Game Analysis of Industry-University-Research Collaborative Innovation Based on Knowledge Potential Difference

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Abstract. With the continuous deepening of the theory and practice of Industry-University-Research collaborative innovation in China, the Industry-University-Research alliance has become an important guarantee for promoting national independent innovation and technological progress. However, because the collaborative innovation of Industry-University-Research involves tacit knowledge, there is a knowledge potential difference between enterprises and academics, and this will affect the efficiency of knowledge sharing and knowledge transfer, resulting in a large extent affecting the stable development of Industry-University-Research alliance and the efficiency of collaborative innovation. In order to study the influence of knowledge potential difference between enterprises and academics on the performance of collaborative innovation of Industry-University-Research alliance, this paper constructs a game model of collaborative innovation of Industry-University-Research alliance considering knowledge potential difference, in order to provide theoretical support and practical guidance for improving the stability and efficiency of collaborative innovation of Industry-University-Research alliance.

Introduction

In 2015, the report of the 18th National Congress of the Communist Party of China clearly stated: We must continue to deepen the reform of the scientific and technological system, actively promote the transformation of scientific and technological achievements into real productive forces, and constantly establish a sound national innovation system, taking enterprises as the mainstay and market-oriented, and actively promote the combination of industry, education and research. Scientific and technological innovation and Industry-University-Research cooperation have been upgraded to a new level, and the relevant theoretical research will therefore produce more valuable guiding significance for practical activities [1].

With the advent of knowledge economy, knowledge is not only increasingly important for enterprises, but also has become a key element for enterprises to enhance core technology, and even to build core competitiveness. Compared with universities and scientific research institutions, enterprises have relatively low levels of knowledge and a huge demand for technology. Through the collaborative innovation of Industry-University-Research, universities and research institutions can transfer advanced technology to enterprises and realize knowledge sharing. Collaborative innovation of Industry-University-Research has become an important way for many enterprises to acquire advanced technology and continuously improve their core competitiveness.

However, due to the existence of knowledge potential difference between enterprises and academics, they face many obstacles in the process of knowledge transfer and sharing, and these obstacles will seriously affect the performance of collaborative innovation [2].Therefore, how to reduce the knowledge potential difference between the enterprises and academic, and transform the scientific and technological achievements of academics into the productivity of the enterprises through cooperation? This is of great significance to promote the knowledge transfer and enhance

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the efficiency of innovation of Industry-University-Research collaborative innovation.

Literature Review

Collaborative innovation of Industry-University-Research means that academics and enterprises can achieve innovations through resource sharing or complementary advantages, and coordinate and cooperate with each other on the basis of benefit sharing and risk sharing to complete a technology or knowledge innovation. Activity process [3].

The energy of matter and the state it is in is called potential. Potential is a physical concept, and any substance has potential energy at any position [4]. Du Jing puts forward the concept of “knowledge potential” in the research of knowledge growth mechanism, and describes the potential existence due to the knowledge stock possessed by the knowledge subject. The lower the knowledge position of the knowledge subject, the more the subject will generate knowledge needs, and absorb more knowledge from the outside through various ways and means. In different periods, the knowledge potential of the same knowledge subject is different; in the same period, the knowledge potential of different knowledge subjects is also different, which forms the knowledge potential difference [5]. Griliches (1984) [6] holds that the analysis and comparison of potential differences exist in all knowledge. It is the existence of knowledge potential differences that makes it possible for different knowledge subjects to cooperate. The subjects need to integrate the original knowledge with the newly acquired knowledge. Zhang Yujie (1999) [7] believes that different countries and enterprises will have different knowledge and technology potential because of the different level of knowledge and technology they master. Therefore, enterprises will constantly improve their knowledge and technology level by learning and introducing technology, and narrow the gap between enterprises with high knowledge potential.

Summing up the above scholars' viewpoints, this study holds that the greater the knowledge potential gap, the easier it is for enterprises and researchers to derive such speculative behavior to overcome the obstacles of knowledge transfer caused by the excessive potential gap. That is to say, the objective existence of knowledge potential difference provides the source power for knowledge transfer at the same time increases the possibility of speculative behavior for the purpose of transfer. The knowledge transfer mentioned in the description refers to the process of knowledge transfer from the sender to the receiver (Ma Qingguo 2006)[8].

