國立交通大學

經營管理研究所

碩 士 論 文

上游獨占下之外部授權者的最適授權策略

The Optimal Licensing Strategy of an Outsider Patentee under

the Single Upstream Supplier

研 究 生：林錦宏

指導教授：胡均立 教授

中 華 民 國 九 十 八 年 五 月

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摘要

本論文探討加入上游獨占廠商後，對外部授權者授權策略的影響。我們建立一個模型，其中包含了單一外部授權者、提供中間財的獨占上游廠商以及兩個進行數量競爭的下游廠商。隨後我們比較外部授權者透過單位權利金和固定權利金所獲得的利潤，結果我們發現不論是在非劇烈創新和激烈創新下，單位權利金是外部授權者的最適策略。這與 Kamien 和 Tauman (1986)在無上游供應商模型下所提出的論點不同，他們推論固定權利金才是外部授權者的最佳策略。除此之外，透過單位權利金可以影響上游廠商對中間財的定價以及削弱上游廠商的議價能力。

關鍵詞：授權、單位權利金、固定權利金、Cournot 競爭

The Optimal Licensing Strategy of an Outsider Patentee under the Single Upstream Supplier

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Abstract

This thesis examines the impact of incorporating an upstream supplier to the outsider patentee's licensing decision. The basic model includes an outsider patent holder, an upstream supplier providing the intermediate good, and two downstream firms competing in quantity. The outsider patentee can receive profits by means of either fixed fee licensing or royalty licensing. The optimal licensing for the outsider patentee is royalties in both drastic and non-drastic innovation cases. This result compares to Kamien and Tauman (1986) in which without an upstream supplier a fixed fee is always the optimal licensing strategy for an outsider patentee. Besides, the royalty licensing can affectively affect the price setting on the intermediate good, which weakening bargaining power of the upstream supplier.

Keywords: Licensing, Royalty, Fixed Fee, Cournot Competition

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能順利完成論文，首先我要感謝指導教授胡均立老師開了賽局論，這門課除了使我見識到賽局的魅力外，更讓我有這個能力來完成本篇文章的推導過程；也感謝老師讓我自行選擇研究題目，並且在旁提醒與協助。另外，也感謝張民忠老師在授權議題上的建議與指導，讓我在模型的建構上更有想法。也承蒙口試委員楊雅博老師和曾芳代老師對於本論文的諸多建議，讓本篇論文可以更加完善。

其次，我要感謝我的家人，謝謝他們的陪伴與支持，並且讓我有這個機會在交大專心完成學業。最後，感謝這兩年陪我運動打球的學長、同學和學弟妹，讓我可以遺忘論文寫不出來時的痛苦與煩悶。在研究所的歲月中，感謝大家的幫助讓我可以完成六月畢業的美夢。謹以此論文獻給所有敬愛的師長、家人、同學、學弟妹，謝謝你們！

林錦宏 謹誌

中華民國九十八年 六月

Table of Contents

List of Figures

1. Introduction

Although R&D is a powerful means to grow the corporations, it not only takes much money and time but also faces vast risks. For many companies, they do not have budget to invest in R&D; therefore, they adopt the paten licensing. Patent licensing has been a very popular strategy for corporations in almost all industries recently. Through licensing, the licensee can acquire the external knowledge to improve their technology. On the other hand, the innovator (patentee) can earn the rent; furthermore, patent licensing is also a way to transform proprietary technology into an industry standard. Consequently, the patent licensing has become a growing business, and the revenue is estimated more than $100 billion annually in the US (Kline, 2003).

There is vast literature focusing on the optimal licensing decision by the patentee. The formal analysis on the profit of the patentee through the licensing innovations that reduce the production costs can be traced back to Arrow (1962). Afterwards, many papers showed up and various situations have been discussed to infer different results. For example, they analyze the patentee, who may be an outsider or an insider, and the firms compete in quantities or price. Therefore, we can classify the early literature into four cases. The first case considers the outsider patentee with Cournot competition. Kamien and Tauman (1986) showed that licensing by means of a fixed fee is superior to that by means of a royalty for both the paten holder and consumers. The second case considers the outsider patentee with Bertrand competition. Muto (1993) considered licensing policies under price competition in a duopoly model with differentiated goods, demonstrating that a royalty is superior to a fixed fee and auction when innovations are not large. Poddar and Sinha (2004) introduced a spatial framework, considering the Hotelling's linear city model, and showed that the royalty is always better than auction and the fixed fee for the patentee in both drastic and non-drastic innovation. In contrast to the outsider cases, the following cases consider the insider patentee. The third case considers the insider patentee with Cournot competition. Wang (1998) found that the patent-holding firm licenses by means of royalty when innovation is non-drastic, and chooses to be monopoly when innovation is drastic. The last case considers the insider patentee with Bertrand competition. Wang and Yang (1999) showed that royalty licensing is better than fixed fee licensing for the patent-holding firm, irrespective that the innovation is drastic or non-drastic. Poddar and Sinha (2004) found that the patent-holding firm offers no license when the innovation is drastic, while licenses by means of royalty when the innovation is non-drastic.

