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LICENSING IN A VERTICALLY SEPARATED INDUSTRY

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Abstract: The literature on technology licensing has ignored the importance of market power of the input supplier. In this paper we examine the incentive for licensing in the downstream industry when the firms in the upstream industry have market power. We show that licensing in the downstream industry is profitable if and only if licensing increases competition in the upstream industry. We also find that a monopolist in the final goods market has the incentive for licensing if licensing changes the market structure of the upstream industry. Thus, our analysis provides a rationale for 'second sourcing'.

Key Words: Entry, Licensing, Downstream industry, Upstream industry

JEL Classifications: 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(s) do not compete in the same market, others have focused on the situations where licenser and licensee(s) compete in the same market. Sufficient attention has also been paid to see the importance of informational structure on licensing. For a representative sample of works on technology licensing, 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) and Schmitz (2002).[1]

However, the previous works share one common feature, viz., the ignorance of the strategic decisions in the input market. Like final goods market, input markets are often characterized by imperfect competition. For example, the energy sector or power-generating sector is characterized by oligopolistic competition. As demonstrated by Tyagi (1999), the market for microprocessors, aircraft-engines and many others are also characterized by oligopolistic competition. Therefore, while the results of the previous works on technology licensing are relevant for the perfectly competitive input markets or vertically integrated industries, those analysis are not suitable for industries where the input suppliers have significant market power. Hence, we feel that it is important to consider the role of the vertically separated industry on technology licensing.

The purpose of this paper is to fill this gap in the literature. We examine the possibility of technology licensing in a vertically separated industry where the firms in the upstream industry possess market power. Particularly, we show that the structure of the upstream industry has important implications for a profitable licensing in the downstream industry. 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 industries. There are Cournot duopolists in the downstream industry who purchase input for their production from the upstream industry. One downstream firm is assumed to be 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. This simple model of incumbent and entrant in the upstream industry will help us to show the importance of the upstream market structure on the profitability of licensing in the downstream industry. 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 fixed-fee licensing contract in the downstream industry. As already noted in the literature, the possibility of imitation or 'inventing around' the licensed technology by the licensee or lack of information needed for a royalty provision might be the reason for a licensing contract with up-front fixed-fee only (see, e.g., Katz and Shapiro, 1985 and Rockett, 1990a).

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 under licensing and non-licensing then input price increases under licensing. This increment in input price reduces the profitability of the downstream firms. The effect of higher input price 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 of the upstream industry.

Licensing in the downstream industry helps to increase the profits of the upstream firms by raising the demand for input. Thus, licensing in the downstream

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[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).

industry increases the possibility of entry in the upstream industry. If licensing in the downstream industry enhances competition in the upstream industry by encouraging entry in the upstream industry, we find that licensing can be profitable in the downstream industry. When the initial technological differences in the downstream industry are not sufficiently large, higher competition in the upstream industry may lower input price under licensing. This benefit from lower input price along with the effect of cost efficiency in the licensee's firm may outweigh the negative impact of higher competition faced by the licenser and makes licensing in the downstream industry profitable.

But, if the technological differences of the downstream firms are sufficiently large then input price increases under licensing in the downstream industry even if licensing encourages entry in the upstream industry. If technological differences in the downstream industry are sufficiently large then licensing in the downstream industry raises the demand for input significantly. This higher demand for input outweighs the effect of higher competition in the upstream industry and raises the input price under licensing. Hence, in this situation, even if licensing changes the upstream market structure, licensing in the downstream industry is not optimal.

If the technological differences between the downstream firms are very large then we find that, under non-licensing, the upstream industry finds it profitable to supply the input for the technologically efficient downstream firm only. Hence, in this situation, the downstream industry is effectively monopoly without licensing. We find that here licensing is always optimal in the downstream industry if licensing creates higher competition in the upstream industry. Even if licensing increases competition in the downstream industry, in this situation, it helps to reduce input price by encouraging entry in the upstream industry. This benefit from lower input price outweighs the effect of higher competition in the downstream industry. Hence, the monopolist final goods producer has the incentive to license its technology to another firm if licensing enhances competition in the upstream industry. This result is in sharp contrast to the previous literature where a firm behaving as 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).

