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Licensing in a Vertically Separated Industry

by

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Date September 2002

Abstract The literature on technology licensing has ignored the importance of market power of the input supplier. In this paper we examine the impact of licensing in the downstream industry when the firms in the upstream industry have market power. We show that licensing in the downstream industry can make the upstream industry more competitive. However, licensing in the downstream industry is profitable if and only if licensing changes the concentration in the upstream industry. We also show that a monopolist in the final goods market has the incentive for licensing if licensing changes the market structure of the upstream industry.

Keywords Entry, Licensing, Downstream industry, Upstream industry

J.E.L. Class D43, L13, O34

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1 Introduction

The existing vast literature on technology licensing in imperfectly competitive markets mainly address the issues such as the feasibility of technology licensing, the quality of the transferred technology, optimal patent licensing contract, the concentration effects of technology licensing, effects of licensing on government policies, role of product differentiation and pre-commitment strategies on technology licensing. While some of the previous works have considered the situations where licenser and licensee do not compete in the same market, others have focused on the situations where licenser and licensee compete in the same market. Sufficient attention has also been paid to see the importance of informational structure on licensing. For a representative sample, one may look at Gallini and Winter (1985), Katz and Shapiro (1985), Rockett (1990a, b), Gallini and Wright (1990), Marjit (1990), Beggs (1992), Kamien and Tauman (1986), Kabiraj and Marjit (1992, 1993, 2002), Kamien et al. (1992), Kabiraj (1994), Bousquet et al. (1998), Mukherjee (2001, 2002), Mukherjee and balasubramanian (2001), Schmitz (2002).[1] Surprisingly previous works have ignored the importance of vertically separated industries on technology licensing. The results of the previous papers will hold in a vertically separated industry with competitive upstream industry, but are not suitable for industries where the upstream firms have significant market power.

The purpose of this paper is to fill this gap in the literature. We examine the role of technology licensing in a vertically separated industry when the upstream firms have market power. Particularly, we show that the structure of upstream industry has important implications for a profitable licensing in the downstream industry. We find that technology licensing in the downstream industry influences and also influenced by the market structure of the upstream industry.

In what follows, in the next section we consider an economy with downstream and upstream industry. There are Cournot duopolists in the downstream industry who buys input for their production from the upstream industry. One of these firms in the downstream industry is technologically superior compared to its competitor. There is an incumbent input supplier and a potential entrant in the upstream industry. While the production technologies of the upstream firms are same, the entrant in the upstream industry needs to incur an entry cost. In case of entry in the upstream industry, we consider that the input suppliers compete like Cournot duopolists.[2] In this framework, we examine the profitability of licensing contract with up-front fixed fee. As already noted in the literature, the possibility of imitation or inventing around the technology easily by the licensee after getting the licensed technology or lack of information needed

[1] For surveys, one may look at Reinganum (1989) and Kamien (1992).

[2] Researchers have already focused on successive Cournot oligopolies in different contexts. For example, one may look at Abiru (1988), Salinger (1988), Abiru et al. (1998) and Desquilbet and Guyomard (1999).

for a royalty provision may be the reason for licensing contract with up-front fixed fee only (see, e.g., Katz and Shapiro, 1985 and Rockett, 1990).

Licensing in the downstream industry increases the derived demand for input as well as the profits of the upstream firms. Thus, licensing in the downstream industry increases the possibility of entry in the upstream firm.

If licensing occurs in the downstream industry then it increases the cost efficiency of the licensee and also increases competition faced by the licenser for a given input price. However, if the market structure of the upstream industry remains unchanged due to licensing in the downstream industry then input prices increases under licensing. This increment in input prices reduces the profitability of the downstream firms. The effect of higher input prices and higher competition faced by the licenser outweighs the positive effect of cost efficiency in the licensee's firm. As a result, licensing is not optimal if licensing in the downstream industry does not change the market structure in the upstream industry.

If licensing in the downstream industry enhances competition in the upstream industry, we find that licensing is always profitable in the downstream industry. There could be situations where upstream industry becomes a monopoly in absence of licensing in the downstream industry and a duopoly in case of licensing in the downstream industry. In that case, licensing helps to reduce input price. This lower input price under licensing along with the effect of cost efficiency in the licensee's firm outweighs the negative impact of higher competition faced by the licenser. Therefore, licensing is always profitable where licensing changes the market structure of the upstream industry from monopoly to duopoly.

