Research on the Participation Risk of Non-core Enterprises in the Distributed Innovation Network ——Based on the Perspective of Knowledge Spillover

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Abstract—Distributed innovation network, as a new platform, has been accepted by more and more enterprises. Non-core enterprises are in a weak position, facing the core intellectual property risk of spillover. This study uses the Black-Scholes model in real options and calculates the economic value of intellectual property with financial methods. Furthermore, this study comprehensively measures the effects of various factors in the model from the perspective of non-core enterprises. The results are shown as following: That non-core enterprises choose to join distributed innovation network can reduce cost of commercialization of intellectual property and increase the economic life of intellectual property rights.

Keywords-component, Distributed innovation network, Non-core enterprises, Real options, Black-Scholes model

1 INTRODUCTION

In the context of economic globalization and the rapid development of information technology, a new mode of technological innovation-distributed innovation has emerged. Distributed innovation refers to innovation activities carried out within an enterprise and between enterprises with cooperative relationships (upstream and downstream) based on a common network platform in different regions. This innovative model is adopted by many multinational enterprises and large enterprises such as Boeing and Procter & Gamble.

In a distributed innovation network, each participating enterprise is a node of the network, and knowledge is highly shared between each node. This is the biggest feature of distributed innovation that distinguishes it from traditional innovation models. Jorge believes that the distributed innovation network can effectively meet the needs of enterprises for obtaining external resources, knowledge, information, and provide support for the smooth development of enterprise innovation activities [1]; Liu defines a distributed innovation network as an institutional arrangement. Under this institutional arrangement, enterprises cooperate effectively through resource sharing, mutually benefit each other to complete specific innovation goals [2]. The network node in the special position or the network node with strong innovation ability

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becomes the core of the innovation network, which can be called the core enterprise [3]. Corresponding other nodes can be called non-core enterprises. Non-core enterprises refer to those unit groups that have weak control, small market share, and follow the technological development trend of the industry in the innovation network. They are usually regarded as the subsidiary role of core enterprises in the ecosystem provides supporting, assembly and OEM production [4]. Compared with core enterprises, non-core enterprises are in a disadvantaged position due to the disadvantages of network location and lack of their own strength. They are restricted by core enterprises and other non-core enterprises. At the same time, they also face many risks, the most serious of which is the spillover of core intellectual property rights.

Entering the innovation network, enterprises often need to invest their intellectual property rights into the network, and face risks such as technology theft and spillover. The core enterprise is in a network-dominant position and can protect its own interests in knowledge transfer through contracts, while the non-core enterprise is at a disadvantaged position and under the risk of intellectual property spillover. What should non-core enterprises do in this situation? Some literatures use game theory and principal-agent model to solve the problem [5]. However, the existing research only regards income as the standard, ignoring the value of corporate intellectual property rights. This study analyzes this issue from the perspective of non-core corporate intellectual property value measurement.

2 MATERIALS AND METHODS

2.1 Research hypothesis

In the distributed innovation network, the environment faced by non-core enterprises is complex and changeable, so this study makes the following basic assumptions before analyzing:

1) In the distributed innovation network, it is the responsibility of non-core enterprises to circulate intellectual property rights in the network.

2) The circulated intellectual property rights of non-core enterprises refer to their core patents, which are the pillars of enterprise survival.

3) The decision-making of non-core enterprises depends entirely on the amount of the income, and there is no external intervention.

4) For non-core enterprises, once they have obtained the right to use a certain patent, they will face two decision-making paths: one is to participate in a distributed innovation network, and the core patent is handed over to the network in order to obtain benefits. The economic value of the intellectual property is C_a; the second path is to commercialize the core patent. The economic value of the intellectual property is C_b.

2.2 Models

The mainstream method of evaluating the value of intellectual property is to use the present value method of income [6]. However, this method does not consider the characteristics of knowledge spillover risk and a high degree of uncertainty in the future, so this study introduces the idea of

real options to measure the value of intellectual property rights. There are currently two main real option pricing models: binomial model and Black-Scholes model. As the calculation process of the binomial model is more complicated and the results are more susceptible to subjective factors when applied, this study uses the Black-Scholes model.