However, only few papers consider the outsourcing. Arya and Mittendorf (2006) considered the impact of outsourcing on the decision to license. They built the model including one supplier that provides the intermediate good, and two firms in homogeneous-good Cournot competition, where one of the firms has a cost-reducing innovation. Arya and Mittendorf (2006) found that the paten-holding firm prefers royalty licensing to fixed fee licensing when the innovation is drastic. Therefore, we introduce the single supplier idea into our model. We built the model which includes the single upstream supplier, an outsider patentee, and two downstream firms competing in quantity.

In this article, we consider the game that consists of three stages. In the first stage, the outsider patentee will decide the fixed licensing fee or the royalty rate. In the second stage, the suppler will set the price of intermediate good to maximize his profit. In the last stage, the two firms compete in qualities. We analyze the game with backward induction. Figure 1 shows the game tree.

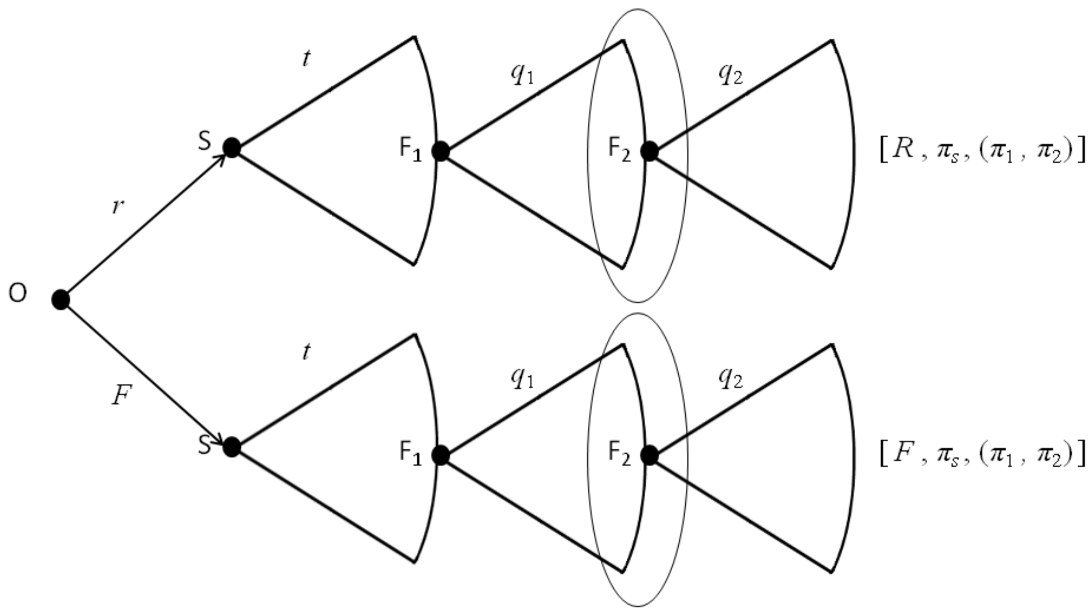

Figure 1 Game tree

In the following sections, section 2 describes the benchmark model that only considers the single upstream suppler and the two firms in the downstream. Next, we will introduce the outsider patentee in the model in section 3; furthermore, we will discuss the two cases: non-drastic innovation and drastic innovation. Finally, we will discuss the result in section 4.

2. Benchmark Model

In the section, we only consider the downstream firms and the upstream supplier. There are two firms playing Cournot competition and one supplier providing the intermediate good in the model. Both firms produce the homogeneous product and face the consumer (inverse) demand function $p = a - Q$, where p and Q are the price and the quantity of the product, respectively.

To make the product, the firms require an intermediate good that is provided by the single supplier. We assume: (1) one unit of the final product requires one unit of the intermediate good, (2) the unit cost of the intermediate good is zero, and (3) the supplier sets its per unit price of the intermediate good at t. Furthermore, we assume the unspecified constant unit production cost of c_1 $(0 < c_1 < a)$ and c_2 $(0 < c_2 < a)$ for firm 1 and firm 2, respectively. The c_1 (c_2) will change after firm 1 (2) acquiring the new innovation through licensing. Throughout this study, subscripts 1, 2 and s denote firm 1, firm 2 and supplier, respectively.

The two firms' profit functions are represented as follows:

$$\pi_1 = [a - (q_1 + q_2) - c_1 - t]q_1$$

$$\pi_2 = [a - (q_1 + q_2) - c_2 - t]q_2 \qquad (1)$$

We can choose q_1 (q_2) to maximize π_1 (π_2) and yield firm 1's (2's) quantity-reaction function. Solving the intersection of the reaction functions:

$$q_1 = \frac{a - 2c_1 + c_2 - t}{3} \text{ and } q_2 = \frac{a + c_1 - 2c_2 - t}{3}. \tag{2}$$

