Technology Transfer and its effect on Innovation

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Abstract

This paper analyses technology transfer and innovation activities by the high cost firm in a Cournot duopoly framework, where technology transfer between the firms may occur after the innovation decision. The two effects of innovation are to access the superior technology of the low cost firm if higher cost prohibits technology transfer and to affect the pricing rule of technology transfer via higher bargaining power. The incentive for innovation is more in fixed-fee licensing than in two-part tariff (royalty) licensing if cost difference between firms is low. The possibility of licensing, irrespective of the licensing scheme, encourages innovation if the cost difference between the firms is high.

JEL classification: L 24, D 45
Keywords:Technology licensing; Innovation; Welfare

1. Introduction

Technology transfer is an area of long standing interest in the literature of industrial organization. Broadly, two possible channels have been identified via which an inefficient firm can acquire the superior technology (there by reducing cost of production). It can buy the technology directly from the research labs/outside innovators (see Kamien & Tauman (1986), Katz

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& Shapiro (1985)), or may buy it from the more efficient (rival/producing) firm (see Marjit (1990), Wang (1998, 2002), Fauli-Oller & Sandonis (2002) etc). The present paper is related to the second genre of literature, where the low cost firm licenses its technology to the high cos firm at an appropriate price. A parallel strand of literature in industrial organization deals with innovation in an oligopolistic framework. In Cournot oligopoly structure Delbono & Denicolo (1991) have captured the effect of increase in the number of firms on the equilibrium R&D effort of each firm.[2] Reinganum (1983) shows that in presence of technological uncertainty[3] the incumbent firm, after a sufficiently high share of the post-innovation market, invests less on a given project than the challenger.

Several attempts have been made later to incorporate technology transfer and cost reducing innovation in Cournot competitive market. Gallini & Winter (1985) is the initial work to consider the interaction between licensing opportunities and innovation incentives. It shows that the availability of royalty licensing encourages research when the firms' initial production technologies are close in costs and discourages research when initial costs are asymmetric. However, Mukherjee and Mukherjee (2013) shows that fixed-fee licensing decreases innovation while under a two-part tariff licensing contract licensing increases innovation. Chang et al. (2013) also shows that if the licensor firms R&D efficiency is high, the availability of licensing subdues the firms R&D incentive, leading to a lower social welfare level. All these works consider that producing firms internal to the industry make the innovation decision. There is also a parallel literature which deals in comparing innovation incentives of the patentee internal to firm vs the external patentee. Sen and Tauman (2007) and Fauli-Oller et al. (2013) contributes to this field.

The present paper, however, is of the first genre, where in a Cournot duopoly the higher cost firm decides for innovation in the pre-licensing stage. It incorporates technology transfer and cost reducing innovation simultaneously, where technology transfer between the firms may occur after the innovation decision is made by the high cost firm. Licensing can be ei-

[2] It shows that an increase in the number of firms may results in a decrease in the equilibrium R&D effort of each firm and the equilibrium total effort may be underinvestment with respect to social optimum.

[3] Technological uncertainty takes the form of a stochastic relationship between the rate of investment and the eventual date of successful completion of the new technology.

ther through payment of fixed-fee, per-unit royalty or two-part tariff. Using Nash-bargaining the optimal volume of payments are also identified for these different forms of licensing contract[4]. In fixed-fee licensing, the technology is transferred if the cost difference between the firms is low. Contrarily in two-part tariff licensing scheme, where optimality ensures only positive royalty, whatever be the cost difference technology is always transferred.

In the present era of globalization and integration technology transfer between firms has become more common than ever (See Vishwasrao, 2007). The present model can be used to envisage a role of the government in the developing countries. It can be assumed that the low cost firm and the high cost firm are located in developed and developing respectively and compete in quantities in the market of the developing country. In this regard the present paper is built on the assumption that the low cost firm is passive in regards to innovation, as the objection is examine the effect of licensing opportunities on high cost firm's R&D incentives. It therefore analyses innovation incentives only of the high-cost firm under different forms of licensing contract.[5] The present work also highlights the innovation incentives of the high-cost firm even if it knows that it cannot outstrip the low cost firm in cost. Hence, the two possible effects of innovation are: i) accessing the superior technology of the low cost firm if higher cost prohibits technology transfer and ii) affecting the pricing rule of technology transfer via higher bargaining power.

A number of empirical studies, for example Deolalikar and Evenson (1989), Cohen and Levinthal (1989), Ferrantino (1992) and Hu et al. (2005) have been concerned with relationship between R&D and technology transfer. As reported in these works technology transfer and R&D can be either be complements or substitutes. It was believed that the transfer of technology from foreign can reduce indigenous R&D effort and therefore the Indian government restricted the purchase of foreign technology (Deolalikar and Evenson, 1989). The present paper therefore is an attempt to explain the relation of technology transfer and R&D, i.e either complements or substitutes, in terms of cost difference between the firms. It shows that both in

[4]See Kishimoto & Moto (2012) and Monerris & Vannetelbosch (2001) for a similar type of analysis

[5]In empirical literature the interaction of domestic R&D and (foreign) technology transfer is an important issue. Hu et al. (2005) for example study this interaction in the context of Chinese industry.

fixed-fee as well as in two-part tariff (royalty) licensing, allowing licensing (removing barriers) discourages innovation (research) if the cost difference is low.[6] This result is in contrast to Gallini & Winter (1985), where in a duopoly the availability of royalty licensing encourages research when the firms' initial production technologies are close in costs and discourages research when initial costs are asymmetric. In the present model technology transfer and R&D exhibits to be substitutes if the cost difference is low, as in such case licensing reduces the incentives for investment in innovation. However, the relation is complementary if the cost difference is high, as for higher difference in cost licensing encourages innovation. In a firm level analysis in China, Hu et al. (2005) also shows that the addition of technology transfer, both foreign and domestic, raises the returns to indigenous R&D. Moreover particularly in the present model in case of fixed-fee licensing, the high cost firm licenses in the technology only if R&D activities reduces its cost below a particular threshold. This idea therefore validates the complementary relation for higher difference in cost.

