Strategic Pricing of Technology License under Product Differentiation

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Abstract

This paper studies factors that might affect the price (i.e. a fixed licensing fee) and the demand for technology licensing. The author finds that the licensor's licensing fee is found to increase in the degree of product differentiation between technology holders, the degree of knowledge inappropriability, and the level of transaction costs of technology licensing. Also, product differentiation between technology holders raises the licensees' demand for technology.

1. Introduction

Technology licensing, where the appropriation and adaptation of technological advances takes a central role, has become increasingly important for the competitive strategy of firms in high technology industries. As Anand and Khanna (2000) observe, it is one of only a few significant methods of technology transfer between firms, and one of the most commonly observed inter-firm contractual agreements these days.

Reflecting an increasing importance of licensing activity, it has been a popular subject of industrial economics. Since Arrow has (1962) acknowledged the profits a patent holder can obtain from licensing, Kamien and Tauman (1986) and Katz and Shapiro (1985, 1986) establish a game theoretic framework for the analysis of the technology owner's optimal licensing strategies. Issues related to technology holders' strategic incentives to license are addressed by many other studies as well. In Gallini (1984), licensing can be used strategically to limit potential entry and reduce competition while Shepard (1987) observes that licensing can also be used to enhance demand by creating a supply. The relationship between sequential innovations and licensing strategies are also examined in Green and Scotchmer (1994).

Voluminous prior studies focus on technology holder's strategic licensing behavior including, for example, the optimal number of licenses to sell. The more realistic setup, however, would be that technology holders compete with price rather than quantity of licenses. In addition, literature has mostly dealt with the supply side of technology licensing (i.e. licensor), and the demand side of technology licensing (i.e. licensee) has been somewhat ignored in the model.

This paper tries to fill this void and theoretically examines factors that affect the licensor's price (i.e. fixed licensing fee) of license in the market where multiple sellers and buyers of technology exist. Technology owners perform the price competition based on a licensee's demand for technology assuming imperfect price competition of duopoly at the technology market. We assume that multiple technology holders provide differentiated products. This is a plausible assumption since companies may try hard to differentiate themselves from each other to avoid fierce competition at the product market.

The next Section 2 develops the model and Section 3 concludes.

2. The model

Consider that there exist two firms, firm *y* and firm *z*, that have independently developed and patented propriety technologies, *y* and *z*, for the production of a good. Such a good can either be perfectly homogeneous between the products produced with the two technologies or differentiated. Apart from two technology holders, we assume that there are *N* (*i = 1,2,...N*) heterogeneous firms that own *b* branches each who cannot innovate, but can produce if they receive the rights to use the technology from one of incumbent technology holders. Assume that all potential entrant branches of firms are able to obtain technology from either one of technology holders and technology holders supply their technologies whenever there is a demand.

It is assumed that incumbent licensor collects a fixed licensing fee, *F*, from each licensee through the use of the licensor's technology. We also assume that technology licensing from the licensor to the licensee involves a fixed transaction cost, $T \geq 0$. These include costs of writing contracts, enforcing contracts, gathering information about licensees and bargaining with them. The theoretical framework of the model is a three-stage game. We use a backward induction approach.

Game Structure

The First Stage: Technology holders compete with licensing fee they charge to licensees.
The Second Stage: C.E.O.s of potential licensee firms choose optimal technology for their branches of firms.
The Third Stage: All firms (including both licensors and licensees) that have technology produce products and compete at the product market.

The Third Stage: "Product Market" – Competition in output

We assume Cournot competition in the product market. Inverse demand functions for product produced with each technology, *y* and *z*, are as follows:

$$p_y = 1 - (x_y + \sum_{D_y} x_y) - \mu(x_z + \sum_{D_z} x_z), \tag{1}$$

$$p_z = 1 - (x_z + \sum_{D_z} x_z) - \mu(x_y + \sum_{D_y} x_y), \tag{2}$$

where p_y, p_z denote the prices, $(x_y + \sum_{D_y} x_y)$ is the quantity supplied by firms producing with technology *y*, $(x_z + \sum_{D_z} x_z)$ is the quantity supplied by firms endowed with technology *z*, and D_y and D_z are total demand for technology *y* and *z* respectively.