Model Construction

Basic nature of game model. In the collaborative innovation alliance of Industry-University-institute, there are various kinds of knowledge transfer among enterprises, universities and research institutes. Participants in the alliance will exchange and share knowledge in order to achieve the goal of collaborative innovation. However, due to the different knowledge attributes and objectives of the participants, there will be a knowledge potential difference. In the alliance, the academics often possess advanced knowledge and technology and have a high level of knowledge. They are the providers of advanced knowledge. Enterprises are relatively low in knowledge and are knowledge recipients [9].The Industry-University-Research Collaborative Innovation Alliance includes many participants, such as enterprises, research institutions, government and so on. In order to facilitate the research, we simplify the participants into two parts: enterprises and academics. In the process of collaborative innovation, both the research institute and the enterprise have two decisions: cooperation and non-cooperation. According to the characteristics of Industry-University-Institute alliance and the related content of game theory, the game model of Industry-University-Institute alliance has the following characteristics:

Both sides of the game are rational. Enterprises and academics participate in the collaborative innovation alliance of Industry-University-Institute based on certain purposes. The starting point of their decision-making is to invest the least resources to obtain the greatest benefits. When cooperation is profitable, that is to say, the benefits of cooperation are higher than the resources they invest, they will choose cooperation. However, they will not choose to cooperate when the

resources they invest are far higher than the benefits they can get. When one party does not cooperate, it will bring inevitable risk to the other party.

Game is a Non-zero-sum game. The Non-zero-sum game is different from the zero-sum game. Zero-sum game means that the sum of the returns of the two sides is zero, that is to say, one side gains profits and the other side inevitably loses the same amount. The Non-zero-sum game means that the sum of the profits of both players is not zero. Because of the synergistic effect in the Industry-University-Research alliance, the profit of one side of the game is not based on the loss of the other side. Therefore, there is a possibility of "win-win" between the two sides of the game, thus enterprises and academics can realize cooperation.

The decision of both sides is uncertain. Both sides of the game are in a constantly changing environment. And their decision-making is based on investing the least resources to obtain the highest return. Therefore their decisions will change with time, interests and goals. When one party's decision changes, the other party will change its decision in order to avoid risks and obtain maximum benefits. Therefore, the decision of both sides of the game is unpredictable and uncertain.

The game is continuous and repetitive. The collaborative innovation cooperation between enterprises and academics is not a short-term cooperation, but a continuous cooperation. Their cooperation will not be terminated due to the emergence of a technology. In addition, there are costs in the process of participating in the alliance. So in order to maximize their profits, they will repeat the game continuously [7].

Basic assumptions of the game model. Suppose that each time the enterprise and the research party invest in the alliance is I, in which the proportion of the enterprise invested in the total fund is a, while the proportion of the research party invested in the total fund is b, and a + B = 1.

Assume that the total benefit of collaborative innovation is kI (where K represents the coefficient of collaborative innovation and k > 1, and the income of both sides is distributed according to the proportion of income). If the enterprise and the research party do not participate in the collaborative innovation alliance, the input of the participants will be obtained by the non-participants. If neither enterprise nor Research Institute participates in the collaborative innovation alliance of industry, University and research institute, then both sides pay 0.

The decision-making of both sides is uncertain. Assuming that the probability of enterprises choosing cooperation is p, enterprises only have two kinds of decision-making: cooperation and non-cooperation, so the probability of choosing non-cooperation is 1-p. Similarly, for the academic and research parties, the probability of cooperation is q, and the probability of non-cooperation is 1-q.

In the process of collaborative innovation, enterprises and researchers are affected by positive feedback incentives. The incentive coefficient is expressed by $（1+\delta）^{n-1}$ (where delta is also called incentive factor, $\delta=\frac{1}{r}$, r is interest rate). With the increase of the number of cooperation between the two sides, the positive feedback incentive effect is more obvious, and the incentive effect is cumulative. The stronger the effect of positive feedback incentives is, the stronger the ability of enterprises and research institutes to collaborate and innovate, and the higher the returns.

If in the process of collaborative innovation, one party of the enterprise or the research party chooses to cooperate while the other party chooses not to cooperate, the non-cooperative party will be punished accordingly. The penalty coefficient is expressed in x, and the penalty is cumulative. With the increase of the number of times of non-cooperation, the profit in the collaborative innovation alliance will decrease.

