ESSAYS ON PATENT LICENSING & TECHNOLOGY TRANSFER

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<u>Certified that the Thesis entitled</u>

"ESSAYS ON PATENT LICENSING & TECHNOLOGY TRANSFER" submitted by me for the award of Degree of Doctor of Philosophy in Arts at Jadavpur University is based upon my own work carried out under the supervision of Dr. Swapnendu Banerjee (Bandyopadhyay), Professor, Jadavpur University. Neither this thesis nor any part of it has been submitted before for any degree or diploma anywhere/elsewhere.

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Contents

Page No.

CHAPTER 1

Introduction

1.1. Overview

Invention or innovation of technology is essential for continuous growth and development of an economy. Whereas, the patent of an invention or innovation plays an important role to reap the economic benefit on the investment in research and development. According to World Intellectual Property Organization (WIPO), a patent provides exclusive right granted by the state for an invention which can be a product or a process. [1] The first recorded patent for an industrial invention was granted in 1421 in Florence, Italy to the architect and engineer Filippo Brunelleschi. It provided him a three-year monopoly on the manufacture of a barge with hoisting gear used to transport marble. In next two centuries these privileged grants to inventors were spread from Italy to other European countries. In 1623, Parliament in England enacted the "Statute of Monopolies" which had protected the right for inventions of new manufactures for up to 14 years. In the United States the Congress passed the first Patent Statute in 1790. France sanctioned its patent system the following year. Many other countries had patent laws in place by the end of the nineteenth century. Thereby, today there are more than 100 separate jurisdictions regarding patents. There are wide variations in the patent systems across the countries (Fisher, 2019).

The patent allows its holder the exclusive right to use or exploit the invention or the innovation and prevents others from using it without consent. Patent rights are specific to the country where the patent has been filed and granted to an individual or a

[1] See *Patents*. (n.d.). World Intellectual Property Organization. Retrieved June 5, 2022, from https://www.wipo.int/patents/en/#:~:text=In%20principle%2C%20the%20patent%20owner,without%20the%20patent%20owner's%20consent .

company against a payment of a regular maintenance fee for a limited period of time. It not only provides legal protection to the invention from counterfeiting but also incentivizes the inventor for further innovation. If the patent holder does not wish to exploit the invention by itself, the holder can transfer the right to commercialize it.[2] The patented technologies can be monetized through licensing and selling the rights. These two are widely used mode of technology transfer. The potential of an invention or innovation can be widely explored through the technology transfer. It is essential to move the new technologies from the research laboratories, independent research and development (R&D) companies to the marketplace. It also helps the developing countries to get the access of newer technologies invented in developed countries. The revenue earned by the patent holder from the technology transfer can be plowed back into further research which, in turn, can create new ventures. In a broader perspective, it helps the society by creating better job opportunities, health facilities, cleaner environment and innumerable technical advances which can improve standard of living. There are various aspects of patents which are covered in literature till date. This present dissertation mainly focuses on technology transfer from the perspective of the innovator who owns a patent of a cost-reducing innovation.

1.2. Theoretical Concepts of Technology Transfer

1.2.1. Licensing vs Selling

Commonly the innovator can transfer the patent right to the licensee through licensing or selling. Through licensing the patent holder is transferring the right to use the

[2] See *Patents*. (n.d.). World Intellectual Property Organization. Retrieved June 5, 2022, from https://www.wipo.int/patents/en/#:~:text=In%20principle%2C%20the%20patent%20owner,without%20the%20patent%20owner’s%20consent .

technology to the licensee against a regular fee or payment, while the ownership of the patent still lies with the patent-holder. The licensee will be unable to license the technology further. Basic licensing contracts such as Fixed fee licensing, Royalty licensing, Auctioning and Two-part tariff licensing are widely observed in real world. In fixed fee licensing the licensee pays an upfront fee to the licensor to obtain the technology license. Under royalty licensing the innovator offers the license against a per unit royalty rate. In two-part tariff licensing the innovator charges a combination of fixed fee and royalty rate from the licensee. In case of auctioning, potential licensees bid for the innovation and the highest bidder gets it and pays the amount of second highest bid to the innovator. Based on various situations the innovator optimally chooses the licensing contracts among available contracts. One of the most crucial parts of licensing is the optimal choice of the contract by the innovator as it helps to recover the capital invested in R&D of the new technology. This profit can be plowed back in further innovation. In many industries like pharmaceutical and chemical, electronics, telecommunications and computer, technology licensing is widely used as a measure of commercializing the innovations (Anand and Khanna, 2000). It is of no doubt that technology licensing occurs more frequently in high technology intensive industries where patent protection is more effective.

Since the publication of the seminal work by Arrow (1962), different aspects of technology licensing have been explored by the researchers of modern Industrial Economics till date. In case of outright sale of a patent, the buyer will become the new owner of the patent, who can use the technology, innovate it or license it further. Seranno (2010) provides an empirical study of selling the patent rights[3] and finds that

[3] Empirical studies on patent sales have been carried out using data on patent auctions (Cahoy et al., 2016; Caviggioli and Ughetto, 2013; Fischer and Leidinger, 2014; Odasso et al., 2014; Sneed and

the proportion of transferred patents is large and differs across technology fields. Whereas, the theoretical concept of selling the patent right was first introduced by Tauman and Weng (2012) under Cournot competition. They have found that selling the innovation can be strictly better than direct licensing strategy for a significant but non-drastic innovation with four or more potential licensees. The concept of non-drastic innovation will be explained later in this chapter. The main focus of our dissertation is on patent licensing. We also try to explore the option of selling as well.

1.2.2. Types of Patent Licensing

The innovator decides to license the patentee either exclusively or non-exclusively based on its own requirement. An exclusive patent license means no one has the right to use the technology except the licensee which may become a monopoly as it is the sole acquirer and can exploit it fully. In turn the cost will become higher than usual and the licensor can extract the higher revenue from the licensee. For example, Serum Institute of India (SII) got into the licensing agreement with AstraZeneca over the Oxford-AstraZeneca COVID-19 vaccine which is developed to strengthen the immune system for combating the deadly Coronavirus. Hence SII is the exclusive patent owner in India who will produce, distribute and sell that particular vaccine named as COVISHIELD. All rights are vested with the licensee except for the right to license it further. Due to huge demand and a high royalty payment to the licensor, the price of vaccine is also high. SII CEO Adar Poonawalla has justified the high rates of vaccine by stating that his firm has to pay 50 per cent royalty to AstraZeneca.[4] In case of non-

Johnson, 2009) and on patent reassignments (De Marco et al., 2017; Drivas and Economidou, 2015; Figueroa and Serrano, 2013; Galasso et al., 2013; Serrano, 2010).

[4] See Wikipedia contributors. (2022, June 1). Oxford–AstraZeneca COVID-19 vaccine. In Wikipedia, The Free Encyclopedia. Retrieved 08:16, June 5, 2022, from

exclusive licensing the same right is offered to more than one licensee. It implies that the license of the invention has been given for the same product and they are eligible to exploit it equally. The patented product is of such a nature that to generate more revenue the licensor has to give it as much as possible. For example, let us assume a company deals with steering technology of the cars and comes up with an invention which will be patented. Rather than giving a license to just one car manufacturing firm to use the patented technology, the licensor will give permission of using right to different car manufacturing firms to generate more royalty from the companies.[5] We have tried to capture the implications of both exclusive and non-exclusive licensing in this dissertation.

1.2.3. Types of Patentee

In the seminal work of patent licensing Arrow (1962) considered an inventor who is from outside the industrial system (e.g., universities, independent research organisations, upstream enterprises and private individuals) and not involved in any production process. This kind of innovator or inventor is known as outsider or outside patentee or outside innovator or outside inventor.

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https://en.wikipedia.org/w/index.php?title=Oxford%E2%80%93AstraZeneca_COVID-19_vaccine&oldid=1090926994,

Rajagopal, D. (2020, June 4). AstraZeneca & Serum Institute of India sign licensing deal for 1 billion doses of Oxford vaccine. *The Economic Times*. https://economictimes.indiatimes.com/industry/healthcare/biotech/pharmaceuticals/astrazeneca-serum-institute-of-india-sign-licensing-deal-for-1-billion-doses-of-oxford-vaccine/articleshow/76202016.cms,

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https://www.theweek.in/news/biz-tech/2021/04/24/serums-covid-vaccine-costlier-in-india-explained.html.

[5] See Dalbehera, R. (2019, March 12). India: Patent Licensing. *Mondaq-India*. https://www.mondaq.com/india/patent/789046/patent-licensing

Few literatures such as Kamien and Tauman (1986), Kamien et al. (1992), Kamien (1992), Katz and Shapiro (1985), Bagchi and Mukherjee (2014) considered the optimal licensing strategy of the outsider who maximizes the revenue earned from the cost-reducing innovation. The significance of an outside innovator can be understood in a scenario where R&D requires lot of investment of time and money. Industry firms do not have enough capital or time to engage in high-risk R&D. Therefore, they always opt for technology licensing to enhance the firm's profit and competitiveness. The concept of an outside innovator will be clearer if we consider the previous example of Oxford-AstraZeneca and SII. The University of Oxford and AstraZeneca came together to develop the COVID-19 Vaccine and licensed SII to manufacture and supply the vaccine to India and low to medium income countries. Here, the Oxford-AstraZeneca is the outside innovator. In our dissertation we have considered technology transfer from the perspective of an outside innovator. In literature Insider (also known as insider patentee, inside innovator, incumbent innovator etc) is the patent holder which is also a producer within the industry (Wang, 1998; Wang and Yang, 1999). This implies the inside innovator develops a technology and earns a revenue from licensing the technology to its rival firm and a profit from competing in product market. Therefore, unlike the outsider, the inside innovator (the incumbent firm) cares not only about the licensing revenue but also the effect of licensing on its market share. Sen and Tauman (2007) is one of the few papers which has analysed both the cases of outside and incumbent innovator in patent licensing.

1.2.4. Market Structure and Strategic Decision of Licensees

Innovator licenses the technology to potential licensees who are final goods producers and the product market structure varies with difference in demand and competition among the producing firms. In this dissertation we consider an outside patent holder and two producing firms who compete in price in product market. Innovator's final choice of technology transfer depends on firms' market decisions which implies that the patent holder chooses the licensee(s) and the mode of transfer (i.e., licensing or selling) considering the performance of competing firms in product market if the technology is transferred in the first stage of licensing game. We assume all the participants of the game have complete information. In the duopoly structure the producing firms can compete in their strategic variables: quantity and price. Among various related literature Mukherjee and Balasubramanian (2001), Sen and Tauman (2007), Stamatopoulos and Tauman (2009), Poddar and Sinha (2010), Tauman and Weng (2012), Sinha (2016) and many more worked on patent licensing in Cournot quantity competition and Muto (1993), Wang and Yang, (1999) Fauli-Oller and Sandonis (2002), Colombo and Filippini (2015) in Betrand price competition. Bagchi and Mukherjee (2014) showed the effect of both quantity competition and price competition on technology licensing by an outside innovator. Kabiraj (2005)[6], Filippini (2005), Li and Yanagawa (2011) are few related literatures which shed light on technology licensing with Stackelberg price competition. In line with Shapiro (1989), it has been observed that in practice businesses choose price rather than quantities as their strategic variable. Here in our present work, to be more realistic we consider price competition in a spatial model. According to Poddar and Sinha (2004), Lu and Poddar (2014) the spatial models, like Salop's circular city and Hotelling's linear city, are appropriate to study the licensing behaviour of firms in the industries where markets are already developed and demands are not changing rapidly over time. We consider Hotelling's linear city with a length of 1 unit, where the continuum of consumers is

[6] Corrections of this article are provided in Cao and Kabiraj (2018)

located uniformly along the segment between 0 and 1. As per the celebrated paper of Hotelling (1929), both of the sellers always had a tendency to agglomerate towards the centre of the city; as a result, no price equilibrium will exist. To avoid this problem d'Aspremont et al. (1979) showed that both the sellers always try to maximize their differentiation by locating as far as possible from each other because the price competition between the firms becomes less fierce. To capture the patent licensing in a market where product differentiation is maximum, i.e., brands are well established, we consider the locations of the two competing firms fixed at two extremes of the city throughout this dissertation. Choice of location (optimal product differentiation) of the firms is not the current target of our study. Here, location of the firms is exogenously given, it’s not a choice variable for the firms. It is possible that pure-strategy price equilibrium may not exist in determining the locations endogenously due to linear transportation cost as assumed here. This existence problem can be sorted with quadratic transportation cost. So, we keep aside the endogenous location choice with quadratic transportation cost and its effect on different modes of technology transfer as future extension of our present dissertation work.

1.2.5. Product differentiation

Broadly there are two types of product differentiation: Vertical and horizontal product differentiation. In vertical product differentiation when all products are offered at the same price all consumers prefer the same product. Consumers rank all the products based on a measurable factor, such as price or quality, for example, one good which is available with its low-quality and high-quality variation, all consumers will prefer the high-quality product if both variations are provided at the same price. Gabszewicz and Thisse (1979) first introduced vertical product differentiation in quality ladder.

When horizontal product differentiation exists, all products are offered at the same price, different consumers prefer different products i.e., consumers choose between products based on personal preference. Let us take bakeries with different locations as the example. Even though both the bakeries provide identical products, a consumer may prefer one bakery over other based on their location i.e., a consumer will always buy from its nearer bakery. We can view this distance as the measurement of the preference. Lower the distance, higher will be the preference for the bakery. The first prototype of horizontal product differentiation was introduced by Hotelling (1929). His results show that sellers choose the same mid location and given the same price, the consumers will be indifferent between two sellers while buying the good. In contrast we assume the locations of the firms to be fixed at the end of the city to study the licensing behaviour of firms in the industries where the differentiation over the brands is well established. Consumers are evenly distributed along the line, and each consumer buys exactly one unit of this commodity from any of these two, irrespective of its price. The goods produced by both the firms are homogenous and identical, but a customer will prefer to buy it from the nearest firm. Differentiation in Hotelling's model is fundamentally different from product differentiation in Bertrand and Cournot framework (a la Singh & Vives, 1984), where the demand is typically elastic, and also changes with the degree of product differentiation. Because of these fundamental differences in the structure, we believe the impact of technology transfer of cost reducing innovations will have different impact on the optimal licensing contracts and the ensuing market equilibrium.

1.2.6. Innovation

Innovations are broadly divided in two types depending on the purpose of such innovation: product innovation and process innovation. In a differentiated product market if the innovation enhances quality of an existing product and introduces new goods and services to the market, then it is a product innovation. Process innovation reduces the marginal production cost of the licensee with products remain unchanged. Process innovation are of types based on the magnitude of cost reduction. As per Arrow (1962), if the magnitude of innovation is such that it reduces licensee's marginal cost to an extent that it can undercut its rivals and drives them out of market and becomes a monopoly, then that kind of innovation is drastic innovation. If the innovation is not so large (i.e., does not reduce the unit costs enough), so that the market competition prevails and no one becomes monopoly in that case the innovation is known as non-drastic innovation. That cost reduction can be either same or different for both firms. If the magnitude of cost reduction due to the innovation is same for both the firms, then that will be a common innovation. In literature the influence of innovation is very evident on technology transfer. Rockett (1990) considered that an improved technology enhances process quality and then induces a lower marginal cost. Erkal (2005) examined that there will be no technology transfers at optimal if the innovation size is sufficiently small and degree of product differentiation is sufficiently low. In this current dissertation the innovation we consider is a process innovation all along. The influence of drastic and non-drastic innovation on innovator's optimal licensing choice has also been studied distinctly. We also considered uniform cost reduction and non-uniform cost reduction for different firms for various situations.

1.2.7. Patent Policy

Technological innovation plays a crucial role in designing development policies at both national and international level. Understandably "Industry, Innovation and Infrastructure" is included as one of the seventeen Sustainable Development Goals adopted by the United Nations General Assembly in 2015 to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation by 2030.[7]

In that context, significance of patent policy and its effect on technology transfer is always the matter of concern. Patent protection has two effects from policy perspective. The positive effect is on the innovator as the system allows the innovator to earn a profit. In contrast, the negative effect is on the market competition. Exclusivity of patent right makes monopoly which reduces the competition and hinder the complete diffusion of technology. Here comes the role of a government to balance these two effects to improve the diffusion of patented inventions, e.g., through the promotion of patent pools and the publication of licensing guidelines with encouragement in further innovation. Through licensing the innovator can not only recover the early investment needed for R & D projects, but also realize a real growth in profit. This has been supported by World Development Indicators database where it is observed that the licensing fee paid by Chinese firms to foreign firms had an annual growth rate of over 34 percent between 1998 and 2009 (Nguyen et al., 2016).

Though the patent right is confined only within the country in which it is granted, there are some international agreements such as Trade Related Aspects of Intellectual Property Rights (TRIPS), signed in 1994 and monitored by the World Trade Organisation (WTO), to introduce intellectual property rules into the multilateral trading system for the first time as an attempt to ensure the same minimum standards of protection across countries.[8]

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[7] See *The 2030 Agenda and the Sustainable Development Goals*. https://sdgs.un.org/goals/goal9

[8] Organisation for Economic Co-operation and Development. (2004). *Patents and innovation: Trends and policy challenges*. OECD Publishing. https://www.oecd.org/science/inno/24508541.pdf

Patent policies in developed countries are more stringent than those in the developing countries, which may discourage innovation and enhancement of knowledge in latter. Therefore, shifts in the legal and regulatory framework of patent regimes are essential in those countries to foster the fast-paced development in the industries. Among various dimensions, we encompass patent policies from innovator's perspective under different circumstances and we believe that these will give an insightful contribution in economic evaluation of the current policies. Recently India is facing surge in innovations notably via start-ups. These innovators might get benefitted greatly through the patent regimes, which in turn would help them to attract capital required to expand. Therefore, policy makers also adjust various factors which influence the patent system such as market environments, infrastructure etc to provide a framework that supports transfer of technology at the national and international level.

1.3. Literature Review

We have already cited some references above in support of the structure considered in this dissertation. Now we will get into the detailed review of literatures relevant to our work.

The vast literature on patent licensing shows the significance of this topic in the field of Industrial Organisation. This area of research has come a long way since the seminal work of Arrow (1962) which has substantiated that under royalty licensing a perfectly competitive industry provides a higher incentive to innovate than a monopoly. Kamien and Tauman (1984,1986), Katz and Shapiro (1985), Kamien et al. (1992), Sen and Tauman (2007) showed that in a Cournot oligopoly, either fixed fee licensing or auctioning a certain number of licenses is superior to royalty licensing for an outsider innovator, irrespective of the industry size or magnitude of the innovation. Rostocker

(1984) found that royalty is used 39% of the time, fixed fee alone 13%, and both instruments together 46%. Taylor and Silberston (1973) reported similar kind of results. Macho-Stadler et al. (1996) showed, 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) found royalties are most frequently used with 81% of respondents "almost always" use royalties, while 16% report to have used royalties "often". Bousquet et al. (1998) used data from French firms to show that 78% of contracts include royalties. But wide prevalence of royalties in real world remained as unsolved riddle which had created significant interest in explaining the rationale behind.[9] Wang (1998, 2002), Kamien and Tauman (2002) have observed that royalty licensing is optimal for the insider to extract maximum surplus. However, most of the studies above are limited to homogenous goods case except Wang (2002). Muto (1993), Bagchi and Mukherjee (2014) look into the effect of product differentiation on optimal licensing. Earlier, Muto (1993) looked into three licensing schemes, auction, fixed fee and royalty for an outside patentee in Bertrand price competition with firms producing differentiated goods and established that only royalty licensing is optimal (compared to auction and fixed fee). Fosfuri and Roca (2004) studied licensing under Cournot competition with one innovator and two other firms and have proved that for an insider patentee a royalty is optimal when it licenses to both firms, but a fixed fee might be optimal when it licenses to only one firm. The optimality of royalty licensing for a certain range of product differentiation is achieved irrespective of Cournot and Bertrand competition by Bagchi and Mukherjee (2014). Wang and Yang

[9] Later on, prevalence of royalty is explained theoretically by the factors such as asymmetry of information (Gallini and Wright, 1990; Macho-Stadler et al., 1991; Beggs, 1992; Bousquet et al.,1998; Poddar & Sinha, 2002, Schmitz, 2002; Sen, 2005b etc.), variation in innovation quality (Rockett, 1990), moral hazard (Macho- Stadler et al., 1996; Choi, 2001), risk aversion (Bousquet et al., 1998), strategic incentive delegation (Mukherjee, 2001; Saracho, 2002), input market power (Mukherjee, 2010a) and convex costs (Mukherjee, 2010b).

(1999) were the first to consider technology licensing for an inside innovator in a Bertrand price competition and they arrived at a result where fixed-fee licensing is preferred when product substitution is small while royalty licensing is preferred otherwise. The optimality of a two-part tariff licensing contract under complete information is analysed by Fauli-Oller and Sandonis (2002) in the context of differentiated Bertrand competition with an insider patentee and by Sen and Tauman (2007), Mukherjee and Balasubramanian (2001) in a Cournot competition and by Saracho (2002) in the context of strategic delegation. Erkal (2005) considered the licensing of cost-reducing innovations between horizontal competitor firms in a differentiated Bertrand market. Colombo and Filippini (2015) delved into the two-part licensing mechanism in a differentiated Bertrand duopoly model where royalty can be ad valorem or per-unit. Ghosh and Saha (2015), on the other hand examined how the optimal trade policy is affected by the possibility of technology licensing in a differentiated duopoly with price competition.