We assume that $\mu \in [0,1]$, with products being homogeneous for $\mu = 1$ and completely differentiated for $\mu = 0$. Higher values of μ represent more homogeneous products between incumbent technology holders. It is also assumed that, once the production technologies have been acquired, the cost of production is negligible; these costs are set at zero.

Any firm (either technology holder or licensee branches of firms) producing with technology y, z, maximizes the following profits at the product market, choosing the quantity of x_y, x_z, respectively,

$$\max_{x_y} \pi^y = p_y x_y, \tag{3}$$

$$\max_{x_z} \pi^z = p_z x_z, \tag{4}$$

The first order condition of (3) is given by:

$$1 - 2 x_y - \sum_{D_y} x_y - \mu(x_z + \sum_{D_z} x_z) = 0. \tag{5}$$

Imposing symmetry above across firms using same technology, we obtain:

$$1 - 2 x_y - D_y x_y - \mu x_z - \mu D_z x_z = 0, \tag{6}$$

from which

$$x_y = \frac{1 - \mu x_z(1 + D_z)}{2 + D_y}. \tag{7}$$

Similarly, for the firm with technology z is:

$$x_z = \frac{1 - \mu x_y(1 + D_y)}{2 + D_z}. \tag{8}$$

From (7) and (8), we obtain the Nash equilibrium output by the firm with technology y and technology z, respectively:

$$x_y = \frac{(2 + D_z) - \mu(1 + D_z)}{(2 + D_y)(2 + D_z) - \mu^2(1 + D_y)(1 + D_z)}, \tag{9}$$

$$x_z = \frac{(2 + D_y) - \mu(1 + D_y)}{(2 + D_y)(2 + D_z) - \mu^2(1 + D_y)(1 + D_z)}. \tag{10}$$

Substituting (9) into (1) and (3), (10) into (2) and (4) respectively, we can compute the equilibrium price and thus equilibrium profit at the product market for each firm endowed with technology y as follows:

$$\pi^y = \left[\frac{(2 + D_z) - \mu(1 + D_z)}{(2 + D_y)(2 + D_z) - \mu^2(1 + D_y)(1 + D_z)} \right]^2, \tag{11}$$

Similarly, for the firm with technology z is:

$$\pi^z = \left[\frac{(2 + D_y) - \mu(1 + D_y)}{(2 + D_y)(2 + D_z) - \mu^2(1 + D_y)(1 + D_z)} \right]^2. \tag{12}$$

Proposition 1. Each firm's profit in the product market is decreasing in μ.

Proof. $\dfrac{\partial \pi^y}{\partial \mu} < 0$ and $\dfrac{\partial \pi^z}{\partial \mu} < 0$.

The above proposition implies that each firm's profit decreases due to an increased competition at the product market when goods produced by firms are more homogeneous (i.e.

the higher μ) between technology holders. The more similar goods produced by firms are, the fiercer the competition they face at the goods market. This competition effect lowers firms' profits accordingly.

The Second Stage: Licensee's demand for technology

Assume that each N ($i = 1,2,…,N$) licensee firm consists of the same number of branches *b* that can adopt new technology and produce outputs. Also, each branch is assumed to have a unique branch characteristic χ_i (i.e. amount of know-how or tacit knowledge, number of high-skilled engineers, commercialization and marketing ability, organizational structure, management skills, R&D intensity, size …). Thus licensee firms are heterogeneous in a sense that the heterogeneity of branch characteristics among licensee firms may lead to heterogeneous behavior. It is assumed that the branch characteristic is uniformly distributed between 0 and 1, $\chi_i \in [0,1]$. For instance, 0 % chemical engineer (100 % biotechnicians) for χ_i = 0, while 100% chemical engineers (0 % biotechnicians) for χ_i = 1.

