The Optimum R&D and Licensing Strategies

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ABSTRACT

We acknowledge that past researches discuss the strategy of the technology licensing by patentees all assume that technology innovation is exogenous. In this paper, we study on the patentee’s research and development (R&D) and licensing if the patentee is not in production. It is found that under different strategy, the level of R&D is different. And the fixed fee royalty is still the best licensing way to the patentee himself and to the whole society.

Keywords: technology licensing, research and development, patent
JEL Classification: D45, D82, O30

I. Introduction

R&D is very important, not only for an individual industry but the whole economic system. From the past review, we know that two basic types of economic growing models are accumulation-based and technology-based models. Solow (1957) finds that capital accumulation can not explain the economic growth and one of the economic growing momentum is the technological progress. His study is based on the data of the average national income of the U.S.A. from 1909 to 1949. To study the impact of the R&D on the economic growing become a hot issue. Romer (1987, 1990) utilizes developing new commodities and the improvement of

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existing commodities, respectively, to explain the impacts of technological progress on the economic growth. On the other hand, many researches focus on the rapid economic growth in Asia for the past fifty years. Lau and Kim (1994) think that the Asian economic growth is resulted from the effect of capital accumulation more than the effect of technological progress. However, Chuang (1995) finds that technological progress do contribute a lot to Taiwan’s economic growth.

The significant performance of Taiwan’s economy, it is mostly due to the communication electronic industry’s progress. Taiwan’s total hardware output in the information industry ranks the fourth in the world, only next to U.S.A., Japan and follows China. And the vital factor of the success for further development in this industry is to obtain the technology. Because many patent and technology in high-tech industry are owned by foreign firms, domestic firms should be authorized to use them. On the other hand, Taiwan’s government and industry are making efforts on the inputs of R&D. From Table 1, we figure that the ratio of R&D expense on GDP is up to 2.4% in 2004, which is equivalent to some developing countries, although it is less than U.S.A. and Japan.

Table 1  Ratios of major countries’ R&D expense on GDP

<table>
<thead>
<tr>
<th></th>
<th>Taiwan</th>
<th>U.S.A.</th>
<th>Japan</th>
<th>German</th>
<th>France</th>
<th>U.K.</th>
<th>Italy</th>
<th>Canada</th>
<th>Korea</th>
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<tr>
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<td>1.70</td>
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<td>2.90</td>
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<td>2.29</td>
<td>1.95</td>
<td>0.97</td>
<td>1.72</td>
<td>2.37</td>
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<td>1996</td>
<td>1.70</td>
<td>2.55</td>
<td>2.77</td>
<td>2.26</td>
<td>2.30</td>
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<td>2.58</td>
<td>2.83</td>
<td>2.29</td>
<td>2.22</td>
<td>1.81</td>
<td>1.05</td>
<td>1.68</td>
<td>2.69</td>
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<tr>
<td>1998</td>
<td>1.90</td>
<td>2.61</td>
<td>2.95</td>
<td>2.31</td>
<td>2.17</td>
<td>1.80</td>
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<td>1.79</td>
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<td>2.96</td>
<td>2.44</td>
<td>2.18</td>
<td>1.87</td>
<td>1.04</td>
<td>1.82</td>
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<td>3.07</td>
<td>2.46</td>
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<td>1.87</td>
<td>1.09</td>
<td>2.13</td>
<td>2.59</td>
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<td>2002</td>
<td>2.20</td>
<td>2.65</td>
<td>3.12</td>
<td>2.49</td>
<td>2.23</td>
<td>1.89</td>
<td>1.13</td>
<td>2.06</td>
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<td>2003</td>
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<td>1.88</td>
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<td>2004</td>
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<td>2.68</td>
<td>3.13</td>
<td>2.49</td>
<td>2.16</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>1.99</td>
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Data source: OECD, "Main Science and Technology Indicators"; secondary data from Taiwan Indicators of Science and Technology, 2005.

