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‘To sell or not to sell’: Licensing versus Selling by an Outside Innovator ♦

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Abstract

We study various modes of technology transfer of an outside innovator in a spatial framework when the potential licensees are asymmetric. In addition to different licensing options, we also look into the option of selling the property rights of innovation and find the optimal mode of technology transfer. For licensing we find the optimal policy is to offer pure royalty contracts to both licensee firms when cost differentials between the firms are relatively small compared to the transportation cost, otherwise offer a fixed fee licensing contract to the efficient firm only. Interestingly, we show the innovator is always better-off selling the innovation to any one of the firms who further licenses it to the rival firm. The result holds irrespective of the size of the innovation (drastic or non-drastic) and the degree of cost asymmetry between the licensees. 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 technology transfer in spatial competition is relatively sparse. Product differentiation through spatial models is well understood in the industrial organization literature, however, the impact of technology transfer in a spatial model of product differentiation is less well understood. We see a huge literature that studies technology transfer in the conventional models of price (Bertrand) or quantity (Cournot) competition with or without product differentiation. However, in most of those studies, the standard notion of technology transfer is through various licensing contracts from the patentee to the licensee(s). 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 competitor(s)) is a relatively new area of research and should be looked upon more closely. We see ample evidence of that in the real world, particularly in the modern hi-tech industries.[1] The concept of selling the right of innovation in a theoretical framework 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.

In a recent study, Lu and Poddar (2014) examined various licensing schemes of an *insider patentee* under spatial competition for a licensee and found a fairly robust outcome that two-part tariff licensing is optimal among all possible licensing arrangements. Given this outcome with an insider patentee, a natural question arises, what happens when the patentee is an *outsider* and there are two potential licensees. Secondly, if we introduce selling of the patent right as an option to the patentee to one of the licensees, does it improve patentee's payoff? We try to address those questions.

The other important question is, why do we choose the spatial framework, particularly, a linear city model with two firms to analyze the problem? The answer is, we want to look into the impact of technology transfer in the markets which are matured (i.e. demand is not growing) and where the competing products are well differentiated i.e. respective product brands are well

[1] For empirical studies on selling patent rights in tech-industries, see Seranno (2010), Odasso et.al (2015) among others.

established, and each consumer has her ideal brand (i.e. inelastic demand).[2] These features are very well represented in a Hotelling type linear city framework where consumers are heterogeneous and uniformly distributed, the two firms are located at the extreme ends of the city, and the market is always fully covered. This is in contrast to many studies of technology transfer and patent licensing in standard models of product differentiation in Bertrand and Cournot framework (*a la* Singh and Vives, 1984) where the demand is elastic; and also changes with the degree of product differentiation. We will show how the feature of constant market demand in our model plays an important role in the analysis.

In our study, we will first explore various licensing arrangements systematically, followed by exclusively focusing on selling the innovation by the innovator. 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 maximizes the payoff of the outsider innovator and the social welfare. Since in our framework, in all the considered scenarios/regimes, the market size is constant, the comparisons of equilibrium prices, profits and consumer surplus across various regimes can be understood meaningfully.

The next objective of the study 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).[3] In reality, we more often see firms are asymmetric. Thus, in this study, we assume potential licensees can be asymmetric, and find the impact of asymmetric cost structures on the optimal mode of licensing and selling, and subsequent market competition.

Tauman and Weng (2012), inspite 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 looking for situations where the result of dominance

[2] As an example, think of a matured market of mobile devices (matured market implies a market with very high penetration rate of mobile device usage, almost close to hundred percent, e.g. markets in most developed countries), say smart-phones, with two established brands Apple or android phones (e.g. Samsung). Everybody needs one mobile phone and each consumer has a distinct preference over one particular brand. It represents a typical situation with two competing firms where the demand is inelastic and the market is fully covered.

[3] To our knowledge, few studies which relax the assumption of symmetric licensees are Wang et al. (2013), Sinha (2016), Chang et al (2016) and Fan et al. (2017).

of selling holds without much restriction in case selling is indeed a profitable strategy to the innovator. Interestingly, we find if the problem of technology transfer is addressed in a spatial model of product differentiation, we get a 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 are necessary to generate the result. 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 conclude that in reality we find a good mix of fixed fee and royalty contracts among all the licensing contracts that are offered. Given this, we are interested to see why that is the case. In our patent licensing analysis part, we do find both types of licensing, namely, fixed fee and royalty, emerge as optimal licensing contracts in equilibrium. Thus our result on licensing validates the empirical findings.