Fauli-Oller et al. (2013), Mukherjee and Mukherjee (2013) and Chang et al. (2013) consider symmetric cost for the firms in the pre-licensing stage and therefore licensing can takes place only when innovation activities are carried out. However, the present paper considers asymmetric cost structures such the even if innovation activities are not undertaken, then also technology may be transferred. Empirically, as ample evidence is observed in regards to licensing of technology from a (foreign) firm to a domestic firm even when R&D is not undertaken, it therefore validates cost asymmetry rather than symmetry.[7] In contrast to Mukherjee and Mukherjee (2013), it is observed that the incentives for innovation is more (less) in fixed-fee licensing than in two-part tariff/royalty licensing if the cost difference is low (high). The welfare effect of innovation is also formalised. In fixed-fee licensing scheme innovation by the high cost firm increases welfare when the

[6] According to Hu et al. (2005) in China foreign technology transfer tends to be relatively more intensive in the technologically less advanced industries, i.e. tobacco, textile, apparel, leather, furniture, paper, printing, and rubber, in which firms spend equal or greater amounts on foreign technology transfer than on R&D. The industries which are thought to be more technologically sophisticated, such as pharmaceutical, electric, electronics, and instruments, invest far more in R&D than in technology transfer.

[7] In the literature on horizontal mergers (e.g., Farrell and Shapiro, 1990) cost asymmetry and cost synergy also plays an important role. Lahiro and Ono (2004) presents a series of theoretical tudies of important issues in international trade premised on the assumption that firms have asymmetric costs.

cost difference between the firms is high. On the other hand in case of royalty licensing, the welfare effect is ambiguous. This posits an intervention in regulating innovation by the government.

The scheme of this paper is follows. In section 2 and section 4 technology transfer via fixed-fee and royalty (two-part tariff) respectively are discussed. Section 3 and section 5 incorporate the incentive of the high-cost to innovate and its effect on welfare under fixed-fee and royalty (two-part tariff) licensing respectively. The last section finally concludes.

2. Technology transfer via fixed-fee

Consider a Cournot duopoly producing a homogeneous product. The market demand is given by $P = a - bQ$, where Q is industry output. The two firms, firm 1 and firm 2 produce output (Q_1 and Q_2) at constant unit production cost c_1 and c_2 respectively($c_1 > c_2$). P is the market price; $a, b > 0$ are constants. Assume $a > c_i$ (i=1,2) and $c_1 < \bar{c_1} = \frac{a+c_2}{2}$. For $c_1 \geq \bar{c_1}$, firm 2 is the monopolist. The profits of the duopolists are given by

$$\Pi_i(c_i, c_j) = \frac{(a - 2c_i + c_j)^2}{9b} \tag{1}$$

where $i, j = (1, 2)$ and $i \neq j$. It is shown by Marjit (1990) that technology is transferred from firm 2 to firm 1 via fixed-fee, as captured by a reduction in the value of c_1 to c_2, if $c_1 \leq \frac{2a+3c_2}{5} = \tilde{c_1}$. This implies that if the cost difference between the firms is not too high the transfer of technology will take place.

In Wang (1998) firm 2 licenses its superior technology to firm 1 by charging a maximum fixed-fee (as enjoys full bargaining power) such that firm 1 is indifferent between licensing and not licensing. The present paper while introduces Nash-Bargaining for determining fixed fee (f) in this duopoly framework of cost asymmetry such that both firms gains after the technology is transferred. The optimal value of f is solved by

$$\max_f \Big[\Pi_1(c_2, c_2) - f - \Pi_1(c_1, c_2)\Big]\Big[\Pi_2(c_2, c_2) + f - \Pi_2(c_2, c_1)\Big] \tag{2}$$

such that $\Pi_1(c_2, c_2) - f \geq \Pi_1(c_1, c_2)$ and $\Pi_2(c_2, c_2) + f \geq \Pi_2(c_2, c_1)$ or $c_1 \leq \tilde{c_1}$. As for $c_1 > \tilde{c_1}$ there does not exist any f that would be mutually beneficial. $\Pi_1(c_2, c_2) - f$ is the profit of firm 1 with the new technology net of payment of fixed-fee and $\Pi_2(c_2, c_2) + f$ is the sum of profit and fee of firm 2 after the technology is transferred. $\Pi_i(c_i, c_j)$'s for $i = 1, 2$ are the pre-licensing profits (reservation pay-off). The optimal fixed fee for licensing is

$$f^*(c_1) = \frac{\Pi_2(c_2, c_1) - \Pi_1(c_1, c_2)}{2} = (c_1 - c_2)(2a - c_1 - c_2)/6b. \qquad (3)$$

Therefore transfer of technology will take place for $c_1 \leq \tilde{c_1}$ and $f = f^*(c_1)$.

Proposition 1. *Transfer of technology from the efficient firm to the technologically inefficient firm in terms of fixed-fee takes place if* $c_1 \leq \tilde{c_1}$ *and under Nash-bargaining the optimal fixed-fee is* $f^*(c_1) = (c_1 - c_2)(2a - c_1 - c_2)/6b$.

The above proposition highlights two things. First, if $c_1 > \tilde{c_1}$ by reducing c_1 below $\tilde{c_1}$ via innovation firm 1 can enjoy technology of firm 2. Second, if $c_1 \leq \tilde{c_1}$, it can also reduce the burden of fixed-fee by reducing its cost. The next section therefore takes care of innovation incentives of firm 1 for reducing its unit cost.