Based on the data of the authorized number by U.S.A. in Table 2, we find that Taiwan ranks the fourth in the world from 1999 to 2004, which is next to U.S.A., Japan and German. It is obvious that Taiwan has a certain position in the world. We can deduce that the power of R&D activities is one of the niche for Taiwan’s industries to maintain the international competition.
Table 2    Numbers of authorized patent by U.S.A. (new style is excluded)

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<th></th>
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<td>1</td>
<td>86,977</td>
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<td>87,901</td>
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<td>33,223</td>
<td>2</td>
<td>34,859</td>
<td>2</td>
<td>35,517</td>
<td>2</td>
<td>35350</td>
<td>2</td>
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<tr>
<td>German</td>
<td>10,234</td>
<td>3</td>
<td>11,260</td>
<td>3</td>
<td>11,277</td>
<td>3</td>
<td>11,444</td>
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<td>5,431</td>
<td>4</td>
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<td>4</td>
<td>5938</td>
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<tr>
<td>Korea</td>
<td>3,314</td>
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<tr>
<td>U.K.</td>
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<td>4,041</td>
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<td>3,869</td>
<td>6</td>
<td>3380</td>
<td>7</td>
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</tbody>
</table>

Data source: U.S. Patent and Trademark office, secondary data from Taiwan Indicators of Science and Technology, 2005.

From a view of micro-side, why an individual firm should engage R&D? What is the incentive to adopt a new technology? And the answers are interested. Schumpeter (1943) thinks that “Innovation” will be a new way of production which recombines all the production factors in order to raise efficiency and reduce production cost. Besides, he also points out that the only way to let innovation in progress, the revenue from innovation of the firm should be protected. Therefore, the structure of monopoly market becomes a must of evil. Arrow (1962) studies on the impacts of R&D on the market structure through discussion about the licensing of the production innovation. He finds that the patente’s licensing in a perfect competition market could earn more profit than in a monopoly market, and R&D activities will not decrease.

Based on the above, we acknowledge the importance of R&D to macro-economy and individual industry. The more interesting is the relationship between R&D activities and the licensing strategy of firm. The past researches focus on the endogenous R&D, especially on the strategic effects of R&D. That is, they only consider how to make an industry being a leading position through R&D activities and ignore those activities under licensing strategy. Other studies focus on the exogenous R&D activities, i.e., to discuss the choice of patente’s licensing under given technology innovation in different market structures. The purpose of this paper is to study on the inter-impacts between endogenous R&D activities and the choice of technology licensing strategy which is lack of previous researches.

About the researches of endogenous R&D activities, Tirole (1988) has perfect review and discussion. In his study, he distinguishes innovations into product
innovations and process innovations. Product innovations means to develop new products and services, and process innovations is to reduce production cost of the existing products. Here, we will focus on the process innovations.

As we know, researches are focus on the discussion of the patentee’s licensing strategy under the assumption that technology innovation is given exogenous. On the other hand, it could be discussed by the patentee is in production or not in production. As to the part of patentee is not in production, Kamien and Schwartz (1982), extending Arrow’s model, explore how the patentee licenses the technology in the oligopoly market; Kamien and Tauman (1984), assuming a perfect competition market, compare the situation in royalty with that in fixed-fee royalty. Kamien and Tauman (1986) further explore how the patentee, when there are n homogeneous firms in Cournot competition, utilizing the licensing method—unit royalty, fixed fee royalty or both—to achieve his maximum profit. Muto (1993) suggests the optimum licensing strategy for the patentee when there are two heterogeneous oligopolists in Bertrand competition (price competition), and his study results in the unit royalty as the best solution. Lee and Huang (2006a), exploiting the vertical differentiation model, discuss the foreign patentee’s best licensing choice--fixed fee royalty, unit royalty, or mixed one--, and the domestic monopolist’s decision of the product quality and price. Sen (2005) suggests that when the authorized firm owns self information of cost type itself, the patentee may let this firm reveal his real type through choosing the menus of contacts. A standard screening model exists in his study since there is a reverse choice in the market. However, Sen’s research neglects that whether the patentee is willing to choose even he has the menus of contracts. Lee and Huang (2006b) proves that when authorized firm own the private information about cost type pooling equilibrium is not necessary the optimum choice for patentee. In above literature, when it comes to the patentee’s licensing, it is assumed that patentee is isolated from any production activities; that is, the patentee only specializes in licensing and decides whether to authorize the firm to produce or not. In other words, these literatures study about the patentee’s behavior, always partially focuses on the royalty benefit.