In our study, we use the following game structure. As for the licensing game is concerned, in the first stage, we allow the innovator to license its innovation to a single firm or both the firms. Once the licensing 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 look into all possible licensing scenarios, namely, 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. If the innovation is sold, the new patent holder has the option to license it further to the rival. We end our study by doing welfare analysis to see which mode of technology transfer between selling and licensing generates higher welfare and its comparison to pre-technology transfer scenario.

Our main findings of the study 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).

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 cost differentials between the firms are relatively small compared to the transportation cost; otherwise fixed fee licensing to the efficient firm only is optimal. Thus, we find cost asymmetries of the potential licensees as well as the transportation costs matter, so far as the optimal mode of licensing for the innovator is concerned. This also explains the prevalence of both fixed fee and royalty licensing in reality as we observe in various empirical studies. We also show that the gain in welfare is always positive from licensing the new technology compared to no-licensing.

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 competing 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 licensing firms. We also find that selling unambiguously leads to greater social welfare vis-à-vis licensing under all situations.

In a recent related study, Sinha (2016) considered technology transfer from an outsider patentee to potential licensees with asymmetric costs, and finds that technology selling is the best way to transfer an innovation. It is important to compare our findings with Sinha. First of all, the basic model of Sinha is greatly different from us, Sinha considered a homogenous good quantity competition model, ours is a differentiated product price competition framework. The main finding of the two studies is rather contrasting. In Sinha the innovator sells the patent only to the *efficient* firm, whereas in our case the innovator sells the technology to any one of the firms regardless of their cost asymmetries. In that sense our result is bit more general and robust. In Sinha, in the case of drastic common-innovation, once the technology is sold to the efficient firm, it is not further licensed; whereas in our case, irrespective of the size of innovation, once the technology is sold and it will be always further licensed to the other firm. Thus is our model we get a higher degree of diffusion of technology which is absent in Sinha's framework. We will see this particular aspect has positive implications on consumer surplus as well as on welfare. Sinha actually did not focus on these aspects or in general the welfare implications of technology transfer after innovation; we do that in detail in our analysis.

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 licensee(s). 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]. Here in our analysis of technology transfer in a spatial competition with an outside innovator, we get a different and new set of results on optimal licensing contracts which also depends on the cost asymmetries of the licensees. We show pure royalty contracts to both firms or fixed fee licensing to the efficient firm can be both optimal depending on the degree of cost asymmetry between the licensees.[5] Recently Chang et al., (2016) in an asymmetric duopoly framework with differential absorptive capacity show that the patent-holder may adopt exclusive licensing if the difference in the absorptive capacity of two firms is large enough; otherwise, it will license to both firms, which in essence has some similarity with our licensing results.

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

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

[5]In a pioneering work on 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.

oligopoly industry. Poddar and Sinha (2010) analyzes a situation where the insider patentee is relatively inefficient in terms of cost of production compared to the licensee and finds even a drastic innovation can be licensed by a two-part tariff. Muto (1993), using a standard product differentiation framework and price competition, showed that only royalty licensing is optimal (compared to auction and fixed fee) with an outsider patentee. In a different work, Fauli-Oller and 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. Ebina and Kishimoto (2012) consider optimal licensing from the viewpoint of an external public licensor maximizing social welfare and find that fixed fee licensing is always at least as good as royalty licensing. Bagchi and Mukherjee (2014) examined the impact of product differentiation on optimal licensing schemes by an outsider patentee. Their model especially looks into the relationship between the degree of product differentiation and the number of potential symmetric licensees to determine the dominant mode of licensing. In our case, the degree of product differentiation and the number of licensees are fixed and our focus is on the cost asymmetry part of the licensees on the mode of licensing. Bagchi and Mukherjee (2014) showed the dominance of royalty licensing whereas our paper finds a good mix of fixed fee and royalty licensing contract from the innovator. Moreover in all the above mentioned studies, the option of selling the patent rights is never considered.

At this point of time, the theoretical literature of selling patent rights is thin. However, the benefits of acquiring a patent rather than obtaining a license are well understood long back. Grossman and Hart (1986) showed the potential hold-up problems are reduced as ownership offers a higher degree of residual control rights than a license does. In the empirical literature, we find evidence of selling the rights in Seranno (2010), which studies the transfer of ownership of patents, and finds proportion of transferred patents is large and differs across technology fields. Odasso et. al. (2015), studies impact of patent bibliographic indicators and patent characteristics on the economic value of patents put on sale in an auction, considering different typologies of sellers and buyers.

The rest of the paper is organized as follows. In section 2, we lay out the model. The licensing game is analyzed in detail in section 3. We analyze the selling game in section 4 and draw our main conclusion based on the analysis in sections 3 and 4. We take up the welfare analysis in section 5. Section 6 discusses some robustness issues related to our modeling structure. Finally section 7 concludes.