We show that licensing is profitable even if the downstream firm is the monopoly without licensing. Even if licensing encourages competition in the downstream industry, it helps to reduce input price when licensing in the downstream industry encourages entry in the upstream industry. Thus, it shows that a monopolist in the final goods market has the incentive to increase competition in the downstream industry by providing license to the technologically inefficient firms if licensing helps to enhance competition in the upstream industry. Higher competition in the upstream industry will reduce input price and will make licensing profitable. Hence, this result is in sharp contrast to the previous literature where a firm behaving as a monopolist or near monopolist in the product market does not provide license to the technologically inefficient competitor (see, e.g., Katz and Shapiro, 1985, Marjit, 1990 and Mukherjee, 2001).

Thus, we show that when the upstream firms have significant market power then it creates upward bias and downward bias on licensing compared to the situation where the upstream industry is competitive. Whether market power of the upstream firms will create upward or down ward bias on licensing depends on the influence of licensing on the upstream market structure. Thus, unlike the previous contribution on licensing (see, e.g., Schmitz, 2002), we show the possibility of both upward and downward bias on licensing and also without informational problem.[3]

Rest of the paper is organized as follows. The next section provides the model and the results. Section 3 concludes the paper.

2 Model and results

Consider an economy with firms in upstream and downstream industry. Consider the following structure of the upstream industry. Assume that there is already one input supplier in the upstream industry along with another potential input supplier in the upstream industry. We assume that each of the input suppliers has same production technology and faces constant marginal cost of production, which is, for simplicity, assumed to be zero. However, we assume that the entrant in the upstream industry needs to incur an entry cost F if it decides to enter the upstream industry. If there is no entry in the upstream industry, the incumbent input supplier becomes the monopoly in the upstream industry and takes its production decisions. Input price will be determined from the input demand. In case of entry, these input suppliers act as Cournot oligopolists in the upstream industry. Each input supplier decides its volume of production. Price of the input will be determined from the demand for input for the total supply of input. We assume that there is no further cost associated with input production. We define the input suppliers by I_1 and I_2.

Assume that there are two downstream firms. Denote these firms by F_1 and F_2. Assume that firm 1 needs one unit of input to produce one unit of output and firm 2 needs λ units of input to produce one unit of output, where $\lambda > 1$. This implies that firm 1 has a better production technology compared to firm 2. These firms buy inputs from the upstream firms. For simplicity, assume that the downstream firms need this input only for their production. Hence, input price behaves as the marginal cost of production for each of the downstream firm. These firms compete in the product market like Cournot duopolists. Further, it has been assumed that are no other costs associated with final goods production.

We consider the following game. In stage 1, the downstream firms decide whether to engage in licensing or not. In case of licensing, F_1 gives a take-it-or-leave-it offer to F_2. F_2 accepts the licensing contract if it does not make F_2 worse-off compared to no licensing. Following Katz and Shapiro (1985), Marjit (1990), Mukherjee (2001, 2002) and many others, we assume that licensing involves up-front fixed fee only. As already mentioned in the introduction, the possibility of imitation by the licensee or lack of information needed for a provision of royalty in the licensing contract could be the reason for licensing with up-front fixed fee only (see, e.g., Katz and Shapiro, 1985 and Rockett, 1990). In stage 2, the entrant upstream firm, i.e., I_2, decides whether to enter

[3] Mukherjee (2001) has shown the possibility of upward and downward bias on licensing when the firms have the option for pre-commitment strategy.

the upstream market. In stage 3, upstream firms take their output decisions conditional on the decision on entry by I_2. In stage 4, the downstream firms produce their products with the inputs provided by the upstream firms and consider the input prices as given. The downstream firms take their production decisions like Cournot duopolists. We solve the game through backward induction.

Assume that the inverse market demand for the products of F_1 and F_2 are given by

$$P = a - q_1 - q_2, \tag{1}$$

where, q_1 and q_2 are the outputs of F_1 and F_2 respectively and P is the price of the final product.