The Black-Scholes model [7] was derived in 1973 by Fischer Black and Myron Scholes. They used the principle of heat conduction in physics to derive the value estimation formula of the call option. This model uses the concept of risk-free hedging to derive the fair price of the option. The basic assumptions are as follows:

1) The short-term interest rate is known and fixed;

2) The stock price obeys geometric Brownian motion, whose distribution satisfies the lognormal distribution, and the variance of the stock price return rate is a constant;

3) No dividend payment;

4) The option is a European option, so the right can only be exercised on the expiry date;

5) No transaction costs or taxes;

6) Ability to sell securities at short-term interest rates;

7) Short selling is allowed.

The basic form of the Black-Scholes model is:

$$C = SN（d_1）- Xe^{-rT}N(d_2) \tag{1}$$

$$d_1 = \frac{\ln\frac{S}{X}+(r+0.5\sigma^2)}{\sigma\sqrt{T}} \tag{2}$$

$$d_2 = \frac{\ln\frac{S}{X}+(r-0.5\sigma^2)}{\sigma\sqrt{T}} = d_1 - \sqrt{T} \tag{3}$$

C is the buyer option value; S is the value of the underlying asset evaluation base date; X is the option exercise price; T is the option exercise period; σ is the underlying asset's corresponding stock price volatility; r is the risk-free rate of return.

2.3 Redefinition of Black-Scholes model variables

The Black-Scholes model was initially only applicable to securities. Some scholars have discovered through research that this model can be used to evaluate the value of assets traded in the market. Therefore, this study chooses to use this model to evaluate the value of intellectual property rights, and use Lin's method [8] to redefine the parameters in the model (Table 1):

Table 1 Redefinition of variables

Option value	Variable	Intellectual property value
Call option value	*C*	The economic value of intellectual property

Value of the underlying asset assessment base date	*S*	Current market value corresponding to intellectual property
Option exercise price	*X*	Pre-determined costs for the commercialization of intellectual property rights
Option exercise period	*T*	Use time for the commercialization of intellectual property rights
The underlying asset corresponds to the stock price volatility	*σ*	Intellectual property corresponds to the volatility of market present value changes
Risk-free rate	*r*	Risk-free rate

3 RESULTS & DISCUSSION

3.1 Data

This study randomly selects a sample of some listed enterprises in the "Second Phase of the Demonstration Project for Promoting the Industrialization of Patented Technology" of the State Intellectual Property Office, which is a total of 50 technology transfer transaction data. Therefore, we can get the value range of S, X, T, σ, r (Table 2).

Table 2 value range of Variables

Type	Average	Maximum	Minimum
Current market value corresponding to intellectual property rights (million yuan)	874.7097	1331.264	7.12
Pre-determined cost required for the commercialization of intellectual property rights (million yuan)	47.5565	813	0.29
Commercialization of intellectual property rights (years)	1.73	3	0.1
Risk-free interest rate (%)	5.22	8	4
The volatility rate of intellectual property corresponding to the current value of the market (%)	49.25	72.71	26.52

3.2 Results

The economic value of commercializing intellectual property by an enterprise is mainly affected by the five variables: S, X, T, σ, r. It can be expressed in the form of a function: C= f (S, X, T, σ, r). It is simulated with MATLAB to find out the effect of a certain variable on the same amount of change in its value interval when other variables take a fixed value.

1) The effect of S on C: When S changes between 7.12 million yuan and 1331.2264 million yuan, and X, T, σ, r take their averages, the effect of S on C is shown in Fig. 1. When S increases, C increases accordingly. S and C are positively correlated.