Licensing under Stackelberg leadership structure is studied by Kabiraj (2004), Filippini (2005) and Li and Yanagawa (2011). Kabiraj (2004) has discussed how auction outperforms all licensing schemes regardless of innovation size. Filippini (2005) has inferred that the patentee can charge a bigger optimal royalty rate as it serves as a Stackelberg leader rather than a Cournot competitor. Li and Yanagawa (2011) has showed that with an in-house development division the leader will use a fixed fee contract for sufficiently high product differentiation and higher cost advantage whereas royalty will be used for smaller cost advantages.

Most of the existing literature on technology transfer of cost-reducing innovations is based on conventional models of quantity (Cournot) or price (Bertrand) competitions. Spatial competition is gaining importance recently in patent licensing.

So, there are many questions remained unearthed on the various aspects of technology transfer through patent licensing. To the best of my knowledge Caballero et al. (2002), Poddar and Sinha (2004) and Matsumura and Matsushima (2008) are the first few research papers which considered patent licensing in spatial framework. Caballero et al. (2002) considered an outside licensor and two price-setting firms located on a circumference and showed that royalty is optimal regardless of the size of the innovation.

Poddar and Sinha (2004) analysed optimal licensing strategy for outsider patentee as well as an insider patentee in the Hotelling framework with symmetric pre-innovation costs of the competing firms. In the case of an outsider patentee, they found that royalty licensing to both turns out to be better compared to auction or fixed fee as it always yields higher payoff to the patentee irrespective of the innovation size. In the case of insider patentee licensing, royalty licensing is more profitable when the innovation is non-drastic. When the innovation is drastic, no licensing is optimal for the insider patentee. Incentive for innovation is always higher for the outsider patentee. But as per welfare analysis consumers are better off if innovator is an insider.

Matsumura and Matsushima (2008) examined how licensing activities following R&D affect the product choices of firms (i.e., the degree of product differentiation) and the incentive for R&D investment in a standard linear city model with two firms. They showed that licensing activities after R&D always lead to maximum differentiation between firms and mitigate price competition.

Lu and Poddar (2014) extended the analysis with asymmetric potential licensees. They analysed licensing schemes of an inside innovator in an asymmetric duopoly model of spatial competitions (both Hotelling and Salop) and found that two-part tariff licensing is optimal licensing arrangement to extract the maximum surplus regardless of innovation size or pre-innovation cost asymmetries between the competing licensee firms. Banerjee and Poddar (2019) investigated what happens if the innovator is an outsider in a spatial competition with asymmetric licensee firms. They explored both licensing and selling policies and observed that based on the degree of cost asymmetry between the competing licensee firms, pure royalty contracts to both firms or fixed fee licensing to the efficient firm can be both optimal. Between selling and licensing, the outside innovator will always prefer selling the property right to any one of the licensees (who then further licenses to its rival firm) irrespective of innovation size or pre-innovation cost asymmetries of the firms.

The selling of patent is very common among the firms in the tech-industry (Seranno, 2010; Odasso et al.,2015). However, theoretical studies on selling the property rights of an innovation are relatively less explored in the field of technology transfer. The concept of selling the right of innovation as a mode of technology transfer was considered by Tauman and Weng (2012), Banerjee and Poddar (2019), Banerjee et al. (2020). It has been established by Banerjee and Poddar (2019) and Banerjee et al. (2020) that selling should be preferable to licensing.

Stamatopoulos and Tauman (2009) identified an interesting situation regarding an innovation which is beneficial to the inefficient firm only. Even though the exclusive innovation cannot improve the marginal cost of the efficient firm, it might be willing to pay for that license and keep it aside (shelve it) to outcompete its rival. This phenomenon is widely known as “killer acquisition” in literature. In this type of acquisition, dominant firms buy the technologies to gain market power by “killing” potential technologies of competitors (Fumagalli et al.,2020; Norbäck et al., 2020; Cunningham et al.,2021; Letina et al.,2021). Cunningham et al. (2021) have laid out empirical evidence on killer acquisitions in the pharmaceutical industries where between 5.3% and 7.4% of all acquisitions in the sample are killer acquisitions. The sample consists of projects initiated between 1989 and 2010, i.e., 16,015 projects originated by 4,637 firms. They also provided a theoretical model to explain the rationale behind. They found that acquired drug projects are less likely to be developed if they overlap with the acquirer's existing product portfolio, especially when the acquirer has larger market power due to weak competition or distant patent expiration. In the context of interactions between mergers and innovation, Letina et al. (2020) have formulated a theory of strategic choice of innovation projects by incumbents and start-ups which allows for endogenous acquisition and commercialization decisions. They have found that prohibiting killer acquisitions of start-ups strictly reduces the variety of pursued research projects which will be resulted in lesser chance of innovation and induce the incumbent firm to copy the projects of the entrant to prevent competition strategically, whereas prohibiting other acquisitions has a weakly negative innovation effect for innovations with sufficient commercialization potential. Fumagalli et al. (2020) have analysed the optimal policy of an antitrust authority towards the acquisitions of potential competitors on the basis of merger standard. In a model with financial constraints where a takeover by the incumbent may be anti-competitive as it could shelve the project of the potential entrant, they conclude that a lenient merger policy may in some circumstances be optimal. Norbäck et al. (2020) have showed that 'acquisitions for sleep' can happen if and only if the quality of a process invention is low; otherwise, the acquirer would commercialize the invention as it is too costly not to do so. They also showed that the incentive for acquisition for sleeps decreases when IP law becomes stricter as stricter laws causes higher entry profit value than entry-deterring value.

In most of the literature of licensing of a cost-reducing innovation, the type of innovation that is considered is common innovation which implies that cost advantages to two different licensee firms are same irrespective of their efficiency level. Stamatopoulos and Tauman (2009), Chang et al. (2016) recognized this possibility of non-uniform cost reduction for different firms from the same innovation. Stamatopoulos and Tauman (2009) inquired into the licensing of an innovation which reduces the marginal cost of less efficient firm only, but not less than marginal cost of efficient firm in a Cournot competition. This asymmetry in cost reduction can be characterized by the influence of absorptive capacity of manufacturing firms (Chang et al., 2016). This paper showed that in an asymmetric duopoly framework with differential absorptive capacity the patent-holder may adopt exclusive licensing if the difference in the absorptive capacity of two firms is large enough; otherwise, it will license both firms.

1.4. Motivation and Outline of the Thesis

The above literature review on patent licensing exhibits that there are few relevant areas which are yet to be explored. This dissertation endeavours to discuss three among them. We attempt to analyse the effects of innovation size, cost asymmetry and other influencing factors on optimal patent licensing for a well-developed market with established brands in the following three chapters.

First, in chapter 2, *"Technology Transfer in Spatial Competition when Licensees are Asymmetric"*, we discuss the implications of "once-for-all" or "take-it or leave-it" offer from the innovator on its optimal licensing strategy among various available licensing strategies. Here, the outside innovator (independent research laboratory) wishes to license a new cost-reducing innovation to the competing firm(s) in a duopoly market under spatial competition. Further, we look into another form of technology transfer by the innovator for cost-reducing innovation, i.e., selling the patent right to one of the firms, instead of licensing.

Chapter 3, entitled as, *"Innovation, Shelving and Technology Transfer",* explores the anti-competitive issue of "shelving" a new technology. To understand this phenomenon in greater depth and to avoid this type of strategic shelving we also look into alternative technology transfer arrangements by the outside innovator in this chapter.

Chapter 4, *"Technology Licensing with Asymmetric Absorptive Capacity without Leapfrogging",* examines the impact of asymmetric absorptive capacity of potential licensees on various licensing policies of a cost-reducing innovation separately. Here we assume that less efficient firm's marginal cost reduces more than that of efficient firm, but the reduced cost of the former will still not be lower than the latter's initial cost. This implies the inefficient firm is unable to leapfrog its rival in efficiency with the help of the innovation. Finally, we have also discussed effects of asymmetric absorptive capacity on optimal licensing decision of the outside innovator.

Finally, in chapter 5 we have concluded the discussion of the entire work by summarizing the results of three core chapters of the dissertation. This dissertation ends with a brief outlook on the future scope of studies in this direction.

CHAPTER 2

Technology Transfer in Spatial Competition when Licensees are Asymmetric

2.1. Introduction

In this chapter, we address the problem of the 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 of the product, hence the demand is inelastic. We assume the market is fully covered, hence the total market demand is fixed.[10] These features of Hotelling's model are 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 modelling structure, the impact of technology transfer of cost reducing innovations will have different implications on the optimal licensing contracts and the ensuing market equilibrium. To explore that systematically, we focus our attention specifically on the following issues.

[10] In other words, we are looking into matured markets with established brands. As an example, think of a full-grown market of mobile devices (the market for mobile devices has very high penetration rate, almost near to hundred percent in most developed countries), say smart-phones, with two established brands iPhone or android phone. Everybody needs at least 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.

(i) The outside innovator decides how many licenses to offer (one or two) when there are two potential licensees with a once-for-all type offer (same as take-it or leave-it offer),

(ii) Consider all possible available licensing schemes in this environment: 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,

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

The second objective is to verify our findings with the licensing practices in reality. In an empirical study, Rostoker (1983) finds that licensing by royalty alone is 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. Thus, there is clear dominance of royalty licensing coming out from the empirical observations and in this chapter, we explore whether we get a result that can support the empirical finding.

In our study, we use 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” game. The innovator chooses to license to a single firm, it also decides whether it will license the efficient or the inefficient firm. The firm(s) can accept or reject the offer, in case of license to single firm, if the firm rejects, the game ends there. In the second stage, the firms compete in prices in the product market.

Now moving on to the practical implications of once-for-all offer, we try to find out whether this type of offer will be more attractive to the innovator. Overall, it appears that once-for-all offer will be less costly (both in terms of real time and real cost) as opposed to sequential offers to the innovator and participating firms. In sequential offers of licensing game if one license is being offered to any firm, say, to the first firm. If the first firm rejects the offer, it goes to the second firm (Banerjee & Poddar, 2019), but in case of once-for-all offer, the game ends after rejection by the first firm i.e., the offer does not go to the other firm. Therefore, under once-for-all game the innovator can save its time and cost by not transferring that one license further after rejection by one of the licensees. The change in time structure of the game by once-for-all offer, changes the opportunity cost (payoff from outside options) of the licensees which, in turn, influence the results differently. Banerjee and Poddar (2019) show without once-for-all offer, optimal licensing policies not only depend on the innovation size but also on the degree of cost asymmetry between the licensees. Whereas with once-for-all offer, optimal licensing policy neither depends on the size of the innovation nor on the cost asymmetry between the licensees.[11]

Our main findings 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 fee licensing is to license both firms for smaller size of

[11] Although the 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 & Poddar, 2019), it opens the possibility of complete diffusion of the new technology irrespective of innovation size and cost asymmetry.

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 is 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 being 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 far as the overall optimal licensing for the innovator is concerned, we arrived at 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 explains the overall dominance of royalty contracts in practice.

We further extend our analysis to see if instead of licensing, the innovator wishes to transfer the technology by selling the right of the 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 not identified before in the literature of patent licensing. In literature, 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) unlike what we got here. This implies the nature of competition and the structure of the game (once for all contract) actually matters.

In recent studies, Banerjee and Poddar (2019) has investigated optimal licensing and selling policies of an outside innovator under spatial competition with asymmetric cost licensees. They show that 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. The main deviation from this paper to this chapter is with the rules of the game. Banerjee and Poddar (2019) consider a sequential offer game i.e., when the innovator offers one licensing contract, the offer goes sequentially to the competing firms, namely, if the first firm rejects the offer, then it goes to the second firm. In our case, the licensing game is with "once-for-all offer" implying that if the firm which is being offered the license rejects, the game ends i.e., the offer *does not* go to the other firm and the status-quo (i.e., pre-licensing situation) prevails. It is interesting to note that a subtle difference in game structure, impacts the nature of optimal licensing contracts significantly. In terms of results, offering one license is optimal (the case of fixed fee) in Banerjee and Poddar (2019) and complete diffusion of technology does not happen while in our case, it always happens as both firms get the new technology in equilibrium under optimal licensing.

Earlier Poddar and Sinha (2004) analysed 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, naturally a question arises 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 chapter as well.

Earlier, 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 both Muto (1993) and our present analysis here, broadly one thing comes out that 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 outsider patentee under quantity competition and royalty licensing is typically optimal with an insider patentee.[12]

The rest of this chapter is organized as follows. In section 2, we lay out the model. Different licensing schemes are analysed in detail with optimal licensing policy in section 3. Section 4 discusses the extension to the selling game of patent right. Section 5 includes conclusions of the chapter.

2.2. The Linear City Model

Consider two firms, firm A and firm B located in a linear city represented by a 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, which is horizontally differentiated, 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

[12] 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 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)).

A or firm B. The transportation cost per unit of distance is t and it is borne by the consumers.[13]

The utility function of a consumer located at x is given by[14]:

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

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

We assume that the market is fully covered 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

[13] 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 chapter, 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 exists 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.

[14] This particular formulation of the utility function in a Hotelling's linear city model is typical, see Shy (1996), Shy (2000).

market and the licensee becomes the monopoly.[15]

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) can accept or reject 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.

2.2.1. Pre-innovation- No licensing Case

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 $\delta = c_B - c_A$. 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:

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

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

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

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

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

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

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

2.3. 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. When $\epsilon > 3t - \delta$ but $\epsilon < 3t + \delta$ and firm A rejects and B accepts, then 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.

2.3.1 Fixed Fee Licensing

2.3.1.1 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:

$$p_A^F = c_A - \epsilon + \frac{1}{3}(3t + \delta + \epsilon) \tag{2.1}$$

$$p_B^F = c_B + \frac{1}{3}(3t - \delta - \epsilon) \tag{2.2}$$

$$Q_A^F = \frac{1}{6t}(3t + \delta + \epsilon) \tag{2.3}$$

$$Q_B^F = \frac{1}{6t}(3t - \delta - \epsilon) \tag{2.4}$$

$$\pi_A^F = \frac{1}{18t}(3t + \delta + \epsilon)^2 - F_A \tag{2.5}$$

$$\pi_B^F = \frac{1}{18t}(3t - \delta - \epsilon)^2 \tag{2.6}$$

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

We show if one license is being offered under fixed fee, it will always be offered to the efficient firm 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 the innovation 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.

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

2.3.1.2. Fixed Fee Licensing to Both Firms

Consider the case when the outside innovator is licensing its innovation to both the firms A and B by charging a fixed fee. In this situation the marginal costs of both firms fall by ϵ and Therefore, the optimal prices, market demands, and profits are calculated as follows:

$$p_A^{Fboth} = c_A - \epsilon + \frac{1}{3}(3t + \delta) \tag{2.7}$$

$$p_B^{Fboth} = c_B - \epsilon + \frac{1}{3}(3t - \delta) \tag{2.8}$$

$$Q_A^{Fboth} = \frac{1}{6t}(3t + \delta) \tag{2.9}$$

$$Q_B^{Fboth} = \frac{1}{6t}(3t - \delta) \tag{2.10}$$

$$\pi_A^{Fboth} = \frac{1}{18t}(3t + \delta)^2 - F_A \tag{2.11}$$

$$\pi_B^{Fboth} = \frac{1}{18t}(3t - \delta)^2 - F_B \tag{2.12}$$

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 i.e., $\epsilon < \frac{2(3t-\delta)}{3}$ 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.

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 from the licensing vis-à-vis no licensing (i.e., the outside option) is low compared to obtaining license when the innovation size is large 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 the payoff from licensing the single efficient firm only. But for relatively large innovation, i.e., $\epsilon \geq \frac{2(3t-\delta)}{3}$, the efficient firm's gain from the new technology vis-à-vis no licensing (the outside option) is sufficiently high and more compared to added-up net payoff of both the firms under licensing. When the innovation is licensed to both the firms, then costs of both the firms get reduced and the competitive 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 single firm license 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. From consumers' perspective, it will be beneficial for them, if the innovator licenses to both the firms. The consumer surplus will be higher due to lower prices of the products, which is caused by post-licensing cost reduction of both the firms. Therefore, to avoid monopoly situation the competition may enforce licensing to both firms which ensures a level playing field and increased consumer surplus.

Next, we analyse licensing through auction policy.

2.3.2. Auction Policy

In case of auction policy when one license is offered, 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 are being offered the no-acceptance payoff will be calculated as if the other firm can potentially win the contract and therefore it will be similar to the one license auction case.

2.3.2.1. Auction Policy - Only One License Offered

Lemma 2: *When only one license is auctioned then the efficient firm always wins the auction irrespective of whether the size of the innovation be i.e., drastic or non-drastic.*

Proof: See Appendix.

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.

2.3.2.2. 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)[16]. Both the bidders pay their respective bids. Comparing the payoffs of one license and two license case of auctioning, we get the result stated below.

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

Proof: Appendix.

When two licenses are offered, both firms' cost 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 if it can just bid enough (equal to the inefficient firm's bid), it will get the license. All these above effects drive down the bids of both firms and the total revenue which is equal to twice of the inefficient firms bid. The total revenue from both the firms 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.

2.3.2.3. Comparing Fixed Fee and Auction Policy

Now we can compare the payoffs of the innovator from fixed fee licensing and auction policy.

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

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.

Here we get that 'by-an-large' if the cost difference between firms is sufficiently high then fixed fee licensing to the efficient firm is optimal whereas if the cost difference is not that much 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', 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 transferred to both firms which dampens the payoff of the innovator because of the competitive effect of both firms' cost reduction. Thus, 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 contrast 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.

Next, we proceed and analyze royalty licensing in detail.

2.3.3. Royalty Licensing

2.3.3.1. 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.[17] 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:

$$p_A^R = c_A - \epsilon + r + \frac{1}{3}(3t + \delta + \epsilon - r) \tag{2.13}$$

$$p_B^R = c_B + \frac{1}{3}(3t - \delta - \epsilon + r) \tag{2.14}$$

$$Q_A^R = \frac{1}{6t}(3t + \delta + \epsilon - r) \tag{2.15}$$

$$Q_B^R = \frac{1}{6t}(3t - \delta - \epsilon + r) \tag{2.16}$$

$$\pi_A^R = \frac{1}{18t}(3t + \delta + \epsilon - r)^2 \tag{2.17}$$

$$\pi_B^R = \frac{1}{18t}(3t - \delta - \epsilon + r)^2 \tag{2.18}$$

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.

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.

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

The innovator's optimal royalty contract and the revenue to the efficient firm A, can be characterized as follows: $r^* = \epsilon$ and $Rev_A^r = \frac{\epsilon}{6t}(3t + \delta)$ $\forall\, \epsilon \leq (3t + \delta)$, $r^* = \frac{3t+\delta+\epsilon}{2}$ 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.

2.3.3.2. 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. [18] 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 $r_A \neq r_B$. Let us denote $\Delta r = r_A - r_B > 0$. The optimal prices, quantities and profits can therefore be calculated as

$$p_A^{\text{RBoth}} = c_A - \epsilon + r_A + \frac{1}{3}(3t + \delta - \Delta r) \tag{2.19}$$

$$p_B^{\text{RBoth}} = c_B - \epsilon + r_B + \frac{1}{3}(3t - \delta + \Delta r) \tag{2.20}$$

$$Q_A^{\text{RBoth}} = \frac{1}{6t}(3t + \delta - \Delta r) \tag{2.21}$$

$$Q_B^{\text{RBoth}} = \frac{1}{6t}(3t - \delta + \Delta r) \tag{2.22}$$

$$\pi_A^{\text{RBoth}} = \frac{1}{18t}(3t + \delta - \Delta r)^2 \tag{2.23}$$

$$\pi_B^{\text{RBoth}} = \frac{1}{18t}(3t - \delta + \Delta r)^2 \tag{2.24}$$

[18] Market is covered according to our assumption.

When firm A accepts its payoff given by the expression (2.23). If firm A rejects, firm B can still potentially accept the license and firm A's payoff will be $\frac{1}{18t}(3t+\delta-\epsilon+r)^2$. Given $r \le \epsilon$, 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.

Therefore, to make both the firms accept the royalty licensing 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 the above expressions (2.21) and (2.22), we get that the total industry output is 1 and therefore the total revenue of the outside innovator is $Rev^*_{RoyaltyBoth} = r$. Thus, the outside innovator will optimally choose $r = \epsilon$ and its 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 $\epsilon \ge \epsilon - 3t + \delta \ \forall \ \epsilon > 9t - \delta$ (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.[19]

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

2.3.4. Optimal Licensing Policy

Comparing the payoffs of the innovator from royalty licensing to both firms, fixed fee licensing and auction to efficient firm, 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 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 chapter.

Proposition 5: *Royalty licensing to both firms is optimum for the outside innovator irrespective of the size of innovation and initial cost differences of the licensees. Fixed fee licensing or auctioning of the license is never optimal. The payoff of the innovator*

[19] One can also consider a two-part tariff licensing contract which is a mixture of fixed fee and royalty licensing. However, it can be shown that the optimal two-part tariff licensing actually reduces to pure royalty that is considered here. For this reason, we did not consider it in a different section.

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 innovation sizes and 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 sequentially to the other firm, in that 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 the royalty licensing offer 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.[20]

[20] 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 mentioned in Banerjee and Poddar (2019).

