International Journal of Economics and Finance; Vol. 5, No. 3; 2013
ISSN 1916-971X E-ISSN 1916-9728
Published by Canadian Center of Science and Education

The Optimal Licensing Strategy of an Outside Patentee in Vertically-Related Markets

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Received: December 27, 2012 Accepted: January 16, 2013 Online Published: February 22, 2013

doi:10.5539/ijef.v5n3p102 URL: http://dx.doi.org/10.5539/ijef.v5n3p102

Abstract

We extend the model in Kamien and Tauman (1986) by considering vertically-related markets where the outside innovator transfers new technology by means of either a royalty or a fixed fee. Our conclusion is different with Kamien and Tauman (1986) and announces that the optimal licensing strategy for an outside innovator is a royalty contract with a non-exclusion licensing case. When the innovation size is small, the outside innovator's licensing behavior causes low social welfare.

Keywords: royalty, fixed fee, price discrimination, cournot competition

1. Introduction

Getting new technology through technology licensing involves low risk, yet increases a corporation's profit. Although research and development (R&D) is also a powerful way to stimulate profit growth, it needs a lot of money for investment and those involved must spend a lot of time. However, the firm needs to shoulder uncertain risk of whether the R&D will be successful or not. Many firms do not have enough capital to engage in R&D activity instead of searching for new technology and acquiring technology licensing.

Technology licensing has recently been a very popular strategy for firms in almost all industries, because the licensee can acquire the external knowledge to improve its production technology and the licensor can earn rent so as to increase profit. Hence, technology licensing has become a powerful access to increase a firm's revenue. Licensing revenue is estimated at more than US$100 billion annually in the U.S. (Kline, 2003).

There is a vast amount of literature focusing on the decision of the patentee's optimal licensing strategy. Formal analysis on the patentee's profit through licensing an innovation that reduces production costs can be traced back to Arrow (1962), who concludes that a perfectly competitive industry provides a higher innovation incentive than a monopoly industry. Kamien and Schwartz (1982) extend Arrow's analysis to license an oligopolistic industry by means of both a fixed fee and a royalty. Kamien and Tauman (1986) examine the optimal licensing strategy by comparing a fixed-fee licensing contract and a royalty licensing contract. Katz and Shapiro (1985, 1986) study the auction licensing method.

Much of the literature analyzes the innovator's optimal licensing strategy by various model settings, such as the innovator is either a product's manufacturer in the market, i.e., the inside innovator, or a non-product's manufacturer that is outside of market, i.e., the outside innovator, or such as firms including an innovator engaged in either Cournot competition or Bertrand competition. Along this line, we arrange the licensing literature into the four types as follows.

i) An outside innovator and licensees engage a Cournot competition. Under this situation, Kamien and Tauman (1986) present that the outside innovator has higher profit by the fixed-fee licensing method than that by the royalty licensing method.

ii) An outside innovator and licensees engage in Bertrand competition. Under this situation, Muto (1993) considers the optimal licensing strategy in a horizontal differentiated duopoly model by comparing three kinds of licensing methods among fixed fee, royalty, and auction. He concludes that a royalty is the optimal licensing strategy under a non-drastic innovation. Poddar and Sinha (2004) introduce a spatial framework with the Hotelling linear city model and show that a royalty is always better than an auction and fixed fee for the outside innovator in both drastic and non-drastic innovations.

iii) An inside innovator and firms engage in Cournot competition. Wang (1998), under a homogeneous Cournot model, finds that the licensor prefers the royalty licensing method rather than the fixed-fee licensing method for non-drastic innovation. Kamien and Tauman (2002) extend Wang (1998) by increasing the number of firms in the market from 2 to n and conclude that the optimal licensing strategy among a fixed fee, a royalty, or auction depends on the number of firms in the industry. Wang (2002), under a horizontal heterogeneous Cournot model, discusses the licensing strategy and finds that the licensor is possible to license a drastic innovation by means of royalty when the products are imperfect substitutes. Sen (2005) analyzes the licensor's optimal licensing strategy given the number of licensees is an integer. This assumption induces the innovator's profit to become a step function under the fixed fee licensing contract and the auction licensing contract. This reason induces the royalty licensing to become a better licensing method.

iv) An inside innovator and firms engage in Bertrand competition. Wang and Yang (1999) demonstrate that the royalty licensing method is better than a fixed-fee licensing method, no matter if the innovation size is drastic or non-drastic as long as the products' differentiations are not too much. Poddar and Sinha (2004) conclude that the licensor prefers a royalty licensing method for non-drastic innovation. The licensor does not offer a technology licensing when the innovation is drastic. The papers we note above, however, neglect that the real world exists with many intermediate goods firms.

