will be willing a bid a maximum amount $\frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2 = \frac{\epsilon(6t+2\delta-\epsilon)}{18t}$. On the other hand, if firm B gets the license and both get it, firm B will receive $\frac{1}{18t}(3t-\delta)^2$ whereas if it loses the auction (and firm A wins) firm B's payoff will be $\frac{1}{18t}(3t-\delta-\epsilon)^2$. Thus firm B will be willing to bid a maximum of $\frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 = \frac{\epsilon(6t-2\delta-\epsilon)}{18t}$. The outside innovator will set a minimum bid equal to the inefficient firm's maximum possible bid, in this case firm B's maximum bid $\frac{\epsilon(6t-2\delta-\epsilon)}{18t}$, to ensure that both firms can possibly get the license and also the total revenue is maximized. Firm A being the efficient firm will optimally bid the minimum required to get the license, i.e. $b_A^* = \frac{\epsilon(6t-2\delta-\epsilon)}{18t}$ which is equal to firm B's optimum bid which is $b_B^* = \frac{\epsilon(6t-2\delta-\epsilon)}{18t}$. The outside innovator's payoff will be $\frac{\epsilon(6t-2\delta-\epsilon)}{9t}$and we note that it is strictly lower than the case of a single license being offered (see section 3.2.1).

[9] Note that here this first price auction de facto plays out like a second price auction under complete information.

[10]We assume that the innovator will set a minimum floor bid above which the firms have to bid to get the license.

Non-Drastic Case (ii) $(3t - \delta < \epsilon < 3t + \delta)$*:*

Here, one can show that the optimal bids by both the firms will be $\frac{1}{18t}(3t - \delta)^2$ and the revenue of the innovator will be $\frac{1}{9t}(3t - \delta)^2$. This is lower than $(\epsilon - \delta - t)$ which is the innovator's payoff of licensing one auction (see section 3.2.1).

Drastic Case $(\epsilon > 3t + \delta)$*:*

The optimal bids by both firms will be $\frac{1}{18t}(3t - \delta)^2$ and the revenue of the innovator will be $\frac{1}{9t}(3t - \delta)^2$ and this is again lower than $(\epsilon - \delta - t)$ (see section 3.2.1).

Therefore, we can state our next result:

Proposition 2: *Under auction policy the outside innovator will always offer one license and the efficient firm will win the auction.*

Comparing the payoffs of the innovator between fixed fee and auction licensing, we also find the following.

Corollary 1: *Fixed fee licensing is always better than auction for the innovator.*

3.3. Royalty licensing:

3.3.1. Royalty licensing to one firm:

Again to fix ideas suppose the outside innovator licenses the innovation to firm A by charging a per unit royalty fee denoted by r. Therefore, firm A has to pay rQ_A to the outside innovator. Given this, firm A's profit function will be $\pi_A = p_A Q_A - (c_A - \epsilon + r)Q_A$ and firm B's profit function can be written as $\pi_B = p_B Q_B - c_B Q_B$. The equilibrium prices, demands and profits can be given as:

$$P_A^R = c_A - \epsilon + r + \frac{1}{3}(3t + \delta + \epsilon - r) \tag{19}$$

$$P_B^R = c_B + \frac{1}{3}(3t - \delta - \epsilon + r) \tag{20}$$

$$Q_A^R = \frac{1}{6t}(3t + \delta + \epsilon - r) \tag{21}$$

$$Q_B^R = \frac{1}{6t}(3t - \delta - \epsilon + r) \tag{22}$$

$$\pi_A^R = \frac{1}{18t}(3t + \delta + \epsilon - r)^2 \tag{23}$$

$$\pi_B^F = \frac{1}{18t}(3t - \delta - \epsilon + r)^2 \tag{24}$$

The outside innovator will maximize rQ_A and the optimum royalty rate should have been $r^* = \frac{3t+\delta+\epsilon}{2} > 0$. But one can easily check that $\frac{3t+\delta+\epsilon}{2} > \epsilon \ \forall \ \epsilon < (3t + \delta)$.Therefore, for all non-drastic innovations the optimum r will be set at $r^* = \epsilon$ which is the upper bound of$r$.[11]The optimum revenue of the innovator will be $Rev_R^* = \frac{\epsilon}{6t}(3t + \delta)$.In this situation if firm A accepts the royalty licensing contract it's payoff will be $\pi_A^R = \frac{1}{18t}(3t + \delta)^2$. But if firm A rejects the contract then firm B gets the contract, and firm A's profit would have been $\frac{1}{18t}(3t + \delta)^2$. Therefore, firm A is weakly better-off accepting this contract.