Let us first consider the output decisions of the downstream firms. Given the input price, denoted by w, F_1 and F_2 will produce respectively

$$q_1^* = \frac{(a - 2w + \lambda w)}{3} \quad \text{and} \quad q_2^* = \frac{(a - 2\lambda w + w)}{3}. \tag{2}$$

It is important to note that the output of F_2 will be zero provided $w \geq \frac{a}{(2\lambda - 1)}$. Therefore, total demand for input for a given price of input are given by

$$q^* = \frac{(2a - w - \lambda w)}{3}, \quad \text{for } w < \frac{a}{(2\lambda - 1)} \tag{3}$$

and

$$q^* = \frac{(a - w)}{2}, \quad \text{for } w \geq \frac{a}{(2\lambda - 1)}. \tag{4}$$

It is clear that there will be no input demand for $w > a$. Given this structure of the input demand, it is easy to understand that whether the upstream firm(s) will choose their outputs in a way to serve both downstream firms (i.e., corresponding input price will less than $\frac{a}{(2\lambda - 1)}$) or the technologically efficient downstream firm only (i.e., corresponding input price will more than $\frac{a}{(2\lambda - 1)}$) is also a decision faced by the upstream firms. As we will show in the following analysis, if the value of λ is sufficiently close to one, then it is better for the upstream firms to serve both the downstream firms. In subsections 2.1 – 2.3, we will do our analysis for the situations where both downstream firms will produce positive outputs, which, in turn, implies that optimal price for the input will be less than $\frac{a}{(2\lambda - 1)}$. Further, we will consider symmetric equilibrium only. In section 2.4 we will consider the other situation where the upstream industry will supply for the technologically efficient firm only under non-licensing.[4]

2.1 Non-licensing

Let us first consider the situation under non-licensing in stage 1.

2.1.1 Entry in upstream industry

If I_2 enters into the upstream industry then the firms in the upstream industry will compete like Cournot duopolists. Since, we have considered that these firms decide to supply both downstream firms then the input demand faced by the upstream firms is given by the expression (3). Therefore, the ith, $i = 1,2$, firm in the upstream industry will maximize the following expression

$$\underset{q^i}{Max} \frac{(2a - 3q^i - 3q^j)}{(1+\lambda)}, \tag{5}$$

where, $i \neq j$ and we use the superscripts to imply the output of the upstream firms. Thus, we find that in a symmetric equilibrium each upstream firm will produce $\frac{2a}{9}$ and total input supply will be $\frac{4a}{9}$. Corresponding input price will be $\frac{2a}{3(1+\lambda)}$. Therefore, optimal profit of I_1 and I_2 will be $\frac{4a^2}{27(1+\lambda)}$ and $(\frac{4a^2}{27(1+\lambda)} - F)$ respectively.

We have done our analysis under the assumption that the upstream firms will produce for both downstream firms. If instead they have produced for the efficient downstream firm only then the input demand function would be given by expression (4). In this situation, it is easy to check that both total input supply and corresponding input price will be $\frac{a}{3}$ in a symmetric equilibrium. In that case, the optimal profit of I_1 and I_2 will be $\frac{a^2}{18}$ and $(\frac{a^2}{18} - F)$ respectively. Therefore, each of these firms will prefer to serve both downstream firms compared to serving the technologically efficient downstream firm only provided $\frac{a^2}{18} < \frac{4a^2}{27(1+\lambda)}$ or $\lambda < \frac{5}{3}$. It is easy to check that if $\lambda < \frac{5}{3}$ then the optimal input price, when producing for both downstream firms, is less than $\frac{a}{(2\lambda-1)}$. Hence, except for subsection 2.4, we do our analysis for $\lambda \in (1, \frac{5}{3})$.

When the upstream firms produce for both the downstream firms and the upstream industry is duopoly then we find that profits of F_1 and F_2 are

$$\pi_1^{nl} = \frac{a^2(5\lambda - 1)^2}{81(1+\lambda)^2} \quad \text{and} \quad \pi_2^{nl} = \frac{a^2(5-\lambda)^2}{81(1+\lambda)^2}.^{5} \tag{6}$$

[4] It is easy to understand that in case of licensing, upstream industry will supply inputs to both downstream firms since both downstream firms will produce with similar technology under licensing.

Note that when the upstream industry is duopoly then, given the optimal price of input, both the downstream firms will produce positive output provided $\lambda < 5$.

We have done our analysis under the assumption that I_2 enters in stage 2. However, this will happen provided $\frac{4a^2}{27(1+\lambda)} > F$. But if $\frac{4a^2}{27(1+\lambda)} < F$ then I_1 is the monopoly producer in the upstream industry since, in this situation, I_2 does not enter the upstream industry.