Arya and Mittendorf (2006) is one of the few studies to simultaneously discuss licensing and outsourcing. Their model includes an upstream intermediate goods firm and two downstream final goods firms in a homogeneous Cournot model. The licensor is an inside innovator with a cost-reducing technology in a final goods market, and the upstream firm can take discriminatory pricing against the downstream firms. They conclude that the licensor does not prefer a fixed-fee licensing method, but a fixed-fee licensing method is valuable for the inside innovator to get a double marginalization gain when a fixed fee is used in conjunction with royalties. Sandonis and Fauli-Oller (2006) consider that an upstream outside innovator, such as a laboratory that faces a downstream heterogeneous duopoly market, decides either licensing by two-part tariff or merging with one of the firms to become a vertically-integrated firm. Under the assumptions of linear demand and Cournot competition, they conclude that when the innovation size is small, a vertical merger is profitable to the innovator. Moreover, when the innovation size is large enough, a vertical merger can increase social welfare.

The study scope of recent literature has combined the four lines as mentioned above. Rey and Salant (2012) establish the vertically-related market structure in which one or more upstream patent owners licensed to a downstream industry to study the impact of the licensing policies. They conclude that when only one patent owner in upstream and the monopoly increases the number of licenses, it intensifies downstream competition, and thus dissipates profits. When the multiple patent owners in upstream, the royalty licensing method not only increases aggregate licensing fees but thus reduces the downstream prices for consumers. Similarly, Layne-Farrar and Schmidt (2010) discuss different types of licensing contracts in the vertically-related market. The licensing scenario includes the cross-licensing agreements and non-linear licensing fees. In vertically-related markets in which the labor union is the upstream and the downstream firm is a monopolistic final goods producer, Mukherjee et al. (2008) conclude that the downstream producer can make the profit by licensing the technology when the input market is imperfectly competitive. When the labor union is a centralized style, the licensing by a monopolist is profitable under both uniform and discriminatory wage settings. They also find that licensing by the monopolist is profitable no matter under Cournot or Bertrand competition. The same conclusion holds even with decentralized unions. Kishimoto and Muto (2012) employ Nash bargaining process to examine a Cournot duopoly market in which the patent owner negotiates with its rival firm about payments for licensing a cost-reducing innovation. They take into account two licensing methods - either a fixed fee or a royalty, showing that the royalty licensing is better than fixed fee licensing for both firms if the innovation is not drastic. The royalty licensing is always superior to fixed fee licensing from the viewpoint of social welfare, but there exists a case in which consumers prefer the fixed-fee licensing.

The model set-up in this paper uses the model set-up in Kamien and Tauman (1986), but involves the concept of Arya and Mittendorf (2006). We contribute a vertically-related market in the model of Kamien and Tauman (1986), in which the licensor is an outside innovator and it transfers a cost-reducing technology to both or one downstream firm by means of either a royalty or a fixed fee. Two downstream firms engage in homogeneous Cournot competition.

This is a three-stage game. At stage 1, the outside innovator decides the optimal licensing strategy as being either a fixed fee or a royalty. At stage 2, the upstream intermediate goods firm sets the intermediate goods price to maximize its profit. At stage 3, the two downstream firms compete in a homogeneous Cournot competition. We use backward introduction to get the sub-game perfect Nash equilibrium (SPNE) of this game.

The remainder of this paper is organized as follows. Section 2 presents some licensing models. Section 3 offers the optimal licensing strategy analysis. Section 4 provides the implications of consumer surplus and social welfare. Section 5 reconsiders the optimal licensing strategy after involving the concept of price discrimination on the intermediate goods. Section 6 concludes in this paper.

2. The Licensing Model

A model includes two downstream firms that conduct Cournot competition and one upstream firm to provide the intermediate good. Both downstream firms produce a homogeneous product and the inverse demand function that they face is $p = a - \sum q_i$, where p is the price of the product and q_i is the supply quantity of the ith downstream firm, $i = 1, 2$.

In the production process, we assume that (i) one unit of the final product needs one unit of the intermediate good as an input factor; (ii) the unit production cost of the intermediate good is zero; (iii) the unit price of the intermediate good is t; (iv) the production cost of final goods is c_i for the ith downstream firm. The SPNE for the fixed-fee licensing model is:

$$q_1^* = \frac{2a - 7c_1 + 5c_2}{12},\ q_2^* = \frac{2a + 5c_1 - 7c_2}{12},\ t^* = \frac{2a - c_1 - c_2}{4},$$

$$\pi_i^* = (q_i^*)^2, \text{ and } \pi_u^* = \frac{(2a - c_1 - c_2)^2}{24} \tag{1}$$

where $0 < c_i < a$, and subscript u stands for the case of the upstream firm. An outside patentee does not make anything in the product market, but can license a cost-reducing technology to downstream firms.

The first stage of the game is an outside patentee to decide the optimal licensing contract either as a fixed fee or a royalty rate. The downstream firm decides either to accept the contract or to reject the offer. In the second stage, the upstream firm decides the price of the intermediate good. In the third stage, two firms conduct Cournot competition.

2.1 Pre-Licensing

Assume that the initial unit production costs of two downstream firms are $c_1 = c_2 = c$. Substitute $c_1 = c_2 = c$ into Equation (1), and the profits for two downstream firms, the upstream firm, and the price for intermediate goods are:

$$\pi_i^P = \left(\frac{a - c}{6}\right)^2,\ \pi_u^P = \frac{(a - c)^2}{6} \text{ and } t^P = \frac{a - c}{2} \tag{2}$$

Here, the superscript "P" stands for the pre-licensing case.