Note that in case of royalty licensing the licensee firms effective marginal cost of production is $(c_A - \epsilon + r)$ and at $r^* = \epsilon$ the effective marginal cost becomes c_A. Therefore, we don't need to distinguish between drastic and non-drastic innovation as the licensee firm will never become a monopoly post licensing. Therefore, whatever be the size of the innovation the payoff of firm a will be $\pi_A^R = \frac{1}{18t}(3t + \delta)^2$ even if it accepts or rejects the license and the previous analysis is relevant.[12]

Therefore, we can state the following:

Corollary 2: *The outside innovator will prefer fixed fee licensing over royalty licensing when only one license is offered and this holds for both drastic and non-drastic innovation.*

3.3.2. Royalty Licensing to both Firms:

Consider the case where the outside innovator licenses the technology to both firms through per-unit royalty licensing. To start with suppose we assume asymmetric royalty rates for both firms

[11] We assume royalty rate at $r^* \leq \epsilon$, so that the potential licensee has the incentive to accept the licensing contract.

[12]Note that if the innovator offers the royalty contract to the inefficient firm B, then its payoff is$Rev_R^* = \frac{\epsilon}{6t}(3t - \delta)$, strictly a lower payoff than offering the contract to the efficient firm A.

i.e. r_A for firm A and r_B for firm B where $r_A \neq r_B$. Also to fix ideas denote $\Delta r = r_A - r_B > 0$. The optimal prices, quantities and profits can therefore be calculated as

$$P_A^{\text{RBoth}} = c_A - \epsilon + r_A + \frac{1}{3}(3t + \delta - \Delta r) \tag{25}$$

$$P_B^{\text{RBoth}} = c_B - \epsilon + r_B + \frac{1}{3}(3t - \delta + \Delta r) \tag{26}$$

$$Q_A^{\text{RBoth}} = \frac{1}{6t}(3t + \delta - \Delta r) \tag{27}$$

$$Q_B^{\text{RBoth}} = \frac{1}{6t}(3t - \delta + \Delta r) \tag{28}$$

$$\pi_A^{\text{RBoth}} = \frac{1}{18t}(3t + \delta - \Delta r)^2 \tag{29}$$

$$\pi_B^{\text{RBoth}} = \frac{1}{18t}(3t - \delta + \Delta r)^2 \tag{30}$$

Note the incentives for firm A. When firm A accepts its payoff is given by (29) whereas when firm A rejects (but firm B accepts) it's payoff will be $\frac{1}{18t}(3t + \delta - \epsilon + r)^2$. Given $r \leq \epsilon$ firm A's decision will depend on the relative values of Δr and $(\epsilon - r)$. As we will see that the innovator is better off charging r as close to ϵ as possible and therefore $\epsilon - r \approx 0$ (in fact at the optimum $r = \epsilon$) and thus given $\Delta r > 0$, firm A is better-off not accepting this asymmetric royalty contract. Again if we assume $\Delta r = r_A - r_B < 0$ we can see that firm B is better off not accepting the contract. Therefore, with asymmetric royalty rates any one firm will not accept the contract and we go back to the single firm case. Put differently, asymmetric royalty rates cannot exist together. So to make both the firms accept we need to assume symmetric royalty rates, without loss of generality. To fix ideas, we assume $r_A = r_B$. Now given this,when both firms get the license, from (27) and (28) we get that the industry output is 1 and therefore the total revenue of the outside innovator is $Rev^*_{royaltyBoth} = r$. Thus the outside innovator will optimally choose $r = \epsilon$ and it's revenue will be ϵ. Only we need to check whether both firm A and B accepts this contract under the alternative assumption. Under symmetric royalty if firm A accepts it's profit will be $\frac{1}{18t}(3t + \delta)^2$ whereas if firm A rejects then assuming that firm B is accepting, firm A's payoff will be $\frac{1}{18t}(3t + \delta)^2$. Againif firm B accepts and both accepts, it's profit will be $\frac{1}{18t}(3t - \delta)^2$ whereas if firm B rejects then assuming that firm A is accepting, firm B's profit will be

$\frac{1}{18t}(3t-\delta)^2$. So both firms will accept this symmetric royalty contract (weakly better off). So $r = \epsilon$ is indeed optimal for the outside innovator's revenue will be $Rev^*_{royaltyBoth} = \epsilon$.