3. Incentives for innovation under fixed-fee licensing

As in Mukherjee & Pennings (2011) and Chang et al. (2013) the present section incorporates only firm 1's incentive to innovate for reducing its unit cost in the pre-licensing stage.[8] In Gallini & Winter (1985), where licensing is through per-unit royalty, both firms make decisions on research (innovation) for cost reduction in ex-ante period and production takes place in the ex-post period. Moreover in Gallini & Winter (1985), the higher cost firm (in pre-innovation stage) after innovation may turn out to be the lower cost firm (in post-innovation stage) and can sell its technology to its rival. Chang et al. (2013) also sets up a three-stage game in which only one of the firms undertakes a cost-reducing R&D and may license the developed technology to the others by means of a two-part tariff (i.e., a per-unit royalty and an upfront fee) contract. However, in the present paper this is not possible. *Contrarily the present paper allows innovation by firm 1 but restrict the possibility of turning out to be the lower cost firm in the post-innovation stage. Holding firm 2 inactive in regards to innovation is to observe firm 1's incentive to innovate even if it knows that it cannot outstrip firm 2 in cost.*

[8] It can be assumed that firm 2's unit cost is very low and it does not innovate as undertaking innovation activities for further cost reduction is very costly.

Without loss of any generality it is assumed that $c_2 = 0$. Firm 1 invests an amount K (> 0) and the post-innovation cost of firm 1 (say c) follows a uniform distribution in the interval $[0, c_1]$, where c_1 is the initial unit cost of firm 1 in the pre-innovation stage.

Consider $c_1 \leq \tilde{c_1}$, and let $L(c_1)$ be the profit (net) of firm 1 after technology transfer if innovation activities are not undertaken and $f^*(c_1)$ is the optimal fixed-fee. Then $L(c_1) = \Pi_1(c_1, 0) - f^*(c_1) = \frac{a^2}{9b} - \frac{c_1(2a-c_1)}{6b}$. Indeed, as the solution to the bargaining game is mutually beneficial therefore $L(c_1) \geq \Pi_1(c_1, 0)$ for $c_1 \leq \tilde{c_1}$. It follows that, for any c_1:

$$\int_0^{c_a} L(c)g(c)dc + \int_{c_a}^{c_1} \Pi_1(c, 0)g(c)dc \geq \int_0^{c_1} \Pi_1(c, 0)g(c)dc \tag{4}$$

where $c_a = \min\{c_1, \tilde{c_1}\}$. The left hand side and the right hand side of the above inequality measures respectively the *expected returns from investment* when technology is transferable and when technology is not transferable[9]. Thus no matter what the cost of firm 1 is, the *expected returns from investment* are always greater when technology is transferable.

Under fixed-fee licensing, for all $c_1 > \tilde{c_1}$, when the firm does not invest it gets $\Pi_1(c_1, 0)$, whether or not technology is transferable, as there is no mutually beneficial solution to the bargaining game. Thus incentives to invest are stronger when technology is transferable because

$$\int_0^{\tilde{c_1}} L(c)g(c)dc + \int_{\tilde{c_1}}^{c_1} \Pi_1(c, 0)g(c)dc - \Pi_1(c_1, 0) > \int_0^{c_1} \Pi_1(c, 0)g(c) - \Pi_1(c_1, 0) \tag{5}$$

where the left hand side is $M(c_1)$ and the right hand side is $M_0(c_1)$. $M(c_1)$ is the *expected increase in profit due to innovation* when technology is transferable and $M_0(c_1)$ is the *expected increase in profit due to innovation* when technology is not transferable. The expected increase in profit due to innovation can be called as the *"innovation incentives"*.[10]

On the other hand for all $c_1 \leq \tilde{c_1}$, when the firm does not invest it gets $L(c_1, 0)$, as technology is transferable, as there is mutually beneficial

[9]It can be considered that the Government is restricting the transfer of technology.

[10]In the rest of the paper the term "innovation incentives" is used hence forth to signify the expected increase in profit due to innovation.

solution to the bargaining game. However incentives to invest may not be stronger when technology is transferable because for $c_1 \leq \tilde{c_1}$

$$\int_0^{c_1} L(c)g(c)dc - L(c_1) \;\; may \;\; not \;\; be \;\; \leq \int_0^{c_1} \Pi_1(c,0)g(c) - \Pi_1(c_1,0) \quad (6)$$

where the left hand side is $M(c_1)$ and the right hand side is $M_0(c_1)$.

From equation (5) and (6), we get

$$\begin{aligned} M(c_1) &= \frac{3ac_1 - 2c_1^2}{18b} \;\; for \;\; c_1 \leq \tilde{c_1} \\ &= \frac{a^3 z}{bc_1} + \frac{2ac_1}{9b} - \frac{8c_1^2}{27b} \;\; for \;\; c_1 > \tilde{c_1} \end{aligned} \quad (7)$$

where $z = 0.002963$ and

$$M_0(c_1) = \frac{2ac_1}{9b} - \frac{8c_1^2}{27b}. \quad (8)$$

To decide on whether it invests or not the firm compares $M(c_1)$ or $M_0(c_1)$ with K. *If technology is transferable, firm 1 innovates if* $M(c_1) > K$. *On the other hand if technology is not transferable, firm 1 innovates if* $M_0(c_1) > K$. It will be interesting to compare the innovation incentives with and without the possibility of technology transfer with the help of Figure 1 (see Appendix A.1). From figure 1, it follows that only if $c_1 \leq \hat{c_1}(< \tilde{c_1})$, the incentives is more when technology is not transferable than without it, i.e

$$\begin{aligned} M(c_1) &< M_0(c_1) \;\; if \;\; c_1 < \hat{c_1}, \\ M(c_1) &= M_0(c_1) \;\; if \;\; c_1 = \hat{c_1} \;\; and \\ M(c_1) &> M_0(c_1) \;\; if \;\; c_1 > \hat{c_1} \end{aligned}$$

where $\hat{c_1} = \frac{3a}{8}$ and $\tilde{c_1} = \frac{2a}{5}$. Therefore the incentive for innovation is higher under the possibility of technology transfer if the cost difference is high or $c_1 > \hat{c_1}$. *The expected returns from investment are inverted U shaped (see Figure 1) not only technology is transferable but also when it is not.* This suggests that incentives to invest (whether technology is transferable or not) are initially increasing and then decreasing in c_1.

