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Technology licensing, R&D and welfare[☆]

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ABSTRACT

This paper sets up a three-stage (R&D, technology licensing, and output) oligopoly 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. It is found with surprise that if the licensor firm's R&D efficiency is *high*, the availability of licensing subdues the firm's R&D incentive, leading to a lower social welfare level. This result implies that a government has to be cautious when encouraging technology licensing among firms.

1. Introduction

This paper examines how technology licensing affects a firm's incentive for innovation. The benefits of cost-reducing R&D are two-fold. It gives the innovator a competitive edge over its rivals; it also provides the licensor with licensing revenue. It is generally believed that allowing a firm to license out its technology has a positive effect on its R&D (Salant, 1984; Gallini and Winter, 1985). In this paper however, we will show a counter example that licensing may cause an innovator to invest less.

Firm's R&D behavior and its effect on social welfare have drawn considerable attention and been debated extensively in the literature (see, for example D'Aspremont and Jacquemin, 1988; Suzumura, 1992). But, they do not assume a firm's R&D outcomes can be licensed out and fail to explain the burgeoning trend of technology licensing.[1]

Our paper is also related to the literature on insider licensing which mainly focuses on optimal forms of contracts (see, for example Wang, 1998; Kamien and Tauman, 2002). There are few papers along this strand addressing both R&D and licensing, including (Salant, 1984; Gallini, 1984; Gallini and Winter, 1985), but their focuses are quite different from ours. They all treat R&D as a binary variable and ignore that the intensity of R&D could be strategically affected by licensing. By treating R&D as exogenously given, they find that licensing is welfare-enhancing. In contrast, we treat R&D as an endogenous variable and show that the availability of licensing may subdue a firm's R&D incentive, leading to a lower social welfare level.[2] This kind of disincentive on R&D differs from those in the literature, such as technological spillover

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1 Nadiri (1993) shows that international payments for patents, licenses and technical know-how for Japan, U.K., France and U.S. were growing substantially between 1979 and 1988.

2 Mukherjee and Mukherjee (2002) also consider an endogenous decision on R&D. However, unlike our paper, the licensing effect on R&D in their paper is due to the effect on total profit and not due to the effect on marginal profit.

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(D'Aspremont and Jacquemin, 1988), product differentiation (Lin and Saggi, 2002) and multi-product monopolist (Lin, 2007), and has never been documented in the literature. Furthermore, our result on welfare complements the welfare-reducing licensing literature which shows that licensing may reduce welfare if it facilitates a collusive outcome (Faulí-Oller and Sandonis, 2002), affects the R&D organization (Mukherjee, 2005), creates excessive entry (Mukherjee and Mukherjee, 2008); or changes the mode of operation of the foreign firm (Sinha, 2010).

2. The model

Assume that there is a market with $n+1$ firms—one insider innovator, called Firm I, and the other n homogeneous firms, called Firm i, $i=1,\ldots,n$, all producing a homogeneous good, having the same marginal production cost c and competing in Cournot fashion. We assume that only Firm I undertakes a cost-reducing R&D, x, at the cost function $V(x;v)$ with $\partial V/\partial x>0$, $\partial V/\partial v>0$, $\partial^2 V/\partial x\partial v>0$, where v is a parameter reflecting the R&D efficiency and a higher v indicates lower R&D efficiency.[3] The R&D investment is assumed to be non-drastic throughout the paper.[4] We further assume that Firm I (hereafter, the licensor firm) can license its technology to all the no-R&D firms (hereafter, the licensee firms) via a two-part tariff contract, i.e., a fixed fee (F) and a royalty rate (r). Thus, the licensor firm's marginal production cost after licensing becomes $c-x$ whereas those of the licensee firms are $c-x+r$. The inverse demand function for the good takes the following implicit form: $p=p(Q)$ with $p'(Q)<0$ and $Q=q_I+\sum_{i=1}^{n}q_i$ where q_I and q_i are respectively the outputs of the licensor firm and the licensee firm.

The game in question comprises three stages. In the first stage, the licensor firm determines its R&D investment. In the second stage, for a given R&D, the licensor firm licenses its technology to the licensee firms by means of a two-part tariff contract. In the third stage, all the firms compete in Cournot fashion in the final good market. The profit functions for the licensor firm and the licensee firms can be respectively expressed as follows:

$$\pi_I^L(q_I,q_i;F,r,x,v) = (p(Q)-(c-x))\,q_I + \sum_{i=1}^{n} rq_i + nF - V, \tag{1}$$

$$\pi_i^L(q_I,q_i;F,r,x,v) = (p(Q)-(c-x+r))\,q_i - F, \quad i=1,\ldots,n, \tag{2}$$

where variables with a superscript "L" represent that they are associated with the licensing regime. The first-order conditions for profit maximization are as follows:

$$\frac{\partial \pi_I^L}{\partial q_I} = p-(c-x)+p'q_I = 0, \tag{3}$$

$$\frac{\partial \pi_i^L}{\partial q_i} = p-(c-x+r)+p'q_i = 0, \quad i=1,\ldots,n. \tag{4}$$