2.4. Technology Selling Possibility

We now examine the possibility of selling the patent right to one of the firms.[21] For this purpose we make use the results and expressions of Banerjee and Poddar (2019) and Lu and Poddar (2014). 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 upfront 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 $F_A^{Sell} = \epsilon + \frac{1}{18t}(3t-\delta)^2 + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2 - \frac{1}{18t}(3t+\delta)^2 = \epsilon + \frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\varepsilon)^2$ from the efficient firm. Similarly, if the innovator sells it to inefficient firm then the innovator can potentially charge $F_B^{Sell} = \epsilon + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\varepsilon)^2$. Comparing the payoffs of the innovator 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, for $3t - \delta < \epsilon < 3t + \delta$, 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 firm B. Comparing, we get that, given $3t - \delta < \epsilon < 3t + \delta$, the innovator will optimally sell the technology

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

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 than royalty licensing to both firms with once-for-all contract. 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 from 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.

2.5. 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 possible 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). Analysing 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 outcomes.

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 chapter, 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. In next chapter we adopt non-uniform cost reduction by considering licensing of a small technology innovation which is only beneficial to inefficient firm, the innovation cannot improve the technology of the efficient firm.

Appendix

Proof of Lemma 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 the firms get their pre-technology transfer profits (outside option) and therefore firm A will get $\frac{1}{18t}(3t+\delta)^2$. 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. Similarly, if the license is offered to firm B, the innovator 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 $F_A^* = \frac{1}{18t}(3t+\delta+\epsilon)^2 - \frac{1}{18t}(3t+\delta)^2 = \frac{\epsilon(6t+2\delta+\epsilon)}{18t} = Rev^*_{FixedSingle}$ 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 the fixed fees, 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, $Rev^*_{FixedSingle} = (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta)^2$ 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 $Rev^*_{FixedSingle} = (\epsilon + \delta - t) - \frac{1}{18t}(3t + \delta)^2$.

Proof of Proposition 1

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, then 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 the offer, 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 fixed fees charged from firm A and B, one can calculate the outside innovator's total revenue as $Rev^*_{FixedBoth} = \frac{\epsilon(6t-\epsilon)}{9t} > 0$. Comparing $Rev^*_{FixedBoth}$ and $Rev^*_{FixedSingle} = F^*_A = \frac{\epsilon(6t+2\delta+\epsilon)}{18t}$, we get $F^*_A < Rev^*_{FixedBoth}\ if \epsilon < \frac{2(3t-\delta)}{3}$.

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 $Rev^*_{FixedBoth} = \frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2 + \frac{1}{18t}(3t-\delta)^2$. Comparing this $Rev^*_{FixedBoth}$ and $Rev^*_{FixedSingle} = F^*_A = (\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta)^2$, we find that $Rev^*_{FixedSingle} > Rev^*_{FixedBoth}\ \forall\ 3t-\delta \leq \epsilon < 3t+\delta$.

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 $Rev^*_{FixedBoth} = \frac{1}{18t}(3t+\delta)^2 + \frac{1}{18t}(3t-\delta)^2$. Comparing this $Rev^*_{FixedBoth}$ and $Rev^*_{FixedSingle} = F^*_A = (\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta)^2$, we finally get that $Rev^*_{FixedSingle} > Rev^*_{FixedBoth}$ for all $\epsilon \geq 3t+\delta$.

Proof of Lemma 2

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 to 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 will win 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) ($3t-\delta \le \epsilon < 3t+\delta$)*:*

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 $Rev^*_{Auctionsingle} = \frac{1}{18t}(3t-\delta+\epsilon)^2 + k$.

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

Under this situation if firm A wins its payoff from winning will be $(\epsilon+\delta-t)$ 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 $b_A^* = (\epsilon - \delta - t) + k$, $k \approx 0$ and therefore $Rev_{Auctionsingle}^* = (\epsilon - \delta - t) + k$, $k \approx 0$.

Proof of Proposition 2

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

In this non-drastic case if both firms get the license, then firm A's payoff will be $\frac{1}{18t}(3t+\delta)^2$ and if firm A doesn't get the license (and firm B gets it) firm A's payoff will be $\frac{1}{18t}(3t+\delta-\epsilon)^2$. Therefore, firm A's maximum possible bid is $\frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2 = \frac{\epsilon(6t+2\delta-\epsilon)}{18t}$. Similarly, firm B will be willing to bid a maximum of $\frac{1}{18t}(3t-\delta)^2 - \frac{1}{18t}(3t-\delta-\epsilon)^2 = \frac{\epsilon(6t-2\delta-\epsilon)}{18t}$ when two licenses are auctioned. Thus, 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 revenue earned optimally in single license auction.

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.

Proof of Proposition 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 innovation sizes: $\frac{2(3t-\delta)}{3}$ 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 compar $F^*_A = \frac{\epsilon(6t+2\delta+\epsilon)}{18t}$ 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 innovation sizes: $\frac{2(3t-\delta)}{3}$, $6(t-\delta)$ and $(3t-\delta)$ to 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 $(3t-\delta) \leq \epsilon < (3t+\delta)$. If $0.3t < \delta < 0.6t$, then $\exists\, \tilde{\epsilon} = [(6t+\delta) - \sqrt{\delta(30t-\delta)}] \in [(3t-\delta),(3t+\delta))$ such that if $\epsilon < \tilde{\epsilon}$ auction policy is optimal, whereas for $\epsilon > \tilde{\epsilon}$ 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 $(3t-\delta) \leq \epsilon < (3t+\delta)$.

Finally, for the drastic range $\epsilon \geq (3t+\delta)$, we need to compare $F_A^* = (\epsilon+\delta-t) - \frac{1}{18t}(3t+\delta)^2$ 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 $\delta > 0.3t$.

Proof of Lemma 3

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 $\frac{3t+\delta+\epsilon}{2} > \epsilon\ \forall\ \epsilon \leq (3t+\delta)$. Therefore, in this case the optimum r will be set at $r^* = \epsilon$ which is the upper bound of r.[22] 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

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

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 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.

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 $Rev_B^r = \frac{\epsilon}{6t}(3t-\delta)\ \forall\, \epsilon \le (3t-\delta)$, $r^* = \frac{3t-\delta+\epsilon}{2}$ 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 $Rev_A^r \ge Rev_B^r$ for all values of ϵ with strict inequality for some ϵ and therefore the innovator will optimally offer the license to Firm A.

CHAPTER 3

Innovation, Shelving and Technology Transfer

3.1. Introduction

In the previous chapter, the innovation we conceive is 'common' innovation in the sense that after licensing per unit cost falls by same amount from both firms' respective unit costs. There is another possibility where the new technology can reduce both firms' unit costs in a non-uniform way. In the light of non-uniform cost reduction, we explore the issue of shelving of innovation, often known as "killer acquisition" or "acquisitions for sleep" in this chapter.

We observe scenarios where a firm sometimes pays to acquire new technologies (patents), however, does not use them in production process but shelves them. The question is, why a firm would do that when acquiring a new technology (patent) is costly. One would think patents can have option value, even when it is not clear how they ultimately be used. However, it is hard to justify the that companies have been spending large amount of money for patent portfolios simply based on option value. Looking at the recent literature on technology transfer particularly in pharmaceutical and tech industries, we find there is another compelling explanation emerging to understand this kind of firm behavior. It is the story of "killer acquisitions"; where dominant firms acquire inventions without the aim of using the invention or developing it further but only for reducing competition (see Cunningham et al. (2020), Fumagalli et al. (2020), Letina et al. (2020), Norbäck et al. (2020)).[23] This is more in the line of

[23] Cunningham et. al. (2020) using pharmaceutical industry data, show that acquired drug projects are less likely to be developed when they overlap with the acquirer's existing product portfolio, especially when the acquirer's market power is large Conservative estimates indicate 5.3 percent to 7.4 percent of acquisitions in our sample are killer acquisitions. Fumagalli et al. (2020) analyse the optimal policy of an antitrust authority towards the acquisitions of potential competitors in a model with financial constraints where the acquirer may decide to shelve the project of the potential entrant. Letina et al.

‘strategic shelving’. It is found that strategic shelving can happen just in case of an exclusive licensing of a technology. The important reason for acquiring the new technology (patent) exclusively is the acquirer firm can prevent its competitor from using it, and thus maintain its strategic advantage in the market. Patent licensing of a new technology can happen exclusively or non-exclusively. Under exclusive licensing, the innovator chooses a specific licensee to transfer the technology among all the potential licensees. This could be a natural choice, as the process of technology transfer and licensing is often costly. The relationship between exclusive licensing and strategic shelving is not adequately explored, and we believe there is a big gap to be filled in here to understand this phenomenon and the consequences thereafter on the markets and consumer welfare.

Exclusive licensing could be even more relevant now-a-days. Recently we have seen a race against time for production of COVID-19 vaccine globally. Transferring and licensing the vaccine production technology to a vaccine manufacturer is complicated and a costly process, therefore exclusive licensing from the innovator could be a natural choice. Now it is not unlikely to have potential vaccine manufacturers in competition with significant asymmetric absorptive capacity of the technology (since the technology for COVID-19 vaccine production is relatively new), we may very well see instances of strategic shelving due to profit motives.

Here is some real evidence (source: Hagiu and Yoffie, 2013) which show this is actually happening a lot in the tech-sector.

(2020) provides a theory of strategic innovation project choice by incumbents and start-ups and show that prohibiting killer acquisitions strictly reduces the variety of innovation projects, whereas prohibiting other acquisitions only has a weakly negative innovation effect. Norbäck et al. (2020) shows ‘acquisitions for sleep’ can occur if and only if the quality of a process invention is small; otherwise, the entry profit will be higher than the entry-deterring value.

- In 2011, a consortium of Apple, Microsoft, and other large firms bought a portfolio of about 6,000 patents from Nextel for $4.5 billion (outbidding Google).
- Google later acquired Motorola Mobile for $12.5 billion, which gave Google a portfolio of over 17,000 patents.
- In 2012, Microsoft bought nearly 1,000 patents from AOL for about $1 billion, and then sold some of the patents to Facebook for $550 million.

It is quite evident from the above large volume of patent transactions, a lot of 'shelving' of the patents indeed happen. In this chapter, we aim to do an in-depth analysis of this phenomenon and other related issues with regard to patent licensing and technology transfer.

The chapter aims at investigating in both theoretical and policy perspective of patent licensing of an innovation which is only beneficial to the inefficient firm in a oligopolistic market structure. Economic theory has substantially contributed to the understanding of private and social incentives towards licensing, which has also become central to research and development literature. Following up on that we look into the shelving aspect or killer acquisition of patents and its consequences among other issues.

We also note that there is a literature which talk about "sleeping patents" and its implications. The basic idea of sleeping patents is that a firm may have an incentive to patent new technologies before potential competitors do, but then never bring those patents to the market i.e., hold "sleeping patents".[24] Through sleeping patents, firms more often engage in strategic blocking, namely they prevent competitors from

[24] This is essentially a brief summary of the main points in Gilbert and Newbery (1982).

imitating their products and enter the market. Our analysis here is also closely related to this idea where the general theme is strategic patenting of technologies.

The other important aspect we address in this chapter is the following. It is true any kind of killer acquisition that leads to shelving of the technology defeats the whole purpose of new innovations. This would be an undesirable outcome from an innovator's and/or society’s point of view if these things happen too often. One of the things we show in this chapter is that the innovator can actually avoid this bad outcome by licensing or even selling the new innovation to the competitor firm. This is where other forms of technology transfer particularly play an important role to avoid those licensing mechanisms (like exclusive auctions) via which shelving or killer acquisitions of new innovation happens. In these contexts, the killer acquisition or shelving loses much of its relevance when there exist other instruments to transfer a new technology by the innovator. This is also what we show in this chapter.

One of the recent works on shelving a patent is found in Stamatopoulos and Tauman (2009), when the authors, while addressing a story of licensing of a new innovation, came across a situation where shelving of new technology indeed happens by one of the licensees. In their story under a Cournot framework, there is an outside innovator and two asymmetric firms (licensees) with different marginal costs. The innovator offers a technology that reduces the marginal cost of the less efficient firm only. This feature is also known as asymmetric absorptive capacities of new innovation by potential licensees. In that context, they show that even though innovation cannot improve the technology of the efficient firm, but there might be situations where the efficient firm will pay and acquire the technology and then shelve it to prevent the inefficient firm acquiring it, which is akin to killer acquisition. This happens in the exclusive auction under certain cost conditions. Although this outcome is a possibility, licensing through fixed fee still can be profitable to the innovator under other cost conditions. To this end, we found the relationship between shelving and asymmetric absorptive capacity of an innovation is particularly an interesting aspect. We wanted to pursue this more closely in a different framework where firms compete in prices in a differentiated product market. The main differences of our paper with Stamatopoulos and Tauman (2009) is while they consider only two licensing schemes namely exclusive auction and fixed fee, we consider several licensing schemes and later find the overall optimal licensing contract of the innovator. Secondly, if only two licensing schemes namely, auction and fixed fee are available to the innovator, killer acquisition will not always happen in their paper whereas shelving (or a killer acquisition) will always happen in our framework. Therefore, it is required to look into a broader set of licensing arrangements to avoid the undesirable outcome of shelving or a killer acquisition.

Our model consists of two asymmetric firms (efficient and inefficient), i.e., the potential licensees producing a good which is horizontally differentiated and an outside innovator (e.g., independent research lab) and the demand is inelastic.[25] The cost-reducing technology from the innovator reduces the marginal costs of the two firms in a non-uniform manner (asymmetric absorptive capacities). In particular, like Stamatopoulos and Tauman (2009), we make the extreme assumption that the innovation reduces the marginal cost of the inefficient firm only, and the efficient firm does not get any benefit from it at all. In this analysis, we first consider a licensing game where the innovator specifically opts for a fixed fee or an exclusive auction to license the technology. We look into the possibility of shelving or a killer acquisition. Since

[25] See footnote 13.

shelving always happens in this economic environment, we explore other possible licensing contracts where the innovator avoids this and yet transfer the technology profitably to one of the potential licensees. We also consider the option for selling the right, and find the most profitable way for the innovator to transfer the new technology and avoid any kind of shelving as well. We also find situations where despite successful transfer of technology, consumers may not get the benefit.

We capture the horizontal product differentiation through the well-known spatial framework of linear city model (*a la* Hotelling, 1929) where firms (licensees) are located at the end points of a unit interval and consumers are uniformly distributed over the interval. Each consumer buys exactly one unit of the product (inelastic demand) and we assume the market is fully covered. The game structure is as follows. For the licensing game, in the first stage, we allow the outside innovator to decide on the licensing schemes. Licensees (firms) decide whether to accept or reject the offer. In the second stage, firms produce and compete in prices in the product market. Similar game structure is assumed in the selling game. We first analyse the licensing game and later take up the selling game.

In the licensing game, first we look between two schemes, fixed fee licensing and auction, find the optimal licensing contract and address the issue of technology shelving. It is well-known that in many situations these two licensing schemes could only be feasible to the innovator when monitoring the output of the licensees is not possible. However, to find the overall optimal licensing contract and avoid the shelving issue, we also consider other licensing schemes, namely royalty and two-part tariff licensing. Finally, we introduce the selling game and find the most profitable mode of technology transfer of the innovator in this environment and discuss the benefits (or no benefits) to the consumers from the innovation. At the end of our analysis, it becomes apparent that a killer acquisition or shelving may not always pose as a substantial problem if alternative modes of technology transfers are there which has significant policy implications.

Our main results are as follows. In the case of fixed fee licensing, since the inefficient firm benefits from it only, the innovator will always license technology to the inefficient firm and technology diffusion takes place. Interesting outcome occurs, when the innovator auctions-off an exclusive license, we show that the efficient firm wins the auction, however, shelves the innovation. This is equivalent to a killer acquisition. Moreover, for the innovator, auctioning-off the license is more profitable than fixed fee licensing, hence the outcome under exclusive auction will always prevail in this environment. Given this negative outcome, where a new technology is shelved prohibiting any further benefit of innovation to the firms and consumers, we look into other possible licensing schemes where this undesirable outcome can be prevented and which is also profitable to innovator (in particular more profitable than exclusive auction). We find such schemes do exist; therefore, strategic shelving/killer acquisitions actually becomes less relevant.

We explore royalty, and two-part tariff licensing schemes and also find the overall optimal licensing contract of the innovator. We find optimal licensing policy essentially is either pure royalty or two-part tariff and the inefficient firm will acquire it. In particular, for relatively small innovation royalty licensing is optimal, otherwise the optimal licensing scheme is two-part tariff. Under these schemes, the technology is always transferred to the inefficient firm as the efficient firm has no incentive to acquire the technology, and also under this situation, it cannot stop the inefficient firm from acquiring it. In this case, the new technology is put to use.

Then we move to analyse the selling game in order to find, given a choice between selling the right and licensing, what the innovator would optimally choose. We find it is always optimal for the innovator to sell the new technology, and interestingly, it will always sell it to the efficient firm, unlike the case of licensing where it licenses to the inefficient firm. The efficient firm buys the right of the new technology, and in this case cannot not shelve it, but further licenses it to the inefficient firm. It is to be noted here that shelving the technology is not a credible strategy for the efficient firm, and therefore no reason for the innovator to believe on that path. Hence when it sells the technology to the efficient firm, it internalizes this fact and sets the selling price accordingly. The other interesting aspect here is the efficient firm is forced to buy the technology and, in the process, gets worse off than the pre-licensing situation. This happens because if it does not buy the technology the rival will buy it making the efficient firm further worse off. The inefficient firm's payoff stays at the pre-licensing level and the innovator extracts all the additional surplus making it the most profitable way to transfer the technology. Note that this process also avoids shelving (any killer acquisition); technology is transferred to the inefficient firm via the efficient firm. More specifically, under selling, profit of the inefficient firm remains unchanged, while consumer surplus and the profit of the efficient firm declines significantly from pre-licensing stage. All the gain from the technology transfer is appropriated by the outside innovator.

However, the benefit of the new innovation goes on to the consumers in terms of lower price of the good (i.e., higher consumer surplus) occurs only under the optimal two-part tariff licensing. Consumer surplus remains unchanged to the pre-innovation level under the optimal pure royalty licensing; thus, consumers do not get any additional benefit after innovation. In case of selling the consumers do not get the benefit of the new innovation because of higher prices compared to pre-technology transfer and the consumers are better-off (at least weakly) under optimal licensing policies than selling.

The rest of the chapter is organized as follows. In the next section, we describe the model, then discuss about shelving followed by an analysis of the licensing policies and its implications in section 3. We analyse when the technology is transferred by selling the right and find out the optimal technology transfer policy of the innovator in Section 4. The impact of the innovation on the consumers are also discussed in section 5. Finally this chapter concludes in section 6 followed by Appendix.

3.2. The Model

The basic structure of the model here is same as the linear city model of previous chapter. We consider two firms, firm A and firm B located in a linear city represented by a 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 $(price\ p_A)$ or firm B $(price\ p_B)$. $v > 0$ denotes gross utility of the consumer derived from the good. The transportation cost per unit of distance is t and it is borne by the consumers.

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 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 $Q_B = 1 - Q_A$

We assume that firm A is more efficient than firm B, so the marginal cost of firm A (c_A) is less than marginal cost of firm B (c_B).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 inefficient firm (i.e., firm B only) by ϵ but not below c_A i.e., we assume $(c_B - \epsilon) \geq c_A$ or $\epsilon \leq (c_B - c_A)$.

The timing of the licensing game is given as follows:

Stage 1: The outside innovator decides on the licensing schemes. The firm accepts or rejects the offer.

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

3.2.1. Pre-innovation- No licensing Case

First, we examine the case where the outside innovator is not there and the two asymmetric firms A and B are competing in the market. Let us define $\delta = c_B - c_A \geq 0$ to capture the cost difference. We also assume that $\delta \leq 3t$ so that the less efficient firm's equilibrium quantity is positive. The pre-licensing equilibrium prices, demands and profits can be given as[26]:

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

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

[26] No-licensing equilibrium payoffs are same as previous chapter (so the equation numbers are same).

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

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

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

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

3.3. Presence of Outside Innovator – The Licensing Game

3.3.1. Fixed Fee Licensing

Let us first consider the fixed fee licensing. Under the fixed fee policy, the innovator announces a fee at which it licenses the new technology. Any firm that is willing to pay the fee becomes a licensee. Note that firm A has no incentive to have the license since it will gain nothing from this license and also not be able to prevent its rival. Firm B accepts the license, and the equilibrium prices, demands and profits can be given as:

$$p_A^F = c_A + \frac{1}{3}(3t + \delta - \epsilon) \tag{3.1}$$

$$p_B^F = c_B - \epsilon + \frac{1}{3}(3t - \delta + \epsilon) \tag{3.2}$$

$$Q_A^F = \frac{1}{6t}(3t + \delta - \epsilon) \tag{3.3}$$

$$Q_B^F = \frac{1}{6t}(3t - \delta + \epsilon) \tag{3.4}$$

$$\pi_A^F = \frac{1}{18t}(3t + \delta - \epsilon)^2 \tag{3.5}$$

$$\pi_B^F = \frac{1}{18t}(3t - \delta + \epsilon)^2 - F_B \tag{3.6}$$

Since only the inefficient firm B will be willing to get the license, the innovator optimally sets the fee at $F_B = \left[\frac{1}{18t}(3t - \delta + \epsilon)^2 - \frac{1}{18t}(3t - \delta)^2\right] = \frac{\epsilon(6t - 2\delta + \epsilon)}{18t}$.

