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Optimal Technology License Contracts with Quality Improvement Under Stackelberg Competition

Jia Xuanze[1] & Yang Le[1]

[1] Business School, University of Shanghai for Science and Technology, Shanghai, China

Correspondence: Jia Xuanze, Business School, University of Shanghai for Science and Technology, Shanghai, 200093, China. Tel: 0086-130-4609-8388. E-mail: 408743087/at/qq.com

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Abstract

As society develops, the phenomenon of technology licensing is becoming more prevalent. This paper analyzes the optimal licensing contract for the patentor with a quality improvement innovation in a Stackelberg duopoly market. We examine and compare two licensing contracts (fixed-fee licensing and royalty licensing) in terms of the patent-holding firm's profit, consumer surplus, and social welfare. We also study the impact of quality differences on the choice of licensing contract. One might expect that consumer surplus and social welfare are greater under fixed-fee licensing. However, we show that this conclusion seems to be untrue under quality improvement technology licensing. Moreover, we find that (1)A royalty fee is always better than a fixed-fee authorization for the innovator's profits; (2) Relative to social welfare, there is a threshold between fixed-fee authorization and concession authorization, and when this threshold is exceeded, concession fees are adopted, and vice versa for fixed-fee authorization.

Keywords: technology licensing, royalty fee, fixed-fee

1. Introduction

Technology licensing is an important part of enterprise technological innovation, an important form of technology transfer under the patent system, and a means for patent-holding enterprises to obtain licensing income from innovation (Arora & Rønde, 2013, Hong et al., 2017). In addition, technology licensing can play an important role in financing R&D investments for firms that need to improve their products but are constrained by financial limitations. It is also an effective way to promote rapid economic development in developing countries, where today, in addition to the diffusion of technology, intellectual property rights are becoming increasingly important to companies that see them as a core business asset. It has become common for patent holders to strategically manage their licenses to generate returns by evaluating and exploiting them. Philip sold approximately 65 patents to RIM, valued at $173 million. In the United States, patent transactions in 2006 totaled about $500 million (Clark & Monk, 2014). In the computer industry, Texas Instruments earned as much revenue from licenses as it did in cumulative net profits from 1986 to 1993.

There are two main types of technological innovations, namely product innovations and process innovations, which can be categorized as technological innovations, product innovations and process innovations, depending on the type of innovation object. In addition, there are also process innovations, which include innovations to reduce costs and innovations to improve quality innovation. However, product quality can still be seen as an important strategic and competitive tool. As the market becomes saturated, improving products becomes an opportunity for firms to attract more customers. Firms that fail to improve their products will lose the opportunity to expand their markets and may even be eliminated from the market. However, most researchers have studied the licensing of cost-reducing innovations, while little literature has focused on the licensing of quality-improving innovations. To fill this gap, we consider a Stackelberg duopoly model consisting of a licenser and a licensee, where the licenser produces high-quality products with quality-improving innovations, while the licensee produces low-quality products.

This paper makes several theoretical contributions. First, we contribute to the technology licensing literature by considering quality-improving innovations, whereas most of the existing research focuses on cost-reducing innovation licensing. Second, we find that there is a threshold in the degree of quality variation above which royalty licensing is profitable for the patent-holding firm. Third, we find that licensing is always more profitable for the patent-holding firm than not licensing, and that royalty-based licensing is the best option because of the highest profitability from licensees. From the perspectives of customer surplus and social welfare, if quality differences are small, royalty licenses are the optimal contract. Whereas, if quality differences are large, a fixed-fee license is the optimal contract. This is different from other literature.

2. Literature Review

This study addresses the technical licensing problems. The current literature discusses the choice of technology licensing contracts in terms of the characteristics of technology patent holders, which are divided into two categories. The first category is cost-reducing technology. Kamien and Tauman (1986) established a market framework that falls between perfect competition and monopoly to examine and contrast the financial outcomes for the patent holder, the licensee, and the pricing of products under different licensing arrangements, specifically in the context of cost-reducing technological innovations. Agrawal et al. (2016) explored innovations that reduce costs supplied by external sources and analyzed how the extent of such innovations impacts the profits of patent holders, the pricing of products, and the costs associated with production. Kishimoto (2020) examined the role of negotiation in the licensing of cost-reducing technologies between two firms in a Cournot competition scenario. The other type is quality-improving technology. Zhu et al., 2007 explored the coordination mechanisms among supply chain participants aimed at elevating product quality standards. The buyers, responsible for the design of high-quality products, delegate their manufacturing to suppliers and collaborate in bearing the expenses related to enhancing or preserving product quality. Xuan et al. (2014) proposed a quality development model with variable costs and considered the competition between two firms: one that acquired high-quality technology from a multinational corporation and the other that produced low-quality goods. They studied the optimal licensing issue for multinational enterprises.