For $c_1 \leq \tilde{c_1}$, as technology is transferred whether firm 1 innovates or not (if technology is transferable), the motive behind innovation is to reduce the fixed-fee (f^*) by reducing its pre-transfer unit cost (as $\frac{df^*}{dc_1} > 0$, see equation

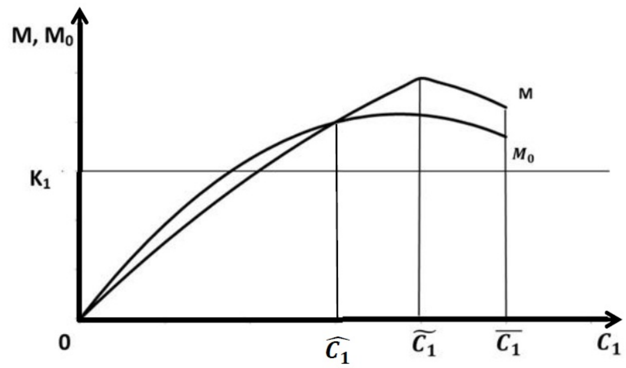

Figure 1: Innovation incentives: Fixed-fee

3) or to increase its reservation pay-off. If c_1 is close to 0, through innovation the unit cost can be reduced marginally. Therefore the gains from reduction in fixed-fee $M(c_1)$ is lower than $M_0(c_1)$. Firm 1 will not innovate if c_1 is very low such that (see figure 1) $K = K_1 > M_0(c_1) > M(c_1)$. Similarly if c_1 is marginally below $\tilde{c}_1$ the possibility of reducing the unit cost of firm 1 is much higher. The optimal fixed-fee can thereby be reduced significantly and therefore $M(c_1) > M_0(c_1)$. However for $\tilde{c}_1 < c_1 < \bar{c}_1$ the incentives to invest are stronger when technology is transferable ($M(c_1) > M_0$) as in that case the firm can have the access of the technology of firm 2 if the post-innovation unit cost c is below $\tilde{c}_1$.

Proposition 2. *The possibility of licensing via fixed-fee encourages innovation if the cost difference between the firms is high and discourages innovation if the cost difference is low.*

In Gallini & Winter (1985) under royalty licensing the availability of licensing encourages research when the firm's initial cost difference is small, while the present paper shows how the availability of licensing encourages innovation if the cost difference between the firms is high and discourages innovation if the cost difference is low. *It is discussed later in the present paper that this result holds even in case of royalty licensing. (See Proposition 5)* It is also to be noted that if the licensing game gives full bargaining power to firm 2 as in Wang (1998), in figure 1, the curve M will coincide with M_0. Then whether government allows licensing or not, innovation incentives will be unaffected.

3.1. Welfare effects

This section discusses the effects on welfare in the presence of licensing possibilities. Welfare is defined as the sum of industry profit and consumer surplus. Let $c_1 \leq \tilde{c_1}$, this implies that if firm 1 does not undertake innovation activities then also technology is transferred. Though in this case firm 1 gets benefit from innovation, from the industry point it is not desirable. This type of innovation only affects the fixed-fee (f^*) which has no role in increasing the post-transfer industry profit and output. The cost of innovation acts as a leakage for the industry in the form of paying an outsider the innovation fee (K). Therefore, undertaking innovation activities only for reducing the fixed fee (f^*) is welfare reducing.

Let us consider the other case $c_1 > \tilde{c_1}$. As innovation by firm 1 increases the profit of firm 1 as $M(c_1) > K$, we therefore focus on the other effects, i.e. on the profit of firm 2 and on the consumer surplus. Let the expected profit of firm 2 (after innovation by firm 1) be $J(c_1)$, where ($\tilde{c_1} < c_1 < \bar{c_1}$)

$$J(c_1) = \int_0^{\tilde{c_1}} \Big\{ \Pi_2(0,0) + f^*(c) \Big\} g(c)dc + \int_{\tilde{c_1}}^{c_1} \Pi_2(0,c)g(c)dc. \tag{9}$$

From Appendix A.2, equation (A.2) we get

$$J(c_1) - \Pi_2(0,c_1) = \frac{a^3 z}{bc_1} - \frac{ac_1}{9b} - \frac{2{c_1}^2}{27b}, \tag{10}$$

which is the expected increase in profit of firm 2 where $z = 0.002963$. On the other hand pre-innovation, industry output is $Q_1 + Q_2 = \frac{2a-c_1}{3b}$ and consumer surplus is equal to $CS(c_1) = \frac{(2a-c_1)^2}{18b}$. Hence the expected consumer surplus (E_{CS}) after innovation by firm 1 is

$$E_{CS}(c_1) = \int_0^{\tilde{c_1}} CS(0)g(c)dc + \int_{\tilde{c_1}}^{c_1} CS(c)g(c)dc. \tag{11}$$

Therefore the expected increase in consumer surplus if firm 1 innovates is (see Appendix A.3, equation (A.3))

$$E_{CS}(c_1) - CS(c_1) = \frac{a^3 v}{bc_1} + \frac{ac_1}{9b} - \frac{{c_1}^2}{27b} \tag{12}$$

where $v = 0.061037$. As the sum of expected increase in consumer surplus and profit of firm 2 is positive or $E_{CS}(c_1) - CS(c_1) + J(c_1) - \Pi_2(0, c_1) > 0$ (see Appendix A.4), innovation by firm 1 will definitely increase the welfare. This ensures that if firm 1 innovates (when $M(c_1) > K$) the welfare (expected) will definitely increase.