3.3.2. Auction Policy

Assume the innovator auctions-off one exclusive license. The maximum amount a firm is willing to pay for the license is the difference between its profit if it acquires the license and its profit if its opponent acquires it. Note that if firm A wins, it will shelve the technology as it gets no benefit from it, hence we will be back to the pre-licensing game. But by doing this it can prevent firm B from getting the license. If firm A gets the license and firm B loses, firm A's maximum possible gain will be $g_A = \left[\frac{1}{18t}(3t+\delta)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2\right] = \frac{\epsilon(6t+2\delta-\epsilon)}{18t}$ and this gain (which is basically loss avoided) comes from being able to prevent firm B from getting the license. Similarly, if firm B gets the license and firm A loses, then firm B's maximum possible gain will be $g_B = \left[\frac{1}{18t}(3t-\delta+\epsilon)^2 - \frac{1}{18t}(3t-\delta)^2\right] = \frac{\epsilon(6t-2\delta+\epsilon)}{18t}$. Since we assume $\epsilon \leq (c_B - c_A)$ i.e., $\epsilon \leq \delta$, it must be the case that $g_A > g_B$. Therefore, firm A can always ensure that it wins the auction by bidding an amount slightly higher than g_B. The equilibrium bid for firm A will therefore be $(g_B + k)$ where $k \approx 0$. Thus, firm A will always win the auction, the innovator will extract revenue of $Rev_A^{Auc} = (g_B + k)$ from firm A and the technology will be shelved. Thus, firm A will optimally prevent firm B from acquiring the license.

Now looking at the payoffs of the innovator under fixed fee and auction we arrive at the following result.

Proposition 1

Between fixed fee and auction policy, it is always weakly optimal for the innovator, to auction off an exclusive license and the efficient firm will get it; however, the technology will always be shelved.

For any positive k (even if $k \approx 0$) the revenue of the innovator is higher in case of an exclusive auction. This result comes from the nature of the licensing environments, i.e., in case of fixed fee both firms can get the license against a fixed payment but in case of auction only the highest bidder gets it. The competitive environment of the auction setting leads to such outcome. As we can see, under this environment, there will be no real diffusion of the new technology. Since the technology is shelved, cost conditions of both firms do not change and the final good will be sold at the same price as the pre-licensing stage in the market. Consumers do not get better off. The profit of the inefficient firm remains same whereas the profit of the efficient firm decreases from the pre-licensing stage by the amount of the revenue extracted by the innovator. Only the innovator benefits from the transaction. This result is in contrast to Stamatopoulos and Tauman (2009) where shelving might happen depending on cost differences of the firms. Whereas in our model shelving always happens with fixed fee and auction. The reason is the exclusive nature of the auction policy.

Given this negative and less desirable outcome under these two licensing policies, we now consider other licensing possibilities to see if a different and possibly better outcome can be achieved, and in that process the threat of shelving can be avoided. First, we consider a royalty licensing policy followed by a two-part tariff licensing scheme.

3.3.3. Royalty Licensing

First note that like the fixed fee licensing, only the inefficient firm B will be interested to get the license. Let the per-unit royalty fee charged by the innovator to firm B is r. Firm B's profit function will be $\pi_B = p_B Q_B - (c_B - \epsilon + r)Q_B$. Firm A's profit function is $\pi_A = p_A Q_A - c_A Q_A$. When firm B accepts the license, the expressions for prices, demands and profits are as follows:

$$p_A^R = c_A + \frac{1}{3}(3t + \delta - \epsilon + r) \tag{3.7}$$

$$p_B^R = c_B - \epsilon + r + \frac{1}{3}(3t - \delta + \epsilon - r) \tag{3.8}$$

$$Q_A^R = \frac{1}{6t}(3t + \delta - \epsilon + r) \tag{3.9}$$

$$Q_B^R = \frac{1}{6t}(3t - \delta + \epsilon - r) \tag{3.10}$$

$$\pi_A^R = \frac{1}{18t}(3t + \delta - \epsilon + r)^2 \tag{3.11}$$

$$\pi_B^R = \frac{1}{18t}(3t - \delta + \epsilon - r)^2 \tag{3.12}$$

The outside innovator will maximize rQ_B and the optimal royalty contract for the outside innovator will be as follows.

Lemma 1:

The optimal royalty contract and the revenue of the innovator is given below:

$$r^* = \epsilon \; \forall \; 0 < \epsilon \leq (3t - \delta) \; and \; Rev_B^R = \frac{\epsilon}{6t}(3t - \delta) \forall \; 0 < \epsilon \leq (3t - \delta).$$

$$r^* = \frac{3t - \delta + \epsilon}{2} \;\; \forall \; (3t - \delta) < \epsilon \leq \delta \; and \;\; Rev_B^R = \frac{(3t - \delta + \epsilon)^2}{24t} \forall \; (3t - \delta) < \epsilon \leq \delta$$

Proof: See Appendix.

3.3.4. Two-Part Tariff Licensing

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

$$p_A^{TPT} = c_A + \frac{1}{3}(3t + \delta - \epsilon + r) \tag{3.13}$$

$$p_B^{TPT} = c_B - \epsilon + r + \frac{1}{3}(3t - \delta + \epsilon - r) \tag{3.14}$$

$$Q_A^{TPT} = \frac{1}{6t}(3t + \delta - \epsilon + r) \tag{3.15}$$

$$Q_B^{TPT} = \frac{1}{6t}(3t - \delta + \epsilon - r) \tag{3.16}$$

$$\pi_A^{TPT} = \frac{1}{18t}(3t + \delta - \epsilon + r)^2 \tag{3.17}$$

$$\pi_B^{TPT} = \frac{1}{18t}(3t - \delta + \epsilon - r)^2 - F_B \tag{3.18}$$

Now, the innovator will maximize the revenue earned from the inefficient firm $Rev_{TPT} = rQ_B^{TPT} + F_B = \frac{r}{6t}(3t - \delta + \epsilon - r) + \frac{1}{18t}(3t - \delta + \epsilon - r)^2 - \frac{1}{18t}(3t - \delta)^2$. Given this, one can calculate the optimal two-part tariff licensing contract for the innovator which is formalized as follows:

Lemma 2:

The optimum two-part tariff contract offered by the innovator will be as follows:

$\{r_B^{TPT} = \epsilon;\ F_B^{TPT} = 0\}$ *if* $\epsilon \leq \frac{3t-\delta}{3}$ *and* $Rev_B^{TPT} = \frac{\epsilon}{6t}(3t - \delta)$.

$\{r_B^{TPT} = \frac{\epsilon-\delta+3t}{4};\ F_B^{TPT} = \frac{(\epsilon-\delta+3t)^2}{32t} - \frac{(3t-\delta)^2}{18t}\}$ *if* $\frac{3t-\delta}{3} < \epsilon < \delta$ *and* $Rev_B^{TPT} = \frac{(\epsilon-\delta+3t)^2}{16t} - \frac{(3t-\delta)^2}{18t}$.

Proof: See Appendix.

3.3.5. Optimal Licensing Contract

We already know that the innovator will prefer auction over fixed fee licensing. Now, we compare payoffs of the innovator from auction, royalty and two-part tariff licensing to find out the optimal contract of the innovator. We get the following result which characterizes the overall licensing policy.

Proposition 2

The optimal licensing contract of the innovator is given as follows:

Royalty to firm B, i.e. $r_B^* = \epsilon$ *for all* $0 < \epsilon \leq \frac{(3t-\delta)}{3}$ *and* $Rev^* = \frac{\epsilon}{6t}(3t-\delta)$.

Two-part tariff to firm B, i.e. $\left\{r_B^{TPT} = \frac{\epsilon-\delta+3t}{4};\ F_B^{TPT} = \frac{(\epsilon-\delta+3t)^2}{32t} - \frac{(3t-\delta)^2}{18t}\right\}$ *for all* $\frac{3t-\delta}{3} < \epsilon \leq \delta$ *and* $Rev^* = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}$.

Proof: See Appendix.

The intuition for the above result is that for relatively higher magnitude of cost reduction the innovator leaves some surplus per-unit output for the licensee firm B as this will increase the operative profit of firm B through relatively greater output and increased market coverage in the subsequent market competition. The innovator then finds it optimal to extract the remaining surplus through an up-front fee. But for lower degree of cost reduction, output and market coverage effect for firm B is not that much and therefore it is optimal for the innovator to extract the entire cost reducing benefit per-unit from the licensee firm B. Thus, a pure royalty will maximize the extraction for the innovator for lower degree of cost reduction. Also note that auction of an exclusive license is never optimal since the auction effectively plays out like a second price auction where firm B's maximum bidding potential is also lower. This makes auction a relatively low-revenue potential technology transfer mechanism for the innovator whereas non-exclusive royalty and two-part tariff fetch better revenue for the innovator.

3.4. Technology Selling Possibility

We now consider the possibility of selling the technology by the outside innovator. The innovator sells it by charging an upfront fee. The innovator can sell the technology to either the efficient firm A or the inefficient firm B. Now, it is straightforward that if the innovator sells it to firm B, then no further licensing happens as firm A has no incentive to acquire the license whereas if the innovator sells it to firm A, then further licensing happens as we will see below.

When the innovator sells the technology to firm B then only firm B's cost is reduced. The gain for firm B from this purchase will be $\frac{1}{18t}(3t-\delta+\epsilon)^2 - \frac{1}{18t}(3t-\delta)^2 = \frac{\epsilon}{18t}(6t-2\delta+\epsilon)$. This will be charged by the outside innovator as the fixed fee for the sale and therefore the revenue of the innovator, if it sells to firm B, will be $Rev_B^{SELL} = \frac{\epsilon(6t-2\delta+\epsilon)}{18t}$. Note that it is same as the fee under fixed fee licensing.

However, if the innovator sells it to the efficient firm A, then firm A has the option of further licensing it to firm B as firm B gains from the transferred technology.[27] And then both firms choose optimum prices. To get the entire picture of this subgame we need to analyse the optimal licensing strategy of firm A in this licensing sub-game. In this licensing sub-game, firm A is an insider who has a better technology. From Lu and Poddar (2014) we know that it is optimum for an insider to go for a two-part tariff per-unit royalty licensing contract. Thus, the optimum two-part tariff contract offered by firm A to firm B in this licensing sub-game can be calculated as $r^* = \epsilon$ and $F^* = \left[\frac{1}{18t}(3t-\delta+\epsilon)^2 - \frac{1}{18t}(3t-\delta)^2\right] = \frac{\epsilon}{18t}(6t-2\delta+\epsilon)$. Firm B gets its outside option $\frac{1}{18t}(3t-\delta)^2$ and will accept the contract. Firm A's gross payoff from this licensing, post technology sale will be $\pi_A = \frac{1}{18t}(3t+\delta-\epsilon)^2 + \frac{\epsilon}{18t}(6t-2\delta+\epsilon) + \epsilon$.

[27] Even if the efficient firm tries to convince the innovator that it would not license further and shelve the technology and hence bargain for a lower selling price, it would not be a credible strategy and the innovator has no reason to believe that.

The innovator will optimally extract the net gain $P_A = \frac{1}{18t}(3t + \delta - \epsilon)^2 + \frac{\epsilon}{18t}(6t - 2\delta + \epsilon) + \epsilon - \frac{1}{18t}(3t + \delta - \epsilon)^2 = \frac{\epsilon}{18t}(6t - 2\delta + \epsilon) + \epsilon$ since the no-acceptance payoff for firm A is $\frac{1}{18t}(3t + \delta - \epsilon)^2$ (since in that case firm B would get the technology) and P_A also denotes the price of sale to firm A. Thus, the revenue of the innovator if it decides to sell the technology to firm A is $Rev_A^{SELL} = P_A = \frac{\epsilon}{18t}(6t - 2\delta + \epsilon) + \epsilon$. One can easily check that $Rev_A^{SELL} > Rev_B^{SELL}$. Thus, the innovator will optimally sell the license to the efficient firm A.

Proposition 3

If the innovator chooses to sell the technology to one of the competing firms, it will choose the efficient firm. The efficient firm further licenses the technology to the inefficient firm.

If the innovation is sold to the inefficient firm B then no further licensing happens. In other words, there is no scope for additional gain. Therefore, if the innovation is sold to firm B the innovator's revenue potential is lower. On the contrary if the innovation is sold to firm A then firm A further licenses it to firm B using two-part tariff licensing which the innovator can potentially extract from firm A. Here the revenue potential is higher and therefore the innovator will optimally sell the technology to the efficient firm A.

Now we look into the optimal method of technology transfer from the innovator's point of view. For that purpose, we need to compare the payoffs of the innovator from selling and optimal licensing.

3.4.1. Comparison between Selling and Licensing

Comparing the optimal technology licensing and the selling scheme we get the following result:

Proposition 4

It is optimal for the innovator to sell the patent to the efficient firm, which will further license it to the inefficient firm. Technology diffusion takes place but all the gain from the technology transfer is appropriated by the innovator.

Proof: See Appendix.

The intuition for the above result is that under selling the efficient firm can further license the technology to the inefficient firm. Thus, the efficient firm can extract the surplus from the inefficient firm which in turn is extracted by the innovator. The total pie of the innovator's revenue is bigger under selling due to two-stage of surplus extraction. Alternatively selling the efficient firm is framed in such a way that licensing game is already embedded in selling. Therefore, all the possibilities in the licensing game have ingrained in selling as well. Thus, under selling the innovator cannot be worse-off (actually gets strictly better here) compared to licensing.

Note that under selling, the profit of the inefficient firm remains unchanged, while the profit of the efficient firm declines compared to pre-technology transfer stage. The outside innovator benefits exclusively from the transaction. Thus, overall, selling leads to further technology transfer, the efficient firm manages to keep its competitive edge by keeping the marginal cost of the inefficient firm at the pre-technology transfer level but gets extracted by the outside innovator.

3.5. Consumer Welfare

Now let us look into the aspect of benefit to the consumers from the innovation under licensing and selling. More precisely, we will look into the consumer surplus under both environments.

The market prices of the good, charged by both the firms, will be $p_A^{SELL} = c_A + \epsilon + \frac{1}{3}(3t + \delta - \epsilon)$ and $p_B^{SELL} = c_B + \frac{1}{3}(3t - \delta + \epsilon)$ under selling. The consumer surplus can be calculated as $CS^{SELL} = \int_0^{\frac{\delta+3t+\epsilon}{6t}} \left(v - (c_A + \epsilon + \frac{3t+\delta-\epsilon}{3}) - tx\right) dx + \int_{\frac{\delta+3t+\epsilon}{6t}}^{1} \left[v - (c_B + \frac{3t-\delta+\epsilon}{3}) - (1-x)t\right] dx = \frac{36vt - 36tc_B - 45t^2 + \delta^2 + \epsilon^2 + 18t\delta - 2\delta\epsilon - 18t\epsilon}{36t}$.

When innovation size $0 < \epsilon \leq \frac{(3t-\delta)}{3}$, pure royalty licensing to the inefficient firm is optimal. Therefore, the optimal royalty rate is $r_B^* = \epsilon$ and the optimal equilibrium prices will be $p_A^R = c_A + \frac{1}{3}(3t + \delta)$ and $p_B^R = c_B + \frac{1}{3}(3t - \delta)$. For $\epsilon < \frac{(3t-\delta)}{3}$, the consumer surplus from licensing is

$$CS^{RLic} = \int_0^{\frac{\delta+3t}{6t}} \left[v - \left(c_A + \frac{3t+\delta}{3}\right) - tx\right] dx + \int_{\frac{\delta+3t}{6t}}^{1} \left[v - \left(c_B + \frac{3t-\delta}{3}\right) - (1-x)t\right] d$$

$$= \frac{36tv - 36tc_B - 45t^2 + \delta^2 + 18t\delta}{36t}$$

If $\frac{(3t-\delta)}{3} < \epsilon \leq \delta$, then two-part tariff to the inefficient firm is the optimal licensing contract and $r_B^{TPT} = \frac{3t-\delta+\epsilon}{4} < \epsilon$ and the prices are $p_A^{TPT} = c_A + \frac{5t+\delta-\epsilon}{4}$, $p_B^{TPT} = c_B + \frac{1}{2}(3t - \delta - \epsilon)$. Therefore, the consumer surplus can be calculated as

$$CS^{TPTLic} = \int_{0}^{\frac{5t+\delta-\epsilon}{8t}} \left[v - \left(c_A + \frac{5t+\delta-\epsilon}{4}\right) - tx\right] dx$$

$$+ \int_{\frac{5t+\delta-\epsilon}{8t}}^{1} \left[v - (c_B + \frac{3t-\delta-\epsilon}{2}) - (1-x)t\right] dx$$

$$= \frac{64tv - 64tc_B - 103t^2 + \delta^2 + \epsilon^2 + 42t\delta - 2\delta\epsilon + 22t\epsilon}{64t}$$

Comparing for both the ranges $\epsilon \leq \frac{(3t-\delta)}{3}$ and $\frac{(3t-\delta)}{3} < \epsilon \leq \delta$, one can show that $CS^{SELL} < CS^{jLic}$ where $j = R, TPT$ for all $\epsilon \in (0, \delta]$. Therefore, consumer surplus is higher under licensing compared to selling. The intuition is that in case of selling, firm A purchases the right and subsequently offers a two-part tariff licensing contract to firm B by charging $r^* = \epsilon$ and a positive fixed fee. Thus, firm B's post licensing per unit cost doesn't fall effectively and also firm A extracts that fixed fee from firm B. This internal technology licensing and subsequent price game creates an upward pressure on both prices compared to pre-technology transfer. In case of licensing, for $0 < \epsilon \leq \frac{(3t-\delta)}{3}$, the innovator offers pure royalty license to firm B charging $r^* = \epsilon$. In this case both the marginal costs of firm A and firm B remain at the pre-technology transfer level and therefore the prices also remain at the pre-technology transfer level**.** But for $\frac{(3t-\delta)}{3} < \epsilon \leq \delta$ the optimal licensing to the inefficient firm B is two-part tariff with a royalty rate less than ϵ (the maximum amount of royalty rate, an innovator can charge in royalty licensing). Thus, in this range, the marginal cost of firm B falls and therefore the price charged by firm B also falls. Since the firms are assumed to compete in prices, firm A also optimally reduces its price. Thus, in both situations the consumers are not worse-off in case of licensing compared to selling. Hence, we summarize the above discussion below.

Proposition 5:

Consumers are better-off (at least weakly) under licensing than selling.

3.6. Conclusion

The basic purpose of innovation gets defeated if the knowledge generated from the innovation is not put to use. The value of a cost- reducing innovation is not realized if that is not used in the production process of the firm. In this paper, we have showed this kind of case where innovation remains unused when the patent is transferred using exclusive auction by the innovator. The phenomenon of acquiring technology and not using it is called shelving and it happens in various industries, particularly in pharmaceutical and tech-industries. By shelving the technology, the technology acquiring firm can strategically prevent its competitor from using it, and thus maintain its strategic advantage in the market. That is why, this type of technology acquisition is often called killer acquisition as the acquisition buries the technology before it gets used in any production process or in further research and development. To understand this phenomenon and to avoid this type strategic shelving we look into alternative technology transfer arrangements in greater depth. We show there exists various other mechanisms through which the technology can be successfully transferred by the innovator and shelving could be avoided thereby making killer acquisitions less relevant.

We considered a framework of horizontal production differentiation with inelastic demand where the cost reductions to the firms are non-uniform from the same innovation. We consider an extreme situation where cost reduction only happens to the inefficient firm but innovation has no impact on the cost of the efficient firm. In this environment, we first show the occurrence of shelving of a technology when fixed fee and exclusive auction are means of technology licensing. Then we consider other possible licensing contracts to avoid shelving. In that process we also find out the optimal licensing policy of the innovator. We show that the optimal licensing policy of the innovator is royalty or two-part tariff depending on the size of the innovation. Moreover, under the two-part tariff policy, the consumers get better off compared to the pre-licensing stage in terms of lower price of the good. Instead of licensing if the innovator sells the right of the new technology to one of the firms, shelving can also be avoided. The efficient firm will acquire the right under selling. However, in this case, instead of shelving the technology, the efficient firm will further license it to its rival firm. The inefficient will use the technology, so technology diffusion takes place under selling. But here the consumers are not better off compared to pre-technology transfer stage as the prices of the good do not fall. The profit of the inefficient firm remains unchanged, while the profit of the efficient firm declines significantly. All the surplus coming from the cost-reducing innovation is extracted by the innovator.

The concept of the next chapter follows on from the kind of innovation we explored in the current chapter. We have already established the influence of the innovation beneficial to only the inefficient firm on technology transfer from an outside innovator. In this case the innovation does not reduce any cost of the efficient firm. Naturally the question emerges what will be the effect on patent licensing if an innovation reduces marginal cost of both firms but in a non-uniform way. We have tried to inquire into this topic in the following chapter.

Appendix

Proof of Lemma 1

The outside innovator will maximize rQ_B and the optimum royalty rate should have been $r^* = \frac{3t-\delta+\epsilon}{2} > 0$. Now $\frac{3t-\delta+\epsilon}{2} > \epsilon \ \forall \ \epsilon \leq (3t-\delta)$. In this case innovator sets $r^* = \epsilon$ and gets revenue $Rev_B^R = \frac{\epsilon}{6t}(3t-\delta)$. Firm B's payoff accepting the royalty licensing will be $\pi_B^R = \frac{1}{18t}(3t-\delta)^2$.[28] If $\epsilon > (3t-\delta)$, then the innovator will charge $r^* = \frac{3t-\delta+\epsilon}{2}$ and earns a revenue of $Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{24t}$.[29] But since we assume $\delta \geq \epsilon$, the optimal royalty contract will depend on the magnitude of δ. Now $\delta > (3t-\delta)$ if and only if $\delta > \frac{3t}{2}$. In this case the innovator charges $r^* = \epsilon$ for $0 < \epsilon \leq (3t-\delta)$ and $r^* = \frac{3t-\delta+\epsilon}{2}$ for $(3t-\delta) < \epsilon \leq \delta$. If $\delta \leq \frac{3t}{2}$, then innovator can only charge $r^* = \epsilon$. To keep things rather general we consider $\delta > \frac{3t}{2}$ since we will have all possibilities open with this assumption and therefore this case is less restrictive to $\delta \leq \frac{3t}{2}$. Therefore given $\delta > \frac{3t}{2}$, the optimum royalty contract will be: $r^* = \epsilon \ \forall \ 0 < \epsilon \leq (3t-\delta)$ and $r^* = \frac{3t-\delta+\epsilon}{2} \ \forall \ (3t-\delta) < \epsilon \leq \delta$. The revenue of the innovator will be $Rev_B^R = \frac{\epsilon}{6t}(3t-\delta) \forall \ 0 < \epsilon \leq (3t-\delta)$ and $Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{24t} \forall \ (3t-\delta) < \epsilon \leq \delta$.