The literature on ‘second-sourcing’ has argued that it is better to create a second source of production when lack of commitment creates opportunism (see, e.g., Shepard, 1987 and Farrell and Gallini, 1988). The possibility of the second source of production helps to reduce the opportunistic behavior of the firms and creates a more efficient outcome. Our result shows that, monopoly final goods producer may find it optimal to create a second source of input demand if that strategy helps to reduce the price of input by creating higher competition in the upstream industry. Thus, we show that ‘second-sourcing’ can be optimal even if there is no problem of commitment.

The present paper suggests that when the upstream firms have significant market power then it creates upward and downward bias on licensing compared to the situation where the upstream industry is competitive, as considered in the previous works on licensing. We find that whether market power of the upstream firms creates upward or downward bias on licensing depends on the effect of licensing on the upstream market structure and also on the initial technological difference between the downstream firms. Thus, unlike the previous contribution on licensing (see, e.g., Schmitz, 2002), the present paper shows the possibility of both upward and downward bias on licensing and also in absence of any informational problem.[3]

Many developing countries are now liberalizing their economies and also encouraging their firms to increase competitiveness through technology licensing. This analysis suggests that while encouraging licensing between the producers of the final goods sector, it is important to consider the implications of licensing on the upstream market structure. We show that sufficiently low cost of entry or sufficiently high cost of entry in the upstream industry can eliminate the incentive for licensing in the downstream industry. But, a moderate cost of entry in the upstream industry can increase the incentive for licensing in the downstream industry. Hence, it may induce a government to design appropriate policies for encouraging entry in the upstream industry.

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

[3] The possibility of upward and downward bias on licensing was also present in Mukherjee (2001) where the firms had the options for pre-commitment strategies.

2 The model and results

Let us assume an economy with upstream and downstream industries. Consider the following structure of the upstream industry. Assume that there is an incumbent firm and a potential entrant in the upstream industry. The firms in the upstream industry produce input for the firms in the downstream industry. We assume that each of the input suppliers in the upstream industry 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 decision. Input price will be determined from the input demand. In case of entry, these input suppliers act as homogeneous Cournot duopolists in the upstream industry. The input suppliers simultaneously decide the volume of production. Price of input, corresponding to the total supply of input, will be determined from the input demand schedule. 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. The downstream firms use the input produced by the upstream industry. For simplicity, assume that the downstream firms need only this input for their production. The downstream firms take the price of inputs given while taking their production decision. Hence, input price acts as the marginal cost of production for each downstream firm. Assume that F_1 needs one unit of input to produce one unit of output and F_2 needs λ units of input to produce one unit of output, where $\lambda > 1$. This implies that F_1 has a better production technology compared to F_2. The downstream firms compete in the product market like homogeneous Cournot duopolists. Further, it has been assumed that there 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 non-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, 1990a). In stage 2, the entrant upstream firm, i.e., I_2, decides whether to enter the upstream market. In stage 3, upstream firms simultaneously take their output decisions conditional on the decision on entry by I_2. In stage 4, the downstream firms simultaneously produce their products with the inputs provided by the upstream firms. We solve the game through backward induction. The sequence of the moves of the game is shown in Figure 1.

Figure 1

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

$$q^* = q_1^* + \lambda q_2^* = \frac{(a(1+\lambda) - 2w(1+\lambda^2) + 2\lambda w)}{3}, \qquad \text{for } w \leq \frac{a}{(2\lambda - 1)} \tag{3}$$

and

$$q^* = q_1^* = \frac{(a-w)}{2}, \qquad \text{for } w \geq \frac{a}{(2\lambda - 1)}. \tag{4}$$

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) produce their outputs in a way to serve both downstream firms (i.e., the corresponding input price will be less than $\frac{a}{(2\lambda-1)}$) or only the technologically efficient downstream firm (i.e., the corresponding input price will be more than $\frac{a}{(2\lambda-1)}$) is also a decision faced by the upstream firm(s). As we will show in the following analysis, if the value of λ is less than 2, then it is better for the upstream firm(s) to serve both downstream firms. In subsections 2.1 – 2.4, we will do our analysis for the situations where the upstream industry will produce for both downstream firms. Further, we will consider symmetric equilibrium in the upstream industry. In section 2.5 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. Conditional on non-licensing in stage 1, there are two possibilities in stage 2: (i) where I_2 enters the upstream industry and (ii) where I_2 does not enter the upstream industry.

