9-14-2020

Technology Transfer in Spatial Competition when Licensees are Asymmetric

Sougata Poddar

Swapnendu Banerjee

Monalisa Ghosh

Technology Transfer in Spatial Competition when Licensees are Asymmetric

Technology Transfer in Spatial Competition when Licensees are Asymmetric

Sougata Poddar[♣]
Argyros School of Business and Economics
Chapman University, Orange CA 92866, USA

Swapnendu Banerjee
Department of Economics
Jadavpur University, Kolkata 700032, India

Monalisa Ghosh
Department of Economics
Jadavpur University, Kolkata 700032, India

August 2020

Abstract

We study technology transfer in a spatial competition with two asymmetric licensees (firms) with an outside innovator who decides how many licenses to offer and the optimal licensing contract. We show the optimal licensing policy is pure royalty contract to both licensees leading to a complete diffusion of the new technology. The result holds irrespective of the cost differentials between the licensees and for innovation of all sizes, i.e. drastic or non-drastic. This robust finding although supports the dominance of royalty licensing in practice, however consumers may not be necessarily better off. We also throw light on the situation where the innovator sells the patent right to one of the firms. Interestingly, we find that the inefficient firm acquires the new technology and further licenses it to the efficient rival.

Key Words: Outside innovator, Cost-reducing innovation, Patent Licensing, Cost asymmetry, Spatial Competition

JEL Classification: D43, D45, L13.

[♣] Corresponding author: Chapman University, Orange, CA, USA, Email: poddar@chapman.edu

1. Introduction

There is vast literature on technology transfer of cost reducing innovations through patent licensing in the conventional models of quantity (Cournot) or price (Bertrand) competitions. Relatively less attention is given on patent licensing in models of spatial competitions. It is a growing area of research and many questions remained unanswered on the nature of licensing contracts and their robustness. In this paper, we address the problem of an outside innovator (independent research lab), who wishes to license a new cost reducing innovation to the competing firm(s) in a duopoly market under spatial competition. The firms are not symmetric on their costs of production and the product is horizontally differentiated. We capture the horizontal product differentiation through the well-known linear city model (*a la* Hotelling, 1929) where firms are located at the end points of a unit interval and consumers are uniformly distributed over the interval. Each consumer buys exactly one unit the product, hence the demand is inelastic. We assume the market is fully covered, hence the total market demand is fixed.[1] These features of Hotelling's model is fundamentally different from the conventional models of product differentiation in Bertrand and Cournot framework (*a la* Singh and Vives, 1984), where the demand is typically elastic, and also changes with the degree of product differentiation. We believe because of these fundamental differences in the modeling structure, the impact of technology transfer of cost reducing innovations will have different implications on the optimal licensing contracts and the ensuing market equilibrium.

In our study, we have the following game structure. In the first stage, we allow the innovator to decide on the number of licenses to offer, i.e. to decide whether license a single firm or both firms. It is a "once for all offer" (same as take-it or leave-it offer) game. In case, it chooses to license to a single firm, it also decides whether it will license the efficient or the inefficient firm and the offer game ends there. The firm(s) accept or reject the offer. In the second stage, the firms compete in prices in the product market regardless whether the offer(s) is accepted or rejected. In this paper, we are particularly interested to see the implications of a

[1] In other words, we are looking into matured markets with established brands. As an example, think of a well-developed 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. Other examples include competition between well-known brands in food and beverage industry in the developed fast food markets.

‘once for all offer’ from the innovator on the licensing policies. We discuss the significance of this particular feature of the game later. First we provide an overview of our main findings.

The main results of the study are as follows. Under fixed fee licensing, if one license is offered, the innovator will always choose to license the efficient firm. The main result under fixed licensing is to license both firms for smaller size of innovations, otherwise license only to the efficient firm. In the case of auction, when one license is auctioned it will be always won by the efficient firm, and is also better than auctioning two licenses for the innovator. Comparing between fixed fee and auction, we get ‘by-an-large’ if the initial cost difference between firms are sufficiently high then fixed fee licensing to the efficient firm is optimal whereas if the cost difference is not that high then auctioning of the license to the efficient firm is optimal. When we consider pure royalty licensing, if one license is offered, it will be always offered to the efficient firm. However, it is optimal to the innovator to offer two licenses under pure royalty. As for the overall optimal licensing for the innovator is concerned, we find a very robust finding, namely, offering pure royalty contracts to both firms is always optimal, and it is true irrespective of the size of innovation, drastic or non-drastic; or the degree of cost asymmetry of the licensees. A complete diffusion of technology also happens in the equilibrium as both firms get the new technology. Fixed fee or auctioning of license(s) are never optimal in this environment. Thus, this result also supports the overall dominance of royalty contracts in practice. To this end, it is also important to note that from the point of view of the competition authority, encouraging fixed fee licensing to both firms would lead to maximization of consumer surplus due to uniform decrease in costs of production of the firms which also lower the final prices of the product. However, from the point of view of the innovator it is optimal to offer two licenses using the royalty licensing scheme. Thus both from the innovator and regulatory perspective offering two licenses are optimal but the nature of the contract will be different.

We further extend our analysis to see if instead of licensing, the innovator wishes to transfer the technology by selling the right of the new innovation to one of the firms. Interestingly, when it comes to selling, we find that the innovator will always choose the inefficient firm to sell the technology. Transferring the new technology to an inefficient firm only is a new finding that was never found in the literature of patent licensing. In other papers, where selling the technology is considered with asymmetric licensees, either it is sold to the efficient firm only (Sinha 2016) or sold to any firm, i.e. cost asymmetry did not matter (Banerjee and Poddar 2019). This implies the nature of competition and the play of the game (e.g. once for all offer contract) actually matters. Noting this and other results we obtain here, below we motivate our analysis of "once for all offer' technology transfer mechanism and its implication from a managerial and regulatory policy perspective.

1.1 Once for all offer – relevance and related study

First of all, we would like to say that once for all or take-it or leave-it offer from the innovator to potential licensees is not new in the industries and majority of the papers in the licensing literature follow this same game structure (starting from Katz and Shapiro (1986), Kamien and Tauman (1986), to the recent ones Poddar and Sinha (2004), Sen and Tauman (2007), Sinha (2016) among many others). It is just that the term take-it or leave-it (i.e. once for all) offer is not explicitly mentioned in the papers. As an exception, Banerjee and Poddar (2019), relaxed the assumption of once for all offer, and looked into the case when an initial offer from the outside innovator is rejected by one licensee, the game continues and the offer goes to the other licensee. In other words, the game in Banerjee and Poddar (2019) has a sequential structure as far as the licensing offer from the innovator is concerned. Because of this fundamental change in the time structure of the licensing game, Banerjee and Poddar (2019) show optimal licensing policies not only depend on the innovation size, but also on the degree of cost asymmetry between the licensees. As the time structure changes, so does the opportunity cost (payoff from outside options) of the licensees which in turn drive the results differently. It is interesting to see when we bring back the more familiar, take it or leave it type offer (time) structure in the context of *asymmetric licensees*, would there be any further implications on the licensing policies. As we show in this study, our results here have an affirmative answer to this question. In particular, we show that the optimal licensing policy neither depends on the size of the innovation nor on the cost asymmetry between the licensees.[2] Therefore, the time structure of the licensing game matters. However, at the same time we would like to point out that equilibrium licensing contract obtained in the take-it or leave-it offer game is (weakly) sub-optimal to the innovator compared to the equilibrium licensing contract offered in the sequential licensing offer game (Banerjee and Poddar 2019).