Proof of Lemma 2

The innovator will offer the two-part tariff licensing contract to firm B by maximizing $Rev_{TPT} = rQ_B^{TPT} + F_B = \frac{r}{6t}(3t-\delta+\epsilon-r) + \frac{1}{18t}(3t-\delta+\epsilon-r)^2 - \frac{1}{18t}(3t -$

[28] If firm B rejects, it gets pre-licensing payoff as firm A has no incentive to acquire the technology.

[29] Once again Firm B will be strictly better off accepting the contract with payoff $\frac{(3t-\delta+\epsilon)^2}{72t}$

$\delta)^2$. The optimal two-part tariff royalty rate can be calculated as $r_B^{TPT} = \frac{\epsilon-\delta+3t}{4}$. Now $\frac{\epsilon-\delta+3t}{4} \geq \epsilon$ if $\epsilon \leq \frac{3t-\delta}{3}$. So $r_B^{TPT} = \epsilon$ if $\epsilon \leq \frac{3t-\delta}{3}$ and $r_B^{TPT} = \frac{\epsilon-\delta+3t}{4}$ if $\epsilon > \frac{3t-\delta}{3}$.

Now once again since the maximum value of ϵ can be δ we need to check whether $\frac{3t-\delta}{3}$ is greater than δ or not. We get that $\frac{3t-\delta}{3} > \delta$ iff $< \frac{3t}{4}$, therefore $\frac{3t-\delta}{3} \leq \delta$ iff $\delta \geq \frac{3t}{4}$. Once again for the sake of generality we assumed in the last section that $\delta > \frac{3t}{2}$ holds implying that $\delta \geq \frac{3t}{4}$ holds. This will keep all possibilities open and we proceed with that.

If the innovator offers the two-part tariff contract to firm B then the optimum two part tariff contracts offered will be $\{r_B^{TPT} = \epsilon;\ F_B^{TPT} = 0\}$ if $\epsilon \leq \frac{3t-\delta}{3}$; $\{r_B^{TPT} = \frac{\epsilon-\delta+3t}{4};\ F_B^{TPT} = \frac{(\epsilon-\delta+3t)^2}{32t} - \frac{(3t-\delta)^2}{18t}\}$ if $\frac{3t-\delta}{3} < \epsilon < \delta$.

The optimal profit of the innovator, therefore, will be $Rev_B^{TPT} = \frac{\epsilon}{6t}(3t-\delta)$ if $\epsilon \leq \frac{3t-\delta}{3}$; $Rev_B^{TPT} = \frac{(\epsilon-\delta+3t)^2}{16t} - \frac{(3t-\delta)^2}{18t}$ if $\frac{3t-\delta}{3} < \epsilon < \delta$.

Proof of Proposition 2

There will be three different cases depending on the size of the innovation, we need to look at.

Case (i) $0 < \epsilon \leq \frac{(3t-\delta)}{3}$

Under this range of innovation payoffs of the innovator from royalty, two-part tariff and auction are as follows:

$$Rev_B^R = \frac{\epsilon}{6t}(3t-\delta)$$

$$Rev_B^{TPT} = \frac{\epsilon}{6t}(3t-\delta)$$

$$Rev_A^{Auc} = \frac{\epsilon(6t - 2\delta + \epsilon)}{18t} + k$$

It is evident that two-part tariff payoff is same as royalty. So, we need to compare between royalty and auction. We get $Rev_B^R > Rev_A^{Auc}$if $\epsilon < (3t - \delta)$. Therefore, for $\epsilon \leq \frac{(3t-\delta)}{3}$ revenue from royalty will be higher than auction. Therefore, it is optimal for the innovator to charge $r^* = \epsilon$ and royalty licensing will be optimal.

Case (ii) $\frac{(3t-\delta)}{3} < \epsilon \leq (3t - \delta)$

Payoffs of the innovator from royalty, two-part tariff and auction are:

$$Rev_B^R = \frac{\epsilon}{6t}(3t - \delta)$$

$$Rev_B^{TPT} = \frac{(3t - \delta + \epsilon)^2}{16t} - \frac{(3t - \delta)^2}{18t}$$

$$Rev_A^{Auc} = \frac{\epsilon(6t - 2\delta + \epsilon)}{18t} + k$$

We know that for $\epsilon < (3t - \delta)$, $Rev_B^R > Rev_A^{Auc}$ and therefore the innovator will always earn a higher profit under royalty than auction. Therefore, we need to check between two-part tariff and royalty licensing. Now $Rev_B^{TPT} - Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t} - \frac{\epsilon}{6t}(3t - \delta)$= $(3t - \delta - 3\epsilon)^2 > 0$ always holds. Therefore, two-part tariff is optimal for $\frac{(3t-\delta)}{3} < \epsilon \leq (3t - \delta)$.

Case (iii) $(3t - \delta) < \epsilon \leq \delta$

Payoffs of the innovator from royalty, two-part tariff and auction are:

$$Rev_B^R = \frac{(3t - \delta + \epsilon)^2}{24t}$$

$$Rev_B^{TPT} = \frac{(3t - \delta + \epsilon)^2}{16t} - \frac{(3t - \delta)^2}{18t}$$

$$Rev_A^{Auc} = \frac{\epsilon(6t - 2\delta + \epsilon)}{18t} + k$$

First, we compare royalty and auction policy in this range and we get that $Rev_A^{Auc} = \frac{\epsilon(6t-2\delta+\epsilon)}{18t} > Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{24t}$ iff $(3t - \delta - \epsilon)[3(3t - \delta) + \epsilon] < 0$ holds. Since $[3(3t - \delta) + \epsilon] > 0$ we need $(3t - \delta - \epsilon) < 0$ to hold implying $\epsilon > (3t - \delta)$ holds. Thus $Rev_A^{Auc} > Rev_B^R$ for $(3t - \delta) < \epsilon \leq \delta$. Finally, in this range we need to compare between auction policy and two-part tariff and we go by the following way. At $\epsilon = (3t - \delta)$, $Rev_A^{Auc} = 0.166\frac{(3t-\delta)^2}{t}$ and $Rev_B^{TPT} = 0.194\frac{(3t-\delta)^2}{t}$. Define $G = Rev_B^{TPT} - Rev_A^{Auc} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t} - \frac{\epsilon(6t-2\delta+\epsilon)}{18t}$. We get that $\frac{dG}{d\epsilon} = \frac{(3t-\delta)+\epsilon}{72t} > 0$. This shows that $Rev_B^{TPT} > Rev_A^{Auc}$ for all $(3t - \delta) < \epsilon \leq \delta$. Therefore, the innovator will license the technology through two-part tariff by charging $r_B^{TPT} = \frac{3t-\delta+\epsilon}{4}$ $and\ F_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{32t} - \frac{(3t-\delta)^2}{18t}$.

Proof of Proposition 4

Case (i) $0 < \epsilon \leq \frac{(3t-\delta)}{3}$

In this range the optimal licensing policy was pure royalty and therefore we need to compare the payoffs of the innovator from selling and royalty licensing. The payoff from selling is $Rev_A^{SELL} = \epsilon + \frac{\epsilon(6t-2\delta+\epsilon)}{18t}$ and the payoff from royalty licensing is $Rev_B^R = \frac{\epsilon}{6t}(3t - \delta)$. Since $\epsilon > \frac{\epsilon}{6t}(3t - \delta)$, it is straightforward that the innovator can generate a higher payoff from selling the patent rather than licensing it.

Case (ii) $\frac{(3t-\delta)}{3} < \epsilon \leq \delta$

In this range we need to compare the innovator's payoffs from selling and two-part tariff licensing which are respectively $Rev_A^{SELL} = \epsilon + \frac{1}{18t}(3t - \delta + \epsilon)^2 - \frac{1}{18t}(3t -$

$\delta)^2 = \epsilon + \frac{\epsilon(6t-2\delta+\epsilon)}{18t}$ and $Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}$. To achieve the task, let us define $H = Rev_A^{SELL} - Rev_B^{TPT} = \epsilon - \frac{(3t-\delta+\epsilon)^2}{144t}$. Now at $\epsilon = \frac{(3t-\delta)}{3}$, $H = \frac{(3t-\delta)(24t+\delta)}{81t} > 0$ and at $\epsilon = \delta$, $H = \delta - \frac{t}{16} > 0$, since we focus on $\frac{3t}{2} < \delta < 3t$. Also, we get $\frac{d^2H}{d\epsilon^2} = -\frac{1}{72t} < 0$. Therefore H is concave with positive values at both $\epsilon = \frac{(3t-\delta)}{3}$ and $\epsilon = \delta$ which means that $H > 0\ \forall\epsilon \in \left[\frac{(3t-\delta)}{3}, \delta\right]$. This shows that $Rev_A^{SELL} > Rev_B^{TPT}\ \forall\epsilon \in \left[\frac{(3t-\delta)}{3}, \delta\right]$.

Therefore, it is optimal for the innovator to sell the patent instead of licensing and this holds for all $0 < \epsilon \leq \delta$. From the above analysis we can state the following.

CHAPTER 4

Technology Licensing with Asymmetric Absorptive Capacity without Leapfrogging

4.1. Introduction

Most of the literature in technology licensing conceive innovation as "common innovation" i.e., all the competing firms, irrespective of their efficiency level, can be benefitted equally from the new technology. But it is commonly observed that different firms derive different benefits from same technology when it is applied to their production process. This is the difference in the way they "absorb" the technology. In accordance with the preceding chapter, we have considered non-uniform cost reduction of the firms by the same innovation. The less efficient firm's marginal cost reduces more than that of efficient firm, but the inefficient still fails to surpass the efficiency level of its competitor in the market. This implies the inefficient firm unable to 'leapfrog' the efficient firm by using the new technology in production process.

In this chapter we characterize the influence of absorptive capacity of manufacturing firms on technology transfer through various licensing contracts. The licensor will be an independent research and development lab who is a non- producer in the industry.

The term "absorptive capacity", was coined by Cohen and Levinthal (1990), means acquisition or assimilation of information and organization's ability to exploit it. In this paper, they explained how absorptive capacity stimulates innovation within research and development companies. Whereas in the context of technology transfer from developed to developing countries through foreign direct investment (FDI), the importance of absorptive capacity of developing countries has been emphasized by

Keller (1996), Glass and Saggi (1998), Ishikawa and Horiuchi (2012), Ghosh and Ishikawa (2018). But impact of absorptive capacity in licensing literature is sparse.[30]

In contrast, we treat absorptive capacity in a different way in this chapter. We consider absorptive capacity of firms which do not involve in any research and development process. In our model we have two asymmetric manufacturing firms which produce horizontally differentiated homogenous goods and the compete in price in the product market. They can acquire a cost-reducing process innovation from an outside innovator and implement that new technology in production as per their absorptive capacity level. Precisely this absorptive capacity is the ability of the firm to implement the innovation in production process. Depending upon various circumstances this ability may vary from firm to firm. Here we deviate from the existing literature which have assumed same level of cost reduction from a new technology and assume that the difference in absorptive capacity can be reflected as difference in cost reduction of the licensee firms (Chang et al.,2016).[31]

These firms are also asymmetric in terms of their initial marginal cost of production. The cost difference arises due to the inefficiency of the high-cost firm (inefficient firm) at some stages of its production process compared to the other firm. These firms are potential licensees of the new technology. The innovator can only transfer the new technology through licensing to either one firm (exclusive licensing) or both the firms (non-exclusive licensing) based on the revenue earned. Thus, both asymmetries of the firms make our model more relevant to the real world.

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[30] Asymmetric absorptive capacity of firms has been mentioned in Stamatopoulos and Tauman (2009), Chang et al. (2016).

[31] Wang et al. (2013), Lu and Poddar (2014), Colombo and Filippini (2015), Banerjee and Poddar (2019), Poddar et al. (2021) are few recent papers which have showed uniform cost reduction after licensing.

There is a notion that efficient firm should always have a better absorptive capacity due to better skill than its competitor. But it is not always true. This kind of presumption may overlook a situation where an efficient firm has lower absorption of technological benefits than inefficient firm. We consider this kind asymmetry in absorptive capacity in this chapter. As the efficient firm has already achieved a high level of efficiency in technological front, additionally from a particular new technology there is a very little scope of improvement (absorption) for efficient firm, whereas inefficient firm can be benefitted much more from the same technology than the efficient firm. Therefore, efficient firm's cost reduction will be lower than that of inefficient firm.

Apart from above two asymmetries, our analysis depends on a restrictive assumption of post licensing cost structure of firms. We assume a priori that post licensing cost of the inefficient firm will not be less than ex ante cost of the efficient firm though the cost-reduction is greater for inefficient firm. That means if the innovation is adopted by the inefficient firm, it will surely narrow down the cost difference between the inefficient firm and efficient firm. But the former will not be able to 'leapfrog' the latter by adopting the new technology. The motive behind this kind of strict assumption is to rule out the possibility of monopoly and encourage market competition. We believe that this kind of cost-reducing innovation will have significant implications in our results.

The aim of this chapter is to study the effect of asymmetries of producing firms on the licensing decision of the outsider innovator in a duopoly market of spatial competition. Compared to the existing literature in patent licensing and absorptive capacity, such as Stamatopoulos and Tauman (2009), Chang et al. (2016) which have used product differentiation in conventional Cournot duopoly model, we consider horizontal product differentiation in a linear city model (a la Hotelling, 1929) with fixed location of the firms at two extremes of the city. This kind of framework is suitable for the markets which are not growing i.e., brands of the product are well established. Each consumer has her own preference for a particular brand (i.e., inelastic demand) and buys exactly one unit of the product at the prevailing market price (fully covered market). All the consumers are assumed to be uniformly distributed over the interval of the city.

In this chapter we present a detailed analysis of all licensing schemes and find that under fixed fee and auction policy innovator's optimal decision does not depend much on absorptive capacity. Whereas royalty and two-part tariff licensing policies are sensitive to the asymmetry in absorptive capacity of the licensee firms. In exclusive royalty licensing, for small to medium innovation size and lower cost difference between the firms, the inefficient firm can get the license from the innovator if the absorptive capacity of the efficient firm is very low, otherwise efficient firm will get the license. In case of higher efficiency level of the efficient firm, the licensor will always offer the exclusive royalty licensing to it irrespective of its absorptive capacity and innovation size. Between exclusive and non-exclusive royalty licensing, the innovator will choose to transfer the technology to both the firms either when innovation size is small, or innovation size and cost difference both are sufficiently large. For large innovation and low to medium cost difference between the licensee firms, innovators decision, on how many royalty license(s) to offer, is contingent upon the asymmetry in absorptive capacity. Similarly, non-trivial effect of asymmetric absorptive capacity is also found in exclusive and non-exclusive two-part tariff licensing. Although for optimal two-part tariff licensing, the significance of absorptive capacity varies with initial cost difference and innovation size. Finally, after comparing all the licensing schemes for all innovation size and cost difference, we obtain the fixed fee licensing to the efficient firm as the overall optimal licensing policy by the innovator. This robust finding is similar to the result of Stamatopoulos and Tauman (2009) paper, though they have considered only auction and fixed fee licensing.

We organize rest of the chapter as follows. In the next section, we introduce the basic model and the timing of the licensing game. In section 3, we analyse various licensing policies and its implications, followed by the discussion on optimal licensing policy. Sections 4 concludes this chapter.

4.2. The Basic Model

Let us consider two firms (firm A and firm B) located in a linear city represented by a unit interval $[0,1]$. Firms are located at the end points of the linear city i.e., firm A is located at 0 whereas firm B is located at 1. 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 at the price P_A or firm B at the price P_B. Gross utility of the consumer derived from the good is denoted by $v > 0$. Even though both the firms produce identical goods, from consumers' perspective the goods are differentiated due to the presence of transportation cost. The transportation cost borne by a consumer is t per unit of distance.

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

$$\begin{aligned} U &= v - P_A - tx && \text{if buys from firm A} \\ &= v - P_B - (1-x)t && \text{if buys from firm B} \end{aligned}$$

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 $Q_B = 1 - Q_A$.

We assume that firm A is more efficient than firm B, so the marginal cost of firm A (c_A) is less than marginal cost of firm B (c_B) and define the initial cost difference as $\delta = (c_B - c_A) > 0$. There is an outside innovator (independent research lab) who has invented a process innovation which can reduce the marginal cost of the firms by ϵ, if the firm can fully utilize or absorb the innovation in production process. ϵ measures the magnitude of innovation as well, alternatively known as innovation size. We assume that when the technology is adopted by the firms, the efficient can reduce its marginal cost by $\lambda\epsilon$,whereas the inefficient firm can reduce its marginal cost by ϵ but not below c_A i.e., we characterize this no-leapfrogging situation by $(c_B - \epsilon) \geq c_A$ or $\epsilon \leq (c_B - c_A)$. Hence the parameter $\lambda \in (0, 1)$ captures the degree of absorptive capacity of the firms. $\lambda < 1$, implies that the absorptive capacity of the efficient firm is less than that of the inefficient firm. Consequently, $\lambda = 0$ denotes that efficient firm has no absorptive capacity and $\lambda = 1$ means the efficient firm has full absorptive capacity. Here we consider $0 < \lambda < 1$ in our analysis.

Now the licensing game will be as follows:

Stage 1: The outside innovator licenses its innovation to either one or both firms. The firm (potential licensee) either accepts or rejects the offer. If one licensee rejects, the offer goes to the other licensee in case of one license (exclusive licensing). When two licenses are offered (non-exclusive licensing), if one licensee rejects, the offer can still remain with the other licensee.

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

4.2.1. Pre-innovation- No licensing Case

We start with a situation where no outside innovator is there, also known as no-licensing scenario. Two asymmetric firms are producing identical goods with an old technology and compete in product market. We assume $3t > \delta$ to ensure that both firms produce a positive output. Thus, we determine the no-licensing equilibrium prices, demands and profits of the both firms as follows:

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

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

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

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

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

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

4.3. Licensing Mechanisms in presence of Outside Innovator

In the following section, we examine various licensing methods widely used in real world, such as fixed-fee, auction, royalty and two-part tariff in order to explore the optimal licensing contract for the outside innovator.

4.3.1. Fixed Fee Licensing

4.3.1.1. Fixed Fee Licensing to One Firm

First, we consider fixed fee licensing, under which the innovator decides whom to license the cost-reducing innovation against a fixed fee F_i where i= A,B. If the innovation is licensed to only firm A (the efficient firm), its post licensing cost will be reduced to $(c_A - \lambda\epsilon)$ and firm B (the inefficient firm) will remain at its' initial cost c_B. If firm B gets the license its cost will become $(c_B - \epsilon)$.

The equilibrium prices, demands and profits are given as follows:

$$p_A^F = (c_A - \lambda\epsilon) + \frac{1}{3}(3t + \delta + \lambda\epsilon) \tag{4.1}$$

$$p_B^F = c_B + \frac{1}{3}(3t - \delta - \lambda\epsilon) \tag{4.2}$$

$$Q_A^F = \frac{1}{6t}(3t + \delta + \lambda\epsilon) \tag{4.3}$$

$$Q_B^F = \frac{1}{6t}(3t - \delta - \lambda\epsilon) \tag{4.4}$$

$$\pi_A^F = \frac{1}{18t}(3t + \delta + \lambda\epsilon)^2 - F_A \tag{4.5}$$

$$\pi_B^F = \frac{1}{18t}(3t - \delta - \lambda\epsilon)^2 \tag{4.6}$$

The maximum licensing fee that can be extracted from the efficient firm will be $F_A^* = \frac{1}{18t}(3t + \delta + \lambda\epsilon)^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2$. If the innovation is licensed to firm B, the licensor will charge a fee $F_B^* = \frac{1}{18t}(3t - \delta + \epsilon)^2 - \frac{1}{18t}(3t - \delta - \lambda\epsilon)^2$.

By comparing the revenues extracted from these two firms respectively, we can conclude to this following lemma:

Lemma 1: *When only one license is offered under fixed fee it is optimal for the innovator to license the cost-reducing technology to the efficient firm for any level of its absorptive capacity.*

Proof: See Appendix.

As the efficient firm is already using a cost-effective technology ex ante i.e., better efficiency than its competitor before licensing, firm A can easily acquire larger share of market with the slightest improvement in its cost condition. Hence firm A earns a higher profit and it has a higher willingness to pay for the technology than the inefficient firm. Therefore, the outside innovator offers the exclusive fixed fee license to the efficient firm.