Again we don't need to distinguish between drastic and non-drastic innovation in this case and the preceding analysis is relevant for innovation of all sizes. Note that $\epsilon > \frac{\epsilon}{6t}(3t+\delta)$ since $\delta < 3t$ (by assumption) and therefore offering two licenses are optimal for the innovator.

Therefore, we can state our next proposition:

Proposition 3:

In case of royalty licensing the innovator will always license its innovation to both the firms irrespective of the size of innovation.

3.4. Two-part Tariff licensing:

3.4.1. Two-part Tariff licensing to any one firm:

Suppose the outside innovator is licensing the innovation to firm A by charging a two-part tariff i.e. a combination of fixed fee F_A and a per unit royalty r. This situation is similar to the royalty licensing except that a fixed fee is charged in addition to the per-unit royalty. In this situation the equilibrium prices, demands and profits can be given as:

$$P_A^{TPT} = c_A - \epsilon + r + \frac{1}{3}(3t+\delta+\epsilon-r) \tag{31}$$

$$P_B^{TPT} = c_B + \frac{1}{3}(3t-\delta-\epsilon+r) \tag{32}$$

$$Q_A^{TPT} = \frac{1}{6t}(3t+\delta+\epsilon-r) \tag{33}$$

$$Q_B^{TPT} = \frac{1}{6t}(3t-\delta-\epsilon+r) \tag{34}$$

$$\pi_A^{TPT} = \frac{1}{18t}(3t+\delta+\epsilon-r)^2 - F_A \tag{35}$$

$$\pi_B^{TPT} = \frac{1}{18t}(3t-\delta-\epsilon+r)^2 \tag{36}$$

The revenue for the outside innovator will be $Rev_{TPT} = rQ_A^{TPT} + F_A = \frac{r}{6t}(3t+\delta+\epsilon-r) +$

$\frac{1}{18t}(3t+\delta+\epsilon-r)^2-\frac{1}{18t}(3t+\delta-\epsilon+r)^2$ and the outside innovator will maximize this subject to r and one can calculate the optimal two-part tariff royalty rate as $r^{TPT}=\epsilon$ which is similar to the royalty case Therefore the optimum F_A will be set at $F_A^{TPT}=0$. Therefore, we have the following result.

Lemma 2: *The optimum two-part tariff contract is in fact the royalty licensing contract.*

The outside innovator's payoff will be exactly equal to the royalty licensing payoff, i.e. $\frac{\epsilon}{6t}(3t+\delta)$ when only one license is offered and the same analysis holds for innovation of all sizes drastic or non-drastic.

3.4.2. Two-part tariff licensing to both firms:

We consider the case where the innovator licenses its innovation to both the firms using a uniform royalty and fixed fee, i.e. $r_A=r_B=r$and $F_A=F_B$. The equilibrium variables in this case will be

$$P_A^{TPT\text{Both}}=c_A-\epsilon+r+\frac{1}{3}(3t+\delta) \quad (37)$$

$$P_B^{TPT\text{Both}}=c_B-\epsilon+r+\frac{1}{3}(3t-\delta) \quad (38)$$

$$Q_A^{TPT\text{Both}}=\frac{1}{6t}(3t+\delta) \quad (39)$$

$$Q_B^{TPT\text{Both}}=\frac{1}{6t}(3t-\delta) \quad (40)$$

$$\pi_A^{TPT\text{Both}}=\frac{1}{18t}(3t+\delta)^2-F_A \quad (41)$$

$$\pi_B^{TPT\text{Both}}=\frac{1}{18t}(3t-\delta)^2-F_B \quad (42)$$

We consider non-drastic innovation first. The outside innovator can optimally charge a royalty rate r and can extract $F_A=\frac{1}{18t}(3t+\delta)^2-\frac{1}{18t}(3t+\delta-\epsilon+r)^2$ from firm A and $F_B=\frac{1}{18t}(3t-\delta)^2-\frac{1}{18t}(3t-\delta-\epsilon+r)^2$ from firm B. The outside innovator's payoff will therefore be $r+\left[\frac{1}{18t}(3t+\delta)^2-\frac{1}{18t}(3t+\delta-\epsilon+r)^2\right]+\left[\frac{1}{18t}(3t-\delta)^2-\frac{1}{18t}(3t-\delta-\epsilon+r)^2\right]$. It is easy to verify that optimal $r^* = \epsilon$. Both the firms accept the contract and $F_A^* = 0$and $F_B^* = 0$. The revenue of the innovator will be $R_{TPTBoth}^* = \epsilon$. Therefore, we have the following result.