We summarize the above discussion in the following lemma.

Lemma 1: *Suppose,* $\lambda \in (1, \frac{5}{3})$ *and* $\frac{4a^2}{27(1+\lambda)} > F$. *In a symmetric equilibrium, profits of* F_1 *and* F_2 *are* $\frac{a^2(5\lambda-1)^2}{81(1+\lambda)^2}$ *and* $\frac{a^2(5-\lambda)^2}{81(1+\lambda)^2}$ *respectively and profits of* I_1 *and* I_2 *are* $\frac{4a^2}{27(1+\lambda)}$ *and* $(\frac{4a^2}{27(1+\lambda)} - F)$ *respectively.*

2.1.2 No-entry in upstream industry

In the previous subsection we have considered a situation where the entrant in the upstream industry enters in stage 2 of the game. This happens for $\frac{4a^2}{27(1+\lambda)} > F$. In this subsection, we will consider the situation for $\frac{4a^2}{27(1+\lambda)} < F$. This implies that the entrant in the upstream industry will not enter in stage 2 and the upstream industry will be a monopoly of the incumbent input supplier, i.e., of I_1. Again, we will do our analysis for the situation where the monopoly input supplier will provide input for both downstream firms, hence, facing the demand for input given by expression (3).

Therefore, here I_1 will maximize the following expression

$$\underset{q^1}{Max} \frac{(2a - 3q^1)}{(1+\lambda)}, \tag{7}$$

In this situation, optimal input production will be $\frac{a}{3}$ and corresponding input price will be $\frac{a}{(1+\lambda)}$, which is lower than $\frac{a}{(2\lambda-1)}$ for $\lambda \in (1, \frac{5}{3})$. Profit of I_1 will be $\frac{a^2}{3(1+\lambda)}$. Following the argument of the previous subsection, it is easy to check that the upstream monopolist will produce for both the downstream firms rather than producing for the efficient downstream firm only when $\lambda \in (1, \frac{5}{3})$.

We find that, in this situation, profits of F_1 and F_2 are

[5] Both firms in the downstream industry produce positive outputs under non-licensing when $\lambda < \frac{5}{3}$.

$$\pi_1^{nl} = \frac{a^2(2\lambda-1)^2}{9(1+\lambda)^2} \quad \text{and} \quad \pi_2^{nl} = \frac{a^2(2-\lambda)^2}{9(1+\lambda)^2}. \tag{8}$$

Note that when the upstream industry is monopoly then, given the optimal price of input, both the downstream firms will produce positive output provided $\lambda < 2$.

The following lemma summarizes the discussion of this subsection.

Lemma 2: *Suppose,* $\lambda \in (1, \frac{5}{3})$ *and* $\frac{4a^2}{27(1+\lambda)} < F$*. In a symmetric equilibrium, profits of* F_1 *and* F_2 *are* $\frac{a^2(2\lambda-1)^2}{9(1+\lambda)^2}$ *and* $\frac{a^2(2-\lambda)^2}{9(1+\lambda)^2}$ *respectively and profit of* I_1 *is* $\frac{a^2}{3(1+\lambda)}$.

2.2 Licensing

Now we do our analysis under the assumption of licensing in stage 1. If licensing occurs in stage 1, both firms in the downstream industry will produce with same technology as we are considering fixed-fee licensing contract. Hence, in case of licensing we have $\lambda = 1$.

Therefore, we see that if licensing occurs in stage 1 then the entrant will enter the upstream market provided $\frac{2a^2}{27} > F$, where $\frac{2a^2}{27} > \frac{4a^2}{27(1+\lambda)}$. Licensing in the downstream market increases the possibility of entry in the upstream industry. If licensing occurs in stage 1 and $\frac{2a^2}{27} > F$ then profits of F_1 and F_2 are

$$\pi_1^l = \pi_2^l = \frac{4a^2}{81}. \tag{9}$$

Further, it is important to note that when licensing occurs in stage 1, both downstream firms will always produce positive outputs as long as $w < a$. Hence, in case of licensing, the upstream firms will always produce for both downstream firms irrespective of the market structure in the upstream firms.