2.1.1 Entry in the upstream industry

If I_2 enters 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

[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.

given by the expression (3). Therefore, the ith firm, $i = 1,2$, in the upstream industry will maximize the following expression

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

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 produces $\frac{a(1+\lambda)}{9}$ and total input supply is $\frac{2a(1+\lambda)}{9}$. Corresponding input price is $\frac{a(1+\lambda)}{(6+6\lambda^2-6\lambda)}$. Therefore, optimal profit of I_1 and I_2 is $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}$ and $\left(\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} - F\right)$ respectively.

We have done our analysis under the assumption that the upstream firms will produce for both downstream firms. If instead they produced only for the efficient downstream firm then the input demand function would be given by the expression (4). In this situation, it is easy to check that total input supply will be $\frac{a(\lambda-1)}{(2\lambda-1)}$, in a symmetric equilibrium. This is because the total input production that maximizes the profits of the upstream firms, i.e., $\frac{a}{3}$, generates input price equals to $\frac{a}{3}$, which is lower than $\frac{a}{(2\lambda-1)}$. Hence, if the upstream firms want to serve only the technologically efficient downstream firm, the total input cannot exceed $\frac{a(\lambda-1)}{(2\lambda-1)}$ and also it will not be less than $\frac{a(\lambda-1)}{(2\lambda-1)}$, as $\frac{a(\lambda-1)}{(2\lambda-1)}$ is less than $\frac{a}{3}$. In the symmetric equilibrium, we assume that the upstream firms share this total input supply equally. Hence, in that case, the optimal profit 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 $\lambda < 2$, each upstream firm will prefer to serve both downstream firms instead of serving the technologically efficient downstream firm since $\frac{a^2(\lambda-1)}{2(2\lambda-1)^2} < \frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}$. It is easy to check that if $\lambda < 2$ then optimal input price, when producing for both downstream firms, is less than $\frac{a}{(2\lambda-1)}$. Hence, in this subsection and in the following subsections, except subsection 2.5, we will do our analysis for $\lambda \in (1,2)$. In subsection 2.5 we will consider the situation for $\lambda > 2$, i.e., under non-licensing, the upstream industry produces for the efficient downstream firm only.

This subsection considers the situation where I_2 enters in stage 2. However, this will happen provided $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} > F$. But, if $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} < F$, I_2 will not enter the upstream industry and I_1 will be the monopoly producer in the upstream industry.

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

$$\pi_1^{nl} = \frac{a^2(4+7\lambda^2-7\lambda)^2}{9(6+6\lambda^2-6\lambda)^2} \quad \text{and} \quad \pi_2^{nl} = \frac{a^2(7+4\lambda^2-7\lambda)^2}{9(6+6\lambda^2-6\lambda)^2}. \tag{6}$$

Note that when the upstream industry is duopoly then, given the optimal price of the input, both downstream firms will produce positive output provided $7+4\lambda^2-7\lambda > 0$. This condition holds for $\lambda \in (1,2)$.

We summarize the above discussion in the following lemma.

Lemma 1: *Suppose,* $\lambda \in (1,2)$ *and* $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} > F$. *In case of a symmetric equilibrium in the upstream industry, profits of* F_1 *and* F_2 *are* $\frac{a^2(4+7\lambda^2-7\lambda)^2}{9(6+6\lambda^2-6\lambda)^2}$ *and* $\frac{a^2(\&+4\lambda^2-7\lambda)^2}{9(6+6\lambda^2-6\lambda)^2}$ *respectively and profits of* I_1 *and* I_2 *are* $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}$ *and* $\left(\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} - F\right)$ *respectively.*

2.1.2 No-entry in the upstream industry

In this subsection we will consider the situation for $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} < F$. This implies that the entrant in the upstream industry will not enter in stage 2 and the upstream industry will be 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 and hence, facing the demand for input given by the expression (3).

Therefore, here I_1 will maximize the following expression

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

In this situation, the optimal input production is $\frac{a(1+\lambda)}{6}$ and the corresponding input price is $\frac{a(1+\lambda)}{(4+4\lambda^2-4\lambda)}$, which is lower than $\frac{a}{(2\lambda-1)}$ for $\lambda \in (1,2)$. Profit of I_1 is $\frac{a^2(1+\lambda)^2}{6(4+4\lambda^2-4\lambda)}$.