According to the two firms' quantities, the supplier sets the prices to maximize his profit, solving:

$$max_t(q_1 + q_2)t. \tag{3}$$

The first-order condition of (3) with respect to t yields the supplier's prices:

$$t^* = \frac{2a - c_1 - c_2}{4}. \tag{4}$$

Subsequently, we substitute the prices into (1) and (2), yielding the product quantities and profits of firms, equal:

$$q_1^* = \frac{2a - 7c_1 + 5c_2}{12} \text{ and } q_2^* = \frac{2a + 5c_1 - 7c_2}{12} \tag{5}$$

$$\pi_1^* = \frac{(2a - 7c_1 + 5c_2)^2}{144} \text{ and } \pi_2^* = \frac{(2a + 5c_1 - 7c_2)^2}{144} \tag{6}$$

If the unit production costs of both firms are equal *c*, the equilibrium quantity and profit of the firms are $q_c = \frac{a-c}{6}$ and $\pi_c = \frac{(a-c)^2}{36}$. In addition, the supplier will set the price $t_c = \frac{a-c}{2}$ and receive the profit $\pi_s^c = \frac{(a-c)^2}{6}$.

3. The strategy of the outsider patentee

We now assume the two firms have the same old technology, and the unit production cost equals *c*. An outsider patentee has a cost reducing innovation, which can reduce the unit production cost by $\varepsilon > 0$. In the section, we will consider two cases: drastic innovation and non-drastic innovation, which depend on the magnitude of the innovation. According to Wang's (1998) definition that a drastic innovation is one firm with new technology will become a monopoly. In other words, the innovation is drastic if one firm that buys the new technology becomes monopoly, while the unlicensed firm produces nothing and drops out of the market. As a result, we can verify that if the innovation is drastic when $\varepsilon \geq \frac{2(a-c)}{5}$, and the innovation is non-drastic when $0 < \varepsilon < \frac{2(a-c)}{5}$.

3.1 Non-Drastic innovation case

First of all, we consider the non-drastic innovation case. Figure 2 illustrates the decision tree of the outsider patentee that can choose to license the new technology to the firms by means of fixed fee or royalty. Furthermore, the outsider patentee can decide to issue exclusive licensing or non-exclusive licensing in each means.

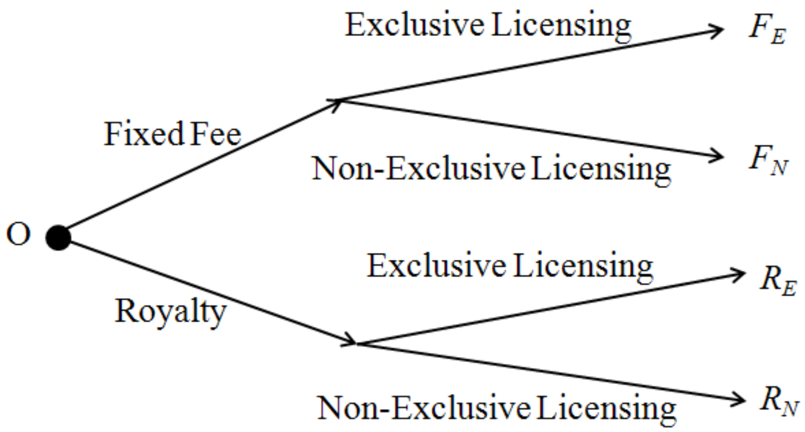

Figure 2 The decision tree of the outsider patentee

3.1.1 Fixed Fee

(i) Exclusive Licensing

Firstly, we consider the case that the outsider patentee decides to license a new technology to one of downstream firms by fixed fee. Subsequently, the supplier decides the prices of the intermediate good for the licensee and the non-licensee. The unit production cost of licensee is $c-\varepsilon$, and the non-licensee is c. We substitute the costs into (5) and (6), yielding:

$$q_E^F=\frac{2a-2c+7\varepsilon}{12} \text{ and } q^{NF}=\frac{2a-2c-5\varepsilon}{12}, \tag{7}$$

$$\pi_E^F=\frac{(2a-2c+7\varepsilon)^2}{144} \text{ and } \pi^{NF}=\frac{(2a-2c-5\varepsilon)^2}{144}. \tag{8}$$

Subscripts F denotes the licensee by the means of fixed fee and NF denotes the non-licensee in the fixed fee contract. Subscript E denotes the exclusive licensing case. We can find that acceptance is the dominant strategy for the firms when $\pi_E^F-F_E$ is at least as good as π_c. F_E is the license fee that the outsider patentee charge.

In the stage 2, the supplier chooses the prices for the intermediate goods to maximize his profit; as a result, the price and the profit are given by:

$$t_E^F = \frac{2a - 2c + \varepsilon}{4}, \tag{9}$$

$$\pi_{s_E}^{F} = \frac{(2a - 2c + \varepsilon)^2}{24}. \tag{10}$$

Comparing t_E^F and t_c shows that the supplier increases the price for the licensee since the average of the production cost decreasing by the licensing. Besides, the supplier can receive more profit since the output quantity is increased.