[2] We understand which time structure in the offer game is preferred is an open question. But we do not get into that debate here.

Now moving on to the practical side, why a take-it or leave-it offer will be generally more attractive to the innovator? Simply because, this offer will be overall less costly (both in terms of real time and real cost) as opposed to sequential offers to the innovator and participating firms. Here for simplification we have two potential firms/licensees, but when we have n asymmetric potential licensees, just assuming a very little cost of delay to the innovator if the offer is rejected in every round, the overall cost to execute the contract to innovator will be prohibitively high. Hence not realistic for the innovator to follow that path. This is also probably the main reason in the literature of patent licensing where we see most of the papers only consider take-it or leave-it offer games, which is indeed practically relevant and observed in most industries. It is of no surprise that most of the licensing contracts in the industries originate from once-for-all i.e. take-it or leave-it offer structures which is closely studied in this paper.

We provide a recent example. Bounie et. al. (2019) examine the strategies of a data intermediary selling customized consumer information to firms for the purpose of price discrimination. Among other data transfer mechanisms they also consider a take it or leave it offer where the data seller doesn't offer the second firm if the first firm declines the offer. They show that for the data intermediary take it or leave it offer is not optimum although consumer surplus is maximum under take it or leave it offer. Thus a data protection authority or a regulatory authority seeking to maximize consumer surplus might find it optimal to implement the take it or leave it offer type data transfer mechanism.

It is also true that a wide variety of licensing mechanisms turn out to be optimal depending on the modeling structure is also verified by the theoretical literature on patent licensing. However, in the empirical literature, we do see a prevalence of one particular kind of licensing contract, namely per-unit royalty. For example, 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. 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). More recently, Thursby et.al (2001) find royalties are most frequently used with 81% of respondents "almost always" use royalties, while 16% report "often" using royalties. Our once for all offer modeling structure here, which provides royalty as the only robust optimal licensing contract from the innovator, does also provide additional support of dominance of royalty in practice although the welfare of the consumers may not get maximized.

Therefore, both from theoretical and empirical perspective, it is important to identify the specific game structure or the play of the game and its implications on the outcome. This study aids in providing a robust foundation on the theory of technology transfer through various licensing schemes in oligopolistic markets when firms are asymmetric. The specific role of once for all offer in this paper essentially makes a case in support of the above objective and fills a gap in the literature.

1.2 Market for technology, number of licenses and factors that affect licensing – managerial and regulator perspective

To explore the facts mentioned above, we needed to do a systematic analysis. To do that in this paper, we also focus our attention on the following issues.

(i) The implication when the outside innovator decides how many licenses to offer (one or two) when there are two asymmetric potential licensees

(ii) Consider all possible available licensing schemes, namely fixed fee, auction, and royalty; and the optimal licensing contract of the innovator

(iii) Find whether a complete diffusion of the new technology occurs in the equilibrium and its implication on consumer welfare

(iv) Instead of licensing, other form of technology transfer for cost reducing innovation, namely selling the patent right to one of the firms

We try to find an answer to all of the above in this study from a policy and managerial perspective. For example, under Banerjee and Poddar (2019) game structure when offering one license is optimal (the case of fixed fee), complete diffusion of technology does not happen, while in our 'once for all offer' game structure, it always happens as both firms get the new technology (under royalty) in equilibrium under optimal licensing. Secondly, even if complete diffusion of technology happens under our game structure, however, consumer surplus is actually maximized when complete diffusion of technology happens through fixed fee contracts to both firms. Some of these outcomes need to be noted.

This paper can also be linked to the work by Rey and Salant (2012) in a vertical structure (upstream-downstream firms). They argue that an upstream patentee might not offer more numbers of licenses since it dissipates downstream firms payoffs through increased competition and therefore reduces possible extraction payoff of the upstream patentee. We see similar effect in our study in the case of auction policy licensing and also the fixed fee licensing scheme where the patentee might optimally offer a single license to reduce the competition effect. Further study by Gambardella (2002), Gambardella, Giuri and Luzzi (2007), Arora and Gambardella (2010) focus on the market for technologies and factors that affect licensing and technology transfer. These papers focus mainly on the transaction costs that are present in these kinds of markets and its impact on the transfer of new technologies and its welfare impacts on the firms and the consumers. In our paper, however there are no information frictions but the optimal number of licenses and the extent of technology diffusion crucially depend on the type of technology transfer regime chosen by an outside innovator which has important policy implications.

1.3 A brief survey relevant to licensing in spatial competitions

Earlier Poddar and Sinha (2004) analyzed optimal licensing strategy for an outside innovator in the Hotelling framework but with *symmetric* firms only. Here we extend that analysis where the potential licensees are asymmetric. Lu and Poddar (2014) examined various licensing schemes of an *insider patentee* in an asymmetric duopoly model of spatial competitions and found a fairly robust outcome that two-part tariff licensing is optimal among all possible licensing arrangements. Given that analysis with an insider patentee, a natural question would be to follow up, what happens when the patentee is an *outsider* and there are two asymmetric potential licensees in a spatial framework? We answer that question in this paper with the added feature of 'once for all offer'.

Muto (1993), using a standard (non-spatial) product differentiation framework and *price* competition with an *outsider* patentee, showed that only royalty licensing is optimal (compared to auction and fixed fee). From Muto (1993) and from our present analysis here, broadly one thing that comes out is, royalty licensing is generally optimal in a model of product differentiation (spatial or non-spatial) with *price* competition and *outsider* patentee. This outcome can be contrasted with the earlier literature on patent licensing where fixed fee licensing is generally shown to be optimal with an *outside*r patentee under *quantity* competition and royalty licensing is typically optimal with an *insider* patentee. Kabiraj (2004) analyzes optimal technology licensing when the market is characterized by Stackelberg competition and shows royalty dominates other modes when the innovation size is small. For larger innovations, while fixed fee dominates royalty; auction is optimal from an outside innovator's perspective.[3]

Among other studies in spatial competition, Kabiraj and Lee (2011) considered an insider patentee model and showed how the existence of a royalty equilibrium can depend on the transport cost. On the other hand, Matsumura and Matsushima (2008) and Matsumura et. al. (2010) endogenize the location choice of the firms in an insider patentee model and show how the technology transfer recovers the existence of a location equilibrium in pure strategies. In this paper, we assumed fixed locations of the firms and focused on the optimal modes of technology transfer.