Lemma 3:*When two licenses are offered, the optimal two-part tariff licensing is a pure royalty contract.*

Note that $\epsilon > \frac{\epsilon}{6t}(3t + \delta)$ since $\delta < 3t$(by assumption) and therefore when innovation is non-drastic the innovator will offer two licenses and again the same analysis holds for drastic innovations.

Therefore, we can state our next result.

Proposition 4:

In case of two-part tariff licensing
(a). The innovator will optimally offer two licenses for all kinds of innovations.
(b).The two-part tariff licensing is in fact royalty licensing and this holds irrespective of whether one license or two licenses are offered and also for innovations of all sizes.

3.5. Optimal Licensing Policy

We know that fixed fee licensing to a single firm is better than offering two licenses and also all kinds of auctioning of licenses. Also we know that royalty licensing to two firms is the optimal two-part tariff licensing scheme. Therefore, to get the optimal licensing scheme we need to compare the payoff of the outside innovator from single firm fixed fee licensing and royalty licensing to both firms. When $\epsilon < 3t - \delta$, $Rev_{royaltyBoth}^* = \epsilon > \frac{2\epsilon(3t+\delta)}{9t} = R_F^*$ if $\delta \leq \frac{3t}{2}$. If $3t - \delta < \epsilon < 3t + \delta$ then $\delta \leq t$ is a sufficient condition for$Rev_{royaltyBoth}^* = \epsilon > (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta - \epsilon)^2 = R_F^*$. When $\epsilon > 3t + \delta$ then $Rev_{royaltyBoth}^* = \epsilon > (\epsilon + \delta - t) = R_F^*$if $\delta \leq t$. Thus, we state the main result below.

Proposition 5:

(a). If the innovation is non-drastic and when $\epsilon < 3t - \delta$ *then royalty licensing to both firms is optimal if* $\delta \leq \frac{3t}{2}$*. Otherwise fixed fee licensing to a single firm is optimal. The payoff to the innovator* $R^* = \epsilon$ *if* $\delta \leq \frac{3t}{2}$*, otherwise* $R^* = \frac{2\epsilon(3t+\delta)}{9t}$*.*

(b). If the innovation is non-drastic and if $3t - \delta < \epsilon < 3t + \delta$ *then royalty licensing to both firms is optimal if* $\delta \leq t$*. The payoff to the innovator* $R^* = \epsilon$ *if* $\delta \leq t$*, otherwise* $R^* = (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta - \epsilon)^2$*.*

(c). If innovation is drastic (i.e. $\epsilon > 3t + \delta$*) royalty licensing to both the firms is optimal if* $\delta \leq t$*. Otherwise fixed fee licensing to only one firm is optimal. The payoff to the innovator is* $R^* = \epsilon$ *if* $\delta \leq t$*, otherwise* $R^* = \epsilon + \delta - t$*.*

Given that we have considered various licensing schemes we now examine what will happen if the innovator decides to sell the property rights of the innovation to any one of the firms.

4. Selling Game:

We consider the possibility where the innovator wants to sell the innovation to one of the firms by charging a fixed price (or fee). Note that selling can be done to only one firm in contrast to licensing where it can be done to both firms. If one firm rejects the selling contract, then it goes to the other firm. Again to fix ideas we assume that the innovator decides to sell the innovation to firm A. Now firm A is the owner of the innovation. Firm A now has the option of licensing the innovation to firm B. This issue in this structure has been analyzed in detail by Lu and Poddar (2014) and we invoke their result in our analysis here.

Result (Lu and Poddar (2014)): *In Hotelling's linear city model, the patentee's optimal licensing strategy is to license its (drastic or non-drastic) innovation using two-part tariff no matter whether the patentee is ex-ante efficient of inefficient or equally efficient as the other firm.*

In this structure when the innovation is non-drastic and $\epsilon < 3t - \delta$, in case of two-part tariff firm A's optimal r and F are $r^{TPT} = \epsilon$ and $F^{TPT} = \frac{1}{18t}(3t - \delta)^2 - \frac{1}{18t}(3t - \delta - \varepsilon)^2$.[13] Firm A's total payoff in case of two-part tariff will be $\frac{1}{18t}(3t - \delta)^2 + \varepsilon + \frac{1}{18t}(3t + \delta)^2 - \frac{1}{18t}(3t - \delta - \varepsilon)^2$. This is the maximum that Firm A can get by licensing the technology to firm B. If firm A