Following the argument of the previous subsection, it is easy to check that if $\lambda \in (1,2)$, the upstream monopolist will produce for both downstream firms. In this situation, the optimal input supply of the upstream firm is $\frac{a(\lambda-1)}{(2\lambda-1)}$ for $\lambda \in (1,\frac{3}{2}]$, and $\frac{a}{4}$ for $\lambda \in [\frac{3}{2},2)$. Because if $\lambda \in (1,\frac{3}{2}]$ and input production is $\frac{a}{4}$ then the corresponding optimal input price is $\frac{a}{2}$, which is less than $\frac{a}{(2\lambda-1)}$, and hence, encourages the downstream technologically inefficient firm to buy input. So, to prevent the downstream technologically inefficient firm, total input supply cannot exceed $\frac{a(\lambda-1)}{(2\lambda-1)}$ for $\lambda \in (1,\frac{3}{2}]$, and also it will not be less than $\frac{a(\lambda-1)}{(2\lambda-1)}$ since, $\frac{a(\lambda-1)}{(2\lambda-1)}$ is less than $\frac{a}{4}$ for $\lambda \in (1,\frac{3}{2}]$. Therefore, optimal profits of the upstream monopolist are $\frac{a^2(\lambda-1)}{(2\lambda-1)^2}$ for $\lambda \in ([1,\frac{3}{2}]$, and $\frac{a^2}{8}$ for $\lambda \in [\frac{3}{2},2)$. But, as mentioned in the above analysis, if, in case of entry, the upstream firm produces for both downstream firms, the optimal input price will be $\frac{a(1+\lambda)}{(4+4\lambda^2-4\lambda)}$. Hence, the optimal profit of the upstream monopolist will be $\frac{a^2(1+\lambda)^2}{6(4+4\lambda^2-4\lambda)}$. Comparing the profit levels we find that $\frac{a^2(1+\lambda)^2}{6(4+4\lambda^2-4\lambda)}$ is greater than $\frac{a^2(\lambda-1)}{(2\lambda-1)^2}$ and $\frac{a^2}{8}$ for the relevant values of λ. Hence, it is optimal for the upstream monopolist to produce for both downstream firms when $\lambda \in (1,2)$.

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

$$\pi_1^{nl} = \frac{a^2(2+5\lambda^2-5\lambda)^2}{9(4+4\lambda^2-4\lambda)^2} \quad \text{and} \quad \pi_2^{nl} = \frac{a^2(5+2\lambda^2-5\lambda)^2}{9(4+4\lambda^2-4\lambda)^2}. \tag{8}$$

Note that when the upstream industry is monopoly then, given the optimal price of the input, both downstream firms will produce positive output provided $5+2\lambda^2-5\lambda>0$. This condition holds for $\lambda\in(1,2)$.

The following lemma summarizes the discussion of this subsection.

Lemma 2: *Suppose,* $\lambda\in(1,2)$ *and* $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}<F$. *In case of a symmetric equilibrium in the upstream industry, profits of* F_1 *and* F_2 *are* $\frac{a^2(2+5\lambda^2-5\lambda)^2}{9(4+4\lambda^2-4\lambda)^2}$ *and* $\frac{a^2(5+2\lambda^2-5\lambda)^2}{9(4+4\lambda^2-4\lambda)^2}$ *respectively and profit of* I_1 *is* $\frac{a^2(1+\lambda)^2}{6(4+4\lambda^2-4\lambda)}$.

2.2 Licensing

Now we do our analysis conditional on 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, if licensing occurs in stage 1 then the entrant will enter the upstream industry provided $\frac{2a^2}{27}>F$, where $\frac{2a^2}{27}>\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}$. Licensing in the downstream industry increases the possibility of entry in the upstream industry. Hence, if licensing occurs in stage 1 and $\frac{2a^2}{27}>F$ then total input supply and the corresponding input price are $\frac{4a}{9}$ and $\frac{a}{3}$ respectively. So, in this situation, the profits of F_1 and F_2 are

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

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

Next, we consider the situation under licensing for $\frac{2a^2}{27} < F$. In this situation, the upstream industry is the monopoly of I_1 since the entrant in the upstream industry does not enter even if licensing occurs in stage 1. Therefore, in this situation, total input supply and the corresponding input price are $\frac{a}{3}$ and $\frac{a}{2}$ respectively. Hence, in this situation, the profits of F_1 and F_2 are

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

2.3 Input prices under licensing and non-licensing

In the previous sections we have considered input prices conditional on licensing and non-licensing in stage 1. We have found that the upstream industry will be duopoly (monopoly) irrespective of licensing in the downstream industry when $F < \frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}$ ($F > \frac{2a^2}{27}$). But, for $F \in (\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}, \frac{2a^2}{27})$, the upstream industry will be monopoly (duopoly) in absence (presence) of licensing in the downstream industry.