The C.E.O. of each potential licensee firm with branch characteristic χ_i is assumed to purchase either variety *y* or variety *z* for his branches from two incumbent technology holders, *y* and *z*. We assume that he considers both explicit profit and implicit (tacit) profit in deciding which variety to choose. That is, the former is the profit licensee branches can obtain at the product market explicitly, and the latter is the inherent profit they can generate from the more efficient production, learning, invention, and the bigger in-house tacit knowledge necessary for the obtained technology. Thus, the two available technologies are not the same to licensee firms in terms of their total potential profits (explicit and implicit) that licensee branches of firms can generate through technology licensing. For instance, suppose variety *y* is bio-related technology. Then technology *y* is assumed to be best suited to branches with branch characteristic χ_i = 0 (i.e. 100 % biotechnicians). In this case, technology *y* has the inherent advantage of implicit profit over technology *z*. In Figure 1, as we move away from branch characteristic 0 toward 1, this inherent profit of technology *y* over technology *z* is assumed to decrease, reducing the per-unit total profit of technology *y*. On the other hand, technology *z*, i.e. chemical-related technology, is best suited to branches with branch characteristic χ_i = 1 (i.e. 100 % chemical engineers), and thus has the inherent implicit profit over technology *y*. As we move away from the branch characteristic 1 toward 0, this profit of technology *z* over technology *y* decreases.

-- In Figure 1, horizontal axis represents branch characteristics χ_i, and line (1) has a negative slope while (2) has a positive slope. Before the increase of the licensing fee, a potential licensee firm with χ_i less than equilibrium χ_i^{*0} would adopt technology *y*, while χ_i greater than equilibrium χ_i^{*0} would purchase technology *z*.

In Figure 2, the demand for technology *y* is derived. Suppose a licensing fee of technology *y* increases from F^{y0} to F^{y1}, then per-unit total profit of technology *y* decreases and this causes line (1) to shift to line (3) in Figure 1. Accordingly, we can derive the demand for technology *y* by connecting those two points in Figure 2. Hence, holding others constant, the market share of technology *y* out of

total technology market decreases from χ_i^{*0} to χ_i^{*1} (note that since χ_i is uniformly distributed between 0 and 1, we can interpret χ_i as the market share). Similarly, we can derive the demand for technology z.
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\<Figure.1\> The per-unit total profit as a function of χ_i
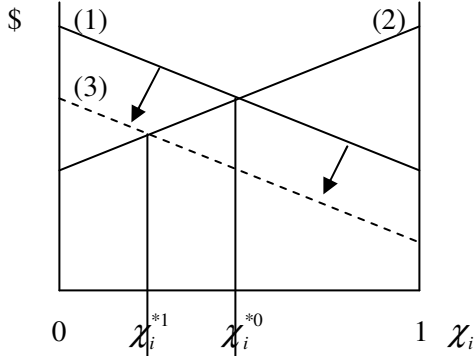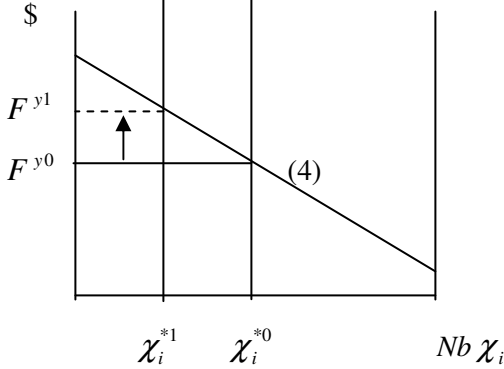