In the collaborative innovation of industry, University and research, the position of enterprises and researchers in knowledge will not be exactly the same, so there will be a knowledge gap between them. Because of this kind of knowledge potential difference, knowledge is transferred between enterprises and researchers, so the knowledge potential of enterprises and researchers is gradually balanced. Assume that the knowledge gap between the enterprise and the research institute is α, and the larger α is the larger the potential between the two.

Model analysis. From the above analysis, we can conclude that the payment matrix of

Enterprises and Academics is as follows (enterprises are represented by A, learning and research parties are represented by B, cooperation is represented by C, and non- cooperation is represented by N) :

Table 1 Payment Matrix of Enterprises and Academics

		Academics	
		cooperation	non-cooperation
Enterprises	cooperation	G_A^{CC}, G_B^{CC}	G_A^{CN}, G_B^{CN}
	non-cooperation	G_A^{NC}, G_B^{NC}	G_A^{NN}, G_A^{NN}

According to the payment matrix shown in the above table, the payment of the enterprise is analyzed in detail.

The first situation: companies and academics choose to cooperate. At this time, the company can obtain the “collaborative value” brought about by collaborative innovation, and obtain the income according to the proportion of capital investment.

$$G_A^{CC}=\alpha pqakI(1+\delta)^{n-1}-pqaI=pqaI[(\alpha k(1+\delta)^{n-1}-1]$$

The second case: the company chooses to cooperate, and the research institute chooses not to cooperate. If one party chooses not to cooperate, it will not produce “collaborative value”, so the loss of the enterprise is the income of the research and development party.

$$G_A^{CN}=-p(1-q)aI$$

The third situation: the company chooses not to cooperate, and the research institute chooses cooperation. At this time, the company's revenue is the total value invested by the research institute.

$$G_A^{NC}=(1-p)qbI-(1-p)q(1+s)^{n-1}$$

The fourth situation: companies and academics have chosen not to cooperate. Both parties choose not to cooperate and will not produce synergistic value, so both sides have zero returns.

$$G_A^{NN}=0$$

Enterprises have complete information on their own decisions, but the decision-making of the Academic is incomplete information. And the enterprise is rational, and it always starts from maximizing its own interests. Therefore, the key prerequisite for enterprises to choose cooperation is whether the expected payment is greater than the payment when they choose not to cooperate.

If ΔGA is the difference between the expected payment of cooperation and non-cooperation, then:

$$\Delta GA=\Sigma(G_A^{CC}+G_A^{CN}+G_A^{NC}+G_A^{NN})(p=1)-\Sigma(G_A^{CC}+G_A^{CN}+G_A^{NC}+G_A^{NN})(p=0)$$

Substituting the company’s payment into the above formula:

$$GA=\alpha qakI(1+\delta)^{n-1}-aI+qaI-qI+q(1+s)^{n-1}$$

When $\Delta GA\geq 0$ enterprise chooses cooperation, which is $a\geq\frac{qI-q(1+s)^{n-1}}{\alpha qkI(1+\delta)^{n-1}+qI-I}\geq\frac{1}{\alpha k(1+\delta)^{n-1}}[1-\frac{(1+s)^{n-1}}{I}]$

The relationship between a and α, k, δ, n, I, s can be obtained by analyzing the above formula:

When k, δ, n, I, s are constant, a and α are in inverse relationship. This shows that when other

conditions remain unchanged, the greater the knowledge gap, the smaller the willingness of enterprises to participate in collaborative innovation. With the increasing knowledge gap between enterprises and academics, knowledge exchange and knowledge transfer between the two are more difficult. Enterprises with lower knowledge potential can't accept the ideas and opinions of the high-knowledge research institutes, so the enthusiasm of enterprises to participate in the collaborative innovation of industry, university and research is not high. This explains precisely that in the early stage of the participation of enterprises and academics in the industry-university-research alliance, because the research institutes have higher knowledge potential than the enterprises, the knowledge transfer efficiency between them is low, and the effectiveness of collaborative innovation is not obvious. Therefore, enterprises and academics need a period of communication and knowledge sharing to reduce the knowledge gap between them, and then take advantage of the industry-university-research alliance.

When k, α, n, I, s are constant, a and δ have a reverse relationship. This means that when the other factors remain unchanged, the value of a can be relatively small when the excitation factor δ is large. Even if the enterprise is in a non-dominant position in the industry-university-research alliance, its willingness to cooperate will be strengthened with the enhancement of the incentive effect brought by the synergy innovation mechanism of industry, academia and research. In other words, when the company pays more attention to the current income than the future income, it will have a lower willingness to cooperate. On the contrary, when enterprises pay more attention to the long-term development, it is not easy to generate Opportunism. Even if the share held by the industry-university-research alliance is low, enterprises will have a higher willingness to cooperate.