[13] In Lu and Poddar (2014), δ is defined as $\delta = c_A - c_B$ hence the difference in the corresponding expressions.

rejects, then firm B becomes the owner of the innovation. Then firm B will optimally offer the two-part tariff contract to firm A and in that case firm A can at most earn its no-licensing payoff of this licensing sub-game which firm B will optimally leave for firm A. So firm A's non-acceptance payoff of this selling game is $\frac{1}{18t}(3t+\delta-\varepsilon)^2$. Therefore, firm A's maximum net gain from purchasing the innovation from the outside innovator is $\frac{1}{18t}(3t-\delta)^2+\varepsilon+\frac{1}{18t}(3t+\delta)^2-\frac{1}{18t}(3t-\delta-\varepsilon)^2-\frac{1}{18t}(3t+\delta-\varepsilon)^2$. The outside innovator can potentially extract this amount and still get firm A to accept the purchase. That is the innovator can potentiallycharge $F^{Sell}=\epsilon+\frac{1}{18t}(3t-\delta)^2+\frac{1}{18t}(3t+\delta)^2-\frac{1}{18t}(3t-\delta-\varepsilon)^2-\frac{1}{18t}(3t+\delta-\varepsilon)^2$. This will be the innovator's maximum revenue while selling the innovation. Previously, we have shown the innovator's maximum possible profit from licensing its innovation is ϵ if $\delta\leq\frac{3t}{2}$ and $R^*=\frac{2\epsilon(3t+\delta)}{9t}$ otherwise. Calculations show that F^{Sell} exceeds both ϵ and $\frac{2\epsilon(3t+\delta)}{9t}$ and this holds for all values of δ. Therefore, when innovation is non-drastic and $\epsilon<3t-\delta$, it is optimum for the innovator to sell the innovation.

When the innovation is non-drastic and $3t-\delta<\epsilon<3t+\delta$, the maximum payoff that firm A can get from licensing is $\frac{1}{18t}(3t-\delta)^2+\epsilon+\frac{1}{18t}(3t+\delta)^2$. The no acceptance payoff of firm A in this situation is $\frac{1}{18t}(3t+\delta-\varepsilon)^2$ since firm A will not go out of the market if it refuses and firm B gets the license. Therefore, the outside innovator can possibly extract a maximum of $\frac{1}{18t}(3t-\delta)^2+\epsilon+\frac{1}{18t}(3t+\delta)^2-\frac{1}{18t}(3t+\delta-\varepsilon)^2$ from firm A. Note again that this exceeds both ϵ and $(\epsilon+\delta-t)-\frac{1}{18t}(3t+\delta-\epsilon)^2$(the profits under licensing) since $\epsilon+\frac{1}{18t}(3t-\delta)^2+\frac{1}{18t}(3t+\delta)^2\geq(\epsilon+\delta-t)$for $0\leq\delta\leq 3t$. Thus selling is optimal for the innovator even if $3t-\delta<\epsilon<3t+\delta$.

Finally, when the innovation is drastic and $\epsilon>3t+\delta$, the patentee's optimal licensing contract is $r^{TPT}=\epsilon$ and $F^{TPT}=\frac{1}{18t}(3t+\delta)^2$. Since firm A will extract the entire surplus from firm B, $\pi_A^{TPT}=\frac{1}{18t}(3t-\delta)^2+\epsilon+\frac{1}{18t}(3t+\delta)^2$. If firm A refuses to purchase the innovation, then firm B gets it. Since the innovation is drastic firm A's no-acceptance payoff goes to zero in this case and therefore the outside innovator can possibly extract the entire amount $\frac{1}{18t}(3t-\delta)^2+$

$\epsilon + \frac{1}{18t}(3t+\delta)^2$ from firm A. Therefore, the outside innovator can sell the innovation and get maximum revenue $F^{Sell} = \frac{1}{18t}(3t-\delta)^2 + \epsilon + \frac{1}{18t}(3t+\delta)^2$. Now one can easily show that this exceeds both $(\epsilon + \delta - t)$ and ϵ (the profits under licensing) and therefore selling is also optimal when innovation is drastic and this holds irrespective of the value of δ.