4.3.1.2. Fixed Fee Licensing to Both Firms

Under nonexclusive fixed fee licensing scenario, outside innovator transfer the license to both firms (A,B) by charging a fee from each firm . Post-licensing marginal costs of the licensees (firm A and B) are reduced by $\lambda\epsilon$ and ϵ respectively due to asymmetric absorptive capacity. Therefore, the optimal prices, market demands, and profits are calculated as follows:

$$p_A^{Fboth} = c_A - \lambda\epsilon + \frac{1}{3}\big(3t + \delta - \epsilon(1-\lambda)\big) \tag{4.7}$$

$$p_B^{Fboth} = c_B - \epsilon + \frac{1}{3}\big(3t - \delta + \epsilon(1-\lambda)\big) \tag{4.8}$$

$$Q_A^{Fboth} = \frac{1}{6t}(3t + \delta - \epsilon(1-\lambda)) \tag{4.9}$$

$$Q_B^{Fboth} = \frac{1}{6t}(3t - \delta + \epsilon(1-\lambda)) \tag{4.10}$$

$$\pi_A^{Fboth} = \frac{1}{18t}(3t + \delta - \epsilon(1-\lambda))^2 - F_A \tag{4.11}$$

$$\pi_B^{Fboth} = \frac{1}{18t}(3t - \delta + \epsilon(1-\lambda))^2 - F_B \tag{4.12}$$

When both firms accept the offer, the total revenue earned by the innovator is

$$F^{Both} = \frac{\lambda\epsilon}{18t}\{6t + 2\delta - 2\epsilon + \lambda\epsilon\} + \frac{\epsilon}{18t}\{6t - 2\delta + \epsilon - 2\lambda\epsilon\}.$$

Comparing the revenues collected by the innovator under licensing to one firm and both firms, we find the following result in next proposition.

Proposition 1: *Under fixed fee licensing, outside innovator will exclusively license the innovation to the efficient firm irrespective of the difference in absorptive capacity between two firms.*

The Intuition behind the above proposition can be given as follows. In case of exclusive fixed fee licensing, even a lesser reduction in cost gives a higher profit to the efficient firm due to its ex-ante better efficiency than its competitor. Therefore, gain from licensing to the efficient firm will be larger for the innovator. When both firms get the new advancement in technology by licensing, inefficient firm's cost reduction is better than efficient firm as the inefficient has more scope of improvement than efficient firm and in this way inefficient firm cut into efficient firm's market share as well as profit. Hence, the competition effect between the firms brings down the gains of both firms. Consequently, the post-licensing cost of inefficient firm is still greater than efficient firm's pre-licensing cost that means the inefficient firm has still not achieved the pre-licensing efficiency level of efficient firm. Thus, there is loss in profit due to loss in efficiency. If the efficient firm only gets the license, then there is a possibility that the firm becomes a monopoly for its' absorptive capacity $\lambda \geq \frac{3t-\delta}{\epsilon}$ with innovation size $\epsilon > 3t - \delta$. In this scenario, the efficient firm acquires larger profit than total profit that both firms can earn under non-exclusive fixed fee licensing. Therefore, it is always beneficial for the outside innovator to license the technology exclusively to the efficient firm.

This above result is consistent with findings in Banerjee and Poddar (2019), Sinha (2016). Even Banerjee and Poddar (2019) can be a special case to our model, where $\lambda = 1$. Another special case is our previous chapter where $\lambda = 0$ and therefore efficient firm has no incentive to pay for the technology as it does not get any benefit from the new advancement of technology.

Now, we will analyse auction policy.

4.3.2. Auction Policy

Now we consider a situation where the outside innovator can license the technology through an auction and both firms can potentially bid for it. The maximum willingness to pay for the license is the difference between the payoff of the firm if it gets the license and its payoff if its competitor wins the license. Potentially inefficient firm has lesser willingness to pay than the efficient firm. All these facts are known to both firms under complete information. Firms will be willing to bid maximum up to g_A and g_B respectively: $g_A = \frac{\epsilon(1+\lambda)}{18t}\{6t + 2\delta - \epsilon(1-\lambda)\}, g_B = \frac{\epsilon(1+\lambda)}{18t}\{6t - 2\delta + \epsilon(1-\lambda)\}$. Now, $g_A > g_B \ \forall \lambda \in [0,1]$, therefore, firm A will always win the auction and gets the technology by bidding, $(g_B + k)$ where $k \approx 0$. When the innovator auctions off one license, the efficient firm wins it by highest bidding and gets the technology by paying the innovator a marginally higher amount than the bid of inefficient firm. It can be shown that auctioning of two licenses is suboptimal to one license auction.

Proposition 2: *Regardless of difference in absorptive capacity of the firms the innovator always auctions off one license and the efficient firm wins it for all size of innovation.*

Now, optimal payoffs under non-exclusive fixed fee and exclusive auction policy reveals that fixed fee licensing to the efficient firm is always strictly better than exclusive auctioning.

Next, we will discuss about royalty licensing.

4.3.3. Royalty Licensing

Under royalty licensing, innovator licenses the new technology to licensee(s) at a royalty rate $r_i, i = A, B$. Due to asymmetric absorptive capacity the benefit from adopting the new technology is different for two firms. Therefore, to derive the maximum revenue the innovator can charge asymmetric royalty rates from different firms ($r_A \neq r_B$).

4.3.3.1. Royalty Licensing to One Firm

Suppose the innovator offers one license to firm A by means of royalty licensing and charges royalty rate r_A. Firm A's post-licensing unit production cost becomes $(c_A - \lambda\epsilon + r_A)$ and its profit will be $p_A^R Q_A^R - (c_A - \lambda\epsilon + r_A)Q_A^R$. The licensor extracts the revenue of $r_A Q_A^R$ from firm A. The equilibrium outcomes are as follows:

$$p_A^R = (c_A - \lambda\epsilon + r_A) + \frac{1}{3}(3t + \delta + \lambda\epsilon - r_A) \tag{4.13}$$

$$p_B^R = c_B + \frac{1}{3}(3t - \delta - \lambda\epsilon + r_A) \tag{4.14}$$

$$Q_A^R = \frac{1}{6t}(3t + \delta + \lambda\epsilon - r_A) \tag{4.15}$$

$$Q_B^R = \frac{1}{6t}(3t - \delta - \lambda\epsilon + r_A) \tag{4.16}$$

$$\pi_A^R = \frac{1}{18t}(3t + \delta + \lambda\epsilon - r_A)^2 \tag{4.17}$$

$$\pi_B^R = \frac{1}{18t}(3t - \delta - \lambda\epsilon + r_A)^2 \tag{4.18}$$

Innovator maximizes $Rev_A^R = r_A Q_A^R = \frac{r_A}{6t}(3t + \delta + \lambda\epsilon - r_A)$ and optimizes a per unit royalty $r_A^* = \lambda\epsilon$. But the royalty rate which maximizesRev_A^R is $r_A^* = \frac{3t+\delta+\lambda\epsilon}{2}$. Innovator will charge the efficient firm a per unit royalty $r_A^* = \frac{3t+\delta+\lambda\epsilon}{2}$ if it is lesser than the benefit generated by the license i.e., $\lambda\epsilon$.

$$\text{If } \frac{3t+\delta+\lambda\epsilon}{2} \geq \lambda\epsilon \Rightarrow \lambda \leq \frac{3t+\delta}{\epsilon} = \lambda^*, \lambda^* \in [0,1],$$

then the innovator can extract the profit from efficient firm by charging optimal royalty rate $r_A^* = \lambda\epsilon$ and earns $Rev_A^R = \frac{\lambda\epsilon(3t+\delta)}{6t}$. Note that in our case we are considering $\epsilon \leq \delta < 3t$ which implies $\lambda < \lambda^*$ condition always holds true.

If the innovator offers a royalty license to the inefficient firm against a royalty rate of r_B. The equilibrium outcomes will be as follows:

$$p_A^R = c_A + \frac{1}{3}(3t + \delta - \epsilon + r_B) \tag{4.19}$$

$$p_B^R = (c_B - \epsilon + r_B) + \frac{1}{3}(3t - \delta + \epsilon - r_B) \tag{4.20}$$

$$Q_A^R = \frac{1}{6t}(3t + \delta - \epsilon + r_B) \tag{4.21}$$

$$Q_B^R = \frac{1}{6t}(3t - \delta + \epsilon - r_B) \tag{4.22}$$

$$\pi_A^R = \frac{1}{18t}(3t + \delta - \epsilon + r_B)^2 \tag{4.23}$$

$$\pi_B^R = \frac{1}{18t}(3t - \delta + \epsilon - r_B)^2 \tag{4.24}$$

Similarly, if the innovator chooses to license the technology to firm B. Innovator will maximize $Rev_B^R = r_B Q_B^R = \frac{r_B}{6t}(3t - \delta + \epsilon - r_B)$. The optimum royalty rate will be $r_B^* = \frac{3t-\delta+\epsilon}{2} > 0$, if $\frac{3t-\delta+\epsilon}{2} < \epsilon \Rightarrow \epsilon > 3t - \delta$ and the innovator will earn $Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{16t}$. For $< 3t - \delta$, innovator will set up $r_B^* = \epsilon$ and yield revenue $Rev_B^R = \frac{\epsilon(3t-\delta)}{6t}$

.

Now, depending on the size of innovation the innovator will decide whom to license by comparing Rev_A^R, Rev_B^R.

Case (i) $0 < \epsilon < (3t - \delta)$

For all size of innovation, the innovator will earn a revenue of $Rev_A^R = \frac{\lambda\epsilon(3t+\delta)}{6t}$ from the efficient firm. By comparing Rev_A^R, Rev_B^R, the innovator will decide to license to firm A if $\lambda \geq \frac{3t-\delta}{3t+\delta} = \hat{\lambda}$ for the feasible range of cost difference $1.5t < \delta < 3t$. Here, we can observe that $\hat{\lambda}$ depends on δ, with the increase in δ, $\hat{\lambda}$ declines. For $\delta \approx 1.5t$, the innovator will license to the efficient firm if its absorptive capacity $\lambda \geq 33\%$. Firm B will get the license if $\lambda < 33\%$.

For $\delta \approx 2t$, firm A requires at least 20% absorptive capacity to win the license. If $\delta \approx 3t$, the innovator will always offer the license to the efficient firm irrespective of its level of absorptive capacity.

Case (ii): $(3t - \delta) \leq \epsilon \leq \delta$

In this case the licensor charges $r_A^* = \lambda\epsilon$ and earns $Rev_A^R = \frac{\lambda\epsilon(3t+\delta)}{6t}$ when the technology was licensed to firm A. Now the outside innovator will compareRev_A^R with $Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{24t}$ and decides to license it to firm A if the absorptive capacity $\lambda \geq \frac{(3t-\delta+\epsilon)^2}{4\epsilon(3t+\delta)} = \tilde{\lambda}$. The critical value of λ ($\tilde{\lambda}$) depends on initial cost difference (δ) and innovation size (ϵ). For lower range value of δ, with increase in ϵ, $\tilde{\lambda}$ rises trivially. Such as, $\delta \approx 1.5t$, $\tilde{\lambda}$ is around 33%. In words, if the efficient firm's ex-ante efficiency level is not so high, for any given level of innovation size the innovator will license to inefficient firm when the efficient firm has less than one third of absorptive capacity as the inefficient firm.

For $\delta \approx 2t$, innovation size will lie between $t \leq \epsilon \leq 2t$. The critical value of λ ranges from 0.20 to 0.22 with rise in ϵ, given δ. This implies, if initial cost difference is equivalent to $2t$, for lower size of innovation, the innovator licenses to firm A if its absorptive capacity is at least greater than 20%. If its below 20%, then innovator will license to firm B.

For higher value of δ, if innovation size is low, $\tilde{\lambda} \approx 0$, which means the efficient firm will always get the license if it has very high efficiency level and the innovation size(ϵ) is small enough. But with rise in ϵ, $\tilde{\lambda}$ increases, which implies, for a substantial innovation size, there exists a certain level of absorptive capacity of firm A, above which its profitable for the innovator to license the technology to the efficient firm.

In all the above cases, if the license is offered to any one of these two firms, then the respective firm will accept the royalty contract as it obtains a weakly greater profit compared to a situation when its competitor gets it.

Now, we can concise this above discussion of one license royalty scheme in following lemma,

Lemma 2:

(i) $\left\{r_B^* = \epsilon, Rev_B^R = \frac{\epsilon}{6t}(3t-\delta)\ if\ \lambda < \hat{\lambda} = \frac{3t-\delta}{3t+\delta}\right\}\ and\ \left\{r_A^* = \lambda\epsilon, Rev_A^R = \frac{\lambda\epsilon(3t+\delta)}{6t}\ if\ \lambda \geq\ \hat{\lambda} = \frac{3t-\delta}{3t+\delta}\right\} \forall\ 0 < \epsilon \leq (3t-\delta).$

(ii) $\left\{r_B^* = \frac{3t-\delta+\epsilon}{2}, Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{24t}\ if\ \lambda < \tilde{\lambda} = \frac{(3t-\delta+\epsilon)^2}{4\epsilon(3t+\delta)}\right\}\ and\ \left\{r_A^* = \lambda\epsilon, Rev_A^R = \frac{\lambda\epsilon(3t+\delta)}{6t}\ if\ \lambda \geq\ \tilde{\lambda} = \frac{(3t-\delta+\epsilon)^2}{4\epsilon(3t+\delta)}\right\} \forall\ (3t-\delta) < \epsilon \leq \delta\ .$

4.3.3.2. Royalty Licensing to Both Firms

In case of non-exclusive royalty licensing the innovator can license to both firms and earn a revenue $Rev^{Rboth} = r_A Q_A^{Rboth} + r_B Q_B^{Rboth}$ by charging different royalty rates from two firms $(r_A \neq r_B)$ due to difference in their absorptive capacity. These two firms utilize the innovation in their production process and compete in product market. The equilibrium outcomes will be as follows:

$$p_A^{Rboth} = (c_A - \lambda\epsilon + r_A) + \frac{1}{3}(3t + \delta + r_B - r_A - \epsilon(1-\lambda)) \tag{4.25}$$

$$p_B^{Rboth} = (c_B - \epsilon\ +\ r_B) + +\frac{1}{3}(3t - \delta - r_B + r_A + \epsilon(1-\lambda)) \tag{4.26}$$

$$Q_A^{Rboth} = \frac{1}{6t}(3t + \delta + r_B - r_A - \epsilon(1-\lambda)) \tag{4.27}$$

$$Q_B^{Rboth} = \frac{1}{6t}(3t - \delta - r_B + r_A + \epsilon(1-\lambda)) \tag{4.28}$$

$$\pi_A^{Rboth} = \frac{1}{18t}\left(3t + \delta + r_B - r_A - \epsilon(1-\lambda)\right)^2 \tag{4.29}$$

$$\pi_B^{Rboth} = \frac{1}{18t}(3t - \delta - r_B + r_A + \epsilon(1-\lambda))^2 \tag{4.30}$$

The innovator will optimize total revenue $\frac{r_A}{6t}\left(3t + \delta + r_B - r_A - \epsilon(1-\lambda)\right) + \frac{r_B}{6t}\left(3t - \delta - r_B + r_A + \epsilon(1-\lambda)\right)$ and impose a per unit royalty $r_A^* = \lambda\epsilon$ on firm A for all λ.

But the optimal royalty rate imposed on firm B depends on λ.

Therefore, r_B^*

$$= \begin{cases} \epsilon\ , if\ \ \delta < 2.25t\ and\ 2.25t < \delta < 3t, 0 < \epsilon < \dfrac{(9t-\delta)}{3}\ when\ \lambda < \lambda = \dfrac{(9t-\delta-2\epsilon)}{\epsilon} \\ \dfrac{9t-\delta+\epsilon-\lambda\epsilon}{3}\ , if\ 2.25t < \delta < 3t, \dfrac{(9t-\delta)}{3} < \ \epsilon < \delta\ when\ \lambda \geq \lambda = \dfrac{(9t-\delta-2\epsilon)}{\epsilon} \end{cases}$$

Depending on the asymmetric royalty rates, total revenue earned by the innovator will be,

$$Rev^{Rboth} = \begin{cases} \dfrac{\lambda\epsilon(3t+\delta)}{6t} + \dfrac{\epsilon(3t-\delta)}{6t}\ , if\ \ r_A^* = \lambda\epsilon, r_B^* = \epsilon \\ \dfrac{\lambda\epsilon(18t+2\delta-2\epsilon-\lambda\epsilon)}{18t} + \dfrac{(2\epsilon+\lambda\epsilon-2\delta)(9t-\delta+\epsilon-\lambda\epsilon)}{54t}, \\ if\ \ r_A^* = \lambda\epsilon, r_B^* = \dfrac{9t-\delta+\epsilon-\lambda\epsilon}{3} \end{cases}$$

Now we compare the profits of the innovator from one license and two licenses to find out the optimal royalty contract and summarize our result in the proposition below.

Proposition 3:

For various innovation size we can get following optimal outcomes under royalty licensing,

(i) *The outside innovator will always license to both firms,* $\left\{r_A^* = \lambda\epsilon, r_B^* = \epsilon, Rev^{Rboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}\right\} \forall\ 0 < \epsilon < (3t-\delta)$.

(ii) *Depending on initial cost difference and absorptive capacity of the efficient firm there can be three possible outcomes* $\forall\ (3t-\delta) \le \epsilon \le \delta$,

a. $If\ 1.5t < \delta < 1.69t$, *then the outside innovator will license only to the inefficient firm* $\left\{r_B^* = \frac{3t-\delta+\epsilon}{2}, Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{24t}\right\}$, *as the absorptive capacity of the efficient firm* $\lambda < \lambda_R = \frac{(9t-\delta-\epsilon)^2}{4\epsilon(3t+\delta)} \forall\ (3t-\delta) \le \epsilon \le \delta$.

b. $If\ 1.69t < \delta < 2.25t\ \forall\ (3t-\delta) \le \epsilon \le \delta$ *and* $if\ 2.25t < \delta < 3t\ \forall\ (3t-\delta) < \epsilon < \frac{(9t-\delta)}{3}$,*then in case of lower innovation size, the outside innovator will license to the inefficient firm* $\left\{r_B^* = \frac{3t-\delta+\epsilon}{2}, Rev_B^R = \frac{(3t-\delta+\epsilon)^2}{24t}\right\}$, *as the critical level absorptive capacity* $\lambda_R > 1$. *For higher innovation size,* $0 < \lambda_R < 1$, *innovator will license to the inefficient firm if* $\lambda < \lambda_R$, *otherwise innovator will license to both firms* $\left\{r_A^* = \lambda\epsilon, r_B^* = \epsilon, Rev^{Rboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}\right\}$.

c. $If\ 2.25t < \delta < 3t, \frac{(9t-\delta)}{3} < \epsilon < \delta$, *then the outside innovator will always license to both the firms* $\left\{r_A^* = \lambda\epsilon, r_B^* = \frac{9t-\delta+\epsilon-\lambda\epsilon}{3}, Rev^{Rboth} = \frac{\lambda\epsilon(18t+2\delta-2\epsilon-\lambda\epsilon)}{18t} + \frac{(2\epsilon+\lambda\epsilon-2\delta)(9t-\delta+\epsilon-\lambda\epsilon)}{54t}\right\}$.

4.3.4. Two-Part Tariff Licensing

Let us now consider the two-part tariff licensing where innovator can charge a combination of both fixed fee and a royalty rate from the licensee(s). Royalty rate for different firms will be different due to asymmetric absorptive capacity of firms ($r_A \neq r_B$).

4.3.4.1. Two-Part Tariff Licensing to One Firm

Suppose under two-part tariff (TPT) licensing scheme innovator licenses the efficient firm against a fixed fee F_A and a per unit royalty r_A. Firm A's marginal cost becomes $(c_A - \lambda\epsilon + r_A)$ and firm B's marginal cost will remain c_B. The calculation shows the following equilibrium outcomes:

$$p_A^{TPT} = (c_A - \lambda\epsilon + r_A) + \frac{1}{3}(3t + \delta + \lambda\epsilon - r_A) \quad (4.31)$$

$$p_B^{TPT} = c_B + \frac{1}{3}(3t - \delta - \lambda\epsilon + r_A) \quad (4.32)$$

$$Q_A^{TPT} = \frac{1}{6t}(3t + \delta + \lambda\epsilon - r_A) \quad (4.33)$$

$$Q_B^{TPT} = \frac{1}{6t}(3t - \delta - \lambda\epsilon + r_A) \quad (4.34)$$

$$\pi_A^{TPT} = \frac{1}{18t}(3t + \delta + \lambda\epsilon - r_A)^2 - F_A \quad (4.35)$$

$$\pi_B^{TPT} = \frac{1}{18t}(3t - \delta - \lambda\epsilon + r_A)^2 \quad (4.36)$$

The profit of firm A if it accepts the licensing scheme will be $\frac{1}{18t}(3t + \delta + \lambda\epsilon - r_A)^2 - F_A$. If firm A rejects the offer, firm B will get it and firm A's profit will be $\frac{1}{18t}(3t + \delta - \epsilon + r_B)^2$. Firm A will accept the offer if $\frac{1}{18t}(3t + \delta + \lambda\epsilon - r_A)^2 - F_A \geq \frac{1}{18t}(3t + \delta - \epsilon + r_B)^2$. The innovator knows it and extracts fixed fee of $F_A = \frac{1}{18t}(3t + \delta + \lambda\epsilon - r_A)^2 - \frac{1}{18t}(3t + \delta - \epsilon + r_B)^2$ from firm A. Therefore, the innovator maximizes total revenue $Rev_A^{TPT} = r_A Q_A^{TPT} + F_A = \frac{r_A}{6t}(3t + \delta + \lambda\epsilon - r_A) + \frac{1}{18t}(3t + \delta + \lambda\epsilon - r_A)^2 - \frac{1}{18t}(3t + \delta - \epsilon + r_B)^2$ and get the optimal royalty rate $r_A^* = \frac{3t+\delta+\lambda\epsilon}{4}$ if $\frac{3t+\delta+\lambda\epsilon}{4} < \lambda\epsilon$, otherwise $r_A^* = \lambda\epsilon$ if $\frac{3t+\delta+\lambda\epsilon}{4} \geq \lambda\epsilon \Rightarrow \lambda \leq \frac{3t+\delta}{3\epsilon} = \lambda^*, where\ \lambda^* \in (0,1)$. λ^*will exist if and only if $\epsilon \geq \frac{3t+\delta}{3}$. In words, the innovator can charge a royalty rate just equivalent to efficient firm's gain out of this licensing, to extract entire benefit from the innovation if its absorptive capacity is less than λ^* ,which in turn depends on the innovation size. In case of moderate to higher size of innovation, there will be a critical level of λ i.e., λ^*, for $\lambda \leq \lambda^*$and for all λ in case of small innovation optimal royalty rate will be $r_A^* = \lambda\epsilon$, otherwise $r_A^* = \frac{3t+\delta+\lambda\epsilon}{4}$. By substituting optimal royalty rate the innovator decides its total revenue which can be charged from the efficient firm.