2. The Linear City Model:

Consider two firms, firm A and firm B located in a linear city represented by an 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 but possibly different marginal costs of production and compete in prices. We assume that consumers are uniformly distributed over the interval $[0,1]$. 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 and it is borne by the consumers.[6]

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 an outside innovator (an independent 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

[6]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 while competing in prices and in this paper, we assume the firms to be at the extremes of the city. Thus, existence related issues do not arise. For further interesting discussions on the existence on of equilibrium location of firms which can even be influenced by the mode technology transfer in a linear city framework, see Matsumura et al. (2010).

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 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.

2.1. Absence of Outside Innovator – Pre-Innovation

First we examine the case where the outside innovator is not there and two firms A and B compete in the market with their respective old production technologies. 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 without loss of generality. We assume that $\delta \leq 3t$ so that the less efficient firm's equilibrium quantity is positive at the pre-innovation stage. Equilibrium prices, demands and profits can be given as:

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

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

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

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

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

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

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

3. Presence of Outside Innovator – The Licensing Game

Now we consider the presence of an outside innovator. 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 assumed that when one license is offered by the innovator and 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 the license, 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.

Given above we consider different forms of licensing and systematically analyze them one by one. 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:

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

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

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

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

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

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

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 $F_A^* = \frac{1}{18t}(3t + \delta + \epsilon)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2 = \frac{2\epsilon(3t+\delta)}{9t}$ from firm A. If the innovator licenses it to firm B it can charge $F_B^* = \frac{1}{18t}(3t - \delta + \epsilon)^2 - \frac{1}{18t}(3t - \delta - \epsilon)^2 = \frac{2\epsilon(3t-\delta)}{9t}$ from firm B. Comparing we get that it is optimal for the innovator to license it to the efficient firm and therefore $F_A^* = \frac{1}{18t}(3t + \delta + \epsilon)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2 = \frac{2\epsilon(3t+\delta)}{9t} = R_F^*$ will be the optimum revenue of the innovator.

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

Under this scenario, if firm A accepts the contract, it becomes a monopoly and its payoff becomes $(\epsilon + \delta - t) - F_A$. Firm A's no-acceptance payoff is $\frac{1}{18t}(3t + \delta - \epsilon)^2$ if firm A rejects and firm B gets the license. Therefore, firm A will accept the license iff $F_A \leq (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta - \epsilon)^2$. Again if firm B is offered the license then both firms remain in the market and firm B's payoff will be $\frac{1}{18t}(3t - \delta + \epsilon)^2 - F_B$. If firm B rejects then firm A would have been offered the contract and in that case firm B would have received zero. Thus the maximum that can be extracted from firm B is $F_B = \frac{1}{18t}(3t - \delta + \epsilon)^2$ and comparing one can see that firm A will again be offered the license for $3t - \delta < \epsilon < 3t + \delta$. 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, it becomes a monopoly and its 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. Thus, in this situation firm A will accept the contract iff $F_A \leq (\epsilon + \delta - t)$. Similar analysis will show that firm B will accept if $F_B \leq (\epsilon - \delta - t)$. Once again the efficient firm A will be offered the contract and therefore the revenue of the outside innovator will be $R_F^* = (\epsilon + \delta - t)$.

Thus under both drastic and non-drastic innovations the outside innovator is better-off licensing it to the efficient firm i.e. firm A. This is due to the fact that the maximum willingness to pay for the efficient firm is always higher than the inefficient firm therefore it is optimal for the innovator to license it to the efficient firm since it can extract more from the efficient firm. Later we will also see that the above intuition is actually 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 marginal costs of both firms fall by ϵ and the relevant variables can be calculated as follows:

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

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

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

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

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

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

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 consider 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 that if firm A accepts and B does not then firm A becomes a 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 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: for a given cost reduction the marginal increment in market share is more for the efficient firm compared to the inefficient firm leading to a greater increase in profit for the efficient firm. Also given the assumption that if the firm rejects, the license goes to the other firm, the efficient firm's potential loss from not accepting is also higher compared to the inefficient firm. Therefore the efficient firm's net gain from the new technology vis-à-vis no acceptance is higher compared to the inefficient firm leading to its higher willingness to pay 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 and the effective cost difference remains the same. This effect drives down gains for both the firms and thus the outside innovator will be able to extract less from both the firms compared to that of the efficient firm since the efficient firm's net gain after cost reduction exceeds the sum of gains of both the competing firms with reduced cost. 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.

Next we look into the auction policy. We summarize the main results below. We relegate the analysis of auction policy to Appendix 1 as we show that auction policy is sub-optimal here.