Thus, we show that the outside innovator is unambiguously better off selling the innovation to any one firm than licensing to one or both the firms. We also note that the selling payoffs of the innovator do not depend on whether the innovator sells it to the efficient or the inefficient firm. The intuition is even if the inefficient firm gets the new technology it can further license it to the efficient firm and can potentially extract all the benefit from the efficient firm which in turn can be potentially extracted by the outside innovator. Therefore, the innovator will be indifferent between selling the innovation to the efficient firm or the inefficient firm and in both situations it gets the same payoff.

Therefore, we can state the main result of our paper:

Proposition 6:

It is optimum for the innovator to sell the license to any one firm and this holds irrespective of whether the innovation is drastic or non-drastic.

The optimality of the selling comes from the fact that in case of selling the purchasing firm has the right to subsequently license it to the other firm and extract more from the other firm. This in turn can be extracted by the outside innovator and the resultant payoff will be higher. Whereas in case of licensing the licensee doesn't have the right to license the technology to the other firm (or take any further action with the technology) and therefore the innovator can extract less if it licenses the technology. This makes selling unambiguously preferred over licensing for the outside innovator.

5. Welfare analysis:

From the above analysis now it is clear that selling is privately optimal to the outside innovator. Now is this outcome socially optimal as well? This is important if we want to make some policy recommendations regarding the optimum organization of technology transfer from a normative point of view. Thus in this section we will make the welfare comparisons when the innovator goes for outright selling vis-à-vis licensing of the innovation. We consider the case of licensing of the innovation first:

Welfare under Optimal Licensing:

(i). Royalty:

While analyzing the licensing of the innovation first we point out that when $\epsilon < 3t - \delta$ and $\delta \leq \frac{3t}{2}$ holds and also when $\epsilon > 3t + \delta$ and $\delta \leq t$ holds then royalty licensing to both firms with $r^A = r^B = \epsilon$ is optimal. Given this one can easily check that from equations 25-30 that the post innovation prices and the profits of both the firms are same as that of the no-licensing case. Therefore, under royalty licensing the consumer surplus and the producer surplus remain the same as that of the no-licensing scenario. The entire gain or surplus is appropriated by the outside innovator and who receives a payoff of ϵ. Therefore, the *increase* in social welfare is ϵ. Also, when $3t - \delta < \epsilon < 3t + \delta$ and $\delta \leq t$ then again royalty licensing is optimal and the social welfare gain is ϵ.

(ii). Fixed Fee:

But if $\epsilon < 3t - \delta$ and $\delta > \frac{3t}{2}$ holds then fixed fee to the efficient firm is optimal and we need to calculate the increase in producers surplus and the consumers surplus in this situation. In case of fixed fee licensing, firm A gets $\frac{1}{18t}(3t + \delta - \epsilon)^2$ after paying the licensing fee, firm B gets $\frac{1}{18t}(3t - \delta - \epsilon)^2$ and the outside innovator extracts $\frac{1}{18t}(3t + \delta + \epsilon)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2$. Adding all these the total producers' and innovator's surplus can be written as $\frac{1}{18t}(3t + \delta)^2 + \frac{1}{18t}(3t - \delta)^2 + \frac{2\epsilon^2 + 4\delta\epsilon}{18t}$ and therefore the increment in surplus is $\frac{2\epsilon^2 + 4\delta\epsilon}{18t}$. To calculate the increment in consumer surplus we need to segment the entire market into three parts, i.e. $\left[0, \frac{1}{2} + \frac{\delta}{6t}\right]$, $\left[\frac{1}{2} + \frac{\delta}{6t}, \frac{1}{2} + \frac{\delta}{6t} + \frac{\epsilon}{6t}\right]$ and $\left[\frac{1}{2} + \frac{\delta}{6t} + \frac{\epsilon}{6t}, 1\right]$. The first segment pre-licensing purchased from firm A and after licensing is still purchasing from firm A. The second segment pre-licensing purchased from firm B but post licensing purchases from firm A. The final segment pre-licensing purchased from firm B and after licensing is still purchasing from firm B. One can also calculate the change in prices post licensing where the price of firm A falls by $\frac{2\epsilon}{3}$ and the price of firm B falls by $\frac{2\epsilon}{3}$. Also we need to calculate the difference in post licensing price of A and pre-licensing price of B and the post licensing price of A is smaller by $\frac{(2\epsilon+\delta)}{3}$. Therefore, consumers in all the segments gain and since we assumed that the consumers are uniformly distributed and purchase only one unit of the good the total change in consumer surplus can be calculated by multiplying the price changes and the length of the intervals and after calculating the total increase in consumer surplus is found as $\frac{\epsilon(9t+2\delta+\epsilon)}{18t}$. Therefore, the total *increase* in welfare compared to no-licensing is found by adding the increase in consumer surplus and the producers and innovator's surplus which we get as $\frac{\epsilon(3t+2\delta+\epsilon)}{6t}$.