(1): per-unit total profit of technology y (before the change of a licensing fee);
$$\left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right] - F^{y0}$$
(2): per-unit total profit of technology z
$$\left[\pi^z + (1-\mu)\pi^z\chi_i\right] - F^{y0}$$
(3): per-unit total profit of technology y (after the increase of a licensing fee);
$$\left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right] - F^{y1}$$

\<Figure.2\> Demand for technology y

(4): Demand for technology y;
$$D_y = N\, b\, \chi_i^* =$$

$$\frac{Nb\left[\pi^y - \pi^z + (1-\mu)\pi^y - F^y + F^z\right]}{(1-\mu)(\pi^y + \pi^z)}$$

Therefore, the C.E.O of each potential licensee firm i maximizes the following total profits (both explicit and implicit) from licensing by selecting the proportion (ϕ_i) of its branches endowed with technology y, subject to inequality constraint, $0 \le \phi_i \le 1$:

$$\max_{\phi_i} v_i = \left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right]b\phi_i - F^y b\phi_i + \left[\pi^z + (1-\mu)\pi^z\chi_i\right]b(1-\phi_i) - F^z b(1-\phi_i) \,, \text{(13)}$$

Lagrangian is as follows:
$$L = \left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right]b\phi_i - F^y b\phi_i + \left[\pi^z + (1-\mu)\pi^z\chi_i\right]b(1-\phi_i) - F^z b(1-\phi_i) \,,$$
$$+ \lambda_i^y(1-\phi_i) + \lambda_i^z(\phi_i) \,, \tag{14}$$

where ϕ_i = the proportion of branches endowed with technology y by licensee firm i.

$(1-\phi_i)$ = the proportion of branches endowed with technology z by licensee firm i.

b = the number of branches of each licensee firm.

F^y, F^z = fixed licensing fee paid to licensor firm y, and firm z, respectively.

π^y, π^z = explicit profit associated with technology y and technology z in the product market, respectively.

$(1-\mu)\pi$ = difference of implicit profit between technologies. Note that μ stands
  for the degree of product differentiation across varieties.

$(1-\mu)\pi^y(1-\chi_i)$ = implicit profit of variety y for the branch with branch characteristic χ_i.

$(1-\mu)\pi^z\chi_i$ = implicit profit of variety z for the branch with branch characteristic χ_i.

The first order condition of the Lagrangian with respect to ϕ_i is given by:

$$\frac{\partial L}{\partial \phi_i} = \left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right]b - F^y b - \left[\pi^z + (1-\mu)\pi^z\chi_i\right]b + F^z b - \lambda_i^y + \lambda_i^z = 0. \quad (15)$$

The Kuhn Tucker conditions are:

$\lambda_i^y \geq 0$, $\lambda_i^z \geq 0$,

$(1-\phi_i) \geq 0$, $\phi_i \geq 0$,

$\lambda_i^y(1-\phi_i) = 0$, $\lambda_i^z\phi_i = 0$,

First, in case where $\phi_i = 1$, and $\lambda_i^y \geq 0$, $\lambda_i^z = 0$, then:

$$\left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right]b - F^y b - \left[\pi^z + (1-\mu)\pi^z\chi_i\right]b + F^z b = \lambda_i^y. \quad (16)$$

That is, total value of technology y minus total value of technology z is greater than or equal to zero since $\lambda_i^y \geq 0$. This means that technology y is more valuable than z, and thus licensees would prefer to license technology y.

Second, in the case where $\phi_i = 0$, and $\lambda_i^y = 0$, $\lambda_i^z \geq 0$, then:

$$\left[\pi^z + (1-\mu)\pi^z\chi_i\right]b - F^z b - \left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right]b + F^y b = \lambda_i^z. \quad (17)$$

This means that technology z is more valuable than y, and thus licensees would prefer to license technology z.