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

The intuition of the above lemma is not difficult to comprehend since the efficient firm's net gain will always be higher than the inefficient firm and therefore the efficient firm can always outbid the inefficient firm and win the auction. Technically the efficient firm can always bid 'epsilon' higher than the inefficient firm and win the auction and therefore the auction effectively plays out like a second price auction.

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

When two licenses are offered both firms' cost gets reduced and the competitive effect drives down possible gain from technology licensing for both the firms compared to the case when only one firm gets the license. Therefore when two licenses are offered, both firms will optimally bid less since the net gain vis-à-vis not accepting is much lower and this is known to both firms under complete information. The efficient firm knows that it can just bid enough (equal to the inefficient firm's bid) to get the license. All these above effects drive down the bids of both the efficient and the inefficient firm and the total revenue which is equal to twice of the inefficient firms bid falls short of the efficient firms bid when only one license is offered. Thus the outside innovator can extract more when only one license is auctioned and it goes to the efficient firm.

Comparing the payoffs of the innovator between fixed fee licensing and auction policy, we find that following is true.

Proposition 3: *Fixed fee licensing is always better than auction for the innovator.*

Since the optimal auction mechanism described (see Appendix 1) plays out like a second price auction, the innovator could only reap the second highest willingness to pay. But with complete information under fixed fee licensing the outside innovator can extract the maximum willingness to pay of the efficient firm with a 'take-it-or-leave-it' offer which is always greater than the second highest willingness to pay in the auction mechanism. Thus fixed fee licensing to the efficient firm will always provide greater return to the outside innovator vis-a-vis auction policy.

Now, we proceed and analyze royalty licensing in detail.

3.2. Royalty licensing:

3.2.1. Royalty licensing to one firm:

Again to start with, 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 $\frac{3t+\delta+\epsilon}{2} > \epsilon \; \forall \; \epsilon \leq (3t + \delta)$. Therefore in this case the optimum r will be set at $r^* = \epsilon$ which is the upper bound of r.[8] The revenue of the innovator will be $Rev_A^r = \frac{\epsilon}{6t}(3t + \delta)$. 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 it can be shown that firm A cannot gain be rejecting[9]. Therefore, firm A is weakly better-off accepting this contract. If $\epsilon > (3t + \delta)$ then there can be two cases. Since the technology transferred is drastic, if r is not sufficiently high then firm A will become a monopoly and firm B has to go out of the market. That critical royalty rate can be easily calculated as $r = \epsilon - 3t + \delta$ and at this royalty rate the effective cost reduction is $3t - \delta$ which is sufficient to drive out firm B from the market. If this is the case then the innovator's revenue will be $(\epsilon - 3t + \delta)$ as the monopolist now caters the entire market. But if r is higher than this then both firms will exist in the market. In that case the optimum royalty charged by the innovator will be $r^* = \frac{3t+\delta+\epsilon}{2}$ and the innovator's revenue will be $Rev_A^r = \frac{(3t+\delta+\epsilon)^2}{24t}$. We need $\frac{3t+\delta+\epsilon}{2} > \epsilon - 3t + \delta$ and this leads us to the restriction $\epsilon < 9t - \delta$. Therefore the innovator's optimal royalty contract and the revenue can be characterized as follows: $r^* = \epsilon$ and $Rev_A^r = \frac{\epsilon}{6t}(3t + \delta) \forall\, \epsilon \leq (3t + \delta)$, $r^* = \frac{3t+\delta+\epsilon}{2}$ and $Rev_A^r = \frac{(3t+\delta+\epsilon)^2}{24t}$ if $(3t + \delta) < \epsilon < 9t - \delta$ and finally $r^* = \epsilon - 3t + \delta$ and $Rev_A^r = \epsilon - 3t + \delta \forall\, \epsilon > 9t - \delta$. In all the above cases firm A is better off accepting the royalty contract.

Now if the innovator decides to license to firm B then it will maximize rQ_B and the optimal royalty rates and revenue can be calculated similarly as $r^* = \epsilon$ and $Rev_B^r = \frac{\epsilon}{6t}(3t - \delta) \forall\, \epsilon \leq (3t - \delta)$, $r^* = \frac{3t-\delta+\epsilon}{2}$ and $Rev_B^r = \frac{(3t-\delta+\epsilon)^2}{24t}$ if $(3t - \delta) < \epsilon < (9t + \delta)$ and finally $r^* = \epsilon - 3t - \delta$ and $Rev_B^r = \epsilon - 3t - \delta \;\forall\, \epsilon > 9t + \delta$. One can check that $Rev_A^r \geq Rev_B^r$ for all values of ϵ with strict inequality for some ϵ and therefore the innovator will optimally offer the license to firm A. Therefore in case of royalty licensing to one firm the innovator offers license to firm A and the optimal revenue for the innovator will be $Rev_R^* = \frac{\epsilon}{6t}(3t + \delta), \forall\, \epsilon \leq (3t + \delta)$, $Rev_R^* = \frac{(3t+\delta+\epsilon)^2}{24t}$ if $(3t + \delta) < \epsilon < 9t - \delta$ and $Rev_R^r = \epsilon - 3t + \delta \forall\, \epsilon > 9t - \delta$ where Rev_R^* denotes optimal