The paper most similar to ours is Zhang (2023), but Zhang (2023) is based on the Cournot model for research, while we analyze from the perspective of the Stackelberg model. Both the Stackelberg model and the Cournot model are economic models used to describe how firms compete in an oligopolistic market, but they have fundamental differences in market dynamics and corporate behavior. In the Stackelberg model, the market consists of a leader with a first-mover advantage and several followers; the leader makes decisions first, and the followers adjust their strategies based on the leader's actions. This sequential decision-making allows the leader to anticipate the reactions of the followers and optimize their strategy accordingly. In contrast, in the Cournot model, all firms make output decisions simultaneously, with no clear distinction between leaders and followers, and each firm assumes that the output of other firms remains unchanged when making decisions. Therefore, the Cournot model focuses more on how firms compete with each other in terms of output, while the Stackelberg model emphasizes the importance of the leader's strategic position and the order of decision-making.

3. Model Building

In this section, we consider Stackelberg duopolies that produce and sell products with quality differences. firm 1's production quality level is s_1 High-quality products, And the level of production quality of firm 2 is s_2 low-quality products. We assume a higher quality index of 1, i.e. $s_1 = 1$, The low-quality index can be $s_2 = ts_1 = t$, $t \in (0,1)$. We assume that customers have different preferences, willing to pay θs_i, for a product of quality s_i, included among these $i = \{1, 2\}$,The consumer's utility formula is

$$U_i = \theta s_i - p_i$$

p_i is the retail price, θ for the customer type.

3.1 No Licensing

In this model, firm 1, which possesses high-quality technology, does not license its innovations to firm 2. Thus, firm 1 produces high-quality products, while firm 2 produces low-quality products. In this model, if the marginal utility is greater than the marginal utility of buying an inferior product and nothing else, then the consumer prefers to buy the superior product, i.e. $1 > \theta > \theta_1$, Accordingly, when the utility of the purchase is greater than zero, customers will buy the inferior product. And purchasing firm 2's products, i.e. $\theta_1 > \theta > \theta_2$. So, in the absence of a license, we can get products belonging to $1 > \theta > \theta_1$ purchasing firm 1. Consumer purchases of firm 2 products within $\theta_1 > \theta > \theta_2$. Under the no-license model, the production of two firms is

$$q_1 = \int_{\theta_1}^{1} d\theta \quad , \quad q_2 = \int_{\theta_2}^{\theta_1} d\theta$$

Based on the first two equations, we can derive the inverse demand function for the two firms The inverse demand function for the two firms

$$p_1 = 1 - q_1 - tq_2$$

$$p_2 = t(1 - q_1 - q_2)$$

Model N is a baseline model that is mathematically described as follows

$$\pi_1^N = (1 - q_1 - tq_2)q_1$$

$$\pi_2^N = t(1 - q_1 - q_2)q_2$$

Equilibrium values can be obtained by performing partial derivative operations on q_1 and q_2

$$q_1^N = \frac{1}{2} \quad q_2^N = \frac{1}{4}$$

Thus, the maximum profit of firm 1 and firm 2 can be written as

$$\pi_1^{N*} = \frac{2-t}{8} \qquad \pi_2^{N*} = \frac{t}{16}$$

The consumer surplus for mode N is

$$CS^N = \frac{5t}{32} + \frac{1}{8}$$

3.2 Fixed Fee

In this section, we will consider a situation where firm 1 licenses its quality improvement innovation to firm 2 through a fixed-fee license. If firm 2 accepts the contract, it has the same level of quality as firm 1. The utility gained by the consumer from purchasing firm i product is

$$U_i = \theta s_i - p_i ,$$

After obtaining the license, both companies produce and sell high-quality products at the same price p Customers will buy a product if they perceive utility to be greater than zero. The inverse demand function is

$$p = 1 - q_1 - q_2$$

Based on the inverse demand function, the profit of their firm is

$$\pi_1^F = (1 - q_1 - q_2)q_1 + F$$

$$\pi_2^F = (1 - q_1 - q_2)q_2 - F$$

We can obtain the optimal response of quantities and prices by means of a first-order condition, $q_1 = \frac{1}{2}, q_2 = \frac{1}{4}$, $p = \frac{1}{4}$