Next, we consider the situation under licensing for $\frac{2a^2}{27} < F$. In this situation, the upstream firm is the monopoly of I_1 since the entrant in the upstream industry does not enter even if licensing occurs in stage 1. It is easy to check that, in this situation, profits of F_1 and F_2 are

$$\pi_1^l = \pi_2^l = \frac{a^2}{36}. \tag{10}$$

2.3 Condition for profitable licensing contract

In the subsections 2.1 and 2.2 we have considered the profits of the downstream firms under the assumption of both non-licensing and licensing. In this subsection we will examine the situations when licensing is profitable in stage 1. Since we are considering licensing contract with up-front fixed fee only, it is enough for us to check industry profits with and without licensing to examine the condition for profitable licensing contract.

Let us first consider the situation where $\frac{4a^2}{27(1+\lambda)} > F$. In this situation, the upstream industry will be duopoly irrespective of the licensing decision in the downstream industry. Therefore, profits of the downstream firms under non-licensing and licensing are given by the expressions (6) and (9) respectively. Comparing (6) and (9) we find that expression (9) will be greater than (6) provided $0 > (\lambda - 1)^2$. Since, this is not possible for any value of λ, we see that licensing is not optimal when the upstream industry becomes duopoly irrespective of the licensing decision in the downstream industry.

Next, we consider the opposite situation of the above case, i.e., where the upstream industry is monopoly irrespective of the licensing decision in the downstream industry. This means we are considering the situation where $\frac{2a^2}{27} < F$. Hence, profits of the downstream firms under non-licensing and licensing are given by the expressions (8) and (10) respectively. Comparing (8) and (10) we find that expression (10) will be greater than (8) provided $0 > (\lambda - 1)^2$. Since, this is not possible for any value of λ, we see that licensing is not optimal when the upstream industry becomes monopoly irrespective of the licensing decision in the downstream industry.

Finally, we consider the situation for $F \in (\frac{4a^2}{27(1+\lambda)}, \frac{2a^2}{27})$. Here, the upstream industry will be monopoly under non-licensing in the downstream industry but will be duopoly under licensing in the downstream industry. Hence, profits of the downstream firms under non-licensing and licensing are given by the expressions (8) and (9) respectively. Comparing (8) and (9) we find that expression (9) will be greater than (8) provided

$$0 > 37 + 37\lambda^2 - 88\lambda . \tag{11}$$

We see that the right hand side (RHS) of (11) is negative for $\lambda = 1$ and $\lambda = \frac{5}{3}$. RHS of (11) is continuous, quadratic and convex for $\lambda \in [1, \frac{5}{3}]$. Hence, we see that condition (11) always holds for any $\lambda \in (1, \frac{5}{3})$. This implies that licensing in downstream industry is always profitable if licensing changes the market structure of the upstream industry.

We summarize the discussion of this subsection in the following proposition.

Proposition 1: *Assume that* $\lambda \in (1, \frac{5}{3})$.

(i) If upstream industry is either duopoly or monopoly irrespective of the decision on licensing in the downstream industry, i.e., either $\frac{4a^2}{27(1+\lambda)} > F$ *or* $\frac{2a^2}{27} < F$*, licensing in downstream industry is never optimal.*
(ii) If $F \in (\frac{4a^2}{27(1+\lambda)}, \frac{2a^2}{27})$ *then licensing will make the upstream industry duopoly but without licensing the upstream industry will be monopoly. In this situation, licensing in the downstream industry is always optimal.*

The above result is in sharp contrast with the previous papers. While ignoring the market power of the upstream firms, the previous papers have shown that licensing in the downstream industry is profitable provided the initial technologies of these firms are sufficiently close (see, e.g., Katz and Shapiro, 1985 and Marjit, 1990). Proposition 1(i) shows that even if the technologies are sufficiently close, licensing is never optimal when the upstream market structure is not affected due to licensing in the downstream industry. On the other hand, Proposition 1(ii) shows that licensing is always profitable when licensing changes the upstream market structure. Therefore, we find that whether the presence of market power of the upstream firms creates upward bias or downward bias on licensing in the downstream industry depends on the influence of licensing on the upstream market structure. Further, unlike Schmitz (2002) we show the possibility of both upward and downward bias on licensing and also without any informational problem.

2.4 When $\lambda > \frac{5}{3}$

The main result of this paper, which is to show the importance of the upstream market structure on licensing in the downstream industry when the upstream firms have market power, has been derived in the previous subsection. The previous subsections have considered the situation where the firms in the upstream industry produce for both downstream firms irrespective of the decision on licensing in the downstream industry. This was consistent for $\lambda < \frac{5}{3}$.