When k, α,δ , I, s are constant, a and n are inversely changing. This shows that when the number of Enterprises and Academics participating in the Industry-University-Research alliance increases, they will form a trust mechanism, and with the increase in the number of cooperation, scientific research results will gradually be transformed into productivity, and the knowledge gap between Enterprises and Academics will also decrease. At this time, even if the Enterprises have a small share of the Industry-University-Research alliance, the Enterprises is more inclined to choose cooperation. When the Enterprises clearly know that it only conducts a game with the Academics, the Enterprises will choose not to participate in the Industry-University-Research alliance for Opportunism.

When k, α, δ, I, n are constant, a and s have a reverse relationship. This shows that with the increase of punishment, even if it does not occupy a dominant position in the Industry-University-Research alliance, Enterprises will continue to cooperate with higher possibility. As the penalties increase, the cost of Enterprises not participating in the Industry-University-Research alliance will increase. From the perspective of minimizing costs, enterprises will choose cooperation.

When I, α, δ, s, n are constant, a and k are inversely changing. This shows that when the collaborative innovation coefficient k is small, the value of a can be larger. When the synergistic innovation effect brought by the Industry-University-Research alliance is large, it can bring high synergy benefits to the Enterprises. Even if the Enterprises have lower dominance in the Industry-University-Research alliance, it is more inclined to choose the cooperation strategy. Conversely, when the coefficient of collaborative innovation is small, that is, the synergistic innovation effect is small, and the Enterprises dominate the Industry-University-Research alliance, it will choose the cooperation strategy.

When k, α, δ, s, n are constant, a and I have a positive change relationship. This shows that as the investment of Enterprises in the Industry-University-Research alliance increases, the control rights will also expand, and Enterprises are more inclined to choose cooperation strategies. In the Industry-University-Research alliance, the cost of Enterprises is often higher than Academics. Therefore, it is more desirable to actively participate in the Industry-University-Research alliance, and then absorb the knowledge of the Academics, transform the scientific research results of the Academics into superior productivity, and make full use of its advantages resources to achieve the goal of maximizing benefits.

The Academics has the same game behavior as the Enterprises, so the conditions for the Academics to choose cooperation are as follows:

$$b\geq\frac{qI-q(1+s)^{n-1}}{\alpha qkI(1+\delta)^{n-1}+qI-I}>\frac{1}{\alpha k(1+\delta)^{n-1}}[1-\frac{(1+s)^{n-1}}{I}]$$

The conditions for Enterprises and Academics to participate in the Industry-University-Research collaborative innovation alliance are as follows:

$$\begin{cases} a\geq\dfrac{qI-q(1+s)^{n-1}}{\alpha qkI(1+\delta)^{n-1}+qI-I} \\ b\geq\dfrac{qI-q(1+s)^{n-1}}{\alpha qkI(1+\delta)^{n-1}+qI-I} \\ a+b=1 \\ a,\ b,\ \alpha,\delta,s>0 \\ k,\ n>1 \end{cases}$$

Let $H0=\dfrac{qI-q(1+s)^{n-1}}{\alpha qkI(1+\delta)^{n-1}+qI-I}$ get the following picture:

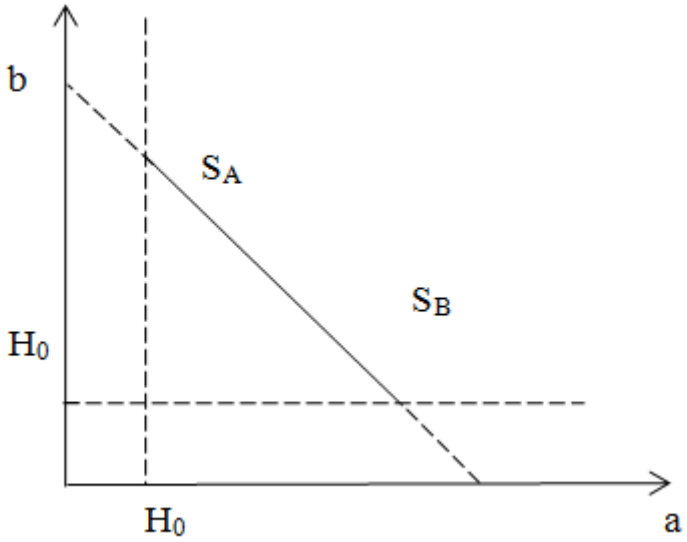

Fig. 1

It can be seen from Picture 2 that on the line segment with a + b = 1 and a, b>0, the interval [SA, SB] is the conditional interval for the collaborative innovation subjects to select the “synergy” behavior, which is the condition for ensuring the smooth development of collaborative innovation activities. The length of the interval [SA, SB] is related to the values of δ, n, k and α. As the value of these parameters increases, the value of S0 will decrease, and the interval [SA, SB] will increase. That is, as the conditional interval of the collaborative innovation subject chooses the "cooperative" behavior, the synergy innovation alliance will increase stable.

Suggestion

Based on the above analysis, suggestions are made to change the parameters of collaborative innovation, in order to improve the efficiency of collaborative innovation and the stability of the Industry-University-Research alliance.

Avoid cooperating with Academics with large Knowledge potential difference of Enterprises itself as far as possible. According to the research results of this paper, with the increase of the knowledge potential difference between Enterprises and Academics in the Industry-University-Research alliance, the knowledge risk of Industry-University-Research cooperation will be greater. On the one hand, when there is a large knowledge potential difference

between the Enterprises and the Academics, it will be difficult to reach a “consensus” for the judgment of value and the evaluation of the value of specific intellectual property. With the increase of knowledge potential difference, it will be more difficult to establish a unified evaluation standard for intellectual property values, and it is more likely to generate intellectual property risks. On the other hand, when the knowledge potential difference between Enterprises and Academics is too large, Enterprises will not be able to eliminate the new knowledge brought by Academics, and the natural diffusion of knowledge will become very difficult and slow. At this point, in order to pursue economic interests, Enterprises may breed more opportunism to quickly compensate for the knowledge potential difference between themselves and the Academics, thereby increasing intellectual property risks, which is not conducive to long-term cooperation between Enterprises and Academics.

Increase penalties for destroying cooperation. In the process of cooperative innovation, Enterprises destroy the cooperation because the benefit of choosing not to share is greater than that of choosing to share. But if we increase the punishment for disrupting cooperation, companies will choose to share. A company’s loss of trust and breach of contract will bear a lot of punishment. The loss caused by this “unjust” behavior is difficult to measure with wealth, and it will affect its future development due to long-term bearing. It is possible to reduce corporate non-sharing behavior by perfecting national laws and regulations and establishing a reputation mechanism.

Increase the number of cooperation. Trust is a new kind of “social capital” that creates wealth. Mutual trust is the soul of knowledge transfer and sharing. Enterprises and academics trust each other, which will reduce the cost and obstacles of communication and promote knowledge sharing. Knowledge owners generally do not share or share their knowledge resources completely, but share a part of them, and constantly adjust the share of knowledge sharing as the degree of trust in shared objects changes. The more times that enterprises participate in cooperative innovation, the more they can understand and trust each other, thus forming a tacit understanding, reducing the uncertainty of the strategy, and gradually establishing a stable and long-term partnership. Cooperative entities are more willing to choose to share knowledge from the perspective of long-term interests in order to maximize the long-term benefits.

Improve the incentive factor. The greater the incentive factor δ, the more cooperative the company has a desire to cooperate. We should strengthen the exchange of knowledge between the partners, and the smooth exchange of knowledge between partners is the basis for successful cooperation between the two parties. Communication facilitates the exchange of knowledge and is considered to be the main manifestation of the vitality of cooperation. An open knowledge exchange system between honesty and partners has a positive impact on the closeness and continuity of cooperation. Second, we should improve the enterprise management system and establish an incentive knowledge sharing mechanism. In order to protect the interests of knowledge holders, enterprises should formulate corresponding compensation systems on the one hand, so that the compensation amount is higher than the monopoly interests, and the benefits are used to drive the sharing of knowledge. On the other hand, an effective credit system should be established so that the knowledge provided by the knowledge provider will not be applied and abused by others.

Increase the expected cooperative innovation synergy coefficient value. It is expected that the greater the synergy coefficient of cooperative innovation, the more the company's desire for cooperation in the future, the more difficult it is to create opportunistic motives. The expected synergy of cooperative innovation