Therefore, the profits of firm 1 and firm 2 are

$$\pi_1^F = \frac{1}{8} + F \text{ , } \pi_2^F = \frac{1}{8} - F$$

Consumer surplus is

$$CS^F = \frac{9}{32}$$

Firm 2 will accept licenses when $\pi_2^F \geq \pi_2^N$, thereby obtaining a fixed fee

$$F = \frac{2-t}{16} \text{ ,}$$

The conditions for firm 1 to choose a fixed use authorization are

$$\pi_1^F \geq \pi_1^N$$

Fixed-fee licensing will be applied at $t \geq 0$, This means that the patent-holding firm (firm 1) are more willing to license their quality improvement technology to competitors through a fixed-fee license when the quality difference is not significant compared to the no-licensing case. Technology licensing can have two types of effects, namely licensing effects and competitive effects. The licensing effect comes from licensing revenues generated by technology licenses and is positive for firm 1. The competitive effect, which is an additional effect of a technology license that improves the quality of firm 2's products and is disruptive to firm 1, With fixed-fee licensing, the licensing effect dominates relative to the competition effect, so the total effect is positive for firm 1.

3.3 Royalty

In this section, we examine the use of per-unit royalties by firm 1 to license its innovation to firm 2. Enterprise 2 will pay Enterprise 1 a fixed royalty per unit $r \in (0,1)$. The inverse demand of this model is the same as that of Model F, which is described mathematically as follows

$$\pi_1^r = (1 - q_1 - q_2)q_1 + rq_2$$

$$\pi_2^r = (1 - q_1 - q_2 - r)q_2$$

The equilibrium price and equilibrium quantity can be obtained by calculating the above two equations

$$q_1^r = \frac{1}{2} \text{ , } q_2^r = \frac{1-2r}{4} \text{ , } p^r = \frac{1+2r}{4}$$

In order for $q_2^r \geq 0$, the range of unit license rates is $r \leq \frac{1}{2}$. It is known that by maximizing the first-order conditions.

$$r^I = \frac{1}{2}$$

Firm 1 profits and consumer surplus

$$\pi_1^r = \frac{3-2r}{8} \text{ , } CS = \frac{1}{8} + \frac{\sqrt{t}}{8} + \frac{t}{32}$$

To ensure that firm 2 accepts the license, it need to be equal to or higher than the profits from not licensing, namely,

$$\pi_2^r \geq \pi_2^N \text{ .}$$

It can be known through calculation,

$$r^c = \frac{1}{2} - \frac{\sqrt{t}}{2}$$

thereby obtaining

$$\pi_1^r = \frac{1}{4} + \frac{\sqrt{t}}{8}$$

It can be verified that the optimal profit of firm 1 satisfies the following constraints

$$\pi_1^r \geq \pi_1^N ,$$

This means that when the quality of a patent improves, the patentee always tends to prefer a royalty license contract. This is because a royalty license can be seen as a marginal cost to the licensee, thereby limiting the licensee's production and reducing competition between the two firms. Thus, the licensing effect can mask the weakening of the competitive effect, and the patentee is more efficient than the licensee. Regardless of differences in quality, it is profitable for a licensor to license its technology to a licensee.

4. Comparison of the Two Models with the Baseline Model

In this section, we compare the optimal values of the two models with the no-license model and find out which licensing strategy is optimal from the point of view of the patentee and the society as a whole