Hence, we have the following proposition comparing the input prices under licensing and non-licensing in the downstream industry.

Proposition 1: *(a) If either $F < \frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}$ or $F > \frac{2a^2}{27}$, input price is higher in case of licensing in the downstream industry compared to non-licensing in the downstream industry.*

(b) If $F \in (\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}, \frac{2a^2}{27})$ then input price, in case of licensing in the downstream industry, is higher (lower) compared to non-licensing in the downstream industry provided the initial technological difference of the downstream firms is sufficiently large (small), i.e., when λ is greater (less) than a critical value, say, λ^c.

Proof: (a) If $F < \frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}$ then the input prices under non-licensing and licensing are $\frac{a(1+\lambda)}{(6+6\lambda^2-6\lambda)}$ and $\frac{a}{3}$ respectively. The comparison of the input prices proves the result.

If $F > \frac{2a^2}{27}$ then the input prices under non-licensing and licensing are $\frac{a(1+\lambda)}{(4+4\lambda^2-4\lambda)}$ and $\frac{a}{2}$ respectively. The comparison of the input prices proves the result.

(b) If $F \in (\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}, \frac{2a^2}{27})$ then the input prices under non-licensing and licensing are $\frac{a(1+\lambda)}{(4+4\lambda^2-4\lambda)}$ and $\frac{a}{3}$. Comparing the input prices we find that $\frac{a}{3} \underset{<}{\geq} \frac{a(1+\lambda)}{(4+4\lambda^2-4\lambda)}$ provided

$$1 + 4\lambda^2 - 7\lambda \underset{<}{\overset{\geq}{-}} 0. \tag{11}$$

The left hand side (LHS) of (11) is negative for $\lambda = 1$ and positive for $\lambda = 2$. Further LHS of (11) is continuous and increasing in λ over the interval $[1,2]$. Therefore, we can say that there exists a critical value of λ, say λ^c, such that input price is higher (lower) under licensing compared to non-licensing for all λ greater (less) than λ^c.

Q.E.D.

2.4 *Condition for profitable licensing contract*

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

Let us first consider the situation where $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} > F$. 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 the expression (9) is greater than (6) provided

$$0 > 9(4 + 7\lambda^2 - 7\lambda)^2 + 9(7 + 4\lambda^2 - 7\lambda)^2 - 8(6 + 6\lambda^2 - 6\lambda)^2. \tag{12}$$

Right hand side (RHS) of (12) is positive for $\lambda \in (1,2)$ (see Figure 2)[5]. Therefore, licensing is not optimal when the upstream industry is duopoly irrespective of the licensing decision in the downstream industry.

Figure 2

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 happens for $\frac{2a^2}{27} < F$. Hence, the 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 the expression (10) is greater than (8) provided

$$0 > 2(2+5\lambda^2-5\lambda)^2 + 2(5+2\lambda^2-5\lambda)^2 - (4+4\lambda^2-4\lambda)^2 . \tag{13}$$

RHS of (13) is positive for $\lambda \in (1,2)$ (see Figure 3). Therefore, licensing is not optimal when the upstream industry is monopoly irrespective of the licensing decision in the downstream industry.

Figure 3

Finally, we consider the situation for $F \in (\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}, \frac{2a^2}{27})$. 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 the expression (9) will be greater than (8) provided

$$8(4+4\lambda^2-4\lambda)^2 - 9(2+5\lambda^2-5\lambda)^2 - 9(5+2\lambda^2-5\lambda)^2 > 0 . \tag{14}$$

[5] We use 'The Mathematica 4.2' for the Figures 2, 3 and 4 of this paper.

LHS of (14) is positive for $\lambda = 1$ but negative for $\lambda = 2$. LHS of (14) is continuous and concave for $\lambda \in [1,2]$ (see Figure 4). Hence, we find that condition (14) always holds for any $\lambda \in [1, \lambda^*]$, where LHS of (14) is equal to zero at λ^*. This implies that licensing in the downstream industry is profitable if licensing changes the market structure of the upstream industry and the initial technology of the downstream firms is sufficiently close.