Distinct form the literature above, some researchers assume that the patentee is a market participant and licensor. Wang (1998), assuming that the technology advantageous firm is a market participant and a licensor, tries to figure out this firm’s optimum licensing way and production activity in the homogeneous oligopolistic Cournot competition. This research finds that when the technology advantage is relatively trivial, the unit royalty, to the patentee, is a better licensing way than the fixed fee royalty. But when the patentee’s technology advantage is superior enough to drive the rival out of the market, he will license none his technology. Wang (2002),
supposing that there is a heterogeneous oligopolistic Cournot competition, suggests
that the foreign firm with technology advantage will determine its licensing strategy
to the extent of the commodity substitutability. The foreign firm is inclined to choose
unit royalty if the substitutability is relatively larger, but prefer to the fixed fee royalty
once the substitutability is relatively smaller. Wang and Yang (2004) discuss the
technology licensing strategy based on the model of Stackelberg competition, they
conclude that patentee would rather licensing to market leader when he is a follower
no matter he is using the unit royalty or fixed fee royalty.

The above studies all assume that the patentee’s technology is exogenous, i.e.,
discussing the licensing strategy without consideration of R&D. Katz and Shapiro
(1985) utilize duopoly model based on the three-step game theory to discuss firm’s
R&D, licensing strategy and production activities. They also explain the existing
and the value of technology innovation. But, they do not discuss the choices of
patentee’s R&D activities, licensing strategy and production. On the other hand, in
the studies of nowadays technology R&D activities, they do not consider the decision
problems of R&D activities under different licensing strategy. Therefore, in this
paper, we discuss the choices of technology R&D activities and licensing strategy
under non-technology licensing, fixed fee royalty licensing and unit royalty licensing
when the patentee is not in production. Here, we also analyze the related social
welfare.

This paper is a theoretical analysis considering the market participants’ strategic
interaction, based on the model of game theory. We focus on the level of technology
R&D and the choice of licensing strategy of patentees, combining the R&D
endogenous research by D’Aspremont and Jacquemin (1988) and the research of
Kamien and Tauman’s (1986) technology licensing model. By following the
traditional analysis, this paper will first focus on maximizing the individual profit
(including the patentee and the authorized firm) as a rule of decision making. That is,
this research will discuss technology licensing related issues under non-cooperative
game structure.

For the solving part, it is discussed under the perfect information which is the
same as in the research of Katz and Shapiro (1985). The decision sequence is as
followed: firstly, overseas patentee makes an optimum decision of R&D, secondly, the
patentee decides the optimum licensing strategy( including non-licensing, unit royalty
and fixed fee royalty), thirdly, domestic firm decide to accept the licensing or reject it,
finally, to decide the competition quantity of entering the market. This licensing
strategy structure could be defined as a dynamic game of complete information. In
this, we will use a backward induction to get the sub-game perfect Nash equilibrium.
There are three sections in this paper, the first one is the introduction, second paragraph will discuss the optimum level of R&D under different licensing strategy, and the patentee’s choice of licensing strategy, in the last part are our conclusion and suggestion.

II. The patentee’s R&D and licensing strategy

This section, first, is going to discuss the domestic monopolist’s optimum production quantity and profit when it is faced with three different situations respectively: (1) the patentee neither invests in R&D nor has any technology authorization. (2) the patentee invests in R&D and licenses this technology by fixed fee royalty or (3) by unit royalty. Then, there is welfare comparison of the patentee’s profits when licensing by different royalties.