2.2 After Licensing

We now consider two kinds of licensing methods: either a fixed fee or a royalty rate. The cost-reducing innovation held by the outsider patentee makes the licensee's unit production cost fall from c to c-ε, where parameter ε is defined as the innovation size and $\varepsilon > 0$. According to the definition of Wang (1998), if the innovation size is large enough, then a firm without a new technology will drop out of the market, i.e., the drastic innovation case. On the contrary, non-drastic innovation means that no firm drops out of market when the outside patentee only licenses to some of the firms.

2.2.1 Fixed-Fee Licensing Method

The outside patentee decides on whom to license the innovation by a contract in which the outside patentee offers innovation ε against a fixed fee to the downstream firm(s) by mode n, given the intermediate goods price t, where $n = E$ stands for the exclusive licensing case or $n = N$ stands for the non-exclusive licensing case.

Under the exclusive licensing case, we assume that the licensee is firm 1. Firm 1's unit production cost is c-ε, and firm 2's unit production cost is c. Substitute $c_1 = c - \varepsilon$ and $c_2 = c$ into Equation (1) and we obtain:

$$q_1^{FE} = \frac{2a-2c+7\varepsilon}{12},\ q_2^{FE} = \frac{2a-2c-5\varepsilon}{12},\ t^{FE} = \frac{2a-2c+\varepsilon}{4},$$

$$\pi_i^{FE} = (q_i^{FE})^2, \text{ and } \pi_u^{FE} = \frac{(2a-2c+\varepsilon)^2}{24} \tag{3}$$

where superscript "*FE*" stands for the fixed-fee contract under the exclusive licensing case. Under the non-drastic innovation, i.e., $0 \le \varepsilon \le (2/5)(a-c)$, $q_2^{FE} > 0$, the market structure is duopoly. Under the drastic innovation condition, i.e., $\varepsilon > (2/5)(a-c)$, $q_2^{FE} = 0$, the market structure is monopoly. The equilibrium solutions under the drastic innovation are:

$$q_m^{FE} = \frac{a-c+\varepsilon}{4},\ t_m^{FE} = \frac{a-c+\varepsilon}{2},\ \pi_m^{FE} = (q_m^{FE})^2, \text{ and } \pi_{um}^{FE} = \frac{(a-c+\varepsilon)^2}{8} \tag{4}$$

Subscript "*m*" stands for the drastic innovation case.

Under the non-exclusive licensing case, the outside patentee licenses to both firm 1 and firm 2. Firm 1 and firm 2's unit production costs are $c-\varepsilon$. Substitute $c_1 = c_2 = c-\varepsilon$ into Equation (1) and we obtain:

$$q_i^{FN} = \frac{a-c+\varepsilon}{6},\ t^{FN} = \frac{a-c+\varepsilon}{2},\ \pi_i^{FN} = (q_i^{FN})^2, \text{ and } \pi_u^{FN} = \frac{(a-c+\varepsilon)^2}{6} \tag{5}$$

where superscript "*FN*" stands for the fixed-fee contract under the non-exclusive licensing case.

At stage 1 of the game, the outside patentee decides the fixed licensing fee by comparing the change between pre-licensing profit and after-licensing profit. Define the symbol Ω as the licensing fee charged by the licensor, and we have:

$$\Omega^{FE} = \frac{28\varepsilon(a-c)+49\varepsilon^2}{144} \text{ if } 0 < \varepsilon \le \frac{2(a-c)}{5}, \text{ and} \tag{6a}$$

$$= \frac{5(a-c)^2+18\varepsilon(a-c)+9\varepsilon^2}{144} \text{ if } \varepsilon > \frac{2(a-c)}{5}. \text{ (Drastic innovation)} \tag{6b}$$

$$\Omega^{FN} = \frac{2\varepsilon(a-c)+\varepsilon^2}{36} \text{ for any } \varepsilon > 0. \tag{6c}$$

Under the fixed-fee licensing contract, we take into account whether or not the licensor should license to one firm or two firms. By comparing Equation (6a) and Equation (6c), we find $\Omega^{FE} - \Omega^{FN} = [20\varepsilon(a-c) + 45\varepsilon^2]/144 > 0$ when $\varepsilon \in (0, 2(a-c)/5)$. By comparing Equations (6b) and (6c), we obtain that $\Omega^{FE} - \Omega^{FN} = 5(a-c+\varepsilon)^2/144 > 0$ when $\varepsilon \in (2(a-c)/5, \infty)$.

Lemma 1 *Under the fixed-fee licensing method, the outside patentee prefers to license to only one firm instead of two firms.*

We can take an extreme example to illustrate the economic intuition of Lemma 1. When the innovation size is large enough and under the fixed-fee licensing method, the outside innovator prefers to only license to one firm and makes the licensee become a monopolist in the market. The outside patentee can then extract the licensee's monopoly profit by means of a fixed fee. On the contrary, if the outside patentee licenses to two firms, then it induces the market structure to become a duopoly. Traditional wisdom tells us that the duopoly profit is always smaller than the monopoly profit.