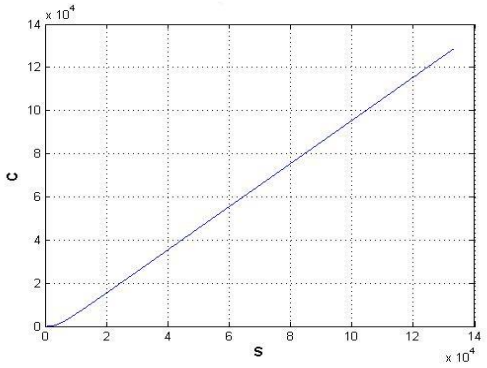

Figure 1 The effect of *S* on *C*

2) The effect of X on C: When X changes between the 0.29 million yuan and 813 million yuan, and S, T, σ, and r take their averages respectively, the effect of X on C is shown in Fig. 2. When X increases, C decreases. X and C are negatively correlated.

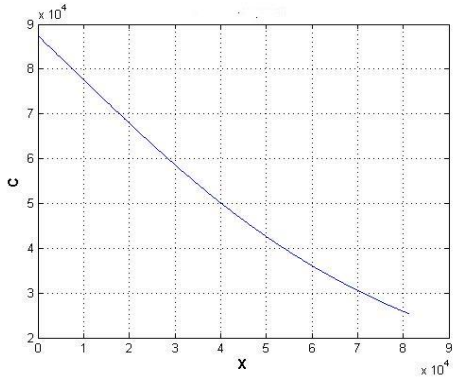

Figure 2 The effect of X on C

3) The effect of T on C: When T changes between 0.1 days and 3 days, and S, X, σ, and r take their averages, the effect of T on C is shown in Fig. 3. When T increases, C increases accordingly. T and C are positively correlated.

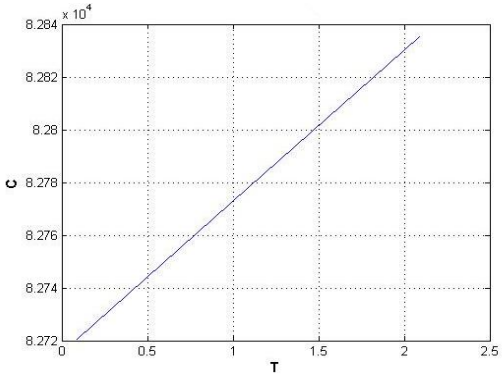

Figure 3 The effect of T on C

4) The effect of σ on C: When *σ* changes between 26.52% and 72.71%, and S, X, T, and r take their averages, the effect of σ on C is shown in Fig. 4. When σ increases to a certain threshold, C begins to increase. σ and C are positively correlated.

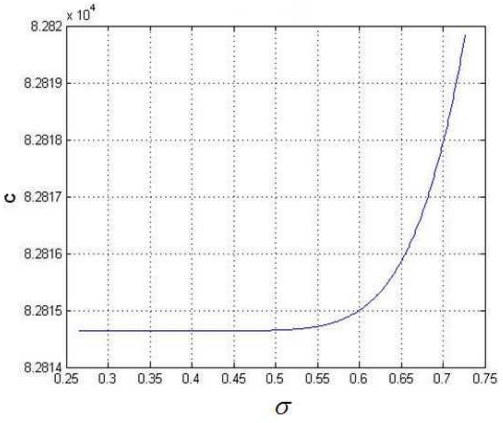

Figure 4 The effect of σ on C

5) The effect of r on C: When r changes between 4% and 8%, and S, X, σ, and T take their averages, the effect of r on C is shown in Fig. 5. When r increases, C increases. r and C are positively correlated.

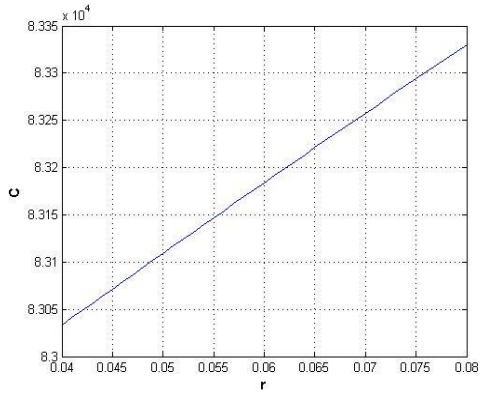

Figure 5 The effect of r on C

3.3 Discussion

Based on the simulation results, we can clearly derive the relationship between various factors and the value of corporate intellectual property. In the function C= f (S, X, T, σ, r), S, T and r all have a positive effect, and X has a negative effect. In addition, σ is has positive effect only when it reaches a certain threshold.