II.A The patentee neither invests in R&D nor has any technology authorization.

We assume that the inverse demand function of the domestic market is $p = a - q$, where $a$ is the parameter of the market scale, $p$ stands for the commodity price, $q$ represents the demand quantity; moreover, before the domestic firm, a monopolist, receive the technology authorization, its marginal cost and fixed cost are $c$ and 0 respectively, and $0 < c < a$. We can accordingly write the domestic firm’s profit as:

$$\pi_d = (p - c)q_d$$  \hspace{1cm} (2.1)

By the first order condition of (2.1), we can derive the domestic firm’s optimum production quantity and profit before the technology authorization:

$$q_d^* = \frac{1}{2}(a - c) \hspace{1cm} \pi_d^* = \frac{1}{4}(a - c)^2$$

II.B The patentee invests in R&D and license this technology by fixed fee royalty (denoted by the lower mark $f$)

Following the model developed by D’Aspremonet and Jacquemin (1988), we have the patentee’s technology research cost function as $RC = \frac{\gamma \varepsilon^2}{2}$, where $\gamma$ represents R&D efficiency parameter ($\gamma > 0$), and a smaller value implies that the patentee owns a higher R&D efficiency; $\varepsilon$, the extent of the reduced cost, is known as the level of technology innovation, which is a kind of process innovation. Moreover, when the patentee authorizes his technology by the fixed fee royalty ($F$), his revenue function is $R_f = F$. Thus, the patentee’s profit function is
\[ \pi_{pf} = F - \frac{\gamma e^2}{2} \quad (2.2) \]

On the other hand, the technology innovation owned by the patentee can help to save the cost to the extent \( e \), so the domestic firm acquiring the authorization can have his marginal cost lower to \( c - e \), where \( 0 < e \leq c \); Besides, it is assumed that the domestic firm will demand the authorization as long as the profit after the authorization is not less than that before the authorization. Here, the domestic firm’s profit function is written as

\[ \pi_{df} = (p - c + e)q_{df} - F \quad (2.3) \]

By the first order condition of (2.3), we derive the authorized firm’s optimal production quantity and profit in the following:

\[ q_{df}^* = \frac{1}{2} (a + e - c) \quad (2.4) \]

It is found that when \( e > 0 \), then \( q_{df}^* > q_d^* \). This is because the firm’s marginal cost is lowered after acquiring the authorization, leading his production quantity to increase. First, we can assume \( \pi_{df} = \pi_d^* \) to derive \( F \), and then substitute \( F \) and (2.4) into (2.2). By deriving the first and second order condition of the patentee’s optimum technology innovation, we get

\[ \frac{\partial \pi_{pf}}{\partial e} = \frac{1}{2} [a - c + (1 - 2\gamma)e] = 0 \quad (2.5) \]

\[ \frac{\partial^2 \pi_{pf}}{\partial e^2} = \frac{1}{2} (1 - 2\gamma) < 0, \text{ when } \gamma \geq \frac{1}{2} \quad (2.6) \]

The equation (2.5), to the patentee, implies that the marginal revenue of the technology innovation equals the marginal cost of the technology innovation, and therefore \( e_{f}^* = \frac{a - c}{(2\gamma - 1)} \), where the increase of \( \gamma \) will drive \( e_{f}^* \) down. In the equation (2.6), when \( \gamma \geq \frac{1}{2} \), there is an inner solution; that is \( e_{f}^* < c \). We can accordingly infer that \( a < 2\gamma c \). However, when \( \gamma > \frac{1}{2} \) and \( a \geq 2\gamma c \), or when \( \gamma \leq \frac{1}{2} \), then \( \frac{\partial \pi_{pf}}{\partial e} > 0 \), implying that the patentee are bound to increase his innovation level as much as possible, and we get \( e_{f}^* = c \). Finally, by \( \pi_{df}^* = \pi_d^* \), we can obtain the corresponding
From the statement above, we can divide the discussion into two different situations according to the numerical order of $\gamma$, $a$ and $c$, and conclude the patentee’s best innovation level, the profit under the fixed fee royalty, and the domestic firm’s production and profit in these two different situations:

**$F_1$**: when $\gamma > \frac{1}{2}$ and $a < 2\gamma c$

$$
\varepsilon_{f1}^* = \frac{a - c}{2\gamma - 1} \quad F_1^* = \frac{(a - c)^2 (4\gamma - 1)}{4(1 - 2\gamma)^2} \quad \pi_{pf1}^* = \frac{(a - c)^2}{8\gamma - 4}
$$

$$
q_{df1}^* = \frac{(a - c)c}{2\gamma - 1} \quad \pi_{df1}^* = \frac{1}{4}(a - c)^2
$$

**$F_2$**: when $\gamma \leq \frac{1}{2}$, or when $\gamma > \frac{1}{2}$ and $a \geq 2\gamma c$

$$
\varepsilon_{f2}^* = c \quad F_2^* = \frac{(2a - c)c}{4} \quad \pi_{pf2}^* = \frac{c[2a - c(1 + 2\gamma)]}{4}
$$

$$
q_{df2}^* = \frac{a}{2} \quad \pi_{df2}^* = \frac{1}{4}(a - c)^2
$$

**Proposition 1:**

Given that the technology is licensed by the fixed fee royalty, when $\gamma$ is relatively large and $a$ is relatively small, there is an inner solution for the optimum technology innovation; that is, $\varepsilon_f^* < c$, where $\frac{d\varepsilon_f^*}{d\gamma} < 0$, $\frac{d\varepsilon_f^*}{da} > 0$, and $\frac{d\varepsilon_f^*}{dc} < 0$, whereas when $\gamma$ and $a$ are both large enough or when $\gamma$ is relatively small, there is a corner solution for the optimum technology innovation; that is, $\varepsilon_f^* = c$.

推論一表示，當研發效率相對低或市場規模相對小時，技術創新幅度存在內解，並且當研發效率愈低、市場規模愈小以及生產邊際成本愈高，都將使得研發幅度下降；亦即是研發的邊際成本愈高或邊際收益愈低時，研發幅度皆會較低。另一方面，當市場規模相對大及研發效率相對高時，研發幅度都達到技術上所能做到的最大情況。

II.C the patentee invests in R&D and license this technology by unit royalty. (denoted by the lower mark $r$)

When the patentee licenses through the unit royalty ($r$), his revenue function is
$R_r = rq_{dr}^*$; therefore, the profit functions of the patentee and the domestic firm are in the following respectively:

$$\pi_{pr} = rq_{dr}^* - \gamma c^2$$  \hspace{1cm} (2.7)

$$\pi_{dr} = \left(p - c + \epsilon - r\right)q_{dr}$$  \hspace{1cm} (2.8)

First, by the first order condition of (2.8), we get the domestic firm’s best production quantity and profit

$$q_{dr}^* = \frac{1}{2}(a + \epsilon - c - r)$$  \hspace{1cm} (2.9)

Then, substitute (2.9) into (2.7). To achieve the optimal solution, differentiate this equation with respect to $r$ to obtain the first order condition. We get an inner solution for the optimal unit royalty, where $r < \epsilon$

$$r = \frac{1}{2}(a - c + \epsilon)$$  \hspace{1cm} (2.10)

By substituting (2.9) and (2.10) into (2.7), and deriving its first order and second order condition with respect to $\epsilon$, we obtain:

$$\frac{\partial \pi_{pr}}{\partial \epsilon} = \frac{1}{4}[a - c + (1 - 4\gamma)e] = 0$$  \hspace{1cm} (2.11)

$$\frac{\partial^2 \pi_{pr}}{\partial \epsilon^2} = \frac{1}{8}(2 - 8\gamma) < 0, \text{ when } \gamma > \frac{1}{4}$$  \hspace{1cm} (2.12)