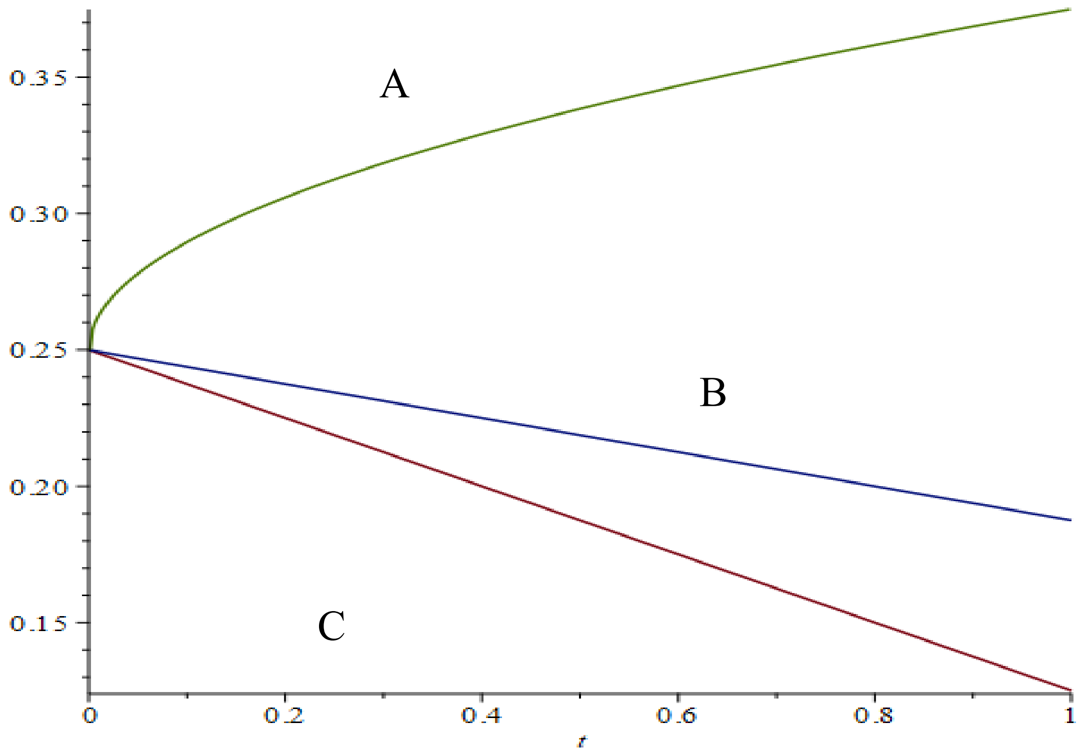

Figure 1. Profit Comparison

A in the figure represents the firm 1's profit after royalty licensing, B represents the change in firm 1 profits after fixed fee licensing, C is the profit of firm 1 when the model is not licensing. As can be seen from the figure, both fixed-fee licensing and royalty fee licensing firm 1 earns more profit than without licensing

For any value of t, the patent-holding firm should choose the new unit licensing strategy over fixed-fee licensing, firm 1 is more profitable under unit license contracts than under fixed-fee license contracts. As shown in the figure, the profits of the patent-holding firm (firm 1) always increase with the value t in a royalty license. The higher the quality, the greater the profit of firm 1 in a fixed-fee license, the profit of the patent-holding firm (firm 1) always decreases as the value t increases, and the higher the quality, the smaller firm 1's profit becomes. Unlike fixed-fee licenses, royalty licenses increase the marginal cost of production for firm 2, reducing competition and restricting output, Therefore, the patent-holding firm (firm 1) is always more efficient than the licensee (firm2)