In the stage 1, the outsider patentee will charge the license fee, which is the difference in the profits of the licensee and π_c:

$$F_E = \pi_E^F - \pi_c = \frac{28\varepsilon(a - c) + 49\varepsilon^2}{144}. \tag{11}$$

(ii) Non-Exclusive Licensing

Next, we consider the outsider patentee decides to license the new technology to both firms by fixed fee l. Their unit production costs equal $c - \varepsilon$; meanwhile, we substitute it into (5) and (6), yielding :

$$q_N^F = q_1 = q_2 = \frac{a - c + \varepsilon}{6}, \tag{12}$$

$$\pi_N^F = \pi_1 = \pi_2 = \frac{(a - c + \varepsilon)^2}{36}. \tag{13}$$

Subscript N denotes the non-exclusive licensing case. Similarly, both firms will accept the license when π_N^F minus the license fee is at least as good as π_c.

In the stage 2, the supplier chooses the price for the intermediate goods to maximize his profit; as a result, the prices and the profit are given by:

$$t_N^F = \frac{a-c+\varepsilon}{2}, \tag{14}$$

$$\pi_{s_N}^{F} = \frac{(a-c+\varepsilon)^2}{6}. \tag{15}$$

Comparing t_N^F and t_c, it also shows that the supplier increases the price since the average of the production cost decreasing by the licensing and receives more profit than that under no license since the total quantity in the market increases. Comparing the conditions between exclusive and non-exclusive licensing, it shows that the supplier will offer the higher price and obtain more profit when the outsider patentee licenses the new technology to both firms. If the two downstream firms are licensed, then the output quantities in the market and the derived demand in the intermediate good are more than that under one licensed firm. Therefore, the supplier is pleasure to see that the outsider patentee licenses the innovation to both firms.

In the stage 1, the outsider patentee will charge the license fee, which is the difference in the profits of the licensee and π_c:

$$F_N = 2(\pi_N^F - \pi_c) = \frac{2\varepsilon(a-c)+\varepsilon^2}{18} \tag{16}$$

Comparing (11) and(16), we can prove that F_E is lager than F_N. As a result, we can show the proposition.

Proposition 1. Under the fixed-fee licensing and a non-drastic innovation case, the outsider patentee will license to only one downstream firm.

When the outsider patentee licenses to single firm, the firm can obtain more revenue than that under non-exclusive licensing case. In other words, the cost-reducing innovation can make the licensed firm obtain more competitive advantage. Therefore, the difference in the revenue of the licensed firm and the orange revenue, π_c, is lager. That is the reason why the outsider patentee chooses to license the innovation to single firm. Indeed, it benefits not only the outsider patentee but also the licensed firm in the exclusive licensing case.

3.1.2 Royalty

(i) Exclusive Licensing

First of all, we consider the case that the outsider patentee decides to license one downstream firm under royalty (r) per unit of production. The unit production cost of licensee is $c - \varepsilon + r$, and the non-licensee is c. Then, we substitute it into (5) and (6), yielding:

$$q_E^R = \frac{2a - 2c + 7\varepsilon - 7r}{12} \ and \ q^{NR} = \frac{2a - 2c - 5\varepsilon + 5r}{12}, \qquad (17)$$

$$\pi_E^R = \frac{(2a-2c+7\varepsilon-7r)^2}{144} \; and \; \pi^{NR} = \frac{(2a-2c-5\varepsilon+5r)^2}{144}. \qquad (18)$$

Subscript R denotes the licensee by the means of royalty and NR denotes the non-licensee in the royalty contract.

In the stage 2, the supplier sets the price for the intermediate goods to maximize his profit:

$$t_E^R = \frac{2a-2c+\varepsilon-r}{4}. \qquad (19)$$

In the stage 1, the outsider patentee sets the royalty to maximize his profit, solving:

$$\max_{0<r\leq\varepsilon} r q_E^R \qquad (20)$$

The outsider patentee will choose $r = \varepsilon$; consequently, the equilibrium qualities and profits of both firms are given by:

$$q_E^R = \frac{a-c}{6} \; and \; q^{NR} = \frac{a-c}{6}, \qquad (21)$$

$$\pi_E^R = \frac{(a-c)^2}{36} \; and \; \pi^{NR} = \frac{(a-c)^2}{36}. \qquad (22)$$

Subsequently, we substitute $r = \varepsilon$ into (19) to yield the prices of the intermediate goods, and obtain the profit of the supplier:

$$t_E^R = \frac{a-c}{2}, \qquad (23)$$

$$\pi_{s_E}{}^R = \frac{(a-c)^2}{6}. \qquad (24)$$

It is obvious that the supplier will keep the same price since the royalty equals the product-reducing cost to cause the production cost remains the same.

Consequently, the qualities of output remain the same and the supplier receives the same revenue.

Finally, we substitute $r = \varepsilon$ into (20) to yield the revenue of the outsider patentee:

$$R_E = \frac{\varepsilon(a-c)}{6}. \tag{25}$$

(ii) Non-exclusive Licensing

Next, we consider the outsider patentee decides to license both downstream firms under a royalty (r); therefore, their unit production cost equals $c - \varepsilon + r$. We substitute it into (5) and (6), yielding:

$$q_N^R = q_1 = q_2 = \frac{a-c+\varepsilon-r}{6}, \tag{26}$$

$$\pi_N^R = \pi_1 = \pi_2 = \frac{(a-c+\varepsilon-r)^2}{36}. \tag{27}$$

In the stage 2, the supplier sets the price for the intermediate goods to maximize his profit:

$$t_N^R = \frac{a-c+\varepsilon-r}{2}. \tag{28}$$

In the stage 1, the outsider patentee sets the royalty to maximize his profit, solving:

$$\max_{0<r\leq\varepsilon} 2rq_N^R \tag{29}$$

Consequently, the outsider patentee will choose $r = \varepsilon$ to maximize the revenue. The equilibrium quantities and profits of both firms are given by:

$$q_N^R = \frac{a-c}{6} \ and \ \pi_N^R = \frac{(a-c)^2}{36}. \quad (30)$$

We then substitute $r = \varepsilon$ into (28) to yield the prices of the intermediate goods, and obtain the profit of the supplier:

$$t_N^R = \frac{a-c}{2} \ and \ \pi_{s_N}^{\ R} = \frac{(a-c)^2}{6}. \quad (31)$$

Similarly, since the royalty equals the product-reducing cost, the supplier will keep the same price. As a result, the qualities of output remain the same and the supplier receives the same revenue.

Finally, we substitute $r = \varepsilon$ into (29) to yield the revenue of the outsider patentee:

$$R_N = \frac{\varepsilon(a-c)}{3}. \quad (32)$$

Comparing (25) and (32), it shows that R_N is larger than R_E under the non-drastic innovation case. The reason is that the production cost can affect the supplier on price setting. When the outsider patentee make r remains at ε, the production cost also remains the same and the supplier can not change the price. Thus, the firms produce the same quantities under the exclusive licensing case and the non-exclusive licensing case. When the outsider patentee licenses the innovation to both firms, he can obtain double revenue. Indeed, we can show the proposition.

Proposition 2. Under royalty licensing and the non-drastic innovation case, it is better for the outsider patentee to license to both downstream firms.

Summarizing the revenues of the outsider patentee in non-drastic innovation case, it is demonstrated that licensing by means of royalty is better than means of fixed fee. Consequently, we can have the proposition.

Proposition 3. Under non-drastic innovation case, licensing the new technology to both firms by means of royalty is better for the outsider patentee.

When the outsider patentee licenses by means of royalty, the outsider patentee can weaken the supplier's advantage. The reason is that royalty affects the production cost. Thus, the price strategy of the supplier also can be affected by the royalty. When the outsider patentee sets the r at ε, the supplier can not change the price of the intermediate good and the production cost keeps the same. As a result, the outsider patentee can obtain all the benefits caused by the innovation.

3.2 Drastic innovation case

Similarly, we use the same idea to discuss the conditions in the drastic innovation case. Firstly, we discuss the means of fixed fee in exclusive licensing and non-exclusive licensing conditions. Second, we discuss the means of royalty in the same way.

3.2.1 Fixed Fee

(i) Exclusive Licensing

First of all, we consider that the outsider patentee decides to license the new technology to one of the firms by fixed fee licensing. The unit production cost of the licensee is $c-\varepsilon$, while the non-licensee drops out of the market. Therefore, we solve the monopoly problem, yielding the equilibrium quantity and the profit of the licensee:

$$q_E^F = \frac{a-c+\varepsilon}{4}, \tag{33}$$

$$\pi_E^F = \frac{(a-c+\varepsilon)^2}{16}. \tag{34}$$

Subsequently, the supplier sets the price of the intermediate good to maximize his profit:

$$t_E^F = \frac{a-c+\varepsilon}{2}, \tag{35}$$

$$\pi_{s_E}^F = \frac{(a-c+\varepsilon)^2}{8}. \tag{36}$$

It is obvious that the supplier will increase the price since the average of the production cost of the firm decrease. In other words, the supplier increases the price to compete with the outsider patentee.

In the first stage, the outsider patentee will set the fixed fee. For the drastic innovation, the licensee will accept the fee that is less than his profit. Hence, the outsider patentee will charge all the profit of the licensee:

$$F_E = \pi_E^F = \frac{(a-c+\varepsilon)^2}{16}. \tag{37}$$

(ii)Non-Exclusive Licensing

Next, we consider that the patentee decides to license the new technology to the two firms by fixed fee licensing; therefore, their unit production costs equal $c-\varepsilon$. We substitute it into (5) and (6), yielding:

$$q_N^F = q_1 = q_2 = \frac{a-c+\varepsilon}{6}, \tag{38}$$

$$\pi_N^F = \pi_1 = \pi_2 = \frac{(a-c+\varepsilon)^2}{36}. \tag{39}$$

According to qualities of the firms, the supplier will set the price of the intermediate good to maximize his profit:

$$t_N^F = \frac{a-c+\varepsilon}{2}, \tag{40}$$

$$\pi_{s_N}^F = \frac{(a-c+\varepsilon)^2}{6}. \tag{41}$$

It also shows that the supplier increases the price contrast with t_c. The total output also increases under both firms obtaining the innovation; thus, the supplier will receive more profit than π_s^c. Comparing (36) and (41), we can find that the supplier will receive more revenue when the outsider patentee licenses the innovation to both firms. The reason is that the firm produces less output as monopoly; that is, the total output increases when the outsider patentee licenses the innovation to both firms. Besides, the supplier sets the same price in both exclusive and non-exclusive licensing cases. As a result, the supplier obtains more revenue when the both downstream firms acquire the innovation.

