The Enterprises’ R&D on High Value Patents Under the Condition of Patents’ Technology Spillover

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Abstract. There are a large number of patent applications and authorizations in China, but it is known that the patents’ value is not high, and many of the core patents are mastered by foreign companies. This paper uses the theory of game theory to build the model of different patents’ strategies, containing R companies which refer to enterprises that obtain high-value patents mainly through independent R&D and B companies which refer to the enterprises that acquire high value patents through purchasing. Research shows that based on the assumption that market participants are rational people, in order to maximize their own interests, enterprises have a tendency to re-select according to the input of other enterprises. When the gap in the scale of enterprises’ R&D investment expands, the R enterprises depend more on B companies’s R&D output. The degree of patent spillover and the number of two types of enterprises with the same scale are important factors affecting the enterprises’ R&D inputs.

1. Introduction
On April 16, 2018, the US Department of Commerce issued a ZTE sanction order, prohibiting all US companies from selling components, software and technology to ZTE within 7 years, triggering ZTE’s chip crisis. ZTE admits that “the US ban may cause ZTE to enter a state of shock.” It reflects that China’s ability in researching and producing cutting-edge chips is insufficient, and its technology is at the low end. The core and key high-value technologies and patents are not mastered, resulting in a passive situation. Chinese enterprises generally face the problem of insufficient research and development of high value patents[4].

Some scholars abroad have recognized the necessity of studying high-value patents and conducted some known studies.[1,2] It has been proved that most of the existing researches in foreign countries focus on the evaluation index of patent value. In addition, Lanjouw of the United States demonstrates that independent research and development and patents have an impact on the market value of the company.[3,4] In recent research, some European scholars have further studied some companies and have reached similar conclusions.[5,6]Technology spillovers are corporate technology diffusion behaviors, not because of their voluntariness, but to improve the technical level and production capacity of other companies. Studies have shown that the economic analysis of cooperative innovation is also based on technology spillovers. Due to some characteristics of technology, cooperative innovation has become an important way for enterprises to develop high-value patents, so technology spillovers are introduced in this paper.

Although the existing research explores the problem of lacking of high value patents in China from various aspects, most of them are based on theoretical research and lack of rigorous economic models,
which makes the theory less convincing and lacks in-depth analysis. This paper uses the game model to analyze the problems of enterprises investing in high value patents with different patent strategies, and provides theoretical basis for enterprises to select high value patent strategies.

2. Model

From a practical point of view, companies choose a patent development strategy, often facing the purchase of patent rights of other companies or the choice of relevant technology through independent research and development. In these two options, different companies have different positioning, which in turn determines that they are different. R&D investment. Compared with ZTE, Huawei has prepared more “grain” than ZTE, and independently developed operating systems and Kirin chips for emergency needs, and has applied this chip to its flagship mobile phone, reflecting that Huawei has autonomy R & D results. There are two types of enterprises in the market. One type of enterprise mainly relies on independent R&D investment to update enterprise technology. One type of enterprise mainly relies on purchasing patents of other companies to meet the technical needs of the company. A large part of the second-class enterprises initially invested heavily in independent research and development, and hoped to develop independently to achieve enterprise development. Due to the hysteresis effect of patent research and development, game theory is used to study and explain the internal mechanism of patent type formation.

Because patented inventions have a lagging effect on innovation performance, many companies choose to purchase high value patents on the market, but to a certain extent, the purchase of patents cannot improve the company's technology research and development capabilities and product market core. In order to prevent enterprises from falling into a passive situation in the market, other enterprises attach importance to independent research and development of high value patents, especially the specific embodiment of patent innovation ability and the potential mark of innovation economic value, which can fully reflect the long-term development potential of enterprise R&D investment. [7]. As a standard to measure the level of innovation, high value patents play an important role in establishing competitive superiority.

Suppose there are K companies with the same size. Here is the variables designed:

\[ p_i: \text{Enterprise i's input of researching for high value patents} \]
\[ q_i: \text{Enterprise i's input of purchasing on high value patents} \]
\[ \omega: \text{Other companies's spillover coefficient} \]
\[ m: \text{The strength of researching for high-value patent output} \]
\[ n: \text{The intensity of purchasing for high-value patent output} \]

2.1. Pareto optimality

Set enterprise i research and develop patents, the input cost per unit of high-value patent is \( c_i \), and the unit cost of non-high-value patent investment is \( c_j \), according to the economic Douglas function, the production function of enterprise i is:

\[ u_i = (p_i + \omega \sum_{j=1}^{k} p_j)^m q_i \]