The rest of the paper is organized as follows. In section 2, we lay out the model. Different licensing schemes are analyzed in detail in section 3. Section 4 discusses the extension to the selling game of patent right. Section 5 concludes the paper.

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 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.[4]

The utility function of a consumer located at x is given by:

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

[3] In a 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 (1984, 1986), Kamien et al., (1992), Stamatopolous and Tauman (2009)); whereas per-unit royalty contract is optimal when the patentee is an insider (see Wang (1998), (2002), Kamien and Tauman (2002)).

[4] 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. 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.

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

We assume that the market is fully covered and the total demand is normalized to 1. 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) who has a cost reducing innovation. The innovation helps reduce the per-unit marginal costs of the licensee firm(s) uniformly by ϵ. ϵ is also known as the size of the innovation. The innovator has the option to choose number of licenses i.e. licensing the innovation to a single firm or both firms. We will consider different forms of licensing viz. fixed fee licensing, auction policy and royalty 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.[5]

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). The firm(s) (potential licensees) accepts or rejects the offer. In case of offering one license, if the first firm rejects the game ends and firms get their pre-licensing profits.

Stage 2: The firms compete in prices and products are sold to consumers.

2.1. Absence of Outside Innovator – The Pre-Licensing Game

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 us denote the constant marginal costs of production of firms A and B by c_A and c_B respectively and define $\delta =$

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

$c_B - c_A$. To fix ideas, suppose $\delta = c_B - c_A > 0$, i.e. firm A is the efficient firm without loss of generality. We also 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 equilibrium prices, demands and profits can be given as:

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

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

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

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

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

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

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 and firm B goes out of the market. On the other hand, if the outside innovator licenses to firm B i.e. the inefficient firm, then firm B becomes monopoly and firm A goes out of the market only when $\epsilon > 3t + \delta$. Now what is interesting to note is that when two licenses are offered, if the first firm rejects, the offer can potentially be accepted by the second firm. So when $\epsilon > 3t - \delta$ but $\epsilon < 3t + \delta$ then if firm A rejects and B accepts, firm B doesn't become a monopoly since the size of the innovation is not sufficient to drive firm A out of the market. Similarly for $3t - \delta < \epsilon < 3t + \delta$ when only one license is offered and it is offered to the inefficient firm B and it accepts, firm A doesn't go out of the market. Hence in our context, an innovation is drastic only when $\epsilon > 3t + \delta$, otherwise it is non-drastic.

Now we consider different forms of licensing one by one. We start with fixed fee licensing.

3.1 Fixed Fee Licensing

3.1.1: Fixed fee licensing to one firm

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:

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

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

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

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

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

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

One can also work out the above expressions when the innovator licenses its innovation to firm B.

We show when one license being offered under fixed fee, the efficient firm will always be offered the license for all kinds of innovations, drastic and non-drastic. Since the maximum willingness to pay for the efficient firm is always higher than the inefficient firm, the outside innovator can always extract more from the efficient firm. Thus it is optimal for the innovator to license it to the efficient firm and we state that formally in the following lemma:

Lemma 1: *When only one license is offered under fixed fee the innovator will always license it to the efficient firm.*

Proof: See Appendix 1.

Next we consider the possibility of the innovator offering more than one license, viz. two licenses in this case.

3.1.2. Fixed Fee Licensing to both Firms

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:

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

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

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

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

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

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

Now since both firms are offered the license if any one firm rejects, the other firm can potentially accept the contract. Thus the no-acceptance outside option payoffs of both the firms is not the pre-licensing payoff anymore. The no-acceptance payoff of any one firm will be calculated assuming the other firm accepts the contract.

Comparing the revenues earned by the outside innovator from licensing to a single firm (efficient firm) and both firms, we find the innovator will always opt to license the technology to the efficient firm A if the innovation size is sufficiently high, i.e. $\epsilon \geq \frac{2(3t-\delta)}{3}$. Otherwise if the innovation size is sufficiently low such $\epsilon < \frac{2(3t-\delta)}{3}$ holds the innovator will license to both the firms. We state the result below:

Proposition 1: *Under fixed fee licensing, the outside innovator will license the innovation to both firms if* $\epsilon < \frac{2(3t-\delta)}{3}$ *holds, otherwise it will license it to the efficient firm for all* $\epsilon \geq \frac{2(3t-\delta)}{3}$.

Proof: See Appendix 2.

The intuition of the above result can be given as follows: when the innovation size is small i.e. when $\epsilon < \frac{2(3t-\delta)}{3}$, the gain to the efficient firm of obtaining the licensing vis-à-vis no licensing (i.e. the outside option) is low compared to obtaining license when the innovation size is big i.e. when $\epsilon \geq \frac{2(3t-\delta)}{3}$. Therefore the gain for the innovator from extraction remains low if it licenses to the efficient firm when innovation size is small. In this scenario, the innovator optimally licenses the technology to both firms since the total added-up net payoff of both the firms exceed that from licensing the single efficient firm only. But for relatively large size of innovation, i.e. $\epsilon \geq \frac{2(3t-\delta)}{3}$, the efficient firm's gain from the new technology vis-à-vis no licensing (i.e. the outside option) is sufficiently high and more compared to added-up net payoff of licensing to both the firms. When the innovation is licensed to both the firms then costs of both the firms get reduced and the competition effect drives down the gains of both firms. Thus the outside innovator extracts less under this case of large innovation. Therefore, in equilibrium we get that the innovator will be able to extract more from both firms if $\epsilon < \frac{2(3t-\delta)}{3}$ whereas it will license the technology only to the efficient firm if $\epsilon \geq \frac{2(3t-\delta)}{3}$.

This result is in stark contrast to Banerjee and Poddar (2019), Sinha (2016) where under fixed fee licensing the innovator will always license its innovation to only one firm viz. the efficient firm. In our case with once-for-all offer the no-acceptance payoff (outside option payoff) is same as pre-licensing payoff which is higher compared to the case where the offer goes to the other firm (if rejected by the initial firm) as assumed in Banerjee and Poddar (2019). Thus a change in the rule of the game, viz. once-for-all contract adds new dimension by increasing the outside option payoff of no-acceptance and we get an interesting twist in our perceived knowledge on technology licensing under fixed fee. But from a normative point of view note that consumer surplus will be higher if the innovator licenses it to both the firms, resulting in lowering of costs for both the firms and lower prices of both the products. Therefore there is a case for the competition authorities to enforce licensing to both firms for all innovation sizes which guarantees a level playing field and increased consumer surplus.

Next, we analyze licensing through auction policy.

3.2. Auction Policy

In case of auction policy when one license is offered/auctioned both firms can potentially win the license depending upon the bids. Therefore both firms know that if it doesn't win then the other firm can potentially win it and therefore the losing payoff (outside option payoff) is not the no-technology transfer payoff anymore. This case is conceptually similar to the case where if one firm doesn't win then the other firm gets the license even with once for all offer. In case of two licenses being offered the no-acceptance payoff will be calculated as if the other firm can potentially win the contract and therefore will be similar to the one license auction case.