Likewise, the equation (2.11) means that the perceived marginal cost equals the marginal cost, which implies that $\epsilon_{r_t}^* = \frac{(a - c)}{4\gamma - 1}$, where the increase of $\gamma$ will lower down $\epsilon^*$. The equation (2.12) implies that there is an inner solution as $\gamma > \frac{1}{4}$. But when $\gamma \leq \frac{1}{4}$, then $\frac{\partial \pi_{pr}}{\partial \epsilon} > 0$, meaning that the patentee should increase his R&D level as much as possible, hence $\epsilon_{r_t}^* = c$. To clearly interpret the royalty revenue and profit of the patentee and the profit of the domestic firm, the analysis is divided into four cases. The first two cases of them are:

1. $R_i$: when $\frac{1}{2} > \gamma > \frac{1}{4}$ and $a < 4\gamma c$

   $$\epsilon_{r_t}^* = \frac{(a - c)}{4\gamma - 1}$$

   $$r_{ri}^* = \frac{2(a - c)\gamma}{4\gamma - 1}$$

   $$q_{drri}^* = \frac{(a - c)\gamma}{4\gamma - 1}$$
\[ \pi_{\text{pri1}} = \frac{(a-c)^2 \gamma}{2(4\gamma-1)} \quad \pi_{\text{dri1}} = \frac{(a-c)^2 \gamma^2}{(4\gamma-1)^2} \]

\[ R_2: \text{ when } \gamma \leq \frac{1}{4} \text{ and } a < 2c \text{ or when } \frac{1}{2} > \gamma > \frac{1}{4} \text{ and } 2c > a \geq 4\gamma c \]

\[ \epsilon_{\text{ret2}} = c \quad \pi_{\text{ret2}} = \frac{a^2 - 4c^2 \gamma}{8} \quad \pi_{\text{dri2}} = \frac{a^2}{16} \]

First, when there is an inner solution for the unit royalty, its optimal value should be smaller than the extent of cost saving; that is, \( r_i^* < \epsilon_{\text{ret}}^* \). Thus, both \( r \) and \( a \) should satisfy the following conditions: \( \gamma < \frac{1}{2} \) and \( a < 2c \). Moreover, under the unit royalty authorization, the decrease of the firm’s marginal cost after acquiring the authorization \( (c - \epsilon + r^* < c) \) will expand the production, and therefore \( \pi_{\text{dri}} > q_{\text{dri}}^* \).

That \( q_{\text{dri}}^* > q_{\text{dri}} \) is resulting from the firm’s even greater marginal cost decrease under the fixed fee royalty authorization. That is, \( c - \epsilon < c - \epsilon + r^* \).

Second, when \( \gamma \geq \frac{1}{2} \) or \( a \geq 2c \), it means that there is a corner solution for the unit royalty; that is, \( r^* = \epsilon^* \). Here by substituting (2.9) to (2.7), and assuming \( r = \epsilon \), its first order and second order condition are in the following:

\[ \frac{\partial \pi_{\text{pr}}}{\partial \epsilon} = \frac{1}{2} (a - c - 2\gamma c) = 0 \quad (2.12) \]

\[ \frac{\partial^2 \pi_{\text{pr}}}{\partial \epsilon^2} = -\gamma < 0 \quad (2.13) \]

Hence, we can infer the royalty revenue and profit of the patentee and the profit of the domestic firm of the other two cases:

\[ R_3: \text{ when } \gamma \geq \frac{1}{2} \text{ and } a < (2\gamma + 1)c \]

\[ \epsilon_{\text{ret2}} = \frac{(a-c)}{2\gamma} \quad r_{\text{ret2}} = \frac{(a-c)}{2\gamma} \quad q_{\text{dri2}} = \frac{(a-c)}{2} \]
\[
\pi_{prc2}^* = \frac{(a - c)^2}{8\gamma} \quad \pi_{drc2}^* = \frac{(a - c)^2}{4}
\]

\[R_4: \text{when } \gamma \geq \frac{1}{2} \text{ and } a \geq (2\gamma + 1)c \text{ or when } \gamma < \frac{1}{2} \text{ and } a \geq 2c\]

\[\varepsilon_{rcl}^* = c \quad r_{c1}^* = c \quad q_{drc1}^* = \frac{(a - c)}{2}\]

\[\pi_{prc1}^* = \frac{c[a - c(\gamma + 1)]}{2} \quad \pi_{drc1}^* = \frac{(a - c)^2}{4}\]