[8] We assume royalty rate $r^* \leq \epsilon$, so that the potential licensee has the incentive to accept the licensing contract. In the literature, this is also called antitrust constraint as license contracts are regulated by antitrust authorities that interfere if they suspect collusive schemes that are geared to raise the equilibrium price (see Fan et al. 2017).

[9] In fact it can be shown that firm A will be weakly worse off by rejecting $\forall\, \epsilon \leq (3t + \delta)$.

revenue for the innovator when it licenses to only one firm. We can state our above finding succinctly in the next proposition:

Proposition 4:

In case of royalty licensing to only one firm the outside innovator always offers the license to the efficient firm.

Since the efficient firm produces more output (at least weakly) compared to the inefficient firm and also the royalty rate is higher for the efficient firm, the revenue for the outside innovator is always higher when it licenses to the efficient firm compared to when it licenses to the inefficient firm. Therefore the innovator will always license it to the efficient firm. Next we consider the possibility of royalty licensing to both firms.

3.2.2 Royalty Licensing to both Firms:

Consider the case where the outside innovator licenses the technology to both firms through per-unit royalty licensing. Since the total output produced by both the firms add up to one, it is optimum for the innovator to charge $r = \epsilon$ to both the firms and the innovator's maximum possible payoff will be ϵ.[10] One can also look at individual firm incentives and rule out asymmetric royalty rates at the equilibrium: Suppose we assume asymmetric royalty rates for both firms 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

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

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

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

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

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

[10]Market is covered according to our assumption and size of the market is assumed to be one.

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

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 have already argued that the innovator is better off charging r as close to ϵ as possible and in fact at the optimum $r = \epsilon$, 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.

So to make both the firms accept we need to assume symmetric royalty rates, without loss of generality. Therefore, assuming $r_A = r_B = r$ when both firms get the license, from (27) and (28) we get that the industry output is one, 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 $Rev^*_{royaltyBoth} = \epsilon$. We have already shown that both firm A and B will accept this symmetric royalty contract.

We don't need to distinguish between drastic and non-drastic innovation in this case as the effective unit cost remains unchanged for both firms and the preceding analysis is relevant for innovation of all sizes. Now for $\delta < 3t$ (true by assumption), it is easy to check that $\epsilon > \frac{\epsilon}{6t}(3t + \delta) \forall \epsilon \leq (3t + \delta)$; $\epsilon > \frac{(3t+\delta+\epsilon)^2}{24t} \forall (3t + \delta) < \epsilon < 9t - \delta$; and $\epsilon \geq \epsilon - 3t + \delta \forall \epsilon > 9t - \delta$. Therefore, in case of royalty licensing offering two licenses is always optimal for the innovator.

Given above, we can state our next proposition:

Proposition 5:

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

When the innovator offers a symmetric royalty contract to both the firms the optimal royalty is set at ϵ and since the market is fully covered the total industry output is one. Thus given the constraint that $r \leq \epsilon$, the maximum possible revenue that the innovator can garner is ϵ. The innovator cannot do better compared to this while offering the royalty contract to a single firm whose output is less than the total market output. Thus it is optimal for the outside innovator to offer the royalty licensing contract to both the firms.

One can consider a two-part tariff licensing contract which is a mixture of fixed fee licensing and royalty licensing. The optimal two-part tariff licensing offered to both firms is in fact royalty licensing with royalty rate equal to ϵ and fixed fee equal to zero. It can be shown that the two-part tariff licensing is never optimal and is either inferior to royalty or fixed fee licensing for all kinds of innovations. The result on two-part tariff licensing is summarized in Appendix 1 as Lemma 2.

Thus without loss of generality we can focus fixed fee licensing and royalty licensing contracts to find the optimal licensing policy for the innovator. The next section follows on that.

