Research on Key Patent Licensing Strategy of 3D Printing Technology

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Abstract. Patent licensing is one of the most important means to gain profits from the commercial application of patents. Based on the analysis of the market sales price, volume and profit of key patented 3D printing technology products, the profit of patentee under the mode of exclusive licensing, sole licensing and general licensing is studied in order to provide reference for formulating the best licensing strategy for key patents of 3D printing technology and speed up the application of patents.

1. Introduction

On May 29, 2016, the Central Committee of the Communist Party of China and the State Council issued the Outline of National Innovation-Driven Development Strategy, proposing to improve the ability of intellectual property creation, utilization, protection and management. On January 18, 2018, according to the data released by the State Intellectual Property Office, in 2017, the volume of patent applications for inventions in China was 1382,000, of which 63.3\% were from enterprises. Patent is one of the important forms of scientific research and innovation. The main purpose of patent application by enterprises is to realize their economic value. It is an important way to realize the economic value of patent application by promoting the transformation of patent application using effective methods.

Patent licensing is one of the important means to obtain profits from the commercial application of patents. Scholars have made many contributions to patent licensing and have made some achievements. Ozel et al. [1] studied the impact of different licensing modes on social welfare with a model of a large scientific and technological institution and four manufacturers, and then made specific suggestions on patent licensing. Thomas [2] studies compulsory licensing strategies for pharmaceutical patents in developing countries and proposes alternative strategies. Simon [3] conducted a questionnaire survey on companies in the pharmaceutical and electronic industries in Japan, studied the patterns of patent licensing and external licensing, and found that reciprocal technology sharing agreements are evolving into more formal relationships, and enterprises are promoting the improvement of their technology brokerage capabilities. Rumyana [4] studied the nature and significance of invention patents for enterprise strategy, and proposed that enterprises classify patents and licenses according to various standards. Pia et al. [5] studied the relationship between innovation model and patent strategy and licensing practices of eight ICT companies in 2004, and found that companies with different attitudes towards innovation are also pursuing funds and benefits from innovation. The common point is that
intellectual property rights are useful only when they are in line with business strategies. Shen Chengran et al. [6] studied the two strategies adopted by the original manufacturer under patent protection in the patent perfection market when facing the competition of re-manufacturer, i.e. unauthorized re-manufacturing and licensed re-manufacturing. Zhang [7] Through the investigation of 350 patent licensing transactions in Chinese universities, found that the duration of patent examination is positively correlated with the delay of patent licensing. Liu et al. [8] From the perspective of 3D printing patent information between China and the United States, this paper makes a comparative study of 3D printing patents between China and the United States, and puts forward some feasible suggestions for the development of China’s 3D printing industry. Ke et al. [9] discussed the price contract of technology license in view of the bargaining power of technology licensee. Tian et al. [10] constructed a two-cycle model to study and compare the decision-making of supply chain members under two different patent licensing strategies of fixed fee and unit fee. Based on the analysis of the characteristics and influencing factors of patent centralized licensing of technology standard alliance, Based on the complete monopoly model and Cournot oligopoly competition model, the product market model is constructed to analyze the patentee's income, and then the optimal licensing strategy is studied.

2. Market game model

2.1. Market demand function model

Assuming that there are n independent product manufacturers in the key product market, the counter-demand function of the product market is as follows:

\[ P = a - b \sum_{i=1}^{n} q_i \]  

(1)

In the formula P is the selling price; \( q_i \) is the sales volume of product manufacturer i, \( i = 1, 2, ..., n \); \( a, b \) is the coefficient of the counter-demand function of the product market, \( a > 0, b > 0 \); \( c \) is the marginal production cost of the product manufacturer, \( c > 0 \).

2.2. Complete monopoly model

In the market model of complete monopoly of key products, only one product manufacturer has obtained patent license for key products. For consumers, it belongs to the typical complete monopoly market. Therefore, this paper uses the model of complete monopoly market to simulate the product market, in which only one product manufacturer is licensed. The profit function of a single product manufacturer in the product market is as follows:

\[ \pi^{dc} = [a - bq^{dc} - c]q^{dc} \]  

(2)

According to the first-order condition of profit maximization, it can be concluded that the selling price of a single product manufacturer is:

\[ p^{dc} = \frac{a + c}{2} \]  

(3)

The sales volume of a single product manufacturer is:

\[ q^{dc} = \frac{a - c}{2b} \]  

(4)

The profits of a single product manufacturer is:

\[ \pi^{dc} = \frac{(a - c)^2}{4b} \]  

(5)
2.3. Cournot oligopoly competition model
In the Cournot oligopoly competition model of key products, there are two or more product manufacturers who have obtained product patent licenses, there are many product manufacturers, which will break monopoly, and there is competition in the market. At this time, Cournot oligopoly competition model can be used to simulate the product market. Assuming that \( n \) product manufacturers operate independently of each other, each product manufacturer determines its own sales volume in order to maximize its own profits, depending on the sales volume of each other. At this time, the profit function of the first product manufacturer is:

\[
\pi_i = q_i (a - b \sum_{i=1}^{n} q_i) - q_i c
\]  