Figure 4

We summarize the above discussion in the following proposition.

Proposition 2: *Assume that* $\lambda \in (1,2)$.

(i) If upstream industry is either duopoly or monopoly irrespective of the decision on licensing in the downstream industry, i.e., either $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} > F$ *or* $\frac{2a^2}{27} < F$, *licensing in the downstream industry is never optimal.*

(ii) If $F \in (\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)}, \frac{2a^2}{27})$ *then the upstream industry is respectively duopoly and monopoly under licensing and non-licensing in the downstream industry. In this situation, licensing in the downstream industry is optimal provided the initial technology of the downstream firms is sufficiently close.*

The above result is in sharp contrast to the previous papers on licensing. Ignoring the market power of the upstream firms, the previous papers have argued that licensing between the firms producing the final product is profitable provided the initial technologies of these firms are sufficiently close (see, e.g., Katz and Shapiro, 1985 and Marjit, 1990). Proposition 2(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 2(ii) shows that licensing is profitable only if licensing changes the upstream market structure. Therefore, whether licensing in the downstream industry is profitable in presence of market power of the upstream firms depends on the effect of licensing on the upstream market structure.

2.5 When $\lambda > 2$

The previous subsections have considered the situation where, under non-licensing, 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 $\lambda < 2$.

In this subsection we will do our analysis for $\lambda > 2$. Here, in a symmetric equilibrium in the upstream industry, the upstream firm(s), under non-licensing, will produce for the technologically efficient downstream firm only. Hence, in this situation, the demand for input, under non-licensing, is given by the expression (4).

It is clear that the possibility of producing 'for the efficient downstream firm only' arises in absence of licensing in the downstream industry. But, under licensing in the downstream industry, both downstream firms are symmetric and hence, the upstream firm(s) 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, under non-licensing, produces for the technologically efficient downstream firm only (i.e., facing the input demand given by (4)), the profits of I_1 and I_2 are $\frac{a^2}{18}$ 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 $\frac{a^2(1+\lambda)^2}{9(6+6\lambda^2-6\lambda)} < \frac{a^2}{18} < \frac{2a^2}{27}$.

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, the industry profit is $\frac{a^2}{9}$ under non-licensing. But, in case of licensing, downstream industry profit is $\frac{8a^2}{81}$ (see expression (9)), which is less than the downstream industry profit under non-licensing, i.e., $\frac{a^2}{9}$. Hence, in this situation, licensing is not optimal in the downstream industry.

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 $\lambda > 2$ then, under non-licensing, the upstream monopolist always finds it optimal to produce for the technologically efficient downstream firm only. Hence, in this situation, the optimal profit of the efficient downstream firm under non-licensing is $\frac{a^2}{16}$. But, under licensing the downstream industry profit is $\frac{a^2}{18}$ (see expression (10)), which is less than the downstream industry profit under non-licensing, i.e., $\frac{a^2}{16}$. Therefore, here licensing is not optimal in the downstream industry.

Lastly, consider the situation where the upstream industry will be monopoly without licensing and duopoly with licensing. This happens for $F \in (\frac{a^2}{18}, \frac{2a^2}{27})$. Therefore, from the above discussions it is clear that, in this situation, downstream industry profits under non-licensing and licensing are $\frac{a^2}{16}$ and $\frac{8a^2}{81}$ respectively. Hence, in this situation, licensing is always optimal as $\frac{8a^2}{81} > \frac{a^2}{16}$.

We summarize the above discussions in the following proposition.

Proposition 3: *Consider that $\lambda > 2$. Here, in a symmetric equilibrium in the upstream industry, the upstream firm(s), under non-licensing, will supply for the technologically efficient downstream firm only. If licensing changes the market structure of the upstream industry then licensing is always profitable.*

The previous works on 'second-sourcing' (see, e.g., Shepard, 1987 and Farrell and Gallini, 1988) argue that alternative source of production units helps to resolve the commitment problem and hence, creates the incentive for licensing by a monopolist producer. The above proposition shows that a monopolist producer has the incentive for licensing if licensing reduces input price by creating higher competition in the upstream industry. Thus, our analysis suggests that 'second-sourcing' is profitable even if there is no commitment problem but if it helps to reduce input price by changing the market structure of the upstream industry.