3.3. Optimal Licensing Policy

We know when one license is offered then fixed fee licensing to a single firm is optimal. When two licenses are offered then pure royalty licensing to two firms is optimal. Therefore, to get the optimal licensing contract we need to compare the payoff of the outside innovator from single firm fixed fee licensing to the efficient firm 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 6:

(a). If the innovation is non-drastic and when $\epsilon < 3t - \delta$ then royalty licensing to both firms is optimal if and only if $\delta \leq \frac{3t}{2}$. Otherwise fixed fee licensing to the efficient firm is optimal. The payoff to the innovator $R^* = \epsilon$ if and only 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 $\delta \leq t$ (sufficient condition). Moreover there exits $\delta^* \in [0, 3t] \forall \epsilon \in (3t - \delta, 3t + \delta)$ such that royalty to both firms is optimal if and only if $\delta < \delta^*$, otherwise fixed

fee licensing to one firm is optimal. The payoff to the innovator $R^* = \epsilon \ if \ \ \delta < \delta^*$, *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 and only if* $\delta \leq t$. *Otherwise fixed fee licensing to the efficient firm is optimal. The payoff to the innovator is* $R^* = \epsilon$ *if and only if* $\delta \leq t$, *otherwise* $R^* = \epsilon + \delta - t$.

Summary and Intuition: If one license is offered, it would be the fixed fee licensing to the *efficient* firm. If two licenses are offered then it must be pure royalty licensing to *both* firms. If the option is to choose between one or two licenses, then if cost differentials between the licensees are relatively small compared to the transport cost, royalty is chosen; otherwise optimal licensing is fixed fee.

The reason can be found from the revenue expressions from fixed fee licensing. First note that for all non-drastic innovations the revenue from fixed fee licensing increases with ϵ and this increment is increasing in the cost difference of firms. Thus the benefit from technology transfer through fixed fee increases the more 'efficient' the efficient firm is and therefore if δ is sufficiently high then this benefit will outweigh the maximum benefit from royalty licensing to both firms which is ϵ. Thus for sufficiently high δ technology transfer through fixed fee licensing is optimal otherwise royalty to both firms are optimal.

For drastic innovation firm A serves the entire market by charging the limit price $\epsilon + \delta - t$. This price increases with δ as well. If δ is sufficiently low implying that the efficient firm's cost advantage is sufficiently low in the sense of $\delta < t$, the limit price falls below ϵ . Therefore for smaller efficiency difference royalty to both firms are always optimal. Note that in case of royalty licensing to both firms, no firm goes out of the market since the cost difference remains the same. Thus, we find initial cost asymmetries of the potential licensees as well as the transport costs matter, so far as the optimal mode of licensing for the innovator is concerned.

We find a mix of royalty and fixed fee as optimal licensing contracts in our spatial framework, which is also consistent with the empirical findings mentioned earlier.

It is also noteworthy that if $\delta = 0$, the optimal licensing strategy is royalty to both firms irrespective of the size of innovation which is exactly the result shown in Poddar and Sinha (2004) with symmetric firms. Thus from that angle our paper is a generalization of Poddar and Sinha's (2004) pioneering work on technology licensing in spatial competition. Moreover, we also get additional results in our framework with $\delta > 0$.

In our results, overall one can conceive of two countervailing effects: the innovator has an incentive to increase the market power (of the efficient firm) by offering one license to the efficient firm. This leads to increased possible payoff for the innovator. On the other hand increased market power of one firm (the efficient firm in this case) leads to reduced competition and in essence greater transportation cost and lower willingness to pay for the consumers which in turn hurts the outside innovator. This tradeoff becomes important in determining the optimal mode of technology licensing. If the efficient firm is too efficient then the first effect dominates and optimal technology licensing is fixed fee to the efficient firm. But if the firms are sufficiently close (in terms of cost) then creating market power (higher price and lower quantity) doesn't benefit the innovator much in generating revenue and the second effect kicks in. This is the situation where the innovator charges royalty per-unit from both firms and extracts the maximum cost difference per-unit from both the firms (and hence on the entire market output). Intuitively, in case of two royalties, lower price but the quantity expansion effect (full market) dominates in extracting a higher revenue. [11]

4. Selling Game:

We now 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*.

[11]We thank an anonymous referee for suggesting this alternative intuition.

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 $F^{TPT} = \frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2$.[12] Firm A's total payoff in case of two-part tariff will be $\frac{1}{18t}(3t+\delta)^2 + \epsilon + \frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2$. This is the maximum that firm A can get by licensing the technology to firm B. If firm A 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 potentially charge $F^{Sell} = \epsilon + \frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2 - \frac{1}{18t}(3t+\delta-\varepsilon)^2$. 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 optimal two part tariff contract offered by firm A will be $r^{TPT} = \epsilon$ and $F^{TPT} = \frac{1}{18t}(3t-\delta)^2$ since the no-licensing payoff of firm B is zero as $\epsilon > 3t - \delta$. 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

[12] In Lu and Poddar (2014), δ is defined as $\delta = c_A - c_B > 0$ hence the difference in the corresponding expressions.