3.2.1. Auction Policy - Only one license offered

We first consider the case where only a single license is being auctioned. We first consider the non-drastic cases.

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

Suppose the innovator wants to license its innovation to only one firm through 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, firm A's payoff will be $\frac{1}{18t}(3t+\delta-\epsilon)^2$. Therefore, firm A will be willing a bid a maximum amount $\frac{1}{18t}(3t+\delta+\epsilon)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2 = \frac{2\epsilon(3t+\delta)}{9t}$. Similarly firm B will be willing to bid the maximum amount $\frac{1}{18t}(3t-\delta+\epsilon)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 = \frac{2\epsilon(3t-\delta)}{9t}$. Since the inefficient firm B's bid is always less than efficient firm A's bid, 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 $k \approx 0$. The outside innovator's payoff will be $Rev^*_{Auctionsingle} = \frac{2\epsilon(3t-\delta)}{9t} + k$, $k \approx 0$. 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) ($3t - \delta \leq \epsilon < 3t + \delta$):

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 therefore $Rev^*_{Auctionsingle} = \frac{1}{18t}(3t - \delta + \epsilon)^2 + k$. In this case also the auction mechanism plays out like a second price auction and firm A always wins it.

Next we consider the drastic innovation case.

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

Under this situation if firm A wins its payoff from winning will be $(\epsilon + \delta - t)$ but if it loses it gets zero. Similarly firm B's payoff from winning is $(\epsilon - \delta - t)$ and the losing payoff will be zero. Thus firm A will be willing to bid the maximum amount $(\epsilon + \delta - t)$ and firm B will be willing to bid at most $(\epsilon + \delta - t)$. Given complete information, firm A can again win the auction by bidding $b_A^* = (\epsilon - \delta - t) + k, k \approx 0$ and therefore $Rev^*_{Auctionsingle} = (\epsilon - \delta - t) + k, k \approx 0$.

Given above we can state the following lemma.

Lemma 2: *When only one license is auctioned then the efficient firm always wins 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 given complete information, the efficient firm can always outbid the inefficient firm and win the auction.

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)[6]. Both the bidders pay their respective bids. We analyze this below:

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

In this non-drastic case 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's maximum possible bid is $\frac{1}{18t}(3t + \delta)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2 = \frac{\epsilon(6t+2\delta-\epsilon)}{18t}$. 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 $\frac{1}{18t}(3t - \delta)^2 - \frac{1}{18t}(3t - \delta - \epsilon)^2 =$

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

$\frac{\epsilon(6t-2\delta-\epsilon)}{18t}$. 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 $Rev_{AuctionBoth}^* = \frac{\epsilon(6t-2\delta-\epsilon)}{9t}$ and we note that it is strictly lower than the case of a single license being offered.

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

Here, the optimal bids by both the firms will be $\frac{1}{18t}(3t-\delta)^2$ and the revenue of the innovator will be $Rev_{AuctionBoth}^* = \frac{1}{9t}(3t-\delta)^2$. This is lower than $\frac{1}{18t}(3t-\delta+\epsilon)^2$ for $3t - \delta < \epsilon < 3t + \delta$, which is the innovator's payoff of licensing one auction.

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

In this situation both firms will optimally bid $\frac{1}{18t}(3t-\delta)^2$ and the revenue of the innovator will be $Rev_{AuctionBoth}^* = \frac{1}{9t}(3t-\delta)^2$ and this is lower than $(\epsilon - \delta - t)$ which is the innovator's payoff of licensing one auction under this case.

Therefore, given above, one can state our next proposition.

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' costs get 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. This result is similar to what we get in the literature on information selling (Montes et. al. (2018)). Montes et. al. (2018) show that a consumer data supplier would optimally sell the data to one firm and would implement that through an auction mechanism. Also if the data purchasing firms differ in efficiency then it will optimally sell to the efficient firm. What we get here in case of technology licensing is in essence similar to their result on information selling. Even if the firms the symmetric, it is optimal for the innovator to auction the technology to any single firm and not both. Given this we now go for a comparison between fixed fee and auction policy licensing schemes.

3.2.3. Comparing Fixed fee and Auction policy

Now we can compare the payoffs of the innovator from fixed fee licensing and auction policy. The next result throws some light on this.

Proposition 3: *Given a choice between fixed fee licensing and auction policy, we get the following:*

(a). For $\epsilon < \frac{2(3t-\delta)}{3}$, *if* $\delta < \frac{3t}{4}$, *fixed fee to both firms is optimum for* $0 < \epsilon < 2\delta$ *and auction to the efficient firm is optimal for* $2\delta < \epsilon < \frac{2(3t-\delta)}{3}$. *If* $\delta \geq \frac{3t}{4}$, *fixed fee is optimal for all* $0 < \epsilon < \frac{2(3t-\delta)}{3}$.

(b). For $\frac{2(3t-\delta)}{3} \leq \epsilon < (3t-\delta)$, *if* $\delta > t$, *fixed fee is better for all* $\frac{2(3t-\delta)}{3} < \epsilon < (3t-\delta)$.

But for $\delta \leq t$, *if* $\delta < \frac{3t}{5}$ *holds, auction policy will be preferred for all* $\frac{2(3t-\delta)}{3} < \epsilon < (3t-\delta)$. *If* $\frac{3t}{5} < \delta < \frac{3t}{4}$, *auction policy is preferred for* $\frac{2(3t-\delta)}{3} < \epsilon < 6(t-\delta)$ *and fixed fee to the efficient firm will be preferred for* $6(t-\delta) < \epsilon < (3t-\delta)$. *When* $\frac{3t}{4} < \delta < t$ *fixed fee to the efficient firm will be preferred for all* $\frac{2(3t-\delta)}{3} < \epsilon < (3t-\delta)$.

(c). For $(3t-\delta) \leq \epsilon < (3t+\delta)$, *if* $\delta < 0.3t$ *auction policy will be preferred to fixed fee licensing for all* $(3t-\delta) \leq \epsilon < (3t+\delta)$. *If* $0.3t < \delta < 0.6t$, *then* $\exists\, \tilde{\epsilon} = [(6t+\delta) - \sqrt{\delta(30t-\delta)}] \in [(3t-\delta), (3t+\delta))$ *such that if* $\epsilon < \tilde{\epsilon}$, *then auction policy is optimal, whereas for* $\epsilon > \tilde{\epsilon}$ *fixed fee licensing to the efficient firm is optimal. If* $\delta > 0.6t$, *then fixed fee licensing over auction for all* $(3t-\delta) \leq \epsilon < (3t+\delta)$.

(d). For $\epsilon \geq (3t+\delta)$ *auction policy will be preferred if* $\delta < 0.3t$ *and fixed fee licensing to the efficient firm will be preferred if* $\delta > 0.3t$.

Proof: See Appendix 3.