When $\epsilon \geq 3t-\delta$and $\delta > t$, the outside innovator goes for fixed fee licensing to firm A and we calculate the change in total welfare similarly. In this situation post licensing firm A becomes the monopolist and charge $P_A^F = c_B - t$. Firm A gets a net payoff of $\frac{1}{18t}(3t+\delta-\epsilon)^2$ and the innovator extracts $(\epsilon+\delta-t)-\frac{1}{18t}(3t+\delta-\epsilon)^2$ from firm A. Firm B gets zero. So total post innovative producers and innovator's surplus will be $(\epsilon+\delta-t)$ and the gain compared to no-licensing will be $(\epsilon+\delta-t)-\frac{1}{18t}(3t-\delta)^2-\frac{1}{18t}(3t+\delta)^2$. To calculate the increase in consumers' surplus we note that post licensing all consumers' purchase from firm A and therefore $\left[0, \frac{1}{2}+\frac{\delta}{6t}\right]$ will continue to purchase from firm A whereas $\left[\frac{1}{2}+\frac{\delta}{6t}, 1\right]$ will now purchase from firm A. Price of good A falls by $\frac{2(3t-\delta)}{3}$ (magnitude) with respect to its pre-licensing price and it falls by $\frac{(6t-\delta)}{3}$ (magnitude) compared to the pre-licensing price of firm B. Therefore, the increase in consumer surplus will be $\frac{\delta(3t-\delta)}{6t}$. Thus the total increase in welfare will be $(\epsilon+\delta-t)-\frac{1}{18t}(3t-\delta)^2-\frac{1}{18t}(3t+\delta)^2+\frac{\delta(3t-\delta)}{6t}$. This also holds for the case where $3t-\delta \leq \epsilon \leq 3t+\delta$ and fixed fee licensing is optimal for the innovator.

Now we look at the welfare increment when the innovator goes for selling of the patent right.

Welfare under Selling:

In case of selling we know following Lu and Poddar (2014) that the patentee firm (in our case firm A) post purchase goes for two-part tariff licensing agreement with firm B and the optimal two-part tariff contract that firm A offers in our structure will be are $r^{TPT} = \epsilon$ and $F^{TPT} = \frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2$ when $\epsilon < 3t-\delta$. Again the optimal price that both firm A and B charges will be $p_A = c_A + \frac{1}{3}(3t+\delta)$ and$p_B = c_B + \frac{1}{3}(3t-\delta)$ which is exactly equal to the pre-innovation prices. Therefore, the consumers do not gain and the consumer surplus remains exactly the same as in the pre-innovation/no-selling scenario. The optimal profit of the firms will also be exactly equal to the pre-innovation level and the outside innovator will extract the entire additional surplus accruing from the innovation. Therefore, the total increase in social welfare will be exactly equal to the fixed fee that the innovator charges while selling the innovation, i.e. $\epsilon + \frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2$.

Again when $\epsilon > 3t-\delta$, by similar argument the increment will social surplus will be $\frac{1}{18t}(3t-\delta)^2 + \epsilon + \frac{1}{18t}(3t+\delta)^2$ while both the consumers surplus and the producers remain at the pre-innovation/no-innovation level.

Welfare Comparison - Selling vs. Licensing:

We can now compare the changes in welfare in both the situations.

When $\epsilon < 3t-\delta$ and $\delta \leq \frac{3t}{2}$ holds then certainly $\epsilon + \frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2 - \frac{1}{18t}(3t+\delta-\varepsilon)^2$ exceeds ϵ and therefore selling is also socially optimal.

When $\epsilon > 3t+\delta$ and $\delta \leq t$ then definitely$\frac{1}{18t}(3t-\delta)^2 + \epsilon + \frac{1}{18t}(3t+\delta)^2$ exceeds ϵ and therefore again selling welfare dominates licensing. Similarly, when $3t-\delta \leq \epsilon \leq 3t+\delta$ and $\delta \leq t$ then also $\frac{1}{18t}(3t-\delta)^2 + \epsilon + \frac{1}{18t}(3t+\delta)^2$ exceeds ϵ and therefore selling leads to greater increased welfare compared to licensing.