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 again$r^{TPT} = \epsilon$ and $F^{TPT} = \frac{1}{18t}(3t-\delta)^2$. Thus, $\pi_A^{TPT} = \frac{1}{18t}(3t+\delta)^2 + \epsilon + \frac{1}{18t}(3t-\delta)^2$. 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. Since market is covered this 'total possible benefit' from technology transfer is fixed. Now it is up to the 'buyer of the technology' to extract the entire surplus from further licensing which in turn is extracted by the 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, from the above detailed analysis we can state the main result of our paper:

Proposition 7:

It is optimum for the innovator to sell the innovation to any one firm and this holds irrespective of whether the innovation is drastic or non-drastic. The owner firm further licenses the innovation to the rival firm.

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. Therefore selling can reap the 'full' willingness to pay from the 'purchasing' firm which is in turn extracted by the outside innovator and therefore 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. But this 'full' willingness to pay is same for both the efficient and inefficient firm since the inefficient firm can also extract from the efficient firm through further licensing. Thus the identity of the 'buyer' doesn't matter in our model. Following Lu and Poddar (2014) we know that the 'buyer' will subsequently license it to the other competing firm using a two-part tariff.

A crucial difference of our result with Sinha (2016) is that in Sinha's paper it was optimal for the innovator to sell the license to the efficient firm only, whereas in our model the identity of the buyer does not matter. The reason is that in Hotelling structure with full market coverage the market size and the total pie is fixed whereas Sinha (2016) considered Cournot competition where total demand is not fixed. The efficient firm's gain from cost reduction is higher compared to the inefficient firm and also the subsequent gain from further licensing is higher due to higher output expansion of the efficient firm post cost reduction compared to the inefficient firm. Thus in the Cournot structure we have a quantity expansion effect that drives Sinha (2016)'s result which is absent in the Hotelling structure with full market coverage. Therefore in Sinha's model the efficient firm can gain more from technology transfer compared to the inefficient firm and it is optimal for the innovator to sell the license to the efficient firm. This 'identity invariance' selling result is one crucial difference that is worth mentioning which differentiates our contribution to Sinha (2016)'s contribution.

5. Welfare Analysis:

5.1 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 or when $3t - \delta < \epsilon < 3t + \delta$ or$\epsilon > 3t + \delta$ and $\delta \leq t$ holds then royalty licensing to both firms with $r^A = r^B = \epsilon$ is optimal. 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.

(ii). Fixed Fee:

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 consumer's 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.

5.2 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.

5.3 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 8:

Selling of the innovation leads to greater increase in welfare vis-à-vis licensing of the innovation.

The intuition of the above result can be subtly put forward as follows: In the selling game the buyer of the technology can further license it to the other firm, meaning further licensing possibilities exist. Put differently in the selling game the potential transferees can take further action(s) (in addition to setting prices and quantities) that is not present in the licensing game. Therefore in the selling game all possible cost reduction and competitive effects are present which are there in the licensing game. Thus the sum of producers' surplus and the consumer surplus cannot be less in the selling game compared to the licensing game[13]. The above result has an interesting policy implication that selling of 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. This result also distinguishes our paper from Sinha (2016), where welfare analysis is absent. We show that selling patent rights is welfare improving and hence socially optimal. This is another area that differentiates our contribution to Sinha (2016).

6. Discussion[14]:

Few comments on our above analysis are in order: First, throughout our analysis we keep the locations of the firms to be at the extremes of the city and fixed. In this paper location is not the choice variable for the firms. In our model, we assume linear transportation costs of the consumers, and 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. This coupled with the fact that location is not a choice variable in our model, existence related issues do not arise in our model. If we had considered a convex transport cost (say a quadratic cost), then from d'Aspremont et al. (1979), we know that the equilibrium location of the firms always exist and are at the two end-points of the city. So even if we had assumed such cost function, the qualitative results of our model would not have changed.

[13] Therefore, using dialectic liberty, one can say that the selling game has more flexibility (for the potential transferees) compared to the licensing game.

[14] We thank an anonymous referee for encouraging us to comment on certain robustness issues and this section is inspired from those comments. We are grateful to the referee for the thoughtful comments.

Second, a few words on what kind of industry and what nature of competition among firms one can analyze using the location model we use here. We believe that the linear city model described here is appropriate to study the behavior of the firms in industries with developed markets which are not growing and where differentiation over product brands is well established (in our model maximal differentiation) and is not rapidly changing. In a typical location model, with full market coverage, the quantity demanded at each price is not very high and does not change (i.e. inelastic). This particular feature of this location model is important, when we compare across equilibrium profits of the firms under different licensing and/or selling regimes as the aggregate demand (or market size) remains constant across the regimes. In this sense location models have an advantage over standard models of product differentiation (a la Singh and Vives, 1984). In the Singh and Vives (1984) model we have elastic demand. Therefore, it may not be proper to compare equilibrium values across different regimes and this could be misleading because of varying demand. Therefore, we think that the linear city model is a more appropriate place to study the outside innovator's licensing or selling strategies when we consider industries with developed and matured markets with inelastic demand.