Similarly, the outsider patentee will charge all of the profits from both firms:

$$F_N = 2\pi_N^F = \frac{(a-c+\varepsilon)^2}{18}. \tag{42}$$

Comparing (37) and (42), it shows that F_E is larger than F_N. The reason is that the revenue of the outsider patentee equals the profit of the firms. It is obvious that the monopoly can obtain most revenue; thus, the outsider patentee chooses to license the drastic innovation to one firm. Therefore, we have the following proposition:

Proposition 4. Under the fixed-fee licensing and a drastic innovation case, the outsider patentee will license to only one firm.

3.2.2 Royalty

(i) Exclusive Licensing

Firstly, we consider the case that the outsider patentee chooses to license the new technology to one firm under royalty (r) per unit of production. The unit production cost of licensee equals $c-\varepsilon+r$, while the non-licensee drops out of the market. We can solve it as a monopoly problem, yielding the quantities and the profits of the licensee:

$$q_E^R = \frac{a-c+\varepsilon-r}{4}, \tag{43}$$

$$\pi_E^R = \frac{(a-c+\varepsilon-r)^2}{16}. \tag{44}$$

In the stage 2, the supplier sets the price of the intermediate good to maximize his profit:

$$t_E^R = \frac{a-c+\varepsilon-r}{2}. \tag{45}$$

In the stage 1, the outsider patentee sets the royalty rate in order to maximize the revenue:

$$\max_r r q_E^R \tag{46}$$

Since the royalty rate is restricted, $r \le \varepsilon$, the maximum is attained at

$$r^* = \min\left[\frac{a-c+2\varepsilon}{4}, \varepsilon\right]. \tag{47}$$

The outsider will choose $r = \varepsilon$ when $\frac{2(a-c)}{5} \le \varepsilon \le (a-c)$. We substitute it into (43) and (44), yielding:

$$q_E^R = \frac{a-c}{4}, \tag{48}$$

$$\pi_E^R = \frac{(a-c)^2}{16}. \tag{49}$$

Subsequently, we substitute $r = \varepsilon$ into (45) to yield the price of the intermediate goods and obtain the profit of the supplier:

$$t_E^R = \frac{a-c}{2}, \tag{50}$$

$$\pi_{s_E}^R = \frac{(a-c)^2}{8}. \tag{51}$$

We can find that the suppler obtains less profit than π_s^c since the total output decreases when the firm is monopoly and he keeps the same price of the intermediate good.

Consequently, the outsider patentee will obtain the revenue:

$$R_E = \frac{\varepsilon(a-c)^2}{4}. \tag{52}$$

On the other hand, the outsider will choose $r = \frac{a-c+\varepsilon}{2}$ when $(a-c) < \varepsilon$. We substitute it into (43) and (44), yielding:

$$q_E^R = \frac{a-c+\varepsilon}{8}, \tag{53}$$

$$\pi_E^R = \frac{(a-c+\varepsilon)^2}{64}. \tag{54}$$

We then substitute $r = \frac{a-c+\varepsilon}{2}$ into (45) to yield the price of the intermediate goods and obtain the profit of the supplier:

$$t_E^R = \frac{a-c+\varepsilon}{4}, \tag{55}$$

$$\pi_{s_E}^R = \frac{(a-c+\varepsilon)^2}{32}. \tag{56}$$

Consequently, the outsider patentee will obtain the revenue:

$$R_E = \frac{(a-c+\varepsilon)^2}{16}. \tag{57}$$

(ii) Non-Exclusive Licensing

Next, we consider the outsider patentee chooses to license two firms under a royalty (r); hence, the both firms' unit production costs equal $c-\varepsilon+r$. We substitute it into (5) and (6), yielding the quantities and the profits of the both firms:

$$q_N^R = q_1 = q_2 = \frac{a-c+\varepsilon-r}{6}, \tag{58}$$

$$\pi_N^R = \pi_1 = \pi_2 = \frac{(a-c+\varepsilon-r)^2}{36}. \tag{59}$$

In the stage 2, the supplier sets the price of the intermediate good to maximize his profit:

$$t_N^R = \frac{a-c+\varepsilon-r}{2}. \tag{60}$$

In the stage 1, the outsider patentee sets the royalty rate to maximize the revenue, solving:

$$\max_r 2rq_N^R \tag{61}$$

Since the royalty rate is restricted, $r \leq \varepsilon$, the maximum is attained at

$$r^* = \min[\frac{a-c+\varepsilon}{2}, \varepsilon]. \tag{62}$$

The outsider will choose $r = \varepsilon$ when $\frac{2(a-c)}{5} \leq \varepsilon \leq (a-c)$. We then substitute it into (58) and (59), yielding:

$$q_N^R = \frac{a-c}{6}, \tag{63}$$

$$\pi_N^R = \frac{(a-c)^2}{36}. \tag{64}$$

Next, we substitute $r = \varepsilon$ into (60) to yield the price of the intermediate goods and obtain the profit of the supplier:

$$t_N^R = \frac{a-c}{2}, \tag{65}$$

$$\pi_{s_N}^R = \frac{(a-c)^2}{6}. \tag{66}$$

Similarly, since the royalty equals the product-reducing cost, the supplier will keep the same price. As a result, the qualities of output remain the same and the supplier receives the same revenue.