When $\epsilon < 3t-\delta$and $> \frac{3t}{2}$, then the increment in welfare from licensing is $\frac{\epsilon(3t+2\delta+\epsilon)}{6t}$ which is a sum of the increased consumer surplus $\frac{\epsilon(9t+2\delta+\epsilon)}{18t}$ and the increase in producer's surplus $\frac{2\epsilon^2+4\delta\epsilon}{18t}$. One can check that $\epsilon > \frac{\epsilon(9t+2\delta+\epsilon)}{18t}$ and $\frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 -$

$\frac{1}{18t}(3t+\delta-\epsilon)^2 > \frac{2\epsilon^2+4\delta\epsilon}{18t} \forall \epsilon < 3t-\delta$. Therefore, the total welfare under selling $\epsilon + \frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2$ exceeds the total welfare under fixed fee licensing $\frac{\epsilon(3t+2\delta+\epsilon)}{6t}$ and thus we get that selling is welfare-optimal for all $\epsilon < 3t-\delta$.

Finally, for the remaining two cases, i.e. $\epsilon > 3t+\delta$ and $\delta > t$ holds and also the case where fixed fee licensing is optimal when $3t-\delta \leq \epsilon \leq 3t+\delta$ the increment in total welfare is $(\epsilon+\delta-t) - \frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t+\delta)^2 + \frac{\delta(3t-\delta)}{6t}$ which is again can be shown to be less than the increment in welfare under selling i.e. $\frac{1}{18t}(3t-\delta)^2 + \epsilon + \frac{1}{18t}(3t+\delta)^2 \forall\, \delta > t$ and $\epsilon > 3t+\delta$. Thus, taking all the above results into account we conclude the following.

Proposition 7:

Outright sell of innovation leads to greater increase in welfare vis-à-vis licensing of innovation.

The above result has an interesting policy implication that selling innovation is not only privately optimal, it is also socially optimal. Hence the optimal policy instrument is to encourage the sale of patent rights than licensing of patents whenever possible.

6. Conclusion and Future Work:

There is a volume of theoretical work on patent licensing studying about the optimal licensing policies from the innovator to the potential licensee(s) under various possible scenarios. Due to that and along with the empirical studies, we now fairly understand how the patent licensing works optimally in any given scenario for the innovator. However, the study of patent licensing under spatial competition is sparse. We would like to have our contribution there as more often it is seen that the optimal licensing contracts differ in a spatial framework compared toa standard framework of price/quantity competition. Hence, some new insights are gained. The other main contribution is to allow the innovator the option to sell the property rights of the innovation to one of the competing firms (who can further license if it wishes to do that) is an area very much under-researched till date. We then examine the incentive of an outside innovator to sell an innovation to a prospective incumbent and compare that with different available licensing schemes. Specifically, in this analysis we assume that there is a non-producing outside innovator (research lab) who has a new cost reducing technology and there are two incumbent firms (the potential licensees) in the product market. The firms are asymmetric in terms of cost of production. Our main finding is the innovator will always sell the innovation to one of the competing firms rather than licensing it to either one or two firms. The result is fairly robust as it true for any drastic and non-drastic innovation as well as any pre-innovation cost asymmetries between the competing firms. The study also extends and compares Tauman and Wang's (2012) and Sinha's (2016) findings studied in a Cournot framework.

One of the highlights of the paper is to show the importance of selling the property right of innovation to any one of the competing firms in the industry. Our main finding not only shows the clear dominance of selling over different types of licensing contracts but also points to the case that in all the previous studies of patent licensing where optimal licensing policies are derived, all will possibly become suboptimal when we provide the selling option to the outside innovator. This is certainly true in a spatial competition as we see here, and we believe is most likely to be true in various other scenarios. This is our conjecture. In our future research, we would like substantiate the claim by analyzing the problem in a general competitive environment (i.e. outside the spatial framework) as well. This would not only provide the innovator a stronger incentive to innovate when it sells since it maximizes the private value of the innovation but from the society's point of view it is welfare improving as well compared to any licensing scheme. Thus we get a Pareto improvement. A strong enough reason for the policy makers to create a policy environment where selling the right of innovation is generally encouraged across industries.

In addition to this we would like to extend our analysis to situations where the market is not fully covered and will also consider alternative standard product differentiation models (e.g. Singh and Vives (1984)). One can also extend our analysis to more than two firms, possibly in a n firm structure and analyze the interplay between licensing, selling and innovation incentives of an outside innovator. Although we conjecture that our main result will go through, nonetheless an exercise worth doing in the future.

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