Third, one can conduct the above analysis in the Salop circular city framework with full market coverage. We conjecture that all our results will go through in the circular city model as well. In Lu and Poddar (2014), it is shown that for an inside innovator the optimal licensing policy does not change between a circular and linear city model. Taking a cue from that model we conjecture that similar result will hold in case of outside innovator as well. Also, since in our analysis further licensing always takes place post selling, that equivalence part is carried forward in either model. Thus the overall impact on our results will be minimal even if we conduct our analysis in the circular city framework.

Finally, one can possibly consider partial market coverage in the Hotelling structure (with possible output expansion effect) and incentives to license or sell by an outside innovator. We do not expect much change in our basic results since Sinha's (2016) model already has that feature. The result in our paper that can possibly change is that with ex-ante partial market coverage, the innovator might optimally sell it to the 'efficient' firm, a result that we get in Sinha (2016). Therefore the 'identity invariance' selling result might not hold but the private and more importantly social optimality of selling will go through.

7. Conclusion:

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 a given scenario for the innovator. However, the study of patent licensing in a spatial framework of product differentiation is sparse. The characteristics of product differentiation under a spatial framework distinctly differ from standard models of product differentiation. In such spatial framework, we show how the optimal licensing contracts depend on the demand characteristics and cost asymmetries of the licensees as well as on the extent of transport cost. Specifically, we show that when initial cost asymmetry is not that high then royalty licensing to both firms are optimal. But when initial cost asymmetry is sufficiently high then fixed fee licensing to the efficient firm is optimal. These results are new to the literature on patent licensing which is also consistent with the empirical findings. Poddar and Sinha (2004) analyzed optimal licensing strategy for an outside innovator in the Hotelling framework but with symmetric firms. New insights are gained in our model with cost asymmetry. In this sense our paper brings new contribution to the technology licensing literature.

The other main contribution is to allow the outside innovator, the option to sell the property rights of the innovation to one of the competing firms (who can further license if it wishes) is an area very much under-researched (except Sinha 2016). We allow selling in our model and examine the incentive of an outside innovator to sell an innovation to a prospective incumbent vis-a-vis licensing the innovation to potential licensees. Our main finding is that the innovator will always sell the innovation to one of the competing firms rather than licensing it to either one or two firms. Moreover, once the new technology is sold, the recipient firm further licenses it to its competitor resulting in overall greater diffusion of technological knowhow. This happens regardless the innovation is drastic or non-drastic, which has further welfare implications. We see that selling not only maximizes the private value of the innovation, it also maximizes the social value of the innovation resulting in higher social welfare compared to any other mode of technology transfer. The result is fairly robust as it is true irrespective of the size of the innovation as well as any pre-innovation cost asymmetries between the licensee firms.

In future, we would like to extend our analysis to more than two licensees, possibly in a n firm structure. Although we conjecture, that our main result will go through, nonetheless this is an exercise worth doing in the future.

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Appendix 1

A.1Auction Policy:

A.1.1 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 $\frac{2\epsilon(3t-\delta)}{9t}+k$. This mechanism, although a first price auction, effectively plays out like a second price auction since the efficient firm bids and pays the second highest bid (marginally higher).

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

Once again this is the case where Firm A becomes a monopoly if it gets the license but Firm B doesn't. 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 $\frac{1}{18t}(3t-\delta+\epsilon)^2$. One can easily show that $(\epsilon+\delta-t)-\frac{1}{18t}(3t+\delta-\epsilon)^2>\frac{1}{18t}(3t-\delta+\epsilon)^2 \forall\, \epsilon\in[3t-\delta,3t+\delta)$. Therefore, firm A will again win the auction by biding $b_A^*=\frac{1}{18t}(3t-\delta+\epsilon)^2+k$ and again this plays out like a second price auction.

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

Under this situation 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.

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.*

The intuition is not difficult to comprehend since the efficient firm's net gain will always be higher than the inefficient firm and therefore the efficient firm can always outbid the inefficient firm and win the auction. Next we consider auctions where two licenses are offered.

A.1.2 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)[15]. 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).

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).

A.1.3 Two-Part Tariff

Lemma 2:

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

Two-part tariff licensing

(a). If offered to both firms, is in fact royalty licensing and this holds for innovations of all sizes.

(b). Is never optimal to either royalty or fixed fee licensing and this holds for all kinds of innovations.