The above result shows that if licensing in the downstream industry changes the market structure of the upstream industry then licensing is profitable even if the technologically efficient downstream firm is a monopoly in absence of licensing. 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 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 hence, affects the marginal cost of production of the final goods producers. In a recent paper Schmitz (2002) has provided the evidence for upward bias on licensing in presence of information problem. Unlike Schmitz (2002), the above two propositions show the possibility of both upward and downward bias on licensing and also without any information problem.

The discussions of this subsection and the previous subsection show that when the technological difference in the downstream industry is sufficiently large (i.e., $\lambda > 2$) then it reduces the range of entry costs in the upstream industry over which licensing is optimal in the downstream industry compared to the situation where the technological difference in the downstream industry is not so large (i.e., $\lambda < 2$). But, the range of technological difference over which licensing is optimal increases under $\lambda > 2$ compared to $\lambda < 2$. Therefore, whether the incentive for licensing increases with sufficiently large technological difference in the downstream industry (i.e., $\lambda > 2$) compared to sufficiently small technological difference in the downstream industry (i.e., $\lambda < 2$) depends on the ease of entry in the upstream industry. The reason for this finding is the following.

Given entry in the upstream industry, the industry profit of the downstream industry under licensing is same under $\lambda < 2$ and $\lambda > 2$. But, the industry profits in the downstream industry under non-licensing will be different for $\lambda < 2$ and $\lambda > 2$. When $\lambda < 2$, the upstream monopolist will produce for the both downstream firms but for $\lambda > 2$, the upstream monopolist will produce for the technologically efficient downstream firm only. The input price in the former situation, i.e., $\frac{a(1+\lambda)}{(4+4\lambda^2-4\lambda)}$, is lower than the input price in the later situation, i.e., $\frac{a}{2}$. Hence, the benefit of lower input price due to licensing is lower in the former situation compared to the later situation. Hence, we have the difference in results mentioned in the Proposition 2(ii) and 3.

3 Conclusion

Researchers have already addressed several issues on technology licensing. While they have addressed the issues such as the importance of informational structure and the role of competition between the licenser and the licensee(s), 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 fixed-fee licensing in the downstream industry.

We show that whether licensing in the downstream industry is optimal depends on the market structure of the upstream industry. 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 price and makes licensing profitable. Thus, our analysis provides a rationale for ‘second sourcing’.

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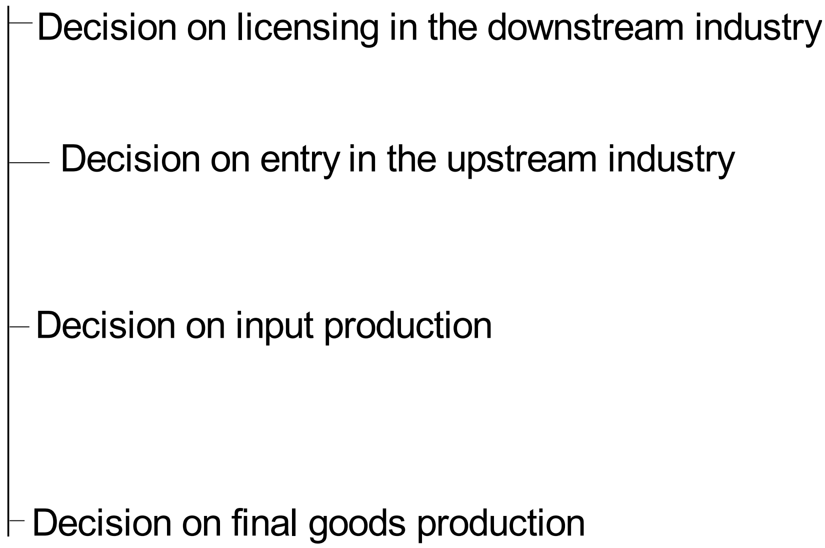