4. Two-part tariff licensing

The present literature on licensing (see Rostocker, 1984) apart from fixed-fee licensing also deals with two-part tariff and per-unit royalty contract. Hence this section deals with two-part tariff contract, a combination of fixed-fee (f) and per unit royalty (r), as a tool of technology transfer in the basic model outlined in section 2. For simplicity we assume $c_2 = 0$ here also. The innovation incentives are also re-analysed for these new forms of licensing contract.

It has been pointed out by Shapiro (1985) that "....under the antitrust laws, and for a good reason! ... a reasonable constraint to put on the two-part tariff contract is that the fixed-fee be non-negative" and "... the licensing contract cannot raise the licensee's unit costs (production cost plus royalty)." This section also introduces Nash-Bargaining for determining the fixed fee and royalty. The optimal value of f, r is solved by

$$\max_{(f,r)} \left[\Pi_1^r(c_1) - \Pi_1(c_1, 0)\right] \left[\Pi_2^r(c_1) - \Pi_2(0, c_1)\right] \tag{13}$$

subject to $f \geq 0$, $c_1 \geq r \geq 0$, $\Pi_i^r(c_1) - \Pi_i(c_i, c_j) \geq 0$; $i, j = 1, 2$ $(i \neq j)$. $\Pi_i^r(c_1)$ and $\Pi_i(c_i, c_j)$ are the post-transfer and pre-transfer profit of firm i respectively; $\Pi_1^r(c_1) = \frac{(a-2r)^2}{9b} - f$, $\Pi_1(c_1, 0) = \frac{(a-2c_1)^2}{9b}$, $\Pi_2^r(c_1) = \frac{(a+r)^2}{9b} + \frac{r(a-2r)}{3b} + f$ and $\Pi_2(0, c_1) = \frac{(a+c_1)^2}{9b}$.

Solving the above problem we find that the optimal f is zero and optimal $r = r^*(c_1) = \frac{a}{2} - \frac{\sqrt{100a^2 - 280ac_1 + 160c_1^2}}{20}$ (see Appendix A.5, equation (A.5)). Under this contract the technology is always transferred for $c_1 < \bar{c_1}$ and the profits of firm 1 and firm 2 after licensing are

$$\Pi_1^r(c_1) = \frac{a^2}{9b} + \frac{8c_1^2 - 14ac_1}{45b} \tag{14}$$

and

$$\Pi_2^r(c_1) = \frac{a^2}{9b} + \frac{7ac_1 - 4c_1^2}{18b}. \tag{15}$$

respectively. If $c_1 > \bar{c_1}$, technology is not transferred as the monopolist (firm 2) will always be worse off if it transfers the technology.

Proposition 3. *Under two-part tariff contract, technology is transferred if and only if* $c_1 < \bar{c_1}$. *Under Nash-bargaining, the equilibrium fixed-fee is zero and royalty is* $r^*(c_1) = \frac{a}{2} - \frac{\sqrt{100a^2 - 280ac_1 + 160c_1^2}}{20}$.

For a similar type of analysis one may see Kishimoto & Moto (2012), where using Nash-bargaining fixed-fee licensing and royalty licensing are dealt separately. As for two-part tariff licensing Nash-bargaining sets fixed-fee to be zero and a positive royalty rate r^*, therefore r^* is also the optimal per-unit royalty under Nash-bargaining for royalty licensing. Therefore in the present context "royalty licensing" and "two-part tariff licensing" are used interchangeably for the rest of the analysis.

5. Incentives for innovation under royalty licensing

Let us analyse firm 1's incentive to innovate for reducing its unit cost in case of royalty licensing. The cost after innovation (c) is assumed to follow a uniform distribution in $[0, c_1]$ as before. As in fixed-fee licensing, here also innovation incentives before the transfer of technology arises only for increasing the reservation pay-off or for reducing the per unit royalty rates for buying the technology. Indeed, because the solution to the bargaining game is mutually beneficial we have $\Pi_1^r(c_1) > \Pi_1(c_1, 0)$ for $c_1 < \bar{c_1}$. It follows that, for any c_1:

$$\int_0^{c_1} \Pi_1^r(c)g(c)dc > \int_0^{c_1} \Pi_1(c, 0)g(c)dc. \tag{16}$$

The left hand side measures the *expected returns from investment* when technology is transferable and the right hand side measures the *expected returns from investment* when it is not. Therefore as in fixed-fee licensing no matter what the cost of firm 1 is, the expected returns from investment are always greater when technology is transferable.