Here we get that 'by-an-large' if the cost difference between firms are sufficiently high then fixed fee licensing to the efficient firm is optimal whereas if the cost difference is not that high then auctioning of the license to the efficient firm is optimal. This is due to the fact that with 'once-for-all' offer the net gain from fixed fee licensing to the efficient firm is sufficiently high only when the efficient firm is 'sufficiently efficient' compared to the inefficient firm, i.e. the cost difference is sufficiently high. This gain is extracted by the innovator through fixed fee and therefore fixed fee licensing outweighs auction policy for higher cost difference between firms. In addition to this, auction policy as a mechanism doesn't really have that 'once-for-all' offer kind of an effect since the other firm can always win if the previous firm doesn't win. Therefore the 'once-for-all' feature does have a bite for fixed fee licensing and therefore we get this result. One minor difference is for the case $\epsilon < \frac{2(3t-\delta)}{3}$ where fixed fee is chosen for lower level of cost difference which is an exactly the opposite result compared to the other ranges of ϵ. This is due to the fact that for $\epsilon < \frac{2(3t-\delta)}{3}$ with 'once-for-all' offer fixed fee licensing is done to both firms which dampens the payoff of the innovator because of the competitive effect of both firms' cost reduction. Thus the cost difference doesn't change is licensing and the payoff from fixed fee licensing is not affected by the initial cost difference of firms that much. But since under auction policy (which plays out like a second price auction) the efficient firm always wins it and only single license is offered, payoff from auction policy increases the more is the cost difference. So when ϵ is sufficiently low, auction policy does better for higher cost difference. For other cases fixed fee does better for higher cost difference.

We note that the above result is again in sharp contract with Banerjee and Poddar (2019) and Stamatopolous and Tauman (2009) where both show the superiority of fixed fee licensing over auction policy. The once-for-all structure of the contract we consider here is the basis of different sets of results. Once again for the competition authorities perspective it might be optimal to encourage fixed fee licensing to both firms compared to auction since that will lead to increased consumer surplus.

Next we proceed and analyze royalty licensing in detail.

3.3. Royalty licensing

3.3.1. Royalty licensing to one firm

Suppose the outside innovator licenses the innovation to firm A by charging a per unit royalty fee denoted by r.[7] 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:

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

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

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

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

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

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

Lemma 3: *In case of royalty licensing to only one firm the outside innovator always offers the license to the efficient firm.*

Proof: See Appendix 4.

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.

The innovator's optimal royalty contract and the revenue to the efficient firm A, can be characterized as follows: $r^* = \epsilon$ and $Rev_A^r = \frac{\epsilon}{6t}(3t + \delta) \quad \forall\, \epsilon \leq (3t + \delta)$, $r^* = \frac{3t+\delta+\epsilon}{2}$ and $Rev_A^r = \frac{(3t+\delta+\epsilon)^2}{24t}$ if $(3t + \delta) < \epsilon < 9t - \delta$ and $r^* = \epsilon - 3t + \delta$ and $Rev_A^r = \epsilon - 3t + \delta$ $\forall\, \epsilon > 9t - \delta$. In all the above cases firm A will accept the contract since it gets weakly greater profit compared to the pre-licensing case.

[7] We also consider when the innovator offers royalty to firm B (Appendix 4).

Royalty Licensing to both Firms

Suppose 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 1 it is optimum for the innovator to charge $r = \epsilon$ to both the firms and the innovator's maximum possible payoff will be ϵ. [8] We can show the following: Suppose we assume asymmetric royalty rates for both firms i.e. r_A for Firm A and r_B for Firm B where $r_A \neq r_B$. 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 then firm B can potentially accept the license and 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 1 and therefore the total revenue of the outside innovator is

[8] Market is covered according to our assumption.

$Rev^{*}_{RoyaltyBoth} = r$. 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.

Now in comparing innovator's respective payoffs from licensing to one firm and to both firms under royalty, we see that $\epsilon > \frac{\epsilon}{6t}(3t + \delta)$ since $\delta < 3t$ (by assumption), also $\epsilon > \frac{(3t+\delta+\epsilon)^2}{24t}$ for all $(3t + \delta) < \epsilon < 9t - \delta$ (given $\delta < 3t$) and finally $\epsilon \geq \epsilon - 3t + \delta \ \forall \ \epsilon > 9t - \delta$ (given $\delta < 3t$). Therefore offering two licenses is optimal for the innovator.

Thus our main proposition under royalty is as follows.

Proposition 4: *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 1. Thus given the constraint that $r \leq \epsilon$, the maximum possible revenue that the innovator can get 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.[9]

Given above we are now in a position to compare all licensing schemes and find out the overall optimal licensing policy for the outside innovator.

3.5. Optimal Licensing Policy

Comparing the payoff of the innovator from royalty licensing to both firms vis-à-vis fixed fee and auction policy we get that $Rev^{*}_{royaltyBoth} = \epsilon$ exceeds both fixed fee licensing and auction policy payoffs for all drastic and non-drastic technologies and therefore we get that it is optimal

[9] One can also consider a two-part tariff licensing contract which is a mixture of fixed fee and royalty licensing. However, we can show that the optimal two-part tariff licensing actually reduces to pure royalty to both firms that is considered here. Proof is available upon request.

for the innovator to go for royalty licensing to both firms and this holds for drastic and non-drastic innovation. Below we state the main proposition of this paper.

Proposition 5: *Royalty licensing to both firms is optimum for the outside innovator irrespective of the size of innovation and initial cost differences to the licensees. Fixed fee licensing or auctioning of the license is never optimal. The payoff of the innovator is* $R^* = \epsilon$*, for all* $\epsilon > 0$*, drastic or non-drastic.*

We find pure royalty licensing to both firms is optimal for innovations of all sizes as well as irrespective of cost differences of the licensees. The intuition of the above result can be put forward as follows: with once-for-all offer the outside option payoff of the firms from rejecting a licensing contract is fixed at the pre-licensing level. Thus the net gain from accepting a fixed fee licensing contract for a firm is lower with once-for-all compared to the case when the offer goes to the other firm in which case the rejection payoff (outside option) is much lower. Since the optimal fixed fee licensing is done mainly to the single efficient firm this once-for-all scenario dampens the net payoff of the licensee (efficient) firm and therefore the innovator can extract less in this case. Whereas, in case of royalty licensing, it is optimal for the innovator to license the technology to both the firms. Here the no-acceptance (outside option) payoff is similar to the case of where if rejected the offer can be potentially accepted by the other firm. Thus the no-acceptance payoff is much lower and therefore the net gain for the licensee firms from accepting vis-a-vis rejecting is much higher. Therefore the innovator can potentially extract more from royalty licensing to both firms compared to fixed fee licensing (to mainly the efficient firm). Thus it is optimal for the innovator to go for royalty licensing to both firms. This result is different from Banerjee and Poddar (2019) for asymmetric firms. In Banerjee and Poddar (2019), fixed fee licensing to the efficient firm was optimal for greater cost difference (greater firm asymmetry) whereas royalty licensing to both firms was optimal for lower cost difference.[10] Interesting to note is that both the firms are extracted their entire cost reduction and are kept at the pre-technology transfer level. The outside innovator does best extracting from both the firms and this is the best that it can do.