In this subsection we will briefly examine the situation where, in a symmetric equilibrium, the upstream firm(s) produce for the technologically efficient downstream firm only under non-licensing. For this we will consider that $\lambda > \frac{5}{3}$. Hence, in this situation, the demand for input is given by the expression (4).

It is clear that the possibility of producing for only the efficient downstream firm arises in absence of licensing in the downstream industry. But, under licensing in the downstream industry, both downstream firms are symmetric and hence, it is trivial that the upstream firms will produce for both downstream firms under licensing.

Let us first consider the situation where the upstream industry will be duopoly irrespective of licensing in the downstream industry. If the upstream industry is duopoly and produces for the technologically efficient downstream firm (i.e., facing the input demand given by (4)) under non-licensing then the optimal input price will be $\frac{a}{3}$, which is lower than $\frac{a}{(2\lambda-1)}$ for $\lambda \in (\frac{5}{3},2)$. Therefore, for $\lambda \in (\frac{5}{3},2)$, this input price is not consistent with the demand for input given in (4). Hence, in this situation, the upstream firms needs to produce in a way so that input price cannot be lower than $\frac{a}{(2\lambda-1)}$. Hence, in this situation, total input supply will be $\frac{a(\lambda-1)}{(2\lambda-1)}$ and input price will be $\frac{a}{(2\lambda-1)}$. In a symmetric equilibrium, both upstream firms will share this total input supply equally. Therefore, under non-licensing (constrained) optimal profits of I_1 and I_2 will be $\frac{a^2(\lambda-1)}{2(2\lambda-1)^2}$ and $\frac{a^2(\lambda-1)}{2(2\lambda-1)^2} - F$ respectively. Therefore, for these values of λ, whether the upstream firms will supply for both downstream firms or for the efficient downstream firm only depends on the unconstrained profits of the upstream firms, while supplying for both downstream firms and the constrained profits of the upstream firms, while supplying for the efficient downstream firm only. It is easy to check that, for these values of λ, the upstream firms prefer to supply for the technologically efficient downstream firm. Therefore, when $\lambda \in (\frac{5}{3},2)$, I_2 will enter the upstream industry under non-licensing in the downstream industry provided $\frac{a^2(\lambda-1)}{2(2\lambda-1)^2} > F$, where $\frac{4a^2}{27(1+\lambda)} < \frac{a^2(\lambda-1)}{2(2\lambda-1)^2} < \frac{2a^2}{27}$.

Therefore, if $\lambda \in (\frac{5}{3},2)$ and $\frac{a^2(\lambda-1)}{2(2\lambda-1)^2} > F$, profit of the technologically efficient firm and hence, downstream industry profit under non-licensing will be $\frac{a^2(\lambda-1)^2}{(2\lambda-1)^2}$. This is because here total output in the final goods market will be $\frac{a(\lambda-1)}{(2\lambda-1)}$ and input price will be $\frac{a}{(2\lambda-1)}$. But, in case of licensing, downstream industry profit will be $\frac{8a^2}{81}$ (see expression (9)). Comparing the downstream industry profits under non-licensing and licensing, we find that here licensing is not profitable.

Now, we consider the situation for $\lambda > 2$. From the above discussion it is clear that here the upstream firms will receive unconstrained optimal profit even if producing for the technologically efficient downstream firm. Here, the profits of I_1 and I_2 will be $\frac{a^2}{18}$ and $\frac{a^2}{18} - F$ respectively. Therefore, for $\lambda > 2$, I_2 will enter the upstream industry provided $\frac{a^2}{18} > F$, where $\frac{4a^2}{27(1+\lambda)} < \frac{a^2}{18} < \frac{2a^2}{27}$. Further, we have $\frac{a^2(\lambda-1)}{2(2\lambda-1)^2} < \frac{a^2}{18}$ for $\lambda > 2$.

So, if $\frac{a^2}{18} > F$ then the upstream industry will be duopoly. It is easy to check that, in this situation, profit of the efficient downstream firm and hence, industry profit will be $\frac{a^2}{9}$ under non-licensing. But, in case of licensing, downstream industry profit will be $\frac{8a^2}{81}$ (see expression (9)), which is less than the downstream industry profit without licensing, i.e., $\frac{a^2}{9}$. Hence, in this situation, licensing is not optimal in the downstream industry.