2.2.2 Royalty Licensing Method

The outside patentee provides the royalty licensing contract to the target firm. The outside patentee charges a royalty licensing fee for transferring a new innovation ε by mode *n*, given the price of the intermediate good *t*.

Under the exclusive licensing case, firm 1's (licensee's) unit production cost is $c-\varepsilon+r$, and firm 2's unit production cost is *c*, where symbol *r* stands for a royalty rate. Substitute $c_1 = c-\varepsilon+r$ and $c_2 = c$ into Equation (1) and solve the optimal royalty rate for the licensor as $r^{RE} = (a-c)/7 + \varepsilon/2$, where superscript "*RE*" stands for the royalty contract under the exclusive licensing case. Since $c_1 = c-\varepsilon+r^{RE} < c$ must hold, the condition that the licensor uses the optimal royalty rate $r^{RE} = (a-c)/7 + \varepsilon/2$ is $\varepsilon > (2/7)(a-c)$. We have equilibrium solutions as follows:

$$q_1^{RE} = \frac{2(a-c)+7\varepsilon}{24},\ q_2^{RE} = \frac{38(a-c)-35\varepsilon}{168},\ t^{RE} = \frac{26(a-c)+7\varepsilon}{56},$$

$$\pi_1^{RE} = \frac{(46a-46c+35\varepsilon)(2a-2c+7\varepsilon)}{2016},\ \pi_2^{RE} = \frac{(58a-58c-7\varepsilon)(38a-38c-35\varepsilon)}{14112},\ \text{and}$$

$$\pi_u^{RE} = \frac{(26a-26c+7\varepsilon)^2}{4704} \tag{7}$$

When $\varepsilon \in (0, (2/7)(a-c))$, the optimal royalty rate is a corner solution, i.e., $r^{RE} = \varepsilon$, which satisfies $c_1 = c - \varepsilon + r^{RE} \le c$. The equilibrium solutions are as follows:

$$q_i^{RE} = \frac{(a-c)}{6},\ t^{RE} = \frac{(a-c)}{2},\ \pi_i^{RE} = \frac{(a-c)^2}{9},\ \text{and}\ \pi_u^{RE} = \frac{(a-c)^2}{6} \tag{8}$$

Let q_2^{RE} in Equation (7) be zero to find the non-drastic innovation condition as $\varepsilon \le (38/35)(a-c)$, which induces a duopoly market structure. On the contrary, when $\varepsilon > (38/35)(a-c)$, the market structure is a monopoly. The equilibrium solutions under the monopoly market structure are:

$$q_m^{RE} = \frac{a-c+\varepsilon}{8},\ t_m^{RE} = \frac{a-c+\varepsilon}{4},\ \pi_m^{RE} = (q_m^{RE})^2,\ \text{and}\ \pi_{um}^{RE} = \frac{(a-c+\varepsilon)^2}{32} \tag{9}$$

Under the non-exclusive licensing case, the outside patentee licenses to both firm 1 and firm 2. Firm 1 and firm 2's unit production costs are $c - \varepsilon + r$. Substitute $c_1 = c_2 = c - \varepsilon + r$ into Equation (1) and we obtain:

$$q_i^{RN} = \frac{a-c+\varepsilon}{12},\ t^{RN} = \frac{a-c+\varepsilon}{4},\ \pi_i^{RN} = (q_i^{RN})^2,\ \text{and}\ \pi_u^{RN} = \frac{(a-c+\varepsilon)^2}{24} \tag{10}$$

where superscript "*RN*" stands for the royalty contract under the non-exclusive licensing case. The optimal royalty rate $r^{RN} = (a-c+\varepsilon)/2$ must satisfy $c_i = c - \varepsilon + r^{RN} < c$, and hence we obtain $\varepsilon > a - c$. On the contrary, when $\varepsilon \in (0, a-c)$, the optimal royalty rate $r^{RN} = \varepsilon$ satisfies $c_i = c - \varepsilon + r^{RN} \le c$. Substitute $c_1 = c_2 = c$ into Equation (1) and we obtain:

$$q_i^{RN} = \frac{a-c}{6},\ t^{RN} = \frac{a-c}{2},\ \pi_i^{RN} = (q_i^{RN})^2,\ \text{and}\ \pi_u^{RN} = \frac{(a-c)^2}{6} \tag{11}$$

At stage 1, the equilibrium licensing revenue for a licensor calculated by the formulations of rq_1 under the licensing mode E and $r(q_1 + q_2)$ under the licensing mode N is represented as follows:

$$\Omega^{RE} = \frac{\varepsilon(a-c)}{3}\ \text{if}\ 0 < \varepsilon \le \frac{2(a-c)}{7},\ \text{and}\ r^{RE} = \varepsilon \tag{12a}$$

$$= \frac{(2a-2c+7\varepsilon)^2}{336}\ \text{if}\ \frac{2(a-c)}{7} < \varepsilon \le \frac{38(a-c)}{35},\ \text{and}\ r^{RE} = \frac{(a-c)}{7}+\frac{\varepsilon}{2} \tag{12b}$$

$$= \frac{(a-c+\varepsilon)^2}{16}\ \text{if}\ \varepsilon > \frac{38(a-c)}{35},\ \text{and}\ r^{RE} = \frac{(a-c+\varepsilon)}{2}.\ \text{(Drastic innovation)} \tag{12c}$$

$$\Omega^{RN} = \frac{\varepsilon(a-c)}{3}\ \text{if}\ 0 < \varepsilon < (a-c),\ \text{and}\ r^{RN} = \varepsilon \tag{12d}$$

$$= \frac{(a-c+\varepsilon)^2}{12}\ \text{if}\ \varepsilon \ge (a-c),\ \text{and}\ r^{RN} = \frac{(a-c+\varepsilon)}{2} \tag{12e}$$