Figure 1: Sequence of the moves of the game

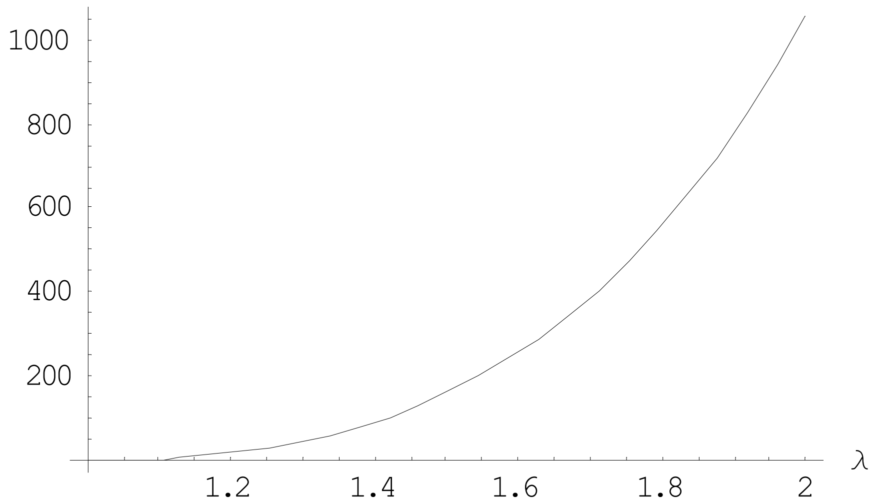

Figure 2: Right hand side of condition (12).

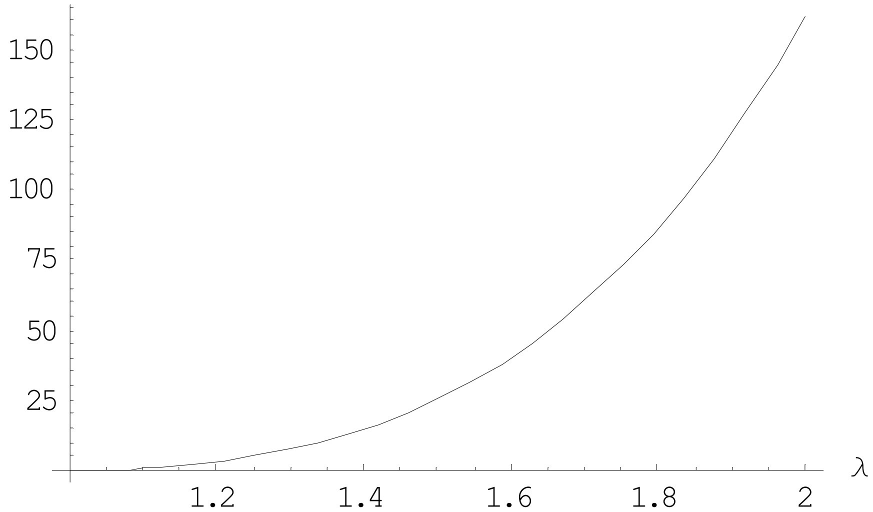

Figure 3: Right hand side of condition (13).

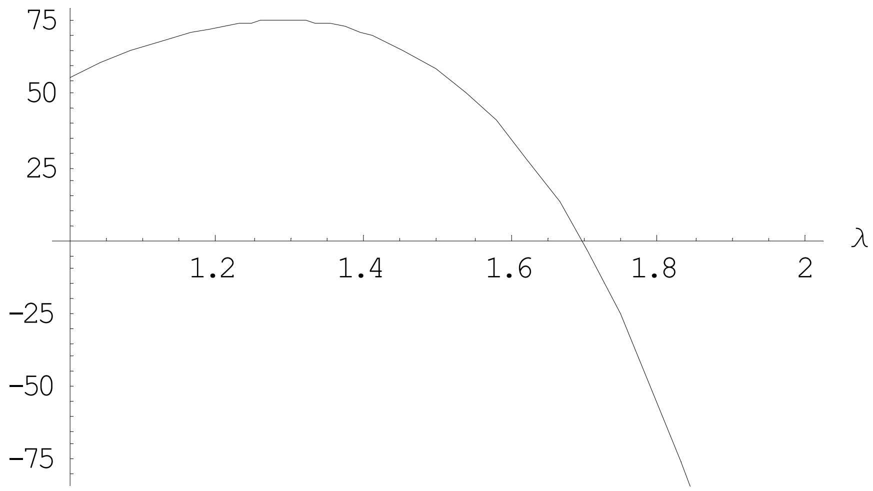

Figure 4: Left hand side of condition (14).