The *expected increase in profit due to innovation* when technology is transferable is

$$H(c_1) = \int_0^{c_1} \Pi_1^r(c)g(c)dc - \Pi_1^r(c_1) = \frac{21ac_1 - 16c_1^2}{135b}. \tag{17}$$

Firm 1 decides to innovate if $H(c_1) > K$. However $M(c_1)$ (see equation 7) is the *expected increase in profit due to innovation* when technology is

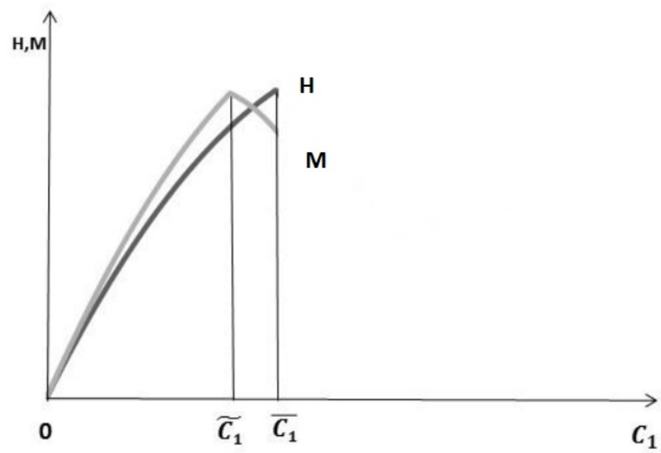

Figure 2: Innovation incentives: Fixed-fee vs Royalty

transferable via fixed-fee and $M_0(c_1)$ (see equation 8) is the *expected increase in profit due to innovation* when technology is not transferable.

Figure 2 (see Appendix A.6) shows how the *innovation incentives* vary under different forms of licensing contract. The *innovation incentives* are more in case of royalty licensing than in fixed-fee licensing only if the initial cost (cost difference) of firm 1 is very high, i.e. $H(c_1) > M(c_1)$ if c_1 is high.

Proposition 4. *Fixed-fee licensing scheme gives more incentive to innovate than royalty licensing if the cost difference between firms is low.*

Therefore given the cost of innovation firm 1 may change the decision towards innovation if the licensing scheme changes. One can explain the above proposition in the following manner. Let us begin with the case $c_1 \leq \tilde{c_1}$, where technology may be transferred profitably without innovation both in fixed-fee as well as in royalty licensing. For firm 1 profit in royalty licensing is higher than in fixed-fee licensing ($\Pi_1^r(c_1) > L(c_1),$)[11]. The difference in

[11]Royalty licensing always leads to higher industry profit than in fixed-fee licensing due to lower competitive effect. Therefore the Nash-bargaining outcome also ensures higher profit for both the firms in royalty licensing than in fixed-fee licensing.

profit, $\delta(c_1) = \Pi_1^r(c_1) - L(c_1)$, also increases in c_1. Therefore the expected increase in profit after innovation is more in fixed-fee licensing than in two-part tariff licensing[12]. On the other hand for $c_1 > \tilde{c_1}$, the incentives for innovation remains higher for fixed-fee licensing than in the royalty licensing for cost slightly higher than $\tilde{c_1}$. This happens due to higher probability of getting the superior technology after innovation if slightly higher cost prohibits technology transfer under fixed-fee licensing. Contrarily the possibility of technology transfer after innovation is less likely for higher cost in fixed-fee licensing. This explains the lower incentive in fixed-fee than in royalty licensing for higher cost as under royalty licensing technology is always transferred.

Let us compare the *innovation incentives* with and without the possibility to licensing. $H(c_1)$ is the expected increase in profit due to innovation or *innovation incentives* when technology is transferable via royalty. However $M_0(c_1)$, is the *innovation incentives* when technology is not transferable. Figure 3 shows that for lower unit cost, if government allows licensing, in-

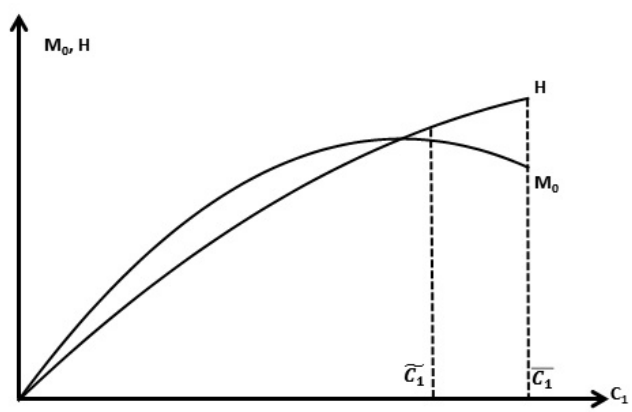

Figure 3: Innovation incentives: Royalty

centive for innovation will decrease; while for higher unit cost, allowing licensing will increase incentive for innovation.

[12]For $0 < c_1 < \tilde{c_1}$ the difference of expected increase in profit in fixed-fee licensing and expected increase in profit in two-part tariff licensing is $[\int_0^{c_1} L(c)g(c)dc - L(c_1)] - [\int_0^{c_1} \Pi_1^r(c)g(c)dc - \Pi_1^r(c_1)] = \Pi_1^r(c_1) - L(c_1) - \int_0^{c_1}[\Pi_1^r(c) - L(c)]g(c)dc = \delta(c_1) - \int_0^{c_1} \delta(c)g(c)dc > 0$ as $\delta(c) \leq \delta(c_1), c \in [0, c_1]$.

Proposition 5. *The possibility of licensing via royalty encourages innovation if the cost difference between the firms is high and discourages innovation if the cost difference is low.*

In case of royalty licensing also if full bargaining power is bestowed on firm 2 as in Wang (1998), innovation incentives will be unaffected by licensing opportunities. This implies that whatever be the form of licensing contract, fixed-fee or per-unit royalty, innovation incentives is unaffected by licensing opportunities if full bargaining power is enjoyed by firm 2.

From Proposition 4 & Proposition 5, it can be argued that the incentive for innovation irrespective of licensing scheme (both in fixed-fee and in royalty licensing) is more without the possibility of technology transfer if the initial cost (cost difference) is low. On the other hand it is less without any barriers to technology transfer if the initial cost (cost difference) is high. This proposition is just in contrast to Gallini & Winter (1985), where royalty licensing encourages research if the cost difference is low. This paper shows that under Nash-bargaining fixed-fee as well as royalty licensing encourages research if the cost difference is high.