[10] This result is also qualitatively similar to Poddar and Sinha (2004) with symmetric firms where they get royalty licensing to both firms to be optimal for innovation of all sizes. Therefore, it seems, that the 'once-for-all' offer to some extent nullifies the 'cost asymmetry' dimension that was there in Banerjee and Poddar (2019).

From the point of view of the regulatory options for a competition authority trying to maximize consumer surplus royalty to both firms doesn't lead to any increase in the total consumer surplus. Therefore from the point of view of the competition authority encouraging fixed fee licensing to both firms lead to maximized consumer surplus but from the point of view of the innovator it is optimal to offer two-licenses using royalty licensing scheme. Thus both from the innovator and regulatory perspective offering two licenses is optimal but the nature of the contract changes.

4. Technology Selling Possibility

We now examine the possibility of selling the patent right to one of the firms.[11] For this purpose we make use of Banerjee and Poddar (2019) and Lu and Poddar (2014)'s results and expressions. It is known from Lu and Poddar (2014) that post technology sale the buyer will optimally license it further to its competitor using a two-part tariff licensing scheme. Internalizing this possibility the innovator will optimally charge a fixed fee for the technology sale. Using the expressions from Banerjee and Poddar (2019) and Lu and Poddar (2014) we can proceed as follows. Suppose the innovation is non-drastic such that $\epsilon < 3t - \delta$, we know that firm A's total payoff from subsequent two-part tariff licensing 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, firm A will get the pre-technology transfer payoff which is $\frac{1}{18t}(3t+\delta)^2$. Therefore the outside innovator can potentially charge $F_A^{Sell} = \epsilon + \frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2 - \frac{1}{18t}(3t+\delta)^2$ which is $F_A^{Sell} = \epsilon + \frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2$ from firm A which will be innovator's payoff. Similarly if the innovator sells it to firm B then the innovator can potentially charge $F_B^{Sell} = \epsilon + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\varepsilon)^2$. Comparing one can show that $F_B^{Sell} > F_A^{Sell}$ and therefore the innovator will optimally sell the technology to the inefficient firm B. Again if $3t - \delta < \epsilon < 3t + \delta$, the innovator can possibly extract a maximum of $\frac{1}{18t}(3t+\delta)^2 + \epsilon + \frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t+\delta)^2$ from firm A and $\epsilon + \frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\varepsilon)^2 - \frac{1}{18t}(3t-\delta)^2$ from

[11] A pioneering study on selling patent right can be found in Tauman and Weng (2012).

firm B. calculating we get that given $3t - \delta < \epsilon < 3t + \delta$ the innovator will optimally sell the technology to the inefficient firm B. Finally, when the innovation is drastic, i.e. $\epsilon > 3t + \delta$, the innovator can possibly extract a maximum of $\epsilon + \frac{1}{18t}(3t - \delta)^2$ from firm A and $\frac{1}{18t}(3t + \delta)^2 + \epsilon$ from firm B. Once again the innovator will sell the license to the inefficient firm B. Also in all the above cases the payoff the innovator is greater than its licensing payoff which is ϵ. Therefore it is optimal for the innovator to sell the license to the inefficient firm B.

Proposition 6: *It is optimum for the innovator to sell the innovation to the inefficient firm and this holds irrespective of whether the innovation is drastic or non-drastic. The recipient firm further licenses the innovation to the rival firm.*

It is bit surprising to see that the innovator optimally sells the new technology to the inefficient firm. This is due to the fact that the outside option (rejection payoff) is higher for the efficient firm and therefore the fixed fee for selling has to internalize that fact. In Banerjee and Poddar (2019) it was optimal for the innovator to sell the patent to any one of the firms who subsequently licenses to the other firm. Thus the 'identity invariance' result of Banerjee and Poddar (2019) doesn't hold here with "once-for-all offer". Moreover, our result is also different to Sinha (2016) under Cournot competition where the innovator optimally sold the technology to the efficient firm whereas we get the counter-intuitive result that the innovation will be sold to the inefficient firm.

5. 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 any given scenario for the innovator. However, the study of patent licensing in a framework of spatial competition of product differentiation is sparse. With outside innovator, apart from Sinha and Poddar (2004) with symmetric firms and Banerjee and Poddar (2019) with asymmetric firms, no paper has tried to fully explore the optimal technology licensing in spatial framework. The spatial model also captures a real world scenario where consumers have their ideal brand of product, buy exactly one unit and hence the demand is inelastic, and the offer from the innovator to the potential licensees is once-for-all (unlike Banerjee and Poddar (2019) or other studies). Analyzing this model, new insights are gained not only on the several modes of technology transfer and their implications, but how once-for-all the game structure and the nature of competition play a crucial role on the final outcome.

The main findings from the study are as follows. We show the optimal licensing contract involves, offering two pure royalty contracts to both licensees under all circumstances, i.e. irrespective of the licensees' cost asymmetry and the size of the innovation. Therefore, a complete diffusion of technology happens in the equilibrium. Our robust finding also supports the dominance of royalty licensing contracts in practice. Moreover, if the innovator wants to sell patent right instead of licensing, the inefficient firm acquires the technology which it further licenses to the efficient firm.

In this paper, the innovation we conceive is 'common' innovation in the sense that after licensing both firms' cost falls by ϵ from their respective unit costs. But one can conceive of a technology which reduces both firms' costs in a non-uniform way. It can also be conceived that a technology reduces both firms' costs to new lower level even below the efficient firm's current unit cost. This type of cost reducing technology is known as "new technology innovation". In future one can examine the optimal mode of technology licensing in a non-uniform cost reduction environment or of a 'new technology innovation' under spatial competitions. We believe one can expect non-trivial changes in the optimal mode of technology licensing scheme under alternative specifications.

Also in this paper the location of the competing firms were fixed since our target was analyzing the optimal mode of technology transfer. But it might be interesting to analyze the impact of different modes of technology transfer on the optimal level of product differentiation (or may be product diversity). In that case, we need to make the location choice of the firms endogenous with the possibility that market may not be fully covered. However, in that set up, to avoid existence related problems in pure strategies we will require quadratic costs of transportation instead of linear transport costs assumed here. Extending the research in that direction (i.e. technology licensing and optimal product differentiation) constitutes an interesting and ambitious future work that we would like to undertake in near future.

References

Arora A. and A. Gambardella (2010), 'Ideas for Rent: An Overview of Markets for Technology**,** *Industrial and Corporate Change*, Volume 19, Issue 3, June, Pages 775–803.

Arrow, K. J., (1962), 'Economic Welfare and the Allocation of Resources for Invention' In: Nelson P.R. (Ed). *The Rate and Direction of Inventive Activity*. Princeton University Press, pp. 609-626.