Finally, the outsider patentee will obtain the revenue:

$$R_N = \frac{\varepsilon(a-c)^2}{3}. \tag{67}$$

On the other hand, the outsider patentee will set $r = \frac{a-c+\varepsilon}{2}$ when $(a-c) < \varepsilon$. We substitute $r = \frac{a-c+\varepsilon}{2}$ into (58) and (59), yielding:

$$q_N^R = \frac{a-c+\varepsilon}{12}, \tag{68}$$

$$\pi_N^R = \frac{(a-c+\varepsilon)^2}{144}. \tag{69}$$

Subsequently, the supplier also decides the price and his profit by $r = \frac{a-c+\varepsilon}{2}$:

$$t_N^R = \frac{a-c+\varepsilon}{4}, \tag{70}$$

$$\pi_{sN}^{R} = \frac{(a-c+\varepsilon)^2}{24}. \tag{71}$$

Consequently, the outsider patentee will obtain the revenue:

$$R_N = \frac{(a-c+\varepsilon)^2}{12}. \tag{72}$$

The above results show that R_N is larger than R_E. The supplier will choose the same price in the same royalty no matter in exclusive or non-exclusive licensing conditions. Besides, the output increases when the outsider patentee licenses the innovation to both firms. As a result, the outsider patentee receives more revenue in the non-exclusive licensing condition. Thus, we have the proposition:

Proposition 5. Under the royalty licensing and a drastic innovation, the outsider patentee can receive more revenues if he licenses to both downstream firms.

Comparing the revenues of the outsider patentee in drastic innovation case, it is demonstrated that R_N is also the best. Consequently, we can obtain the following proposition.

Proposition 6. Under the drastic innovation case, for the outsider patentee licensing to both downstream firms by royalties is superior to the fixed fee.

Similarly, the outsider patentee can weaken the supplier's advantage when he licenses by means of royalty. The royalty affects the production cost and the price strategy of the supplier. As a result, the outsider patentee can obtain more the benefits caused by the innovation when he licenses by royalty.

4. Conclusion

In the last section, we discuss the impact of the supplier. It is demonstrated that licensing by fixed fee contract is better than royalty contract under the situation that both firms compete in quantity and no supplier (see Appendix 1). The result is almost the same with Kamien and Tauman (1986). In the study, we introduce the impact of a supplier; as a result, we find that the outsider patentee will choose the means of the royalty licensing and license the innovation to both downstream firms no matter in the drastic or the non-drastic innovation cases. Besides, we also find that the supplier will use the price strategy to compete with the outsider patentee. The supplier will set the price that is higher or equal to the price under no innovation since he knows that the average production cost decrease. Furthermore, the outsider patentee can weaken the supplier's advantage in royalty licensing condition. In other words, through the royalty, the outsider patentee can obtain more benefits caused by the innovation.

Next, we discuss the difference between our result and Arya and Mittendorf's (2006). They considered the impact of the supplier and built the model, including one suppler and two firms that one is the paten-holding and compete in quantity. They found that the paten-holding firm prefers royalty licensing to fixed fee licensing when the innovation is drastic. We consider the situation that the patentee is an outsider; therefore, we can find the different result that the patentee will choose to license the innovation by royalty not only in the drastic innovation case but also in non-drastic innovation case.

Finally, we consider that the firms compete in quantity in this study. In the future, we can discuss that firms compete in price. Besides, we consider that the firms produce the homogeneous goods and the innovation only reduces the cost of production. In the future, we can introduce the idea of horizontal differentiation into the model. For instance, the same quality good includes different colors. In the other hand, we can also introduce the idea of vertical differentiation into the model. The innovation not only reduces the cost of production but also change the quality of the good for the consumer. Furthermore, we analyze the license contract in fixed fee and royalty here. In the future, we can consider the two-part tariff strategy.

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Appendix 1

Consider the mode only includes the firms and the outsider patentee; thus, the firms have to produce the intermediate good by themselves. The cost of c' equals the original production cost plus the intermediate good cost. The two firms' profit functions are represented as follows:

$$\pi_1 = [a - (q_1 + q_2) - c_1']q_1$$

$$\pi_2 = [a - (q_1 + q_2) - c_2']q_2$$

Solving the intersection of the reaction functions:

$$q_1^* = \frac{a - 2c_1' + c_2'}{3} \; and \; q_2^* = \frac{a + c_1' - 2c_2'}{3}$$

$$\pi_1^* = \frac{(a - 2c_1' + c_2')^2}{9} \; and \; \pi_2^* = \frac{(a + c_1' - 2c_2')^2}{9}$$

We discuss the cases as in section 3.