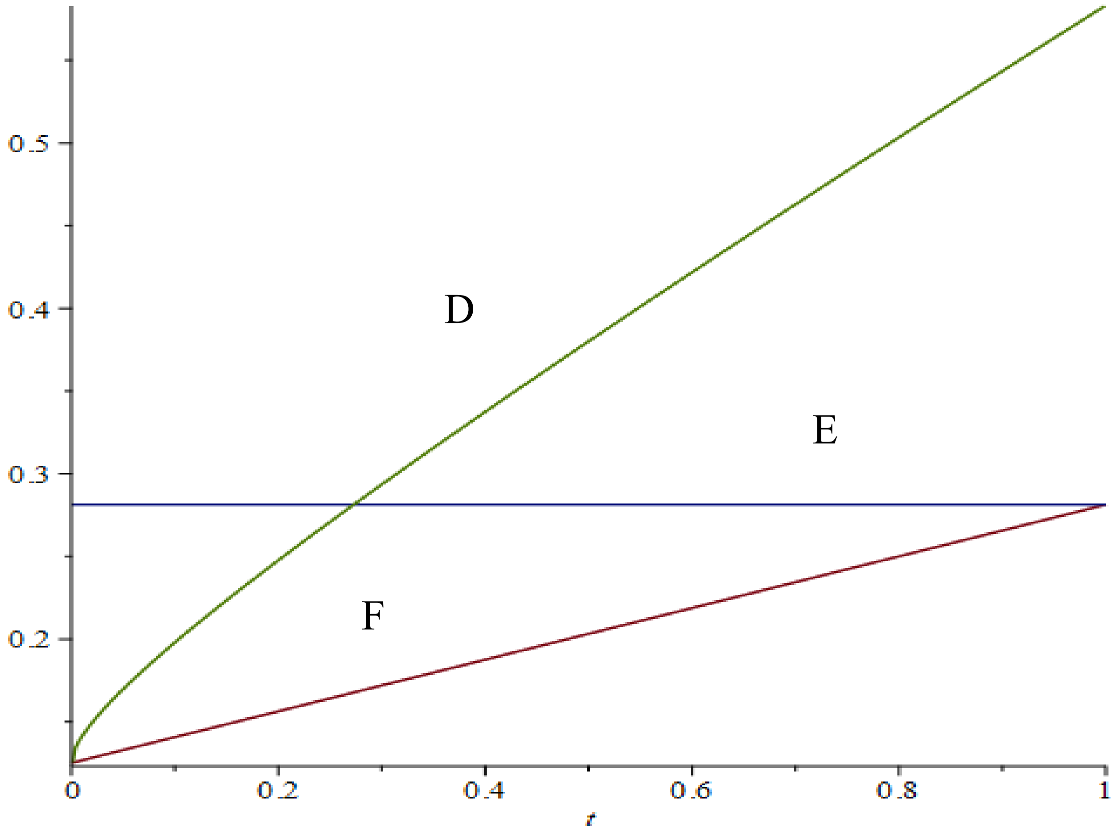

Figure 2. Consumer Surplus Comparison

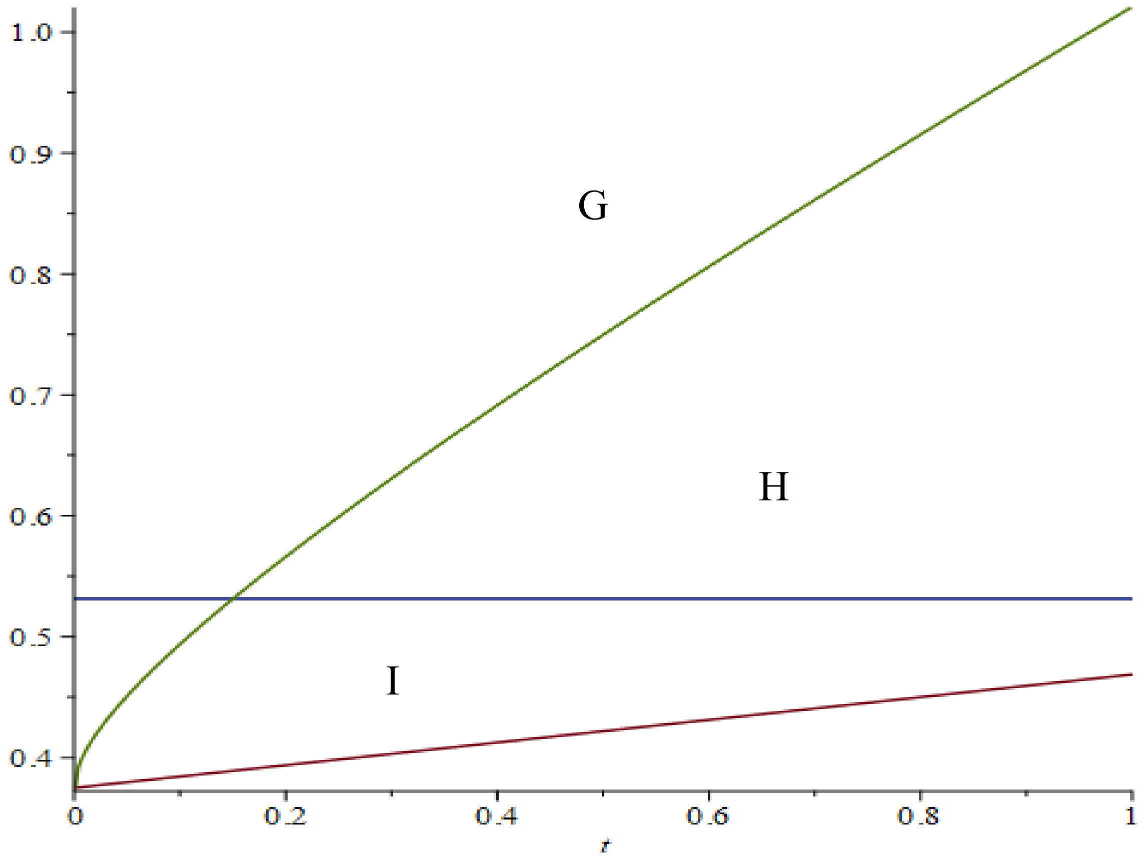

Figure 3. Comparison of Social Welfare

D in the figure represents the change in consumer surplus after the fixed-fee licensing, E represents the change in consumer surplus after the licensing of royalty fee. F represents the consumer surplus of the baseline model, G represents the social benefit when firm 1 is licensing through royalty, H represents the social benefit when firm 1 is licensing through a fixed fee, I represents social benefits when not permitted by company 1. The figure shows that consumer surplus and social welfare are both a deterministic value in the case of a fixed-fee authorization, whereas in the case of the royalty fee, consumer surplus and social welfare are an increasing value as the value of t increases, post-authorization means that customer choice is affected by the degree of quality variation. If there is a large difference in quality, i.e. $0 < t < 0.24$ it is optimal, relative to consumer surplus to license through the option of a fixed-fee license rather than a royalty license, If the quality difference is small, i.e. $0.24 < t < 1$, it is optimal relative to consumer surplus to license through the option of a royalty fee license rather than a fixed-fee license In the case of a unit license, the patent-holding firm and the licensee form an alliance because the competitive effects are mitigated and both firms may set higher prices to capture more consumer surplus.

5. Conclusion

Quality improvement technology introduction is an important channel for technological innovation and development of enterprises in China. It is important to study the factors affecting the decision-making of enterprises' authorization contracts. The study of the influencing factors of enterprises' decision-making on authorization contracts is of great significance for Chinese enterprises to carry out high-efficiency technology introduction and promote the enhancement of the quality of domestic products and services and international competitiveness. Based on the technology licensing model, this paper focuses on the transaction Quality improvement type of technology, combines the contract types of fixed fee licensing as well as royalty fee licensing, and considers the impact of innovative enterprises on the form of authorization of technology licensing and social welfare.