\( C_i \) represents the investment in high value patents of enterprise i, \( C_p \) represents the unit cost of independent R&D on high-value patents, and \( C_q \) represents the unit cost on purchasing high-value patents. The cost function of enterprise i is:

\[ C_i = C_p p_i + C_q q_i \]

The total output and total cost on high-value patents of K companies with the same size in society are:

\[ u_f = \sum_{i=1}^{n} u_i \quad c_f = \sum_{i=1}^{n} C_i = C_p p_f + C_q q_f \]
$q_T$ is the total input for all high value patents with the same scale. Since the enterprise is limited by the production cost, the following model is established.

$$\max u_i = (p_i + \omega \sum_{j=1}^{k} p_j)^m q_i^n$$

subject to $c_i = c_p p_i + c_q q_i$

Constructing a Lagrangian function,

$$L_i = u_i + \mu \left( c_i - c_p p_i - c_q q_i \right)$$

Solueting optimization condition,

$$\frac{\partial L_p}{\partial u_p} = \frac{\partial q_i}{\partial x_{u_p}} - \mu c_p = m \left[ (1 - \omega) p_i + \omega \mu_T \gamma q_i^{n-1} \right] y_i^n - \mu c_p = 0$$

$$\frac{\partial L_q}{\partial q_i} = \frac{\partial u_i}{\partial q_i} - \mu c_p = n \left[ (1 - \omega) p_i + \omega p_T \right] q_i^{n-1} - \mu c_p = 0$$

Then we can get the optimal input of enterprise $i$

$$p_i = \frac{m}{m+n} c_p - \frac{\omega m}{m+n} \sum_{j=1}^{k} p_j$$

Under the condition that the strength of intellectual property protection is certain, according to the rationale of economics, the decision makers of enterprises should maximize the benefits and decide the investment in their high value patents according to other enterprises, if more high value patents other enterprises purchase, the less the enterprise $i$ inputs in high value patents.

R&D on high value patents has a hysteresis effect. Compared with purchasing high value patents, R&D on high value patents is not obvious in short-term innovative performance, and they do not contribute to output. Therefore, enterprises that attach importance to short-term benefits tending to increase their purchase of patents. From the perspective of maximizing profits, if more and more companies purchase high-value patents, enterprises will often reduce their investment in high value patents’ research. In order to calculate the input under the condition of maximizing the collective interest, that is, when the enterprise achieves the Pareto optimality, the conditions for the whole social enterprise meet:

$$\max u_T = \sum_{i=1}^{k} u_i \quad c_T = c_p p_T + c_q \sum_{i=1}^{n} q_i$$

Constructing a Lagrangian function,

$$L_T = \sum_{i=1}^{k} u_i + \mu \left( c_T - c_s x_T - c_y \sum_{i=1}^{n} y_i \right)$$

Under the condition of maximizing the collective interests of social enterprises,

$$\frac{\partial L_T}{\partial p_T} = \sum_{i=1}^{k} \frac{\partial u_i}{\partial p_T} - \mu c_p = 0 \quad \frac{\partial L_T}{\partial q_i} = \frac{\partial u_i}{\partial q_i} - \mu c_p = 0$$

From the above formula, and When a single business achieves optimality, there is

$$\frac{\partial L_T}{\partial p_T} = c_p - \sum_{j=1}^{k} \frac{\partial u_j}{\partial p_T} \exp_T \quad \frac{\partial u_i}{\partial p_T} = c_p$$

$$\frac{\partial L_T}{\partial q_i} = c_q \quad \frac{\partial u_i}{\partial q_i} = c_q$$

When the Pareto optimality is reached, the ratio of the marginal production of high value patents in researching and purchasing is less than the ratio of the individual company achieving optimality. It can
be concluded that the total R&D input in high value patents in Pareto optimal is greater than the total social input when individual companies achieve optimality $P_T$.

Therefore, when a single enterprise achieves optimality, enterprise $i$’s inputs in high value patents is less than the inputs when achieving Pareto optimality.

2.2. Different scales

Assume two types of game subjects, R enterprises and B enterprises. Both of them research and develop high value patents. R companies refer to the enterprises that obtain high-value patents mainly through independent R&D and B companies refer to the enterprises that acquire high value patents through purchasing. Assume that the scale and total investment of the two types of companies are not much different, there are $a$ R enterprises, $b$ B enterprise, and $a+b=k$.

R&D-type companies’ high-value patent R&D costs and inputs are $c_r$ and $x_r$, respectively. The high value patents’ R&D costs and inputs of purchasing companies are $c_b$ and $x_b$, respectively. R companies’ R&D inputs in high value patents is $t$ ($t>1$) times, $c_r=tc_b$.