**Proposition 2:**

(1) Under the unit royalty authorization, given the production cost is \(c\), when \(\gamma\) and \(a\) are relatively small, we infer that \(r^* < \varepsilon_r^*\); otherwise, \(r^* = \varepsilon_r^*\).

(2) When \(a\) is relatively large, we can in further obtain that \(r^* = \varepsilon_r^* = c\). Otherwise, we can obtain the following three results: when \(\gamma\) is relatively large, then \(r^* = \varepsilon_r^* < c\); when \(\gamma\) is relatively small, then \(r^* < \varepsilon_r^* = c\); while when \(a\) is relatively small, \(r^* < \varepsilon_r^* < c\).

In the unit royalty authorization, given the production cost is \(c\), when \(\gamma\) and \(a\) are relatively small, we infer that \(r^* < \varepsilon_r^*\); otherwise, \(r^* = \varepsilon_r^*\).

II.D The welfare comparison under two different licensing ways

According to the foregoing discussion, given the parameters in different intervals, we infer the following proposition by comparing the patentee’s profit and R&D under two different licensing ways.

**Proposition 3:**

*With the assumption that R&D is endogenous, the R&D level under the fixed fee*
royalty is always not less than that under the unit royalty, and the patentee’s optimal licensing strategy is the fixed fee royalty authorization.

Proof: See the appendix.

This result reveals that, given other things be equal, the R&D level under the fixed fee royalty is always not less than that under the unit royalty. On the other hand, when under the fixed fee royalty licensing, the extent of the marginal cost saved by the authorized firm can achieve its maximum. The authorized firm hence can make the most efficient production expansion. As the R&D is endogenous, the fixed fee royalty licensing is not only the patentee’s optimal choice, but also the optimal one from the view of the social welfare.

III. Conclusion and suggestion

The past studies indicated that given that technology innovation is exogenous and the patentee is not in the production, the fixed fee royalty, both to the patentee himself and to the whole society, is the best choice. This research found that even with the endogenous R&D, the fixed fee royalty is still the best licensing way to the patentee himself and to the whole society. It is because that the R&D level under the fixed fee royalty is always not less than that under the unit royalty, and the extent of the marginal cost saved by the authorized firm can achieve its maximum, making the most efficient production expansion.

In the further study, we can explore toward the directions mentioned below:(1) the patentee’s R&D strategy and licensing decision as he participates in the production;(2) the patentee’s R&D strategy and licensing decision when in the homogeneous or heterogeneous oligopoly market.

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APPENDIX

\[(1) \quad \gamma > \frac{1}{2} \quad \text{and} \quad a < 2\gamma c\]

\[\pi_{yr1}^* - \pi_{prc}^* = \frac{(a-c)^2}{8\gamma - 4} - \frac{(a-c)^2}{8\gamma} = \frac{(a-c)^2}{8\gamma(2\gamma - 1)} > 0\]

\[\epsilon_{yr1}^* - \epsilon_{prc}^* = \frac{a-c}{2\gamma - 1} - \frac{a-c}{2\gamma} > 0\]
(2) \( \frac{1}{2} > \gamma > \frac{1}{4} \) and \( a < 4\gamma c \)

\[
\pi_{pf2}^* - \pi_{pr1}^* = c \frac{2a - c(1 + 2\gamma)}{4} - (a - c)^2 \gamma \ \frac{8\gamma - 2}{2}
\]

\[
= -2\gamma \left[ a -\frac{c(6\gamma - 1) - \sqrt{c^2 (1 - 4\gamma ) (1 - 6\gamma + 4\gamma^2)}}{2\gamma} \right] \left[ a -\frac{c(6\gamma - 1) + \sqrt{c^2 (1 - 4\gamma ) (1 - 6\gamma + 4\gamma^2)}}{2\gamma} \right]
\]