we examine the role of quality improvement innovations in the licensing process and the types of licensing contracts in the Stackelberg oligopoly. First, we model the no-licensing case as a baseline. Then, we model two types of licenses: fixed-fee licenses and royalty licenses, and examine the impact of quality innovations on the patentee's profit and consumer surplus, respectively. Finally, the three licensing models are compared on the basis of the benchmark model.

A number of findings shed light on this paper. On the one hand, for innovative firms, innovative firms with quality improvement prefer licensing contracts with unit licensing because, relative to innovative firms that are concerned with their own profits, royalties bring better profits to innovative firms than fixed-fee authorization licensing contracts, regardless of the size of the degree of innovation. On the other hand, as far as consumer surplus is concerned, the government is more concerned about consumer surplus and overall social welfare, and when the degree of innovation is large, the use of fixed-fee licensing is better for social welfare and consumer surplus, but when the degree of innovation decreases, the use of royalties is better than fixed-fee licensing for social welfare and consumer surplus, and at the same time, when the degree of innovation is large, the use of royalties is better than fixed-fee licensing. When authorizing through royalties, it is not only better for consumer surplus and social welfare, but also for the innovative enterprises that are more concerned about their own interests, the profits gained by the innovative enterprises are also greater, so in this case, the innovative enterprises that are more concerned about their own interests and the government that is more concerned about consumer surplus and social welfare reach an agreement on the authorization method that both of them expect. Both of them expect the authorization to be done by way of royalties.

This study has some limitations and future research may extend our study in several ways. First, we assumed that two firms engage in Stackelberg competition. However, in reality, there may be different competitive behaviors between the two companies. Therefore, it is important to analyze the impact of different competitive behaviors on innovators' licensing decisions. Second, we assume that information between two firms is symmetric. However, in reality, information asymmetry is more common when firms enter into licensing contracts. Therefore, future research should analyze asymmetric information in the licensing process. Another limitation of this study is that only one firm was able to license its innovation to another firm; therefore, future research could investigate cross-licensing between two firms.

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