1) Current market value corresponding to intellectual property: S is the most difficult to determine among all variables. We refer to the formula calculated by Tobin intangible assets: intangible asset value = (stock price × number of issued shares) - net asset value. According to the literature, when an enterprise obtains a patent, the market will re-evaluate the value of the enterprise and quickly reflect it in its stock price. Based on this, it can be inferred that whether non-core enterprises participate in the distributed innovation network will not affect the market present value of their intellectual property rights, which is $S_a=S_b$.

2) Pre-determined costs for the commercialization of intellectual property rights: For non-core enterprises, the cost of independent commercialization of intellectual property rights includes R&D, human capital, equipment, plant and other costs. While investing in the innovation network only requires authorization or transfer of patents, the cost is much lower, so we can get: $X_a<X_b$.

3) Use time for the commercialization of intellectual property rights: Intellectual property is a declining asset. As technology advances, the value of patents is getting lower, and other enterprises can easily copy existing products. Therefore, once an enterprise commercializes its intellectual property and puts it into production, its revenue will become lower. If non-core enterprises participate in the distributed innovation network and transfer their intellectual property rights, they can enjoy the excess profits brought by the flow of intellectual property rights during the life cycle of the innovation network. It can be inferred $T_a>T_b$.

4) Intellectual property corresponds to the volatility of market present value changes: Only when σ reaches a certain threshold, a positive effect occurs. σ is affected by many factors such as market competition, market capacity, time, etc. These factors are all related to the industry in which the product is located. For non-core enterprises, whether they join the innovation network

or independently commercialize their intellectual property rights, the corresponding market present value volatility varies because they are in different industries.

5) Risk-free rate: The risk-free interest rate during the transfer of patented technology is measured by the time deposit interest rate of the Bank of China at that time. Therefore, within a certain period of time, no matter which path the non-core enterprise chooses, $r_a=r_b$.

6) The economic value of intellectual property: For non-core enterprises, whether they choose to join the distributed innovation network and circulate intellectual property rights in order to obtain profit dividends, or commercialize intellectual property independently and obtain exclusive profits, S, σ and r will not have a significant effect on the selection. What is more, the economic value of intellectual property obtained through path one is more than that of path two, which means non-core enterprises can obtain higher economic benefits by joining the innovation network.

4 CONCLUSION

This study uses the Black-Scholes model in real options to calculate the economic value of intellectual property rights using financial methods. Next, this study comprehensively measures the effects of various factors in real conditions on whether enterprises participate in the corporate network from the perspective of non-core enterprises. At last, it is concluded that choosing to join the distributed innovation network has more advantages than disadvantages for non-core enterprises that are in a weak position on the network and whose core intellectual property is at risk of spillover.

4.1 Reduce cost of intellectual property commercialization

After a non-core enterprise obtains a certain intellectual property, if it chooses to commercialize it independently, it will incur costs of R&D, manpower, equipment, and plant, which will be relatively expensive. Many non-core enterprises cannot bear the burden or the risks brought by commercialization failure. While choosing to join the distributed innovation network, they face the risk of core intellectual property spillover, and the benefits are lower than expected. However, they only need to authorize and transfer the intellectual property rights, and can get profit dividends. From a cost point of view, joining the network can enjoy excess profits at a lower cost. For non-core enterprises with weak strength, it is undoubtedly a safe and fast way to turn intellectual property rights into economic benefits.

4.2 Increase the economic life of intellectual property

With technological progress and technological spillovers, the economic life of intellectual property is bound to end. If non-core enterprises want to obtain benefits through intellectual property rights, they must commercialize them. The initial profits of independent commercialization can be enjoyed exclusively by enterprises, and once they are marketed, they will be copied and replaced soon, thus accelerating the end of the life of intellectual property rights. Instead, they can authorize and transfer intellectual property rights to a distributed innovation network that operates stably and has a long life cycle. The profit dividend generated

by the intellectual property owned by non-core enterprises will accompany the entire network life cycle.

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