Fixed Fee

(i) Exclusive Licensing

$$q_E^F = \frac{a - c' + 2\varepsilon}{3} \; and \; q^{NF} = \frac{a - c' - \varepsilon}{3}$$

$$\pi_E^F = \frac{(a - c' + 2\varepsilon)^2}{9} \; and \; \pi^{NF} = \frac{(a - c' - \varepsilon)^2}{9}$$

$$F_E = \pi_E^F - \pi^{NF} = \frac{2\varepsilon(a - c') + \varepsilon^2}{3}$$

(ii) Non-Exclusive Licensing

$$q_N^F = q_1 = q_2 = \frac{a - c' + \varepsilon}{3}$$

$$\pi_N^F = \pi_1 = \pi_2 = \frac{(a - c' + \varepsilon)^2}{9}$$

$$F_N = 2(\pi_N^F - \pi^{NL}) = \frac{8\varepsilon(a-c')}{9}$$

Royalty

(i) Exclusive Licensing

$$q_E^R = \frac{a-c'+2\varepsilon-2r}{3} \ and \ q^{NR} = \frac{a-c'-\varepsilon+r}{3}$$

$$\pi_E^R = \frac{(a-c'+2\varepsilon+2r)^2}{9} \ and \ \pi^{NR} = \frac{(a-c'-\varepsilon+r)^2}{9}$$

$$\max_{0<r\leq\varepsilon} rq_E^R$$

Since the royalty rate is restricted, $r \leq \varepsilon$, the maximum is attained at

$$r^* = \min[\frac{a-c'+2\varepsilon}{4}, \varepsilon]$$

The outsider patentee will choose $r = \varepsilon$ when $0 < \varepsilon < \frac{a-c'}{2}$

$$q_E^R = \frac{a-c'}{3} \ and \ q^{NR} = \frac{a-c'}{3}$$

$$\pi_E^R = \frac{(a-c')^2}{9} \ and \ \pi^{NR} = \frac{(a-c')^2}{9}$$

$$R_E = \frac{\varepsilon(a-c')}{3}$$

The outsider patentee will choose $r = \frac{a-c'+2\varepsilon}{4}$ when $\frac{a-c'}{2} \leq \varepsilon \leq (a-c')$

$$q_E^R = \frac{a-c'+6\varepsilon}{6} \ and \ q^{NR} = \frac{5(a-c')-6\varepsilon}{12}$$

$$\pi_E^R = \frac{(a-c'+6\varepsilon)^2}{36} \ and \ \pi^{NR} = \frac{[5(a-c')-6\varepsilon]^2}{144}$$

$$R_E = \frac{\varepsilon(a-c')+6\varepsilon^2}{6}$$

(ii) Non-exclusive Licensing

$$q_N^R = q_1 = q_2 = \frac{a-c'+\varepsilon-r}{3}$$

$$\pi_N^R = \pi_1 = \pi_2 = \frac{(a - c' + \varepsilon - r)^2}{9}$$

$$\max_{0<r\leq\varepsilon} 2rq_N^R$$

The outsider patentee will choose $r = \varepsilon$

$$q_N^R = \frac{a - c'}{3} \ and \ \pi_N^R = \frac{(a - c')^2}{9}$$

$$R_N = \frac{2\varepsilon(a - c')}{3}$$

Summarizing the results, we can demonstrate that fixed fee licensing is better for the outsider patentee.

Next, we consider the drastic innovation case

Fixed Fee

(i) Exclusive Licensing

$$q_E^F = \frac{a - c' + \varepsilon}{2}$$

$$\pi_E^F = \frac{(a - c' + \varepsilon)^2}{4}$$

$$F_E = \pi_E^F = \frac{(a - c' + \varepsilon)^2}{4}$$

(ii)Non-Exclusive Licensing

$$q_N^F = q_1 = q_2 = \frac{a - c' + \varepsilon}{3}$$

$$\pi_N^F = \pi_1 = \pi_2 = \frac{(a - c' + \varepsilon)^2}{9}$$

$$F_N = 2\pi_N^F = \frac{2(a - c' + \varepsilon)^2}{9}$$

Royalty

(i) Exclusive Licensing

$$q_E^R = \frac{a - c' + \varepsilon - r}{2}$$

$$\pi_E^R = \frac{(a - c' + \varepsilon - r)^2}{4}$$

$$\max_r r q_E^R$$

The outsider patentee will choose $r = \frac{a-c'+\varepsilon}{2}$.

$$q_E^R = \frac{a - c' + \varepsilon}{4}$$

$$\pi_E^R = \frac{(a - c' + \varepsilon)^2}{16}$$

$$R_E = \frac{(a - c' + \varepsilon)^2}{16}$$

(ii) Non-Exclusive Licensing

$$q_N^R = q_1 = q_2 = \frac{a - c' + \varepsilon - r}{3}$$

$$\pi_N^R = \pi_1 = \pi_2 = \frac{(a - c' + \varepsilon - r)^2}{9}$$

$$\max_r 2 r q_N^R$$

The outsider patentee will choose $r = \frac{a-c'+\varepsilon}{2}$

$$q_N^R = \frac{a - c' + \varepsilon}{6}$$

$$\pi_N^R = \frac{(a - c' + \varepsilon)^2}{36}$$

$$R_N = \frac{(a - c' + \varepsilon)^2}{6}$$

Summarizing the results, we can also find that it is better to license the innovation to one firm by fixed fee for the outsider patentee.