(6)

In formula \( \pi_i \) is the profit of enterprise \( i \). At this time, according to the first-order condition of profit maximization, it can be concluded that the market equilibrium price in the product market is:

\[
p^e = \frac{a + nc}{n + 1}
\]  

(7)

The sales volume of product manufacturer \( i \) is:

\[
q_i^e = \frac{a - c}{(n + 1)b}
\]  

(8)

The profit of product manufacturer \( i \) is:

\[
\pi_i^e = \frac{(a-c)^2}{(n+1)^2 b}
\]  

(9)

Then, when \( n \geq 2 \), Sales price of product manufacturer:

\[
p^e = \frac{a + nc}{n + 1} < p^{dc} = \frac{a + c}{2}
\]  

(10)

Total sales volume:

\[
q^e = \sum_{i=1}^{n} q_i^e = \frac{n}{n + 1} \frac{a - c}{b} > q^{dc} = \frac{1}{2} \frac{a-c}{b}
\]  

(11)

Total profit:

\[
\pi^e = \sum_{i=1}^{n} \pi_i^e = \frac{n}{(n + 1)^2} \frac{(a-c)^2}{b} < \pi^{dc} = \frac{1}{4} \frac{(a-c)^2}{b}
\]  

(12)

Thus, under the model of complete monopoly, the sales price of products in the product market is increased, the total sales volume is reduced, and the total profit of the product industry is increased, which will increase the profits of product patent owners.

3. Patente profit model

3.1. Profit model of patentee with production capacity

3.1.1. Profit model of exclusive licensing. Under the exclusive licensing mode, when a patent is granted to a single product manufacturer, who will be unique user of the patent. No one else (including the patentee himself) can use the patent. At this time, the exclusive licensing profit model can be expressed as:

\[
\omega_y^{el} = \delta_y^{el} \pi^{dc} = \delta_y^{el} \frac{(a-c)^2}{4b}
\]  

(13)
Where $\delta_{el}^y$ is profit sharing ratio of patentee from licensed single product manufacturer under the exclusive licensing model, $0 \leq \delta_{el}^y \leq 100\%$.

At this time, the key product can obtain monopoly profits. Since the patentee has production capacity, the best strategy is to set the profit ratio as $\delta_{el}^y = 100\%$, or if it produces by itself, it will only license the internal production department of the company, rather than the external producers.

3.1.2. Profit model of sole licensing. Under the sole licensing mode, only the patentee and the licensee can use the patent. The patentee's profits are divided into two parts, the profits from manufacturing products for himself, and the income from licensing a single product manufacturer. At this time, there are two product manufacturers, and the Sole license profit can be expressed as:

$$\omega_y = \frac{1}{2} \pi^e + \delta_{el}^y \frac{1}{2} \pi^e$$

$$= \frac{1}{2} \left[ 1 + \delta_{el}^y \right] \frac{n}{(n+1)^2} \frac{(a-c)^2}{b} \quad (n = 2)$$

$$= \frac{1 + \delta_{el}^y (a-c)^2}{9} \frac{1}{b}$$

Where $\delta_{el}^y$ is the proportion of the profits obtained by the patentee from the licensed product manufacturer under the sole license mode, $0 \leq \delta_{el}^y \leq 100\%$.

3.1.3. Profit model of general licensing. Under the general licensing mode, the patentee can license the patent to multiple product manufacturers at the same time. Both the patentee and the licensed product manufacturers can use the patent. The patentee's profits are divided into two parts, one is the profits from making products for himself, the other is the income from licensing multiple product manufacturers. At this time, the general licensing profit model can be expressed as:

$$\omega_y = \frac{1}{n} \pi^e + \delta_{gp}^y \frac{n-1}{n} \pi^e$$

$$= \left[ \frac{1}{n} + \delta_{gp}^y \frac{n-1}{n} \right] \frac{n}{(n+1)^2} \frac{(a-c)^2}{b}$$

$$= \frac{1 + \delta_{gp}^y (a-c)^2}{(n+1)^2} \frac{1}{b}$$

Where $\delta_{gp}^y$ is the proportion of the profits obtained by the patentee from the licensed product manufacturer under the general licensing mode. $0 \leq \delta_{gp}^y \leq 100\%$.

3.2. Profit model of patentee without production capacity

3.2.1. Profit model of exclusive licensing. Under the exclusive licensing mode, when a patent is granted to a single product manufacturer, only the manufacturer of the product can use the patent. No one else (including the patentee himself) can use the patent. At this time, the exclusive licensing profit model can be expressed as:
\[ \omega^{el} = \delta^{el} \pi^{el} = \frac{\delta^{el} (a-c)^2}{b} \quad (16) \]

Where \( \delta^{el} \) is the proportion of the profits obtained by the patentee from the licensed manufacturer of a single product under the exclusive licensing mode, \( 0 \leq \delta^{el} \leq 100\% \).