Finally, in the case of interior solution where $0 < \phi_i < 1$, and $\lambda_i^y = 0$, $\lambda_i^z = 0$, then:

$$\left[\pi^y + (1-\mu)\pi^y(1-\chi_i)\right]b - F^y b - \left[\pi^z + (1-\mu)\pi^z\chi_i\right]b + F^z b = 0. \quad (18)$$

This means that technology y and z are equally valuable and licensee is indifferent between the two technologies. From (18)

$$\chi_i^* = \frac{\pi^y - \pi^z + (1-\mu)\pi^y - F^y + F^z}{(1-\mu)(\pi^y + \pi^z)}, \quad (19)$$

where χ_i^* denotes the branch characteristic for the potential licensee that is indifferent between technology y and z. Thus all branches with the branch characteristic less than χ_i^* obtain technology y, while all branches of the branch characteristic greater than χ_i^* purchase technology z.

Since we assume that the branch characteristic χ_i is uniformly distributed between zero and one, χ_i is equal to the market share of technology y and $(1-\chi_i)$ is the market share of technology z out of total technology market. Therefore, as Figure 2 illustrates, the total demand

for technology y (D_y) is equal to the product of the number of potential licensee firms (N), the number of branches each licensee has (b), and the market share of technology y (χ_i^*):

$$D_y = N b \chi_i^* = \frac{Nb\left[\pi^y - \pi^z + (1-\mu)\pi^y - F^y + F^z\right]}{(1-\mu)(\pi^y + \pi^z)}. \tag{20}$$

Similarly, we can derive the total demand for technology z:

$$D_z = N b (1 - \chi_i^*) = \frac{Nb\left[\pi^z - \pi^y + (1-\mu)\pi^z - F^z + F^y\right]}{(1-\mu)(\pi^y + \pi^z)}. \tag{21}$$

Proposition 2. The total demand for each technology is decreasing in μ.

Proof. $\dfrac{\partial D^y}{\partial \mu} < 0;\ \dfrac{\partial D^z}{\partial \mu} < 0.$

The above proposition implies that the total demand for each technology decrease with the homogeneity of products between technology holders. Considering that each firm's profit decreases due to an increased competition at the product market when goods are more homogeneous (i.e. the higher μ) between technologies (Proposition 1), product homogeneity gives potential licensees less incentive to adopt technology.

Proposition 3. The total demand for each technology is increasing in terms of the licensing fee of the other technology, and decreasing in terms of its own licensing fee.

Proof. $\dfrac{\partial D^y}{\partial F^y} < 0$ and $\dfrac{\partial D^y}{\partial F^z} > 0,\ \dfrac{\partial D^z}{\partial F^z} < 0$ and $\dfrac{\partial D^z}{\partial F^y} > 0.$

The proposition 3 is very intuitive. Firms tend to demand the cheaper technology.

The First Stage: "Market for Technology" – Competition in a fixed licensing fee

Given the profit at the product market and total demand for each technology, each incumbent technology owner sets its price of technology, a fixed licensing fee, to maximize profit at the technology market (i.e. assuming imperfect price competition of duopoly, no firm can achieve the higher profit by changing the licensing fee charged for its technology). The technology holder y solves the following:

$$\max_{F^y} V^y = \pi^y + \theta F^y D_y - TD_y , \tag{22}$$

where θ denotes the degree of knowledge appropriability (i.e. the level of patent protection enforcement).

We assume that $\theta \in [0,1]$, with perfect knowledge appropriability for $\theta = 1$ and no knowledge appropriability for $\theta = 0$. For instance, lower value of θ represents the weaker patent protection enforcement. The low degree of knowledge appropriability (i.e. strong patent protection enforcement) increases the danger of licensors' patents being infringed and licensee firms can freely copy the licensor's patented technology and use it for generating extra profit without paying for it. Further, licensees may have an incentive to shirk a contract fee under the weak patent protection regime.

Thus, incumbent technology holder y's total profit is the sum of the profits from its own production (= π^y) and total fixed fee payments from D_y licensees (= $\theta F^y D_y$) minus transaction costs of licensing (=$T\,D_y$).