Similarly, if the innovator offers one two-part tariff license to firm B, the equilibrium prices, demands and payoffs of the firms will be as follows:

$$p_A^{TPT} = c_A + \frac{1}{3}(3t + \delta - \epsilon + r_B) \tag{4.37}$$

$$p_B^{TPT} = (c_B - \epsilon + r_B) + \frac{1}{3}(3t - \delta + \epsilon - r_B) \tag{4.38}$$

$$Q_A^{TPT} = \frac{1}{6t}(3t + \delta - \epsilon + r_B) \tag{4.39}$$

$$Q_B^{TPT} = \frac{1}{6t}(3t - \delta + \epsilon - r_B) \tag{4.40}$$

$$\pi_A^{TPT} = \frac{1}{18t}(3t + \delta - \epsilon + r_B)^2 \tag{4.41}$$

$$\pi_B^{TPT} = \frac{1}{18t}(3t - \delta + \epsilon - r_B)^2 - F_B \tag{4.42}$$

The innovator can take out a fixed fee of $F_B = \frac{1}{18t}(3t - \delta + \epsilon - r_B)^2 - \frac{1}{18t}(3t - \delta - \lambda\epsilon + r_A)^2$ from Firm B and charges a royalty rate of r_B. The optimal royalty rate will be determined by maximizing innovator's revenue $Rev_B^{TPT} = \frac{r_B}{6t}(3t-\delta+\epsilon-r_B) + \frac{1}{18t}(3t-\delta+\epsilon-r_B)^2 - \frac{1}{18t}(3t-\delta-\lambda\epsilon+r_A)^2$. We get $r_B^* = \frac{3t-\delta+\epsilon}{4}$ for $\epsilon > \frac{3t-\delta}{3}$ and $r_B^* = \epsilon$ if $\frac{3t-\delta+\epsilon}{4} \geq \epsilon \Rightarrow \epsilon \leq \frac{3t-\delta}{3}$.

Considering the size of innovation, we can get 3 cases while comparing the payoffs between firm A and B:

Case (i): $\epsilon \leq \frac{3t-\delta}{3} < \delta, r_A^* = \lambda\epsilon, r_B^* = \epsilon$

In this range of innovation size, the innovator optimally charges a per unit royalty $r_A^* = \lambda\epsilon$ and earns a revenue of $Rev_A^{TPT} = \frac{\lambda\epsilon(3t+\delta)}{6t}$ if it offers one two-part tariff license to firm A. If the innovator licenses to only firm B, it will charge a royalty rate $r_B^* = \epsilon$ and the optimal revenue will be $Rev_B^{TPT} = \frac{\epsilon(3t-\delta)}{6t}$. This situation is similar to pure royalty of one license. By comparing these two revenues, the innovator decides to license the technology to firm A if $\lambda > \frac{3t-\delta}{3t+\delta} = \lambda_1$. The feasible range of initial cost difference will be $0.75t < \delta < 3t$. We can infer that λ_1 depends on the initial cost difference δ and decreases with increase in δ. For example, at lower range of initial cost difference, say at $\delta = 0.75t,\ \lambda_1 = 0.6$, which implies, the licensor or the outside innovator will offer exclusive license to firm A, when it can reduce its own cost at least 60% of what firm B can reduce if it gets the technology. Higher the pre-licensing efficiency of firm A, lower will be significance of its absorptive capacity. Thus, absorptive capacity of the efficient firm will become insignificant for the innovator when the cost difference is maximum i.e., $\delta = 3t$ and the innovator will always license to firm A as it is highly efficient compared to its rival firm.

Case(ii): $\frac{3t-\delta}{3} < \epsilon < \frac{3t+\delta}{3}, r_A^* = \lambda\epsilon, r_B^* = \frac{3t-\delta+\epsilon}{4}$

For this given innovation size exclusive two-part tariff licensing contract to firm A will generate revenue of $Rev_A^{TPT} = \frac{\lambda\epsilon}{6t}(3t+\delta) + \frac{1}{18t}(3t+\delta)^2 - \frac{1}{32t}(5t+\delta-\epsilon)^2$ for the innovator. If it is licensed to firm B, outside innovator gains a profit of $Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}$. Now the innovator decides whom to license the contract by comparing these two revenues. License will be offered to firm A if its absorptive capacity $\lambda > \lambda_2 = \frac{99t^2-5\delta^2+27\epsilon^2-18t\delta-54\delta\epsilon+18t\epsilon}{48\epsilon(3t+\delta)}$. According to assumptions of our model the feasible range of the initial cost difference is $3t > \delta > 1.5t$. For each δ there will be a range of ϵ. The decision of whom to license indirectly depends on initial cost difference and innovation size. Given a level of ex-ante cost difference, λ_2 falls with increase in innovation size.

For $< 1.74t$, for example if we take $\delta = 1.6t$, innovation size will be $0.47t < \epsilon < 1.53t$. Given this δ and the range of ϵ, the critical absorptive capacity level will be $0.30 < \lambda_2 < 0.05$. Specifically, if we consider a particular combination such as $\delta = 1.6t$, $\epsilon = t$, then we find that the innovator will prefer firm A if its absorptive capacity level $\lambda > 0.07$.

For, $\delta = 1.74t$ and $\epsilon \geq 1.06t$, critical level of absorptive capacity will be $\lambda_2 \leq 0$, that means for these given range of δ, ϵ the innovator always licenses to firm A irrespective of its absorptive capacity.

For $\delta > 1.74t$, say $\delta = 2t$, the critical value of firm A's absorptive capacity will be close to zero with innovation size $1.66t > \epsilon \geq 0.56t$. We can infer that for higher cost differences with medium range of innovation size, it is profitable for the innovator to offer an exclusive two-part tariff license to the efficient firm.

Case(iii)(a): $\epsilon \geq \frac{3t+\delta}{3}, \lambda^* < \lambda < 1, \lambda^* = \frac{3t+\delta}{3\epsilon}, r_A^* = \frac{3t+\delta+\lambda\epsilon}{4}, r_B^* = \frac{3t-\delta+\epsilon}{4}$

By comparing the revenues $Rev_A^{TPT} = \frac{(3t+\delta+\lambda\epsilon)^2}{16t} - \frac{(5t+\delta-\epsilon)^2}{32t}$, $Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(5t-\delta-\lambda\epsilon)^2}{32t}$ earned from exclusive two-part tariff licensing to each firm, the innovator always decides to license the technology to firm A for this given range of innovation size and feasible range of absorptive capacity of firm A.

Case(iii)(b): $\epsilon \geq \frac{3t+\delta}{3}, 0 < \lambda < \lambda^* = \frac{3t+\delta}{3\epsilon}, r_A^* = \lambda\epsilon, r_B^* = \frac{3t-\delta+\epsilon}{4}$

In this case payoffs are like *Case(ii)* but we are analysing the preference of the outside innovator for a larger innovation size. After comparing $Rev_A^{TPT} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}$ and $Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}$, we get $Rev_A^{TPT} > Rev_B^{TPT}$ if $\lambda > \lambda_{3b} = \frac{99t^2-5\delta^2+27\epsilon^2-18t\delta-54\delta\epsilon+18t\epsilon}{48\epsilon(3t+\delta)}$ and $\lambda_{3b} < \lambda^*$ for the feasible range of initial cost difference $3\text{t} > \delta > 1.5\text{t}$. We find out for $\delta \geq 1.76t,\ all\ \lambda_{3b} < 0$ that means the innovator will always license to firm A irrespective of its absorptive capacity, if firm A is efficient enough than firm B, i.e., pre-licensing cost difference is greater than $1.76t$. Absorptive capacity will have any significance only in case of lower initial cost-difference between the two firms. Let us consider $\delta = 1.6t$, innovation size will be $1.53t \leq \epsilon < 1.6t$, we take $\epsilon = 1.56t$. Now, for $\delta = 1.6t$ and $\epsilon = 1.56t$, $Rev_A^{TPT} = 1.196\lambda t + 0.38112t$,$Rev_B^{TPT} = 0.5476t - 0.1088t = 0.4388t$ and firm A will be preferred if $\lambda > 0.048$. Therefore, innovator's choice of firm depends on absorptive capacity for $\delta < 1.76t$, with lower the cost difference firm A will be preferred for absorptive capacity higher than critical level λ_{3b}. This critical level varies from as low as 0 to maximum 8.3%.

Based on above discussion we can formulate the optimal exclusive two-part tariff licensing in the following lemma.

Lemma 3:

(i) $\left\{r_B^* = \epsilon,\ F_B^* = 0,\ Rev_B^{TPT} = \frac{\epsilon}{6t}(3t-\delta)\ if\ \lambda < \lambda_1 = \frac{3t-\delta}{3t+\delta}\right\}$ *and* $\left\{r_A^* = \lambda\epsilon, F_A^* = 0, Rev_A^{TPT} = \frac{\lambda\epsilon(3t+\delta)}{6t}, if\ \lambda > \lambda_1\right\} \forall\ 0 < \epsilon\ \leq \frac{3t-\delta}{3}$.

(ii) $\left\{r_B^* = \frac{3t-\delta+\epsilon}{4}\ ,\ F_B^* = \frac{(3t-\delta+\epsilon)^2}{32t} - \frac{(3t-\delta)^2}{18t}, Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}\ if\ \lambda < \lambda_2 = \frac{99t^2-5\delta^2+27\epsilon^2-18t\delta-54\delta\epsilon+18t\epsilon}{48\epsilon(3t+\delta)}\right\}$ *and* $\left\{r_A^* = \lambda\epsilon, F_A^* = \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}, Rev_A^{TPT} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t},\ if\ \lambda > \lambda_2\right\} \forall\ \frac{3t-\delta}{3} < \epsilon < \frac{3t+\delta}{3}$.

(iii)(a) $\left\{r_A^* = \frac{3t+\delta+\lambda\epsilon}{4}, F_A^* = \frac{(3t+\delta+\lambda\epsilon)^2}{32t} - \frac{(5t+\delta-\epsilon)^2}{32t},\ Rev_A^{TPT} = \frac{(3t+\delta+\lambda\epsilon)^2}{16t} - \frac{(5t+\delta-\epsilon)^2}{32t}\right\} \forall\epsilon\ \geq \frac{3t+\delta}{3}, \lambda^* < \lambda < 1, \lambda^* = \frac{3t+\delta}{3\epsilon}$.

(iii)(b) $\left\{r_B^* = \frac{3t-\delta+\epsilon}{4}\ ,\ F_B^* = \frac{(3t-\delta+\epsilon)^2}{32t} - \frac{(3t-\delta)^2}{18t}, Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}\ if\ \lambda <\ \lambda_{3b} = \frac{99t^2-5\delta^2+27\epsilon^2-18t\delta-54\delta\epsilon+18t\epsilon}{48\epsilon(3t+\delta)}\right\}$ *and* $\left\{r_A^* = \lambda\epsilon, F_A^* = \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}, Rev_A^{TPT} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}, \lambda > \lambda_{3b}\right\} \forall\epsilon \geq \frac{3t+\delta}{3}, 0 < \lambda < \lambda^* = \frac{3t+\delta}{3\epsilon}$.

For all innovation sizes and high absorptive capacity of the efficient firm, it is always profitable for the outside innovator to offer exclusive two-part tariff license to the inefficient firm when the absorptive capacity of the efficient firm is lower than the critical level, except for $\epsilon\ \geq \frac{3t+\delta}{3}$. It implies that the profit of the efficient firm is less than that of the inefficient firm due to efficient firm's low absorptive capacity. The profit margin of the efficient firm is lesser as the low absorptive capacity induces low cost-reduction after licensing. Hence, despite having better efficiency ex-ante, the efficient firm loses the contract. The efficient firm becomes the licensee of the new technology only when its absorptive capacity is greater than critical level across all innovation sizes. Only for innovation size $\epsilon \geq \frac{3t+\delta}{3}$ with high absorptive capacity level, the efficient firm always gets the license as the feasible range of absorptive capacity is already in higher bracket.

It is clear from the above discussion that the efficiency level of the firm is not sufficient to ensure attainment of new technology. Therefore, absorptive capacity of the efficient firm plays a decisive role in exclusive two-part tariff licensing by the outside innovator.

4.3.4.2. Two-Part Tariff Licensing to Both Firms

The outside innovator licenses to both firms through two-part tariff licensing scheme. Post-licensing per-unit cost of firm A will be reduced to $(c_A - \lambda\epsilon + r_A)$. For firm B marginal cost becomes $(c_B - \epsilon + r_B)$ after licensing.

$$p_A^{TPTboth} = (c_A - \lambda\epsilon + r_A) + \frac{1}{3}(3t + \delta + r_B - r_A - \epsilon(1-\lambda)) \qquad (4.43)$$

$$p_B^{TPTboth} = (c_B - \epsilon + r_B) + \frac{1}{3}(3t - \delta - r_B + r_A + \epsilon(1-\lambda)) \qquad (4.44)$$

$$Q_A^{TPTboth} = \frac{1}{6t}(3t + \delta + r_B - r_A - \epsilon(1-\lambda)) \qquad (4.45)$$

$$Q_B^{TPTboth} = \frac{1}{6t}(3t - \delta - r_B + r_A + \epsilon(1-\lambda)) \qquad (4.46)$$

$$\pi_A^{TPTboth} = \frac{1}{18t}(3t + \delta + r_B - r_A - \epsilon(1-\lambda))^2 - F_A \qquad (4.47)$$

$$\pi_B^{TPTboth} = \frac{1}{18t}(3t - \delta - r_B + r_A + \epsilon(1-\lambda))^2 - F_B \qquad (4.48)$$

The outside innovator draws total revenue of $Rev^{TPTboth} = Rev_A^{TPTboth} + Rev_B^{TPTboth}$ from licensing to both firms, $Rev_i^{TPTboth} = r_i Q_i^{TPTboth} +$

F_i $where\ i = A, B$. If firm A accepts the contract, then its profit $\frac{1}{18t}(3t + \delta + r_B - r_A - \epsilon(1 - \lambda))^2 - F_A > \frac{1}{18t}(3t + \delta + r_B - \epsilon)^2$. Innovator knows this and charges a fixed of $F_A = \frac{1}{18t}\left(3t + \delta + r_B - r_A - \epsilon(1 - \lambda)\right)^2 - \frac{1}{18t}(3t + \delta + r_B - \epsilon)^2$ from firm A. Similarly, innovator extracts a fixed fee of $F_B = \frac{1}{18t}(3t - \delta - r_B + r_A + \epsilon(1 - \lambda))^2 - \frac{1}{18t}(3t - \delta + r_A - \lambda\epsilon)^2$ from firm B. Optimal royalty rate will be decided by maximizing total revenue earned by the innovator.

Therefore, optimal non-exclusive two-part tariff licensing contract will be $\{r_A^* = \lambda\epsilon, F_A^* = 0\ and\ r_B^* = \epsilon, F_B^* = 0\}$. This contract appears to be as pure royalty contract to both firms. The optimal profit of the innovator will be $Rev^{TPTboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}$.

Now we will investigate which is more profitable for the innovator under two-part tariff licensing, licensing to one firm or both firms at various levels of innovation size.

Case (i): $\epsilon \leq \frac{3t-\delta}{3} < \delta, r_A^* = \lambda\epsilon, r_B^* = \epsilon$

In this case Rev_A^{TPT}, Rev_B^{TPT} are both suboptimal to $Rev^{TPTboth}$. If the cost reduction is very low, lower will be the profits earned by the firms. As a result, the licensor will opt for non-exclusive licensing to extract higher revenue. Therefore, the innovator will always license to both firms for $\epsilon \leq \frac{3t-\delta}{3} < \delta$.

Case (ii): $\frac{3t-\delta}{3} < \epsilon < \frac{3t+\delta}{3}, r_A^* = \lambda\epsilon, r_B^* = \frac{3t-\delta+\epsilon}{4}$

Comparing $Rev^{TPTboth}$ with Rev_A^{TPT} and Rev_B^{TPT} respectively, we get $Rev^{TPTboth} > Rev_A^{TPT}$ if $81t^2 - 7\delta^2 + 9\epsilon^2 - 6t\delta - 66\delta\epsilon + 54t\epsilon > 0$ or $G > 0$ and $Rev^{TPTboth} >$

Rev_B^{TPT} if $\lambda > \frac{(3t-\delta-3\epsilon)^2}{24\epsilon(3t+\delta)} = \lambda''$. In case of $\delta < 1.568t$, $G > 0$,that implies if the innovator has to choose between licensing to both firms and licensing to the efficient one, it will prefer to license the technology to both the firms for lower initial cost difference $\delta < 1.568t$. For $\delta \geq 1.568t$, the innovator will license it to the efficient firms only. Choice between both firms and firm B depends on λ. Given δ, with increase in ϵ, λ'' increases where $\lambda'' \in (0,1)$. If the innovator has to choose between both and

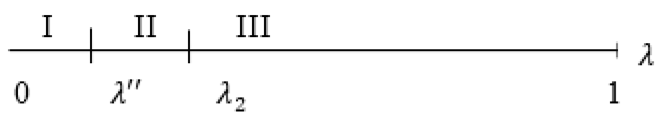

Figure 4.1a.: Optimal TPT and absorptive capacity for $\lambda'' < \lambda_2$

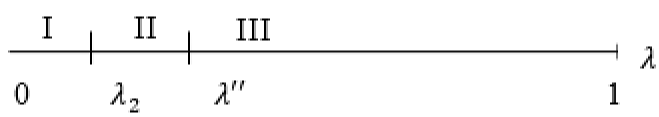

Figure 4.1b.: Optimal TPT and absorptive capacity for $\lambda'' > \lambda_2$

firm B, it will license to both only when absorptive of firm A (λ) is higher than critical level of λ''. If λ is lower than λ'', it will prefer to license the technology only to firm B. This appears to be a little complicated. But it will be easier if we first find out the relative location of λ'' and $\lambda_2 = \frac{99t^2-5\delta^2+27\epsilon^2-18t\delta-54\delta\epsilon+18t\epsilon}{48\epsilon(3t+\delta)}$, when $0 < \lambda_2 < 1$. Then we can understand the overall optimal choices in TPT licensing easily for this given range of innovation size. For $< 1.568t$, at every ϵ , λ'' will always be less than λ_2. In case of $\delta > 1.568t$, for lower range of ϵ, $\lambda'' < \lambda_2$ (Figure 1a) and for higher innovation size $\lambda'' > \lambda_2$ (Figure 1b).

Depending on location of λ'' and λ_2, we get three segments. In segment-I of both figure 1a. and 1b., it is optimal to license the technology to only inefficient firm (firm B). But in segment-II, innovator's choice depends on location of λ'' and λ_2. For

$\lambda'' < \lambda < \lambda_2$ (in Figure 1a.) the innovator will license to both the firms, whereas for $\lambda_2 < \lambda < \lambda''$ (in Figure 1b) innovator will choose to offer the license only to the efficient firm. In segment-III, of both figure 1a and 1b, the innovator's choice is between both firms and firm A. Thus, in this segment the initial cost difference will decide the optimal licensing. If $\delta < 1.568t$, both firms will get the license. For $\delta \geq 1.568t$, only the efficient firm will become sole licensee of the technology.

Case (iii)(a): $\epsilon \geq \frac{3t+\delta}{3}, \lambda^* < \lambda < 1, \lambda^* = \frac{3t+\delta}{3\epsilon}, r_A^* = \frac{3t+\delta+\lambda\epsilon}{4}, r_B^* = \frac{3t-\delta+\epsilon}{4}$

In exclusive two-part tariff licensing case, it is always profitable for the outside innovator to offer the license to the efficient firm. Now we will compare innovator's benefit from one license, i.e., $Rev_A^{TPT} = \frac{(3t+\delta+\lambda\epsilon)^2}{16t} - \frac{(5t+\delta-\epsilon)^2}{32t}$ with that of two license case in two-part tariff licensing scenario, $Rev^{TPTboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}$. Given $1.5t < \delta < 3t$, we have a range of ϵ for each value of δ and for every combination of δ, ϵ, there will exist certain feasible range of absorptive capacity level. In this case we find out, licensing to both firms will be preferred for $\delta < 1.568t$. But the innovator will choose to offer the license only to firm A instead of licensing to both, when $\delta \geq 1.568t$. λ^* ranges from minimum 66% to maximum 100% for different combinations of cost difference and innovation size.