Bounie A., A. Dubus and P. Waelbroeck (2019), 'Data Intermediaries and Selling Mechanisms for customized Consumer Information', *SSRN Working Paper* No. 3454193.

d'Aspremont, C., Gabszewicz, J. J. and Thisse. J, F., (1979), 'On Hotelling's "Stability in Competition"', *Econometrica,* 47, 1145-1150.

Banerjee, S and Poddar, S (2019), 'To Sell or Not to Sell: Licensing versus Selling by an Outside Innovator', *Economic Modelling,* 76, 293-304.

Gambardella (2002), 'Success' and 'Failures' in the Market for Technology', *Oxford Review of Economic Policy*, Vol. 18, No. 1, 53-62.

Gambardella A, P. Giuri and A. Luzzi (2007), The market for patents in Europe, *Research Policy* 36, 1163–1183.

Hotelling, H. (1929), 'Stability in Competition', *The Economic Journal*, 93, 41-57.

Kabiraj T. (2004), 'Patent Licensing in a Leadership Structure' ,*The Manchester School,* Vol 72 No. 2 March. 188–205.

Kabiraj T and Lee, C. C. 'Licensing Contracts in Hotelling Structure', *Theoretical Economics Letters*, 1, 57-62

Kamien, M. (1992), 'Patent Licensing', In Aumann, R. J., and Hart, S. (Eds.), *Handbook of Game Theory with Economic Applications*, Elsevier Science, North Holland, 331–354.

Kamien, M. I., Oren, S. S. and Tauman, Y. (1992), 'Optimal licensing of cost reducing Innovation', *Journal of Mathematical Economics*, 21, 483-508.

Kamien, M. I. and Tauman, Y. (1986), 'Fees versus Royalties and the Private Value of a Patent', *Quarterly Journal of Economics,*101, 471-491.

Kamien, M. I. and Tauman, Y. (2002), 'Patent Licensing: The Inside Story', *The Manchester School*, 70, 7-15.

Katz, M. and Shapiro, C. (1986), 'How to License Intangible Property', *Quarterly Journal of Economics,*101, 567-589.

Lu, Y and Poddar, S (2014), 'Patent Licensing in Spatial Models', *Economic Modelling*, 42, 250-256.

Macho-Stadler, I., Martinez, X., Prerez-Castrillo, D., 1996. The role of information in licensing contract design. Res. Policy 25, 43–57.

Matsumura, T. and Matsushima, N. (2008), 'On patent licensing in spatial competition with endogenous location choice', Mimeo.

Matsumura, T. and Matsushima, N. and Stamatopoulos, G. (2010), 'Location equilibrium with asymmetric firms: the role of licensing', *Journal of Economics*, 99, 267-276.

Montes R., W. Sand-Zantman and T. Valletti (2018), The Value of Personal Information in Online Markets with Endogenous Privacy', *Management Science* 65(3):1342-1362.

Muto, S. (1993), 'On Licensing Policies in Bertrand Competition', *Games and Economic Behavior* 5, 257-267.

Poddar, S. and Sinha, U.B. (2004), 'On Patent Licensing in Spatial Competition', *Economic Record*, 80, 208-218.

Rey, P and D. Salant (2012), 'Abuse of dominance and licensing of intellectual property', *International Journal of Industrial Organization* 30 (2012) 518–527.

Rostoker, M., 1983. A survey of corporate licensing. IDEA J. Law Technol. PTC Res. Rep. 24, 59–92.

Sen, D., Tauman, Y. (2007), 'General Licensing Schemes for a Cost-Reducing Innovation', *Games and Economic Behavior*, 59, 163-186.

Singh, N and Vives, X., (1984), 'Price and quantity competition in a differentiated duopoly', *Rand Journal of Economics*, 15, 546-554.

Sinha, U.B., (2016). 'Optimal Value of a Patent in an Asymmetric Cournot Duopoly Market', *Economic Modelling*, 57, 93-105.

Stamatopolous, G. and Tauman, Y., (2009), On the Superiority of Fixed Fee over Auction in Asymmetric Markets, *Games and Economic Behavior*, 67, 331-333.

Taylor, C., Silberston, Z., (1973). The Economic Impact of the Patent System. Cambridge University Press, Cambridge.

Tauman, Y and Weng, M-H (2012), 'Selling Patent Rights and the Incentive to Innovate', *Economics Letters*, 114, 241-244.

Thursby, J.G., Jensen, R., Thursby, M.C. 2001. Objectives, characteristics and outcomes of university licensing: A survey of major U.S. universities. *Journal of Technology Transfer*, 26, 59-72.
Wang, X. H. (1998), 'Fee versus Royalty Licensing in a Cournot Duopoly Model', *Economics Letters,* 60, 55-62.

Appendix 1

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

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 the game ends and both firm gets their pre-technology transfer profits (outside option) and therefore firm A will get $\frac{1}{18t}(3t+\delta)^2$. Therefore, firm A will accept if $\frac{1}{18t}(3t+\delta+\epsilon)^2 - F_A \geq \frac{1}{18t}(3t+\delta)^2$. Thus the outside innovator will optimally charge $F_A^* = \frac{1}{18t}(3t+\delta+\epsilon)^2 - \frac{1}{18t}(3t+\delta)^2 = \frac{\epsilon(6t+2\delta+\epsilon)}{18t}$ from firm A. If the innovator licenses it to firm B it can charge $F_B^* = \frac{1}{18t}(3t-\delta+\epsilon)^2 - \frac{1}{18t}(3t-\delta)^2 = \frac{\epsilon(6t-2\delta+\epsilon)}{18t}$ from firm B. Comparing we get $F_A^* > F_B^*$ and therefore it is optimal for the innovator to license it to the efficient firm A and $F_A^* = \frac{1}{18t}(3t+\delta+\epsilon)^2 - \frac{1}{18t}(3t+\delta)^2 = \frac{\epsilon(6t+2\delta+\epsilon)}{18t} = R_{FixedSingle}^*$ will be the optimum revenue of the innovator.

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

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 being $\frac{1}{18t}(3t+\delta)^2$, it will be optimally charged $F_A^* = (\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta)^2$. 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 it gets its pre-licensing payoff equal to $\frac{1}{18t}(3t-\delta)^2$. Thus the maximum that can be extracted from firm B is $F_B^* = \frac{1}{18t}(3t-\delta+\epsilon)^2 - \frac{1}{18t}(3t-\delta)^2$. Comparing one can show that $F_A^* > F_B^*$ $\forall \epsilon \in [3t-\delta, 3t+\delta)$ and therefore firm A will again be offered the license for $3t - \delta < \epsilon < 3t + \delta$. Thus $R_{FixedSingle}^* = (\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta)^2$ when $3t - \delta < \epsilon < 3t + \delta$.