5.1. Welfare effects

Whether innovation will increase welfare and how welfare after innovation depends on the initial cost is being discussed. As in this case technology is always licensed consumer surplus without innovation is

$$CS^r(c_1) = \frac{4a^2 - 4ar^* + r^{*2}}{18b} \tag{18}$$

where industry output and price are $\frac{2a-r^*}{3b}$ and $\frac{a+r^*}{3}$ respectively. Therefore the expected increase in consumer surplus due to innovation is

$$E^r_{CS}(c_1) - CS^r(c_1) = \int_0^{c_1} CS^r(c)g(c)dc - CS^r(c_1) = V(c_1) + \frac{21ac_1 - 16c_1^2}{1080b} \tag{19}$$

where
$V(c_1) = \frac{a}{120b}\left[\int_0^{c_1} \frac{1}{c_1}\sqrt{100a^2 - 280ac + 160c^2}dc - \sqrt{100a^2 - 280ac_1 + 160c_1^2}\right].$

Moreover the expected increase in profit of firm 2 due to innovation is

$$J^r(c_1) - \Pi_2^r(c_1) = \int_0^{c_1} \Pi_2^r(c)g(c)dc - \Pi_2^r(c_1) = \frac{16c_1^2 - 21ac_1}{108b}. \tag{20}$$

Therefore the expected increase in welfare (expected increase in profit of firm 1, firm 2 & consumer surplus) after innovation is

$$H(c_1) - K + E_{CS}^r(c_1) - CS^r(c_1) + J^r(c_1) - \Pi_2^r(c_1) \tag{21}$$

$$= H(c_1) - K + V(c_1) - \frac{21ac_1 - 16c_1^2}{120b}. \tag{22}$$

It has been shown that $V(c_1) - \frac{21ac_1 - 16c_1^2}{120b} < 0$ (see Appendix A.7). Therefore the welfare effect is ambiguous which posits a regulatory role for the government to curb innovation if K is very high (close to $H(c_1)$). As in this case innovation by firm 1 will always reduce welfare.

6. Conclusion

This paper shows that in Cournot framework under Nash-bargaining the optimal fixed-fee licensing contract allows transfer if the cost difference is low. On the other hand it has been found that under two-part tariff licensing optimal fixed-fee is zero and the licensing is only through per-unit royalty and technology is always transferred. Secondly, the present analysis also addresses how incentive to innovate is affected by the optimal licensing scheme, where technology transfer between the firms may occur after the innovation decision is made by the inefficient firm. It has been shown that the incentive towards innovation is more in fixed-fee licensing than in two-part tariff (royalty) licensing if cost difference between firms is low. The result is opposite when the cost difference is high. Therefore given the cost of innovation, the firm may change the decision towards innovation if the licensing scheme changes.

In fixed-fee licensing if the cost difference is low such that without innovation also technology will be transferred, innovation will unambiguously reduce the welfare. On the other hand the in fixed-fee licensing innovation by firm 1 increases welfare if high cost difference prohibits technology licensing initially. Contrarily the welfare effect of innovation is ambiguous in royalty licensing. Finally, irrespective of licensing scheme the incentive to innovate is more with barriers to technology transfer than without it if the cost difference is low. On the other hand when the cost difference is high allowing licensing gives more incentive to innovate.

In the present era of globalization and integration technology transfer between firms has become more common than ever. The present model can be used to envisage a role of the government in the developing countries. Suppose the low cost firm and the high cost firm are located in developed and developing respectively and compete in quantities in the market of the developing country. The paper then predicts, once the developing country allows licensing the incentives to innovate of the inefficient firm may either increase or decrease. This depends on the technology difference with the efficient firm. It can also be argued that the government of developing country may give incentive to the home (inefficient) firm in the form of subsidy for innovation if sufficiently high initial cost prohibits technology transfer. This model can also be extended to the literature of strategic trade as in Ghosh & Saha (2008), if we consider that the two firms compete in a third country. The role of the government in regards to allowing licensing and innovation activities can be considered further.

Appendix A.

Appendix A.1.

From equation (8) we have $M_0(c_1) = \frac{2ac_1}{9b} - \frac{8c_1^2}{27b}$ for $0 < c_1 < \bar{c_1}$.

For $c_1 \in (0, \tilde{c_1}]$, $M(c_1) - M_0(c_1) = \frac{10c_1^2 - 3ac_1}{54b}$, as $M(c_1) = \frac{3ac_1 - 2c_1^2}{18b}$. Initially $M(c_1) - M_0(c_1) < 0$ for $c_1 < \frac{3a}{10} = \hat{c_1}$, and $M - M_0 = 0$ at $c_1 = \frac{3a}{10}$. Finally for $\tilde{c_1} \geq c_1 > \hat{c_1}$, $M(c_1) > M_0(c_1)$.

For $c_1 > \tilde{c_1}$, $M(c_1) = \frac{a^3 z}{bc_1} + \frac{2ac_1}{9b} - \frac{8c_1^2}{27b}$ where $z = 0.002963$; and $M(c_1) - M_0(c_1) = \frac{a^3 z}{bc_1} > 0$.

Appendix A.2.

From equation (9) of the main text

$$\begin{aligned} J(c_1) &= \int_0^{\tilde{c_1}} \Big[\Pi_2(0,0) + f^*(c)\Big] g(c)dc + \int_{\tilde{c_1}}^{c_1} \Pi_2(0,c)g(c)dc \\ &= \int_0^{\tilde{c_1}} \frac{1}{c_1}\left[\frac{a^2}{9b} + \frac{c(2a-c)}{6b}\right] dc + \int_{\tilde{c_1}}^{c_1} \frac{1}{c_1}\frac{(a+c)^2}{9b} dc \\ &= \frac{a^3 z}{bc_1} + \frac{a^2}{9b} + \frac{ac_1}{9b} + \frac{{c_1}^2}{27b} \end{aligned} \tag{A.1}$$

where $z = 0.002963$. Therefore

$$J(c_1) - \Pi_2(0, c_1) = \frac{a^3 z}{bc_1} - \frac{ac_1}{9b} - \frac{2{c_1}^2}{27b}, \tag{A.2}$$

which is equation (10) in the main text.