3.2.2. Profit model of sole licensing. Under the sole licensing model, only patentee and licensees can use the patent. Since the patentee does not have production capacity itself, only one product manufacturer in the market produces the barrier-type product, and the sole license profit can be expressed as:

\[ \omega^{sp} = \delta^{sp} \pi^{sp} = \frac{\delta^{sp} (a-c)^2}{b} \quad (17) \]

Where \( \delta^{sp} \) is the proportion of the profits obtained by the patentee from the licensed product manufacturer under the sole license mode, \( 0 \leq \delta^{sp} \leq 100\% \).

3.2.3. Profit model of general licensing. Under the general licensing model, the patentee can license the patent to multiple product manufacturers at the same time, and the patentee and the manufacturer of the licensed product can use the patent. The profit of the patentee is the revenue share obtained from the license of multiple product manufacturers. At this point, the general license profit model can be expressed as:

\[ \omega^{gp} = \delta^{gp} \pi^{gp} = \delta^{gp} \frac{n (a-c)^2}{(n+1)^2} \quad (18) \]

Where \( \delta^{gp} \) is the proportion of the profits obtained by the patentee from the licensed product manufacturer under the general licensing mode, \( 0 \leq \delta^{gp} \leq 100\% \).

4. Numerical simulation

4.1. Problem description
Taking the 3D printer market as an example, it is assumed that there is one 3D printing patent R&D enterprise and eight 3D printer manufacturers in a certain regional market. The sales volume of each 3D printer manufacturer is \( q_i \); the margin of the 3D printer manufacturer is the production cost \( c=3000 \) yuan/set, and the inverse demand function of the 3D printer market is \( P=15000-2 \sum_{i=1}^{n} q_i \) (yuan/set). 

4.2. Profit Model of Patentee with Production Capacity
When the patentee has its own production capacity, the internal 3D printer manufacturer is licensed under the exclusive licensing mode with a profit sharing ratio of 100%; in the sole licensing mode, there are internal 3D printer manufacturers and licensed 3D printer manufacturers. A total of 2, the external profit share ratio is set to 15%; in the ordinary licensing mode, there are 9 internal 3D printer manufacturers and 8 licensed 3D printer manufacturers, the external profit share ratio is set to 15%. According to the above model, the relevant market data of the capacity-type patentee in the three modes is shown in Table 1.
Table 1. Market data of patentee with capacity

| mode   | Price | Volume | Sales profit | Patentee profit |
|--------|-------|--------|--------------|-----------------|
| Exclusive | 9000  | 3000   | 1800         | 1800            |
| Sole   | 7000  | 4000   | 1600         | 920             |
| General | 4200  | 5400   | 648          | 158.4           |

4.3. Profit Model of Patentee without Production Capacity

When the patentee does not have its own capacity, the single external 3D printer manufacturer is licensed under the exclusive licensing model with a profit share ratio of 15%; in the sole license mode, there is only one licensed 3D printer manufacturer. The profit share ratio is set to 15%; under the normal license mode, there are 8 licensed 3D printer manufacturers with a profit share ratio of 15%. According to the above model, the relevant market data of the three types of non-capacity patent holders are shown in Table 2.

Table 2. Market data of patentee without capacity

| mode   | Price | Volume | Sales profit | Patentee profit |
|--------|-------|--------|--------------|-----------------|
| Exclusive | 9000  | 3000   | 1800         | 270             |
| Sole   | 9000  | 3000   | 1800         | 270             |
| General | 4334  | 5333   | 711.4        | 182.3           |

It can be draw from Table 2 that under the same profit sharing ratio, the exclusive license and the sole license are same, so the exclusive license is the optimal strategy under this condition, because the patent holder still enjoys the right. In addition, in the general license, when the volume of licensed manufacturers increased to 9, the patentee's income decreased by 239,000 yuan. Obviously, with the increase of the license manufacturer, the patentee's income is decreasing; when the profit share ratio increased by 30%, and the patentee's income increased by 311,000 yuan. Obviously, as the profit share ratio increases, the patentee's income increases.

5. Conclusion

In the context of technological innovation, the formulation of patent licensing strategies has an important impact on patent rights, consumers and manufacturers.

(1) For a patent holder with production capacity, because the patent of a key product is monopolistic, the maximum monopoly profit can be obtained by a single license to the manufacturer of the internal product;

(2) For those who do not have a capacity-type patentee, they can obtain a maximum monopoly profit share by granting a single license to the external product manufacturer, and retain the rights to the patent;

(3) In the Cournot oligopoly market of product manufacturers, for the patentee, as the license manufacturer increases, the patentee's income is decreasing; as the profit share ratio increases, the patentee's income is increasing.

Further research can be conducted in the following directions:

(1) Building models that take more factors into account, such as complementary technologies, alternative technologies, that affect patent value;

(2) Conducting empirical studies, to verify the effectiveness of the model through case studies.
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