Under the royalty licensing contract, we want to find the optimal licensing strategy. By comparing four intervals of ε in Equation (12), i.e., $(0, (2/7)(a-c))$, $((2/7)(a-c), (a-c))$, $((a-c), (38/35)(a-c))$, and $((38/35)(a-c), \infty)$, we find the optimal licensing strategy for a licensor is to license to both firms. Hence, we have Lemma 2 as follows.

Lemma 2 *Under the royalty licensing method, the outside patentee prefers to license to both firms.*

Since the royalty fee equals the multiplication of the royalty rate and the licensee's output, we summarize two main reasons to illustrate the economic intuition of Lemma 2 as follows: i) one licensee's output is always less than two licensees' output, i.e., $q_1^{RE} < q_1^{RN} + q_2^{RN}$; ii) the licensor decides the royalty rate for maximizing the licensing revenue at Stage 1, and hence both the optimal royalty rate in the excluding licensing case and the optimal rate in the non-exclusion licensing case are appropriate, i.e., $r^{RE} \cong r^{RN}$. Based on the two reasons above, we conclude that the result of Lemma 2 mainly depends on the final goods' market output.

3. The Optimal Licensing Strategy for an Outside Patentee

3.1 The Performance of a Licensing Contract for an Outside Patentee

Based on the analysis in Section 2, we get an equilibrium result that the licensor would like to license to only one firm by means of a fixed fee and license to both firms by means of a royalty. We next want to decide the optimal licensing strategy for the licensor by comparing Equations (6a), (6b), (12d), and (12e). In three intervals, i.e., $(0, (2/5)(a - c))$, $((2/5)(a - c), (a - c))$, and $((a - c), \infty)$, we find the optimal licensing strategy for a licensor is to license to both firms by the royalty licensing method. Equations (12d) and (12e) represent the optimal licensing strategy for the licensor.

3.2 Decision-Making for a Licensee: Accept vs. Reject It

In this subsection we need to examine whether the licensee accepts or rejects the licensing contract provided by the outside patentee. We assume that if the licensee does not become worse after accepting a licensing contract, then it would like to accept the licensing contract.

According to Equations (12d) and (12e), when $\varepsilon \in (0, (a - c))$ with $r^{RN} = \varepsilon$, the licensee's profit is $\pi_i^{RN} = (a - c)^2/36 \geq \pi_i^P = (a - c)^2/36$. The licensee accepts the outside patentee's licensing offer. When $\varepsilon \in ((a - c), \infty)$ with $r^{RN} = (a - c + \varepsilon)/2$, the licensee's profit is $\pi_i^{RN} = (a - c + \varepsilon)^2/144 \geq \pi_i^P = (a - c)^2/36$. In this regime the licensee accepts the outside patentee's licensing offer. Hence, we conclude the optimal licensing strategy for the outside patentee as follows.

Proposition 1. *The royalty contract with non-exclusive licensing is an equilibrium licensing strategy for an outside patentee under vertically-related markets.*

The outside patentee's best licensing strategy is to license to both firms by royalties, because it benefits the licensor's licensing revenue by increasing the market's competitive degree. This finding is totally different from that of Kamien and Tauman (1986) in which the best licensing contract is to license to only one firm by a fixed fee when the licensor is an outside patentee. However, it is noteworthy that after we consider the intermediate goods firm in the model, the result of Kamien and Tauman (1986) reverses. The main reason is that the intermediate goods firm and the outside patentee commonly share the downstream firms' profits, and hence the outside patentee can induce the upstream firm to decrease the intermediate goods price by a royalty licensing contract in order to extract the intermediate goods firm's profit. We use a mathematical result to support our above explanation such as that $t^{RN} < t^{FE}$ with $r^{RN} = \varepsilon$ for $\varepsilon \in (0, (2/5)(a - c))$, $t^{RN} < t_m^{FE}$ with $r^{RN} = \varepsilon$ for $\varepsilon \in ((2/5)(a - c), (a - c))$ and $t^{RN} < t_m^{FE}$ with $r^{RN} = (a - c + \varepsilon)/2$ for $\varepsilon \in ((a - c), \infty)$.

Our conclusion is the same with Arya and Mittendorf (2006) in which an innovator in vertically-related markets does not prefer the fixed-fee licensing method, but the innovator in their model is an insider which is different from ours. The inside innovator in the model set-up of Arya and Mittendorf (2006) can obtain double marginalization gains when a fixed fee is adopted in conjunction with royalties, but the outside innovator in our model set-up can decrease the intermediate goods pricing for extracting the profit from the intermediate goods' supplier by a royalty licensing method. Our conclusion is also the same with Sandonis and Fauli-Oller (2006) in which an outside innovator does not prefer the fixed-fee licensing method, but their model does not include the intermediate goods' firm and the product market structure is a heterogeneous duopoly market.