Similarly, the problem for technology holder z is:

$$\max_{F^z} V^z = \pi^z + \theta F^z D_z - TD_z ,\qquad(23)$$

From the system of the two first order conditions obtained from (22) and (23), we can obtain, by imposing symmetry, the equilibrium licensing fee:

$$F = \frac{\theta(1-\mu)\pi + T}{\theta}.\qquad(24)$$

Proposition 4. The Equilibrium licensing fee F is decreasing in μ.

Proof. $\dfrac{\partial F}{\partial \mu} = (1-\mu)\pi_\mu - \pi < 0$ since $\pi_\mu < 0.$

The proposition 4 implies that the incumbent technology holder firm can charge a higher licensing fee for its technology when goods between technology holders are more differentiated (i.e. the lower μ). The intuition is that when the good is highly differentiated, each incumbent technology holder has its own market niche. Hence product and technology differentiation give each technology holder firm more market power. Considering that market power is positively related with the licensing fee technology holders can charge, a product differentiation between technology holders leads to the higher licensing fee.

Proposition 5. The Equilibrium licensing fee F is increasing in T and decreasing in θ

Proof. $\dfrac{\partial F}{\partial T} > 0,\ \dfrac{\partial F}{\partial \theta} < 0.$

The above proposition shows that equilibrium licensing fee increases with transaction costs of licensing while the high degree of knowledge appropriability (i.e. strong patent protection enforcement) induces firms to charge less for their technology. In the presence of low transaction costs of licensing, weaker pressure may be brought to bear on technology holders to charge the higher price for their technology due to an efficient transaction of technology at the market. In addition, given that strength of patent protection is negatively correlated to transaction costs of technology licensing (Arrow, 1962; Merges, 1998), a strong patent protection leads to fewer incentives for technology holders to set the high price for their licenses due to the similar arguments.

3. Conclusion

This paper studies licensors' strategic pricing of license and licensees' optimal demand for technology when a product is differentiated. The main aspect of the model is the endogeneity of the degree of product differentiation in the oligopoly market, endogeneity that is a function of the relative proportions of firms adopting each technology. Since oligopoly profits are a function of the degree of product differentiation, technology holders will internalize this effect when they set their license price.

We find that the licensor's licensing fee is found to increase in the degree of product differentiation between technology holders, the degree of knowledge inappropriability, and the level of transaction costs of technology licensing. Also, product differentiation between technology holders raises the licensee's demand for technology.

References

Anand, B.N., and T. Khanna, "The structure of licensing contracts", *Journal of industrial Economics* 48(1), 2000, 103-135.

Arrow, K.J., "Economic welfare and the allocation of resources for invention", In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, ed. R.R. Nelson. Princeton University Press. 1962.

Gallini, N.T., "Deterrence through Market Sharing: A Strategic Incentive for Licensing", *American Economic Review* 74, 1984, 931-941.

Gallini, N.T., and B.D. Wright, "Technology Transfer under asymmetric information", *Rand Journal of Economics* 21, 1984, 147-160.

Green, J. and Scotchmer, S., "On the division of profit in sequential innovation", Rand Journal of Economics*, 26, 1995, 20-33.*

Kamien M.I., Y. Tauman, "Fees versus royalties and the private value of a patent", *Quarterly Journal of Economics* 101, 1986, 471-491.

Katz M.L. and C. Shapiro, "On the licensing of innovation", *Rand Journal of Economics* 16, 1985, 504-520.

Katz M.L. and C. Shapiro, "How to license intangible property", *Quarterly Journal of Economics* 101, 1986, 567-589.

Merges, R., Property rights, transactions, and the value of intangible assets. Mimeo, Boalt School of Law, University of California, Berkeley,CA, 1998.

Shepard, A., "Licensing to Enhance Demand for New Technology", *Rand Journal of Economics* 18, 1987, 360-368.

Biography

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