(a) \( \pi_{pf2}^* > \pi_{pr1}^* \), when \( a < \frac{c(6\gamma - 1) + \sqrt{c^2 (1 - 4\gamma ) (1 - 6\gamma + 4\gamma^2)}}{2\gamma} \);

(b) \( \pi_{pf2}^* \leq \pi_{pr1}^* \), when \( a \geq \frac{c(6\gamma - 1) + \sqrt{c^2 (1 - 4\gamma ) (1 - 6\gamma + 4\gamma^2)}}{2\gamma} \), it contradicts \( a < 4\gamma c \),

and we have \( \pi_{pf2}^* > \pi_{pr1}^* \).

\[
\epsilon_{pf2}^* - \epsilon_{pr1}^* = c - \frac{a - c}{4\gamma - 1} > 0
\]

(3) \( \frac{1}{2} > \gamma \) and \( 2c > a \geq 4\gamma c \)

\[
\pi_{pf2}^* - \pi_{pr2}^* = -\frac{a^2 - 4ac + 2c^2}{8\gamma}
\]

\[
= -\frac{a - c(2 - \sqrt{2})}{8\gamma} \left[ a + c(2 + \sqrt{2}) \right]
\]

(a) \( \pi_{pf2}^* > \pi_{pr2}^* \), when \( \gamma \leq \frac{1}{4} \) and \( a < 2c \)

(b) \( \pi_{pf2}^* > \pi_{pr2}^* \), when \( \frac{1}{2} > \gamma > \frac{1}{4} \) and \( c(2 + \sqrt{2}) > a > 4\gamma c \);

(c) \( \pi_{pf2}^* \leq \pi_{pr2}^* \), when \( \frac{1}{2} > \gamma > \frac{1}{4} \) and \( a \geq c(2 + \sqrt{2}) > 4\gamma c \), it contradicts \( a < 2c \),

and we have \( \pi_{pf2}^* > \pi_{pr2}^* \).

\[
\epsilon_{pf2}^* - \epsilon_{pr2}^* = c - \frac{a - c}{2\gamma} > 0
\]

(4) \( \gamma > \frac{1}{2} \) and \( (2\gamma + 1)c > a \geq 2\gamma c \)
\[
\pi_{pf}^* - \pi_{prc}^* = \frac{c[2a - c(1 + 2\gamma)]}{4} - \frac{(a - c)^2}{8\gamma}
\]
\[
= -\frac{a - c(1 - \sqrt{2\gamma} + 2\gamma)}{8\gamma}
\]

(a) \(\pi_{pf}^* > \pi_{prc}^*\), when \(a < c(1 + \sqrt{2\gamma} + 2\gamma)\);

(b) \(\pi_{pf}^* \leq \pi_{prc}^*\), when \(a \geq c(1 + \sqrt{2\gamma} + 2\gamma)\), it contradicts \((2\gamma + 1)c > a\), and we have

\[
\pi_{pf}^* > \pi_{prc}^*.
\]

\[
\epsilon_{pf}^* - \epsilon_{prc}^* = c - \frac{a - c}{2\gamma} > 0
\]

(5) \(\gamma \geq \frac{1}{2}\) and \(a \geq (2\gamma + 1)c\) or \(\gamma < \frac{1}{2}\) and \(a \geq 2c\)

\[
\pi_{pf}^* - \pi_{prc}^* = \frac{c[2a - c(1 + 2\gamma)]}{4} - \frac{c[a - c(1 + \gamma)]}{2} = \frac{c^2}{4} > 0
\]

\[
\epsilon_{pf}^* - \epsilon_{prc}^* = c - c = 0
\]
Reference


Taiwan National Science Council (2004), Taiwan Indicators of Science and Technology, Taiwan National Science Council Press.