4. Intermediate Goods Price, Consumer Surplus, and Social Welfare

We examine the intermediate goods price, consumer surplus, and social welfare under the optimal licensing strategy.

4.1 Intermediate Goods Price

Table 1 arranges the intermediate goods price and the royalty rate in equilibrium. Since the profits of the intermediate goods firm and the outside licensor are respectively calculated by $t^{RN}(\sum q_i^{RN})$ and $r^{RN}(\sum q_i^{RN})$, both of their profit sizes depend on the sizes of the intermediate goods price (t^{RN}) decided in stage 2 and the royalty rate (r^{RN}) decided in stage 1.

Table 1. Intermediate goods price and royalty rate in equilibrium

Interval / Item	Intermediate Goods Price (t^{RN})	Royalty Rate (r^{RN})
$\varepsilon \in (0, (a-c))$	$(a-c)/2$	ε
$\varepsilon \in ((a-c), \infty)$	$(a-c+\varepsilon)/4$	$(a-c+\varepsilon)/2$

When the innovation size is large enough, i.e., $\varepsilon \in ((a-c), \infty)$, the outside licensor has a first-mover advantage since $r^{RN} > t^{RN}$. However, when the innovation size is small, i.e., $\varepsilon \in (0, (a-c))$, the outside licensor may not have a first-mover advantage since there is an uncertain relationship between r^{RN} and t^{RN}. We take an extreme example to illustrate the economic intuition of the result. When the innovation size approaches to zero, the licensing revenue of the licensor also approaches to zero. However, the producer still needs to purchase the intermediate goods as an input factor. The price of the intermediate goods is charged by the upstream firm for maximizing its profit. Hence, we have proposition 2 as follows.

Proposition 2. *The licensor may not have a first-mover advantage when the innovation size is small.*

4.2 Consumer Surplus Analysis

Since the product is homogeneous in our model, consumer surplus can be calculated by $CS^j = (q_1^j + q_2^j)^2/2$, where superscript j represents the licensor's licensing strategy. The optimal licensing strategy in our model is the royalty licensing contract under the non-exclusive case, and many studies conclude that consumers like the fixed-fee licensing method under the non-exclusive case (Wang, 2002). Hence, we here compare the consumer surplus size between CS^{RN} and CS^{FN} as follows:

$$CS^{RN} = \frac{(a-c)^2}{18}, \text{ where } 0 < \varepsilon < (a-c) \tag{13a}$$

$$= \frac{(a-c+\varepsilon)^2}{72}, \text{ where } (a-c) < \varepsilon < \infty \tag{13b}$$

$$CS^{FN} = \frac{(a-c+\varepsilon)^2}{18}, \text{ where } 0 < \varepsilon < \infty \tag{13c}$$

It is easy to calculate and obtain the result that $CS^{RN} < CS^{FN}$ for all $\varepsilon > 0$. Hence, we conclude that the fixed-fee licensing contract induces a higher consumer surplus than the royalty licensing contract in the non-exclusive case. The reason is that the fixed-fee contract does not affect the licensee's marginal production cost. However, the royalty contract can increase the licensee's marginal production cost and then decrease the firm's output. Hence, the total quantity is greater under a fixed-fee contract with non-exclusive licensing than that under a royalty contract with non-exclusive licensing. This result is the same as that in Wang (2002).

4.3 Social Welfare Analysis

Since there is an inconsistent preference between the licensor that would like the royalty licensing contract with a non-exclusive case and the licensee that prefers the fixed-fee licensing contract with a non-exclusive case, we next need to examine the optimal social choice. The social welfare function in our model includes the consumer surplus, and the profits of the downstream firms, the upstream firm, and the outside patentee. We formulate the social welfare function under the licensing case as $S^j = CS^j + \sum_{i=1}^{2} \pi_i^j + \pi_u^j + \Omega^j$, however, the social welfare function under the pre-licensing case is $S^P = CS^P + \sum_{i=1}^{2} \pi_i^P + \pi_u^P$. Hence, we have:

$$S^{RN} = \frac{(a-c)(5a-5c+12\varepsilon)}{36}, \text{ where } 0 < \varepsilon < (a-c) \tag{14a}$$

$$= \frac{11(a-c+\varepsilon)^2}{72}, \text{ where } (a-c) < \varepsilon < \infty \tag{14b}$$

$$S^{FN} = \frac{5(a-c)^2 + 11(a-c)\varepsilon + \frac{11}{2}\varepsilon^2}{18}, \text{ where } \varepsilon > 0 \tag{14c}$$

$$S^P = \frac{5(a-c)^2}{18} \tag{14d}$$

By comparing the royalty licensing contract and the fixed-fee licensing contract under the non-exclusive case, it is easy to calculate and obtain the result that $S^{RN} < S^{FN}$ for all $\varepsilon > 0$. It shows that social welfare is higher under the fixed-fee licensing contract with the non-exclusive case than that under the royalty licensing contract with the non-exclusive case. However, Proposition 1 concludes that the optimal licensing method for the outside patentee is the royalty licensing contract with the non-exclusive case. Hence, we have the proposition as follows.