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

Here if firm A accepts the contract, it becomes a monopoly and its profit net will be $(\epsilon + \delta - t) - F_A$. Thus, similar to the previous case firm A will be optimally charged $F_A^* = (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta)^2$. Similarly if firm B is offered then it becomes a monopoly and therefore firm B will be optimally charged $F_B^* = (\epsilon - \delta - t) - \frac{1}{18t}(3t - \delta)^2$. Since $(\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta)^2 > (\epsilon - \delta - t) - \frac{1}{18t}(3t - \delta)^2$ firm A will be offered the license. The revenue of the outside innovator will be $R_{FixedSingle}^* = (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta)^2$.

Appendix 2

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 can potentially accept the contract, firm A's no-acceptance payoff will be $\frac{1}{18t}(3t + \delta - \epsilon)^2$. Therefore, the outside innovator can optimally charge $\frac{1}{18t}(3t + \delta)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2 > 0$ from firm A. Now take the case of 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 can potentially get the license and therefore firm B's non-acceptance 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 calculate the outside innovator's total revenue as $Rev_{FixedBoth}^* = \frac{\epsilon(6t-\epsilon)}{9t} > 0$.

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

Here we know that if firm A accepts and B does not then firm A becomes a monopoly, but the reverse is not true. Hence, from firm A the innovator can extract $\frac{1}{18t}(3t + \delta)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2$ and from firm B the innovator will be able to extract $\frac{1}{18t}(3t - \delta)^2$. Therefore the innovator can optimally earn $Rev_{FixedBoth}^* = \frac{1}{18t}(3t + \delta)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2 + \frac{1}{18t}(3t - \delta)^2$.

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

Here, both firms become a monopoly if the other rejects. Therefore the outside innovator can optimally extract $\frac{1}{18t}(3t+\delta)^2$ and $\frac{1}{18t}(3t-\delta)^2$ from firm A and firm B respectively and its optimum revenue will be $Rev^*_{FixedBoth} = \frac{1}{18t}(3t+\delta)^2 + \frac{1}{18t}(3t-\delta)^2$.

Appendix 3

For $\epsilon < \frac{2(3t-\delta)}{3}$ one needs to compare $Rev^*_{FixedBoth} = \frac{\epsilon(6t-\epsilon)}{9t}$ and $Rev^*_{Auctionsingle} = \frac{2\epsilon(3t-\delta)}{9t}$. Now $Rev^*_{FixedBoth} > Rev^*_{Auctionsingle}$ if and only if $\epsilon < 2\delta$. Now comparing $\frac{2(3t-\delta)}{3}$ and 2δ we get that $\frac{2(3t-\delta)}{3} > 2\delta$ if $\delta < \frac{3t}{4}$. Therefore, for $\epsilon < \frac{2(3t-\delta)}{3}$ the optimum choice between fixed fee and auction policy crucially depends on δ and can be characterized as if $\delta < \frac{3t}{4}$, fixed fee to both firms is optimum for $0 < \epsilon < 2\delta$ and auction to the efficient firm is optimal for $2\delta < \epsilon < \frac{2(3t-\delta)}{3}$. If $\delta \geq \frac{3t}{4}$, fixed fee is optimal for all $0 < \epsilon < \frac{2(3t-\delta)}{3}$.

For $\frac{2(3t-\delta)}{3} < \epsilon < (3t-\delta)$ we need to compare and $F_A^* = \frac{\epsilon(6t+2\delta+\epsilon)}{18t}$ and $Rev^*_{Auctionsingle} = \frac{2\epsilon(3t-\delta)}{9t}$. Once again $F_A^* > Rev^*_{Auctionsingle}$ if and only if $\epsilon > 6(t-\delta)$. Therefore if $\delta > t$, fixed fee is better for all $\frac{2(3t-\delta)}{3} < \epsilon < (3t-\delta)$. But if $\delta < t$ then we have to check the relative position of $\frac{2(3t-\delta)}{3}$, $6(t-\delta)$ and $(3t-\delta)$ and find the optimum accordingly. After calculations we get that if $\delta < \frac{3t}{5}$, $6(t-\delta) > (3t-\delta)$ which implies that auction will be preferred for all $\frac{2(3t-\delta)}{3} < \epsilon < (3t-\delta)$. For $\frac{3t}{5} < \delta < \frac{3t}{4}$, $\frac{2(3t-\delta)}{3} < 6(t-\delta) < (3t-\delta)$ and therefore auction to the efficient firm is preferred for $\frac{2(3t-\delta)}{3} < \epsilon < 6(t-\delta)$ and fixed fee to the efficient firm will be preferred for $6(t-\delta) < \epsilon < (3t-\delta)$. Finally if $\frac{3t}{4} < \delta < t$, $6(t-\delta) > \frac{2(3t-\delta)}{3}$ and therefore fixed fee to the efficient firm will be preferred for all $\frac{2(3t-\delta)}{3} < \epsilon < (3t-\delta)$.

For $(3t-\delta) \leq \epsilon < (3t+\delta)$ we need to compare $F_A^* = (\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta)^2$ and $Rev^*_{Auctionsingle} = \frac{1}{18t}(3t-\delta+\epsilon)^2$ and after tedious calculations the choice of fixed fee licensing vis-à-vis auction policy is characterized as follows: If $\delta < 0.3t$, auction policy will be preferred to fixed fee licensing for all $(3t-\delta) \leq \epsilon\varepsilon < (3t+\delta)$. If $0.3t < \delta < 0.6t$, then $\exists\ \widetilde{\epsilon\varepsilon} = [(6t+\delta) - \sqrt{\delta(30t-\delta)}] \in [(3t-\delta),(3t+\delta))$ such that if $\epsilon < \widetilde{\epsilon\varepsilon}$ auction policy is optimal, whereas for $\epsilon > \widetilde{\epsilon\varepsilon}$ fixed fee licensing to the efficient firm is optimal. If $\delta > 0.6t$, the outside innovator will always select fixed fee licensing over auction for all $(3t-\delta) \le \epsilon < (3t+\delta)$.

Finally for the drastic range $\epsilon \ge (3t+\delta)$ we need to compare $R_A^* = (\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta)^2$ and $Rev^*_{Auctionsingle} = (\epsilon-\delta-t)$ and we get that auction policy will be preferred if $\delta < 0.3t$ and fixed fee licensing to the efficient firm will be preferred if $\delta > 0.3t$.

Appendix 4

The outside innovator will maximize rQ_A and the optimum royalty rate should have been $r^* = \frac{3t+\delta+\epsilon}{2} > 0$. It can be checked that $\frac{3t+\delta+\epsilon}{2} > \epsilon \; \forall \, \epsilon \le (3t+\delta)$. Therefore in this case the optimum r will be set at $r^* = \epsilon$ which is the upper bound of r.[12] 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 then the game ends and firm A will get its pre-licensing payoff $\frac{1}{18t}(3t+\delta)^2$. 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 tariff 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 $Rev_A^r = \frac{\epsilon}{6t}(3t+\delta) \;\; \forall \, \epsilon \le (3t+\delta)$, $r^* = \frac{3t+\delta+\epsilon}{2}$ 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 will accept the contract since it gets weakly greater profit compared to the pre-licensing case.

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