The second-order conditions require that $\partial^2\pi_I^L/\partial q_I^2<0$ and $\partial^2\pi_i^L/\partial q_i^2<0$, which are assumed to be satisfied. By symmetry, we have $q_1=q_2=\cdots=q_n\equiv q$ in equilibrium. Utilizing this property, we can rewrite (4) as follows:

$$\frac{\partial \pi_i^L}{\partial q} = p-(c-x+r)+p'q = 0, \quad \text{for all } i. \tag{5}$$

From (3) and (5), the comparative statics are derivable as follows:

$$\begin{aligned} \frac{\partial q_I^L}{\partial x} &= \frac{-\pi_{ii}+\pi_{Ii}}{H}, & \frac{\partial q^L}{\partial x} &= \frac{\pi_{iI}-\pi_{II}}{H}, \\ \frac{\partial q_I^L}{\partial r} &= \frac{-\pi_{Ii}}{H}>0, & \frac{\partial q^L}{\partial r} &= \frac{\pi_{II}}{H}<0, \end{aligned} \tag{6}$$

where $\pi_{II}\equiv\partial^2\pi_I^L/\partial q_I^2=2p'+p''q_I<0$, $\pi_{ii}\equiv\partial^2\pi_i^L/\partial q^2=(n+1)p'+np''q<0$, $\pi_{Ii}\equiv\partial^2\pi_I^L/\partial q_I\partial q=n(p'+p''q_I)<0$, $\pi_{iI}\equiv\partial^2\pi_i^L/\partial q\partial q_I=p'+p''q<0$, and $H\equiv\pi_{II}\pi_{ii}-\pi_{Ii}\pi_{iI}=p'\left[(n+2)p'+p''Q\right]>0$.

The profit function of the licensor firm in the second-stage game can be expressed as follows:

$$\max_r \pi_I^L = \left(p\left(Q^L(r)\right)-(c-x)\right)q_I^L(r) + nrq^L(r)+nF(r)-V, \tag{7}$$

$$\text{subject to } (p-(c-x+r))q^L(r)-F \ge (p-c)q^N(x), \tag{8}$$

where variables with a superscript "N" indicate they are associated with the no-licensing regime. By symmetry, the total fee revenue collected by the licensor firm is nF. Following the literature, we assume that the licensor firm is a dominant player in the licensing game and capable of extracting each licensee firm's entire benefit from licensing. Thus, the fixed fee charged by the licensor firm is defined as $F=[p-(c-x+r)]q^L(r)-(p-c)q^N$.

By differentiating (7) with respect to r and utilizing (3) and (5), we can derive the first-order condition for profit maximization as follows:

$$\begin{aligned} \frac{d\pi_I^L}{dr} &= \frac{\partial \pi_I^L}{\partial q^L}\frac{\partial q^L}{\partial r}+\frac{\partial \pi_I^L}{\partial r}+n\frac{\partial \pi_I^L}{\partial F}\frac{\partial F}{\partial r} \\ &= \frac{np'q^L(n\pi_{II}-\pi_{Ii})}{H}=\frac{(np')^2q^L}{H}>0. \end{aligned} \tag{9}$$

This implies that the licensor firm's optimal royalty rate is $r=x$. By substituting $r=x$ into F, we can derive that the optimal fee is equal to zero. The licensor firm uses only royalty to extract the rent of the licensee firm from licensing. Making use of these results, we can define the profit function of the licensor firm for the first-stage game as follows: $\max_x \pi_I^L = \left(p\left(Q^L(r(x),x)\right)-(c-x)\right)q_I^L(r(x),x)+nrq^L(r(x),x)-V(x;v)$.

By differentiating this equation with respect to x, we can derive the first-order condition for profit maximization as follows:

$$\frac{d\pi_I^L}{dx} = \underbrace{\left(np'q_I^L\right)\left(\frac{\partial q^L}{\partial r}\frac{\partial r}{\partial x}+\frac{\partial q^L}{\partial x}\right)}_{\text{strategic effect}} + \underbrace{q_I^L}_{\text{output effect}} + \underbrace{\frac{d(nrq^L)}{dx}}_{\text{licensing revenue effect}} - \underbrace{\frac{dV}{dx}}_{\text{cost effect}} = 0, \tag{10}$$

where $(\partial q^L/\partial r)(\partial r/\partial x)+\partial q^L/\partial x=\pi_{iI}/H<0$ by (6). As shown in (10), there are four terms that jointly determine the licensor firm's optimal R&D. The first term is called the strategic effect, which is positive. The second term is called the output effect, which is also positive. The third term is called the licensing revenue effect. The sign of this effect is ambiguous as $nrq^L$is concave in x. The last term which is negative, represents the R&D cost effect.

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3 This assumption is made to facilitate our analysis on licensing. If all the firms are capable of conducting R&D, there will be no cost difference among firms by symmetry and, as a result, licensing never occurs.

4 Wang (1998) shows that an innovator with a drastic innovation would never license the innovation to its rivals.