Proposition 3. *The licensor and the social planner have an inconsistent licensing preference. However, the social planner's and the consumer's licensing preferences are consistent.*

The reason for the inconsistent licensing preference between the licensor and the social planner is that the total output in the royalty licensing contract is lower than that in the fixed-fee licensing contract. This finding is supported by the evidence that $q_1^{RN} + q_2^{RN} = (a - c + \varepsilon)/6 < q_1^{FN} + q_2^{FN} = (a - c + \varepsilon)/3$ for $r^{RN} = (a - c + \varepsilon)/2$ and $q_1^{RN} + q_2^{RN} = (a - c)/3 < q_1^{FN} + q_2^{FN} = (a - c + \varepsilon)/3$ for $r^{RN} = \varepsilon$.

We next consider whether the technology licensing can increase social welfare by comparing S^{RN} and S^P, and we obtain $S^{RN} < S^P$ with $\varepsilon \in (0, (5/12)(a - c))$, and $S^{RN} > S^P$ with $\varepsilon \in ((5/12)(a - c), \infty)$. It shows that social welfare under the no licensing case may be high when the innovation size is small. Hence, we have a proposition as follows.

Proposition 4. *Technology licensing induces low social welfare when the innovation size is small.*

5. Price Discrimination on Intermediate Goods Pricing

The intermediate goods firm can adopt the price discrimination strategy on intermediate goods pricing when two downstream firms have a cost differentiation caused by an excluded licensing case. Hence, we reconsider here the licensor's optimal licensing strategy when the intermediate goods firm has an ability to take a discriminatory price.

5.1 Price Discrimination under a Fixed-Fee Contract with an Excluded Licensing Case

Because of an excluded licensing, the licensee's, i.e., firm 1, per unit production cost is $c_1 = c - \varepsilon + t_1$, and the non-licensee's, i.e., firm 2, per unit production cost is $c_2 = c + t_2$, where $t_1(t_2)$ is a discriminatory intermediate goods price charged on firm 1(2). By backward induction, we have the SPNE as follows:

$$q_1^{FE'} = \frac{a-c+\varepsilon}{6},\ q_2^{FE'} = \frac{a-c-\varepsilon}{6},\ t_1^{FE'} = \frac{a-c+\varepsilon}{2},\ t_2^{FE'} = \frac{a-c}{2},$$

$$\pi_i^{FE'} = (q_i^{FE'})^2, \text{ and } \pi_u^{FE'} = \frac{(a-c)^2 + (a-c+\varepsilon)\varepsilon}{6} \tag{15}$$

where $\varepsilon \in (0, (a - c))$ and superscript "FE'" stands for the fixed-fee contract with the exclusive licensing case under price discrimination. When $\varepsilon > (a - c)$, i.e., a drastic innovation, the SPNE is the same as that in Equation (4).

The equilibrium licensing revenue for the licensor calculated by the formulation of $\pi_1^{FE'} - \pi_1^P$ is represented as follows:

$$\Omega^{FE'} = \frac{\varepsilon(a-c+\varepsilon)}{9} \text{ if } 0 < \varepsilon \leq (a-c), \text{ and} \tag{16a}$$

$$= \frac{5(a-c)^2 + 18\varepsilon(a-c) + 9\varepsilon^2}{144} \text{ if } \varepsilon > (a-c). \text{ (Drastic innovation)} \tag{16b}$$

5.2 Price Discrimination under a Royalty Contract with an Excluded Licensing Case

Under the royalty licensing method, firm 1's per unit production cost is $c_1 = c - \varepsilon + t_1 + r$, and firm 2's per unit production cost is $c_2 = c + t_2$. According to the calculated result, the optimal royalty rate for the licensor is $r^{RE'} = (a - c + 2\varepsilon)/4$, and the SPNE for firm 2's output in this regime is $q_2^{RE'} = (5a - 5c - 2\varepsilon)/24$, where superscript "$RE'$" stands for the royalty contract with the exclusive licensing case under price discrimination.

Let $q_2^{RE'} \geq 0$, and the non-drastic innovation condition is $\varepsilon \leq (5/2)(a - c)$. Here, $r^{RE'}$ must satisfy the condition for $c_1 = c - \varepsilon + t_1 + r \leq c$, and hence we have $\varepsilon \geq (5/2)(a - c)$ which violates the non-drastic innovation condition. It implies that under the duopoly market structure, the optimal royalty rate is not $r^{RE'} = (a - c + 2\varepsilon)/4$ instead of a corner solution, i.e., $r^{RE'} = \varepsilon$. Hence, we have the SPNE under the duopoly market structure as follows:

$$q_i^{RE'} = \frac{a-c}{6},\ t_i^{RE'} = \frac{a-c}{2},\ \pi_1^{RE'} = \frac{(a-c)^2}{36},\ \pi_2^{RE'} = \frac{7(a-c)^2}{36} \text{ and } \pi_u^{RE'} = \frac{(a-c)^2}{6} \tag{17}$$

Traditional wisdom tells us the intermediate goods firm will charge a high (low) price to a low (high) cost firm. This conclusion is also confirmed in Equation (15) in our paper, i.e., $t_1^{FE'} > t_2^{FE'}$.