Case (iii)(b): $\epsilon \geq \frac{3t+\delta}{3}, 0 < \lambda < \lambda^* = \frac{3t+\delta}{3\epsilon}, r_A^* = \lambda\epsilon, r_B^* = \frac{3t-\delta+\epsilon}{4}$

Innovator's choice between licensing the technology to one firm or to both firms will be determined by relative location of critical values of absorptive capacity $\lambda_{3b} = \frac{99t^2-5\delta^2+27\epsilon^2-18t\delta-54\delta\epsilon+18t\epsilon}{48\epsilon(3t+\delta)}, \lambda'' = \frac{(3t-\delta-3\epsilon)^2}{24\epsilon(3t+\delta)}$ and the value of $= 81t^2 - 7\delta^2 + 9\epsilon^2 - 6t\delta - 66\delta\epsilon + 54t\epsilon$. Based on δ, we get three different types of preference ordering of the innovator.

For $1.5t < \delta \leq 1.561t$, $\lambda_{3b} > \lambda''$ for all ϵ.

Figure 4.2a: Optimal TPT and absorptive capacity

In segment-I of Figure 2a, absorptive capacity of efficient firm is very low $0 < \lambda < \lambda''$, therefore it is profitable for the innovator to license the technology to only inefficient firm. In segment-II, III, innovator will license to both firms as $\lambda'' < \lambda < 1$.

For $1.561t < \delta < 1.568t$, $\lambda_{3b} > \lambda''$ for low ϵ and $\lambda'' > \lambda_{3b}$ for high ϵ.

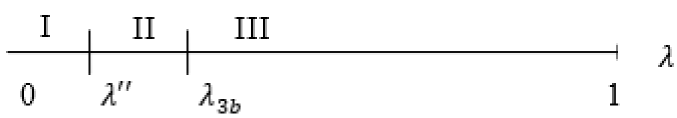

Figure 4.2b.i.: Optimal TPT and absorptive capacity with low ϵ

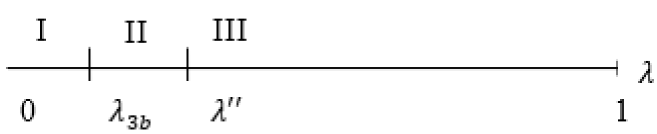

Figure 4.2b.ii: Optimal TPT and absorptive capacity with high ϵ

Given δ, for lower value of ϵ (in Figure 2b. i), optimal TPT will be same as Figure 2a. For higher value of ϵ, in segment-I (in Figure 2b. ii), the innovator prefers to license only to the inefficient firm and in segment-II, III, it is profitable for the innovator to license only to the efficient firm.

For $1.568t < \delta < 3t$, $\lambda'' > \lambda_{3b}$ for all ϵ.

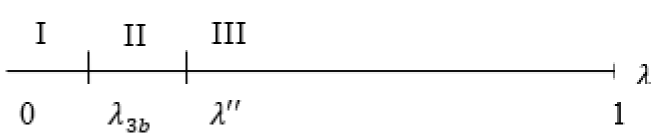

Figure 4.2c: Optimal TPT and absorptive capacity

In segment I of Figure 2c the innovator prefers to license only to the inefficient firm. In segment II, III, the innovator will license only to the efficient firm. For $1.74t \leq \delta < 3t$, $\lambda_{3b} \leq 0$, that implies segment I does not exist, and the innovator will always license only to the efficient firm regardless of its absorptive capacity.

Proposition 4:

For various innovation size we can get following optimal outcomes under two-part tariff licensing,

(i) The outside innovator will always license to both firms, $\left\{r_A^* = \lambda\epsilon, F_A^* = 0\,; r_B^* = \epsilon, F_B^* = 0, Rev^{TPTboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}\right\} \forall\, \epsilon \leq \frac{3t-\delta}{3}$.

(ii) For $\delta < 1.568t, \frac{3t-\delta}{3} < \epsilon < \frac{3t+\delta}{3}$ *and* $\delta > 1.568t$ *with lower range of* ϵ*,* λ''*will be less than* $\lambda_2 = \frac{99t^2-5\delta^2+27\epsilon^2-18t\delta-54\delta\epsilon+18t\epsilon}{48\epsilon(3t+\delta)}$*. Thus the innovator will license to the inefficient firm when* $0 < \lambda < \lambda'' = \frac{(3t-\delta-3\epsilon)^2}{24\epsilon(3t+\delta)}$ *and the contract will be* $\left\{r_B^* = \frac{3t-\delta+\epsilon}{4},\ F_B^* = \frac{(3t-\delta+\epsilon)^2}{32t} - \frac{(3t-\delta)^2}{18t}, Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}\right\}$*, but the innovator will prefer to license to both the firms when* $\lambda'' < \lambda < \lambda_2$*and* $\delta < 1.568t$*,* $\lambda_2 < \lambda < 1$ *and the contract will be* $\left\{r_A^* = \lambda\epsilon, F_A^* = 0\,; r_B^* = \epsilon, F_B^* = 0, Rev^{TPTboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}\right\}$*. For* $\lambda_2 < \lambda < 1, \delta \geq 1.568t$*, only the efficient firm will get it and the contract will be* $\left\{r_A^* = \lambda\epsilon, F_A^* = \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}, Rev_A^{TPT} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}\right\}$.

For $\delta > 1.568t$ *with higher range of* ϵ*,* $\lambda'' > \lambda_2$*. Innovator will license to the inefficient firm when* $0 < \lambda < \lambda_2$ *and to the efficient firm when* $\lambda_2 < \lambda < 1$.

(iii)(a) The outside innovator will prefer to license the technology to both the firms when $\delta < 1.568t,$ *the contract will be* $\Big\{r_A^* = \lambda\epsilon, F_A^* = 0\,; r_B^* = \epsilon, F_B^* = 0, Rev^{TPTboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}\Big\}$ *and license only to the efficient firm when* $\delta \geq 1.568t,$ *the contract will be* $\Big\{r_A^* = \frac{3t+\delta+\lambda\epsilon}{4}, F_A^* = \frac{(3t+\delta+\lambda\epsilon)^2}{32t} - \frac{(5t+\delta-\epsilon)^2}{32t}, Rev_A^{TPT} = \frac{(3t+\delta+\lambda\epsilon)^2}{16t} - \frac{(5t+\delta-\epsilon)^2}{32t}\Big\} \forall\, \delta > \epsilon \geq \frac{3t+\delta}{3}, \lambda^* < \lambda < 1,\ \lambda^* = \frac{3t+\delta}{3\epsilon}$.

(iii)(b) For $1.5t < \delta \leq 1.561t, \lambda_{3b}$ *will be greater than* λ'' $\forall\, \delta > \epsilon \geq \frac{3t+\delta}{3}$*. When the absorptive capacity of efficient firm is very low* $0 < \lambda < \lambda''$*, it is profitable for the innovator to license the technology only to the inefficient firm,* $\Big\{r_B^* = \frac{3t-\delta+\epsilon}{4}, F_B^* = \frac{(3t-\delta+\epsilon)^2}{32t} - \frac{(3t-\delta)^2}{18t}, Rev_B^{TPT} = \frac{(3t-\delta+\epsilon)^2}{16t} - \frac{(3t-\delta)^2}{18t}\Big\}$*. Innovator will license to both firms when* $\lambda'' < \lambda < 1$, $\Big\{r_A^* = \lambda\epsilon, F_A^* = 0\,; r_B^* = \epsilon, F_B^* = 0, Rev^{TPTboth} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{\epsilon(3t-\delta)}{6t}\Big\}$.

For $1.561t < \delta < 1.568t, \lambda_{3b}$ *will be greater than* λ'' *for low innovation size. It is profitable for the innovator to license only to the inefficient firm when* $0 < \lambda < \lambda''$*. Innovator will license to both firms when* $\lambda'' < \lambda < 1$.

For high innovation size, λ_{3b} *will be lesser than* λ''*. Innovator will preferably license the technology to the inefficient firm when* $0 < \lambda < \lambda_{3b}$ *and to the efficient firm when* $\lambda_{3b} < \lambda < 1$, $\Big\{r_A^* = \lambda\epsilon, F_A^* = \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}, Rev_A^{TPT} = \frac{\lambda\epsilon(3t+\delta)}{6t} + \frac{(3t+\delta)^2}{18t} - \frac{(5t+\delta-\epsilon)^2}{32t}\Big\}$.

For $1.568t < \delta < 3t, \lambda_{3b}$ *will be lesser than* λ'' $\forall\, \delta > \epsilon \geq \frac{3t+\delta}{3}\epsilon$*. Innovator will preferably license the technology to the inefficient firm when* $0 < \lambda < \lambda_{3b}$ *and to* *the efficient firm when* $\lambda_{3b} < \lambda < 1$. *For* $1.74t \leq \delta < 3t$, $\lambda_{3b} \leq 0$, *the innovator will always license only to the efficient firm* $\forall\ 0 < \lambda < 1$.

4.3.5. Optimal Licensing Policy

Finally, the innovator will decide the optimal licensing policy out of four available policies by comparing its payoffs from fixed fee, auction, royalty and two-part tariff licensing. We have already found out that fixed fee is better than auction. Among fixed fee, royalty and two-part tariff, it is optimal for the innovator to go for fixed fee licensing to the efficient firm. We can summarize the main result in following proposition.

Proposition 5: *Irrespective of absorptive capacity, initial cost difference and innovation size the innovator will always optimally license the technology to the efficient firm through fixed fee licensing when there is no leapfrogging by the inefficient firm.*

4.4. Conclusion

Various studies have been done by the researchers on technology licensing under different situations since the seminal work carried out by Arrow (1962). The work by Poddar and Sinha (2004) paved a new avenue for theoretical work in technology licensing by introducing spatial framework in it. Our chapter can be depicted as another steppingstone in this path. Here we have considered licensing of a cost-reducing technology by an outside innovator to asymmetric firm(s) who are facing inelastic demand (matured markets) with a horizontal product differentiation in a spatial framework. These cost reductions to the firms are non-uniform due to their asymmetric absorptive capacities. Our concept of asymmetric absorptive capacity has been structured in the line with Chang et al. (2016), although this paper has narrowly considered the choice of the innovator between exclusive and non-exclusive licensing under only two licensing schemes, fixed fee and royalty licensing in a conventional Cournot model. Whereas our chapter provided in-depth analysis of four various licensing schemes: fixed fee licensing, auction, royalty licensing and two-part tariff licensing, considering the implications of not only the absorptive capacity, but also other factors, such as the magnitude of innovation and the efficiency of the licensee firms, on optimal licensing decision of the independent innovator. This comprehensive study of technology licensing with asymmetric absorptive capacity is a major contribution to the existing literature.

Considerable insights are provided in the chapter which can bridge the gap in existing literature. Initially we have said that Banerjee and Poddar (2019) is an extreme case to our model with a common innovation where post licensing cost reduction for two firms are same, i.e., $\lambda = 1$. Our previous chapter deals with the other extreme, i.e., $\lambda = 0$. This current chapter provides the story, in between these two extremes (i.e., λ between 0 and 1), which says fixed fee licensing to the efficient firm is optimal for the outside innovator over other licensing schemes. Now, complete diffusion of technology could be possible under royalty licensing and two-part tariff licensing. But this will not happen due to innovator's profit motive. If all options are available, the innovator always chooses to offer the license which earns maximum profit. Therefore, partial diffusion of the technology will happen by licensing the technology to only efficient firm when the technology improves the efficiency of inefficient firm but not as much as the efficient firm though its absorptive capacity is lower.

The obvious question that arises what will happen if the innovation is such that it helps the inefficient firm to achieve an efficiency level better than its competitor (the efficient firm) who has a lower capacity to absorb the innovation in its production process. We think it as the future extension of our research work.

Appendix

Proof of Lemma 1:

If firm A rejects the licensing contract, then firm B gets it, and firm A's payoff will be $\frac{1}{18t}(3t+\delta-\epsilon)^2$. So, firm A will accept the license if its payoff $\frac{1}{18t}(3t+\delta+\lambda\epsilon)^2 - F_A \geq \frac{1}{18t}(3t+\delta-\epsilon)^2$. Therefore, the maximum licensing fee that can be extracted from the licensee will be $F_A^* = \frac{1}{18t}(3t+\delta+\lambda\epsilon)^2 - \frac{1}{18t}(3t+\delta-\epsilon)^2$.

When one fixed fee license is offered to the inefficient firm, its ex-ante cost will be reduced by ϵ. Thus, the post licensing cost of inefficient firm will be $c_B - \epsilon$ and the efficient firm will remain at its' initial cost of c_A. The equilibrium prices, demands and profits are given as follows:

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

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

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

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

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

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

$F_B = \frac{1}{18t}(3t - \delta + \epsilon)^2 - \frac{1}{18t}(3t - \delta - \lambda\epsilon)^2$

Similarly, if firm B accepts, it receives a payoff $\frac{1}{18t}(3t - \delta + \epsilon)^2 - F_B$. If firm B rejects the offer, the license will be offered to the other firm. Then, firm B's payoff will be $\frac{1}{18t}(3t - \delta - \lambda\epsilon)^2$ for $\epsilon \leq 3t - \delta$. For $\epsilon > 3t - \delta$, if firm B rejects, firm A gets it and becomes monopoly if its' absorptive capacity $\lambda \geq \frac{3t-\delta}{\epsilon}$. Therefore, if the innovation is licensed to firm B, the licensor will charge a fee $F_B^* = \frac{1}{18t}(3t - \delta + \epsilon)^2 - \frac{1}{18t}(3t - \delta - \lambda\epsilon)^2$.

By comparing the revenues extracted from these two firms respectively, $F_A > F_B \ iff \ \lambda > \left(1 - \frac{2\delta}{\epsilon}\right) = \hat{\lambda}$ and $\hat{\lambda} < 0$ as $\frac{\delta}{\epsilon} \geq 1$. Therefore, $> \hat{\lambda} \ \forall \ \lambda \in [0,1]$.

Proof of Proposition 1:

When both firms accept the offer, the payoff of firm A is $\frac{1}{18t}(3t + \delta - \epsilon(1 - \lambda))^2 - F_A$. If firm A rejects, firm B still gets the license and no-acceptance payoff of firm A will be $\frac{1}{18t}(3t + \delta - \epsilon)^2$. Hence, the licensor can charge a fixed fee of $\frac{1}{18t}(3t + \delta - \epsilon(1 - \lambda))^2 - \frac{1}{18t}(3t + \delta - \epsilon)^2$ from firm A. Similarly, if both firms accept the contract, firm B's payoff is $\frac{1}{18t}(3t - \delta + \epsilon(1 - \lambda))^2 - F_B$. If firm B rejects, it will be offered to the firm A. Then, firm B's no-acceptance payoff will be $\frac{1}{18t}(3t - \delta - \lambda\epsilon)^2$ for $\epsilon \leq 3t - \delta$. For $\epsilon > 3t - \delta$, if firm B rejects, firm A gets it and becomes monopoly if its' absorptive capacity $\lambda \geq \frac{3t-\delta}{\epsilon}$. Hence, it is optimal for firm B to accept and pay a fixed fee of $\frac{1}{18t}(3t - \delta + \epsilon(1 - \lambda))^2 - \frac{1}{18t}(3t - \delta - \lambda\epsilon)^2$. Therefore, the total revenue earned by the innovator is $F^{Both} = \frac{\lambda\epsilon}{18t}\{6t + 2\delta - 2\epsilon + \lambda\epsilon\} + \frac{\epsilon}{18t}\{6t - 2\delta + \epsilon - 2\lambda\epsilon\}$.

Comparing the revenues collected by the innovator under licensing to one firm and both firms, we find that $F_A > F^{Both}\ iff\ \lambda > \left(\frac{1}{2} - \frac{\delta}{\epsilon}\right) = \acute{\lambda}$ and $\acute{\lambda} < 0$ as $\frac{\delta}{\epsilon} \geq 1.$ Therefore, we can infer that $\lambda > \acute{\lambda}\ \forall \lambda \in [0,1]$ and conclude the following proposition.

CHAPTER 5

Conclusion

5.1. Summary

In modern industries firms strive to gain its market dominance through improved technological innovation. Developing a technology might be costly and time consuming for the producing firms to sustain their competitive edge in the world of rapid technological advancements. In this context getting a patent license can be effective way to acquire an innovation from the innovator. This can help both stakeholders to achieve their targets. Through licensing the producing firms can improve their efficiency by reducing their per unit operating cost. On the other hand, the independent innovator gets the reward of its toil which will promote further research and development in the concerned field. The growing importance of patent transfer in the field of Industrial Organization has been reflected by the research works in this topic. 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. 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 we do not find any other research work which 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. We find that the fundamental differences in the modelling structure of spatial competition from the conventional models of product differentiation (Bertrand and Cournot framework), actually have impact on the optimal licensing contracts of cost reducing innovations and the ensuing market equilibrium. Overall, we studied the technology transfer choice of a cost-reducing innovation by an outside innovator in the three chapters of the current dissertation. In the second chapter, we address how ‘once-for-all’ offer in the game structure and the nature of competition play a crucial role on the decision of the innovator. The main findings from this chapter 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 third chapter we have adopted a technology which reduces both firms’ costs in a non-uniform way. We assume that the technology is only beneficial to the inefficient firm. In context of non-uniform cost reduction, we explored the issue of shelving of innovation, often known as “killer acquisition” or “acquisitions for sleep” which is anti-competitive. The basic purpose of innovation gets defeated if the innovation does not reach the market. This kind of acquisition enables the dominant firm (who buys the innovation but does not use it in production process) to strategically maintain its competitive edge by ‘killing’ the innovation. Stamatopoulos and Tauman (2009) showed this possibility in a Cournot duopoly. We inquired into the issue of shelving in a spatial competition with horizontally differentiated product market. We first have analysed the licensing game and the considered the selling of the patent right. In the licensing game, first we considered two schemes, fixed fee licensing and exclusive auction, found that its optimal for the innovator to exclusively auction the innovation to the efficient firm, but the innovation was shelved by the firm. This undesirable outcome could be avoided by two other licensing policies, royalty and two-part tariff licensing. We have observed that for relatively small innovation royalty licensing is optimal, otherwise the optimal licensing scheme is two-part tariff. In both cases, inefficient firm gets the innovation and shelving will not occur as the efficient firm is unable to prevent it from getting the technology.

Now given a choice between selling the right and all possible licensing schemes, interestingly the innovator would optimally choose to sell the new technology to the efficient firm. It is to be noted that the efficient firm buys the right of the new technology, and in this case cannot not shelve it, but further licenses it to the inefficient firm. It is observed that the diffusion of technology can happen through various modes of licensing and selling of patent right. Therefore, shelving could be avoided thereby making killer acquisitions less relevant for a small innovation in spatial competition.

The fourth chapter considered licensing of a cost-reducing technology by the outside innovator to asymmetric firm(s) who are facing inelastic demand (matured markets) with a horizontal product differentiation in a spatial framework. These cost reductions to the firms are non-uniform due to their asymmetric absorptive capacities. Our concept of asymmetric absorptive capacity has been structured in the line with Chang et al. (2016), although this paper has narrowly considered the choice of the innovator between exclusive and non-exclusive licensing under only two licensing schemes, fixed fee and royalty licensing in a conventional Cournot model. Whereas our chapter provided in-depth analysis of four various licensing schemes: fixed fee licensing, auction, royalty licensing and two-part tariff licensing, considering the implications of not only the absorptive capacity, but also other factors, such as the magnitude of innovation and the efficiency of the licensee firms, on optimal licensing decision of the independent innovator. This comprehensive study of technology licensing with asymmetric absorptive capacity is a major contribution to the existing literature.

Considerable insights are provided in the fourth chapter. Non-drastic innovation case of Banerjee and Poddar (2019) is an extreme case of this chapter with a common innovation where post licensing cost reduction for two firms are same, i.e., the efficient firms cost reduction is maximum. Another special case of this study is the case of an innovation beneficial to the inefficient firm, i.e., no cost reduction is possible for the efficient firm. This current chapter provides the story, in between these two extremes, which explains fixed fee licensing to the efficient firm is optimal for the outside innovator over other licensing schemes. Complete diffusion of technology could also be possible under royalty licensing and two-part tariff licensing. But this will not happen due to innovator's profit motive. If all options are available to the innovator, it always chooses to offer the license which earns maximum profit. Therefore, partial diffusion of the technology will happen by licensing the technology to only efficient firm when the technology improves the efficiency of inefficient firm but not as much as the efficient firm though its absorptive capacity is lower.

Thus, to summarize that the above three chapters of the dissertation offered substantial contribution in the field of technology licensing in a spatial competition.

5.2. Future Scope of Research

This dissertation has paved a way for few extensions we can envisage for our future research. We can conceive a technology which reduces both firms' marginal costs to new low i.e., even lower than the efficient firm's initial marginal cost. This kind of technology is known as “new technology innovation”. One can explore the optimal mode of technology licensing of a “new technology innovation” under spatial competitions. Throughout this dissertation we assume the location of the competing firms was fixed since our target was analysing the optimal mode of technology transfer not the optimal product differentiation. But it might be interesting to see the impact of different modes of technology transfer on the optimal level of product differentiation. In that case, one has to determine the location choice of the firms endogenously. However, in that set up, market may not be fully covered. We can avoid the possibility of existence-related problems in pure strategies by quadratic costs of transportation instead of linear transport costs assumed here.

From the fourth chapter one possibility can arise with the innovation which helps the inefficient firm to achieve an efficiency level better than its competitor (the efficient firm). This can be called as a leapfrogging by the inefficient firm. We wish to explore the implications of this assumption on technology licensing in a spatial competition.

These are all the extensions of research we wish to work on as we believe that the works would be interesting and give non-trivial results.

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