The above discussion also shows that if the values of λ are sufficiently high so that the upstream firms produce for the efficient downstream firm only, it increases the incentive for entry in the upstream industry. However, as shown by $\frac{a^2}{18} < \frac{2a^2}{27}$, the incentive for entry in the upstream industry is still lower under non-licensing compared to licensing.

Let us now consider the situation where the upstream industry will be monopoly irrespective of licensing in the downstream industry. This will happen if the cost of entry in the upstream industry is sufficiently large, i.e., $\frac{2a^2}{27} < F$. If $\lambda > \frac{5}{3}$ then the upstream monopolist always finds it optimal to produce for the technologically efficient downstream firm.[6] In this situation, it is easy to find that optimal profit of the efficient downstream firm under non-licensing is $\frac{a^2}{16}$, which is greater than the downstream industry profit under licensing, which is $\frac{a^2}{18}$ (see expression (10)). Hence, here also licensing is not optimal in downstream market.

Lastly, consider the situation where the upstream industry will be monopoly without licensing but will be duopoly with licensing. This will happen when $F \in (\frac{a^2(\lambda-1)}{2(2\lambda-1)^2}, \frac{2a^2}{27})$ and $\lambda \in (\frac{5}{3}, 2)$ or $F \in (\frac{a^2}{18}, \frac{2a^2}{27})$ and $\lambda > 2$. Therefore, from the above discussions it is clear that, in this situation, downstream industry profits under non-licensing and licensing will be $\frac{a^2}{16}$ and $\frac{8a^2}{81}$ respectively. Here licensing is always be optimal as $\frac{8a^2}{81} > \frac{a^2}{16}$. Hence, we find conclusions similar to Proposition 1 even if the upstream firm(s) produce for the technologically efficient downstream firm only in case of non-licensing.

We summarize the above discussions in the following proposition.

Proposition 2: *Consider that $\lambda > \frac{5}{3}$ so that, in a symmetric equilibrium, the upstream firm(s) supply for the technologically efficient downstream firm only. The qualitative results of Proposition 1 hold even for these values of λ.*

Proposition 2 has an interesting implication. We find that if licensing in the downstream industry changes the market structure of the upstream industry then licensing is profitable even for $\lambda > 2$. This implies that licensing is profitable even for those technological differences of the downstream firms where only technologically efficient firm produces the final good in absence of licensing. Thus, we show that even if the technologically efficient downstream firm becomes the monopoly in the final goods market in absence of licensing, licensing is still optimal since it encourages entry of a new firm in the upstream industry. This is in sharp contrast to the previous literature on licensing (see, e.g., Katz and Shapiro, 1985, Marjit, 1990 and Mukherjee, 2001) where it has been shown that if the technologically efficient firm is monopoly or near

[6] Further, it is clear from subsection 2.1.2 that when $\lambda > 2$ and there is monopolist in the upstream industry then the technologically inefficient downstream firm will not produce under the optimal input price even if the upstream firm intends to produce for both downstream firms.

monopoly in the product market then licensing is not optimal. The reason for this striking difference between this paper and the previous papers is that here licensing changes the market structure of the input market, which, in turn, reduces input price and makes licensing profitable.

3 Conclusion

Researchers have already addressed several issues on technology licensing. While they have addressed the importance of informational structure and competition between the licenser and licensee, the literature is silent on the implications of vertically separated industries when the upstream firms have significant market power. In this paper, in a vertically separated industry with successive Cournot duopolies, we examine the possibility of licensing in downstream industry. We consider that the upstream firms have significant market power and licensing involves up-front fixed fee only.

We show that licensing in the downstream industry increases the incentive for entry in the upstream industry. However, whether licensing in the downstream industry is optimal depends on the market structure of the upstream industry. We show that if the market structure in the upstream industry remains same irrespective of the decision on licensing in the downstream industry then licensing is not profitable in the downstream industry. Licensing in the downstream industry is profitable provided licensing encourages new firms to enter the upstream industry and enhances competition in the upstream industry.

We also show that a monopolist firm in the downstream industry has the incentive for technology licensing if licensing in the downstream industry changes the market structure of the upstream industry. Higher competition in the upstream industry helps to reduce input prices and makes licensing profitable.

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