Getting R companies’ inputs in high value patents,
$$x_r = \frac{m}{m+n} \cdot \frac{tc_b}{c_x} - \frac{\omega m}{m+n} \left[ (a-1) x_r + b x_b \right]$$

Getting B companies’ inputs in high value patents,
$$x_b = \frac{m}{m+n} \cdot \frac{c_b}{c_x} - \frac{\omega m}{m+n} \left[ (b-1) x_b + a x_r \right]$$

From the above formula,
$$x_r = \frac{m \left[ t \left( m+n \right) + t \left( b-1 \right) \omega n - r \omega n \right]}{m + (1 - \omega) n} \cdot \frac{c_b}{c_x} \quad x_b = \frac{m \left[ (m+n) - (t-1) a \omega n - \omega n \right]}{m + (1 - \omega) n} \cdot \frac{c_b}{c_x}$$

From the above formula, when $t>1$, $r \geq 1$, $x_r>0$. When $t<1+[(m+(1-\omega)n)/r\omega n]$, $x_b>0$. At this time, the Nash equilibrium is:

$$x_r = \frac{m \left[ t \left( m+n \right) + t \left( b-1 \right) \omega n - r \omega n \right]}{m + (1 - \omega) n} \cdot \frac{c_b}{c_x} \quad x_b = \frac{m \left[ (m+n) - (t-1) a \omega n - \omega n \right]}{m + (1 - \omega) n} \cdot \frac{c_b}{c_x}$$

From the above formula, when $t>1$, $r \geq 1$, $x_r>0$. When $t<1+[(m+(1-\omega)n)/r\omega n]$, $x_b>0$. At this time, the Nash equilibrium is:

$$x_r^* = \frac{mt}{m+n+(a-1)\omega n} \cdot \frac{c_b}{c_x} \quad x_b^* = \frac{m}{m+n+(a-1)\omega n} \cdot \frac{c_b}{c_x}$$

When $t \geq 1+[(m+(1-\omega)n)/r\omega n]$, $x_b \leq 0$. When reaching Nash equilibrium, $x_b=0$.

From this, $x_r^* > x_b^*$. When $t<1+[(m+(1-\omega)n)/r\omega n]$ and Nash equilibrium is reached, R companies invest more in high value patents than B companies. As the R&D inputs gap between R and B companies continues to expand, R companies’ inputs on R&D continue to increase, while B companies’ inputs continue to decrease.

When the inputs gap between R companies and B companies is large to a certain extent ($t \geq 1+[(m+(1-\omega)n)/r\omega n]$), B companies invest little in R&D, and the way to obtain high value patents is mainly through purchasing high-value patents from other companies.

It can be concluded that R companies will input more R&D in high value patents after establishing competitive advantages; while B enterprises will reduce their R&D inputs in high value patents. When
the scale gap increases to a certain extent, the B companies will no longer input in researching high value patents.

3. Conclusion

Research shows that under the condition of technology spillover, enterprises are more inclined to adopt other companies’ outputs in order to max their own interests. When more and more companies choose to purchase high value patents from other companies, there are fewer and fewer companies that choose to research high value patents. Reseathering and developing high value patents require overwhelming resources, and there exists greater uncertainty about the research results. As a result, R companies and B companies with the same scale, the research and development of enterprises’ high value patents in order to maintain their competitive advantages, will input more in researching, and B companies will rely more on other companies’ outputs.

When the scale differences between them increase to a certain extent, the B companies will not input in researching high value patents. This explains why ZTE continues to rely on importing chips from other countries without their own chips. The ambiguity of the value of a single patent has distinct high-dimensional characteristics in the process of implementation evaluation. The actual patent transaction is often difficult to evaluate scientific value. Few documents analyze the phenomenon formed by patent activities of a certain enterprise or some enterprises from the perspective of phenomena, and analyze the causes of phenomena, and provide a theoretical basis for the development of patents. The extensive application of new technologies in the field of patent value evaluation will become an emerging research in this field. direction. And as our government pays more and more attention to intellectual property rights, and China is increasingly active in the international market, and emerging markets such as India have also emerged with good innovative products, and sales in developed countries have achieved good results at home and abroad. How to form high-value patents and how to evolve them into new research trends in the future. It can be concluded that the total investment in high-value patent R&D in Pareto optimal is greater than the total social input when individual companies achieve optimality. It can be seen that it is also a difficult problem to solve the contradiction between the two.

In this paper, the game model under the condition of competition between enterprises is established. The situation of enterprises under cooperation conditions is not considered, and further research and improvement are needed.

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