Appendix A.3.

From equation (11), we find that

$$\begin{aligned}
E_{CS}(c_1) - CS(c_1) &= \int_0^{\tilde{c_1}} CS(0)g(c)dc + \int_{\tilde{c_1}}^{c_1} CS(c)g(c)dc - CS(c_1) \\
&= \int_0^{\tilde{c_1}} \frac{2a^2}{9bc_1}dc + \int_{\tilde{c_1}}^{c_1} \frac{(2a-c)^2}{18bc_1}dc - \frac{(2a-c_1)^2}{18b} \\
&= \frac{a^3v}{bc_1} + \frac{ac_1}{9b} - \frac{{c_1}^2}{27b} \qquad \text{(A.3)}
\end{aligned}$$

where $v = 0.061037$, which is equation (12) in the main text.

Appendix A.4.

From equations (8) and (12), it can be said that $E_{CS}(c_1) - CS(c_1) + J(c_1) - \Pi_2(0, c_1) = \frac{a^3v}{bc_1} + \frac{ac_1}{9b} - \frac{{c_1}^2}{27b} + \frac{a^3z}{bc_1} - \frac{ac_1}{9b} - \frac{2{c_1}^2}{27b} = \frac{a^3(v+z)}{bc_1} - \frac{{c_1}^2}{9b} > 0$ for $\tilde{c_1} < c_1 < \bar{c_1}$, where z and v is defined in Appendix A.2 and Appendix A.3 respectively.

Appendix A.5.

From equation (13), the objective function is

$$Z = \left[\Pi_1^r(c_1) - \Pi_1(c_1, 0)\right]\left[\Pi_2^r(c_1) - \Pi_2(0, c_1)\right] \qquad \text{(A.4)}$$

then $\frac{\delta Z}{\delta f} = \left[\Pi_1^r(c_1) - \Pi_1(c_1, 0)\right] - \left[\Pi_2^r(c_1) - \Pi_2(0, c_1)\right]$ and

$\frac{\delta Z}{\delta r} = \frac{a-2r}{9b}\left[5(\Pi_1^r(c_1) - \Pi_1(c_1, 0)) - 4(\Pi_2^r(c_1) - \Pi_2(0, c_1))\right]$.

Now optimal f and r cannot be positive simultaneously as the second order condition is not satisfied for this Kuhn-Tucker maximization problem. Let assume that optimal f is positive then $\frac{\delta Z}{\delta f} = 0$. Solving this we get $f = (2ac_1 - c_1^2 - 3ar + 3r^2)/6b$ and $\frac{\delta Z}{\delta r} = \frac{a-2r}{9b}(\Pi_1^r - \Pi_1(c_1, 0))$. Therefore a possible solution, say solution A, is $f = (2ac_1 - c_1^2)/6b > 0, c_1 \leq \tilde{c_1}$ and $r = 0$. Similarly the other possible solution, say solution B, is $f = 0$ and $c_1 > r > 0$. Solving $\frac{\delta Z}{\delta r} = 0$, we get

$$r = r^*(c_1) = \frac{a}{2} - \frac{\sqrt{100a^2 - 280ac_1 + 160c_1^2}}{20}. \qquad \text{(A.5)}$$

Its been found that Z is higher for solution B than for solution A. Therefore solution B is the optimal solution.

Appendix A.6.

For $c_1 \leq \tilde{c_1}$, from equations (7) and (17) we have, $H(c_1) < M(c_1)$ as $M(c_1) - H(c_1) = \frac{3ac_1+2c_1^2}{270b}$. For $\tilde{c_1} < c_1 < \bar{c_1}$, from equations (7) and (17) we have, $H(c_1) - M(c_1) = \frac{24c_1^2-9ac_1}{135b} - \frac{a^3z}{bc_1}$ and is positive if c_1 is close to $\bar{c_1}$.

Appendix A.7.

From equation (22) we consider only the term $V(c_1) - \frac{21ac_1-16c_1^2}{120b} = U(c_1)$ for $0 < c_1 < \bar{c_1}$, where

$U(c_1) = \frac{a}{120b}\left[\int_0^{c_1} \frac{1}{c_1}\sqrt{100a^2 - 280ac + 160c^2}dc - \sqrt{100a^2 - 280ac_1 + 160c_1^2}\right] - \frac{21ac_1-16c_1^2}{120b}$.

Let $N(c) = \sqrt{100a^2 - 280ac + 160c^2}$, $N'(c) \leq 0$ and $N''(c) > 0$. Therefore,

$$120bU(c_1) = \bar{U}(c_1) = \frac{a}{c_1}\int_0^{c_1}[N(c) - N(c_1)]dc + 16c_1^2 - 21ac_1 \qquad \text{(A.6)}$$

where $\int_0^{c_1}[N(c) - N(c_1)]dc \leq \frac{c_1[N(0)-N(c_1)]}{2} = \frac{c_1[10a-\sqrt{100a^2-280ac_1+160c_1^2}]}{2}$.

Therefore, $\bar{U}(c_1) \leq D = \frac{a[10a-\sqrt{100a^2-280ac_1+160c_1^2}]}{2} + 16c_1^2 - 21ac_1 = (a - c_1)(5a - 16c_1) - \frac{a\sqrt{100a^2-280ac_1+160c_1^2}}{2}$. Therefore $U(c_1) < 0$, as $D < 0$ for $c_1 \in (0, \bar{c_1})$.

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