If $\varepsilon > (5/2)(a - c)$, and the licensor only licenses to one firm, then the market structure will become a monopoly. The SPNE for the drastic innovation in this regime is the same as that in Equation (9).

The equilibrium licensing revenue for the licensor is calculated by the formulation of $r^{RE'}q_1^{RE'}$ and is represented as follows:

$$\Omega^{RE'} = \frac{\varepsilon(a-c)}{6} \text{ for } \varepsilon \in (0,\ (5/2)(a-c)),\text{ and } r^{RE'} = \varepsilon \tag{18a}$$

$$= \frac{(a-c+\varepsilon)^2}{16} \text{ for } \varepsilon \in ((5/2)(a-c),\ \infty),\text{ and } r^{RE'} = \frac{(a-c+\varepsilon)}{2}.\ \text{(Drastic innovation)} \tag{18b}$$

5.3 The Optimal Licensing Strategy after Considering a Price Discrimination Regime

By comparing Equations (16) and (18), we obtain the optimal licensing strategy in a price discrimination regime as follows:

$$\Omega^{RE'} = \frac{\varepsilon(a-c)}{6} \text{ if } 0 < \varepsilon \le (a-c)/2,\text{ and } r^{RE'} = \varepsilon \tag{19a}$$

$$\Omega^{FE'} = \frac{\varepsilon(a-c+\varepsilon)}{9} \text{ if } (a-c)/2 < \varepsilon \le (a-c) \tag{19b}$$

$$= \frac{5(a-c)^2 + 18\varepsilon(a-c) + 9\varepsilon^2}{144} \text{ if } (a-c) < \varepsilon \le (5/2)(a-c),\ \text{(Drastic innovation)} \tag{19c}$$

$$\Omega^{RE'} = \frac{(a-c+\varepsilon)^2}{16} \text{ if } \varepsilon > (5/2)(a-c),\text{ and } r^{RE'} = \frac{(a-c+\varepsilon)}{2}.\ \text{(Drastic innovation)} \tag{19d}$$

We now consider the optimal licensing strategy after considering a price discrimination regime by comparing Equation (19) and Equations (12d) and (12e). By a simple calculation, we find Ω^{RN} is always larger than $\Omega^{RE'}$ for every $\varepsilon \in (0, \infty)$. The result shows that the outside licensor prefers a royalty contract with a non-excluded licensing case instead of an excluded licensing contract in which the intermediate goods firm has price discrimination ability. The reason is that the licensor and the upstream firm commonly share the downstream firm's excess profit. If the upstream firm has price discrimination ability on the intermediate goods, then it will crowd out the profit that the licensor can obtain from the licensee. Hence, we have a proposition as follows.

Proposition 5 *In vertically-related markets, the outside licensor would like the intermediate goods firm to adopt uniform pricing instead of a discriminatory price.*

6. Concluding Remarks

Our model includes an upstream firm which provides the intermediate goods to two homogeneous downstream firms, and an outside patentee with a new production technology that chooses the optimal licensing strategy by means of either a royalty or a fixed fee for maximizing its licensing revenue. The paper most related to our study is Kamien and Tauman (1986) in which their model does not consider the vertically-related market. The main result in this paper is very different from Kamien and Tauman (1986) in which the outside innovator prefers a fixed-fee licensing contract instead of a royalty licensing contract. After involving vertically-related markets in the model of Kamien and Tauman (1986), we get an inverse result that the outside innovator's optimal licensing contract is by means of royalties instead of a fixed fee.

The implications of consumer surplus and social welfare are also important in the firm's optimal licensing behavior. We find there is an inconsistent licensing preference between the consumers and the licensor, and between the social planner and the licensor. The consumers and the social planner prefer a fixed-fee licensing contract, however, an outside patentee prefers a royalty licensing contract. Most importantly, given the firm's optimal licensing behavior, there will be low social welfare after licensing when the innovation size is small.

Under the optimal licensing strategy, the licensor first decides the optimal royalty rate, and then the upstream firm chooses the optimal intermediate goods price. However, the optimal royalty rate is not necessarily higher than the optimal intermediate goods price when the innovation size is small. Hence, we conclude that the licensor may not have a first-mover advantage when the innovation size is small. Finally, we reconsider the optimal licensing strategy after extending the assumption that the intermediate goods firm has price discrimination ability. However, the equilibrium licensing strategy does not change. Since the licensor and the intermediate goods firm commonly share the downstream firms' excess profit, and the discriminatory price on the intermediate goods can increase the upstream firm's profit and then crowds out the licensor's profit, the licensor must not adopt a licensing strategy that lets the intermediate goods firm have an opportunity to realize the discriminatory price.

Acknowledgements

The authors appreciate financial support from Taiwan's National Science Council (NSC 101-2410-H-424 -012 and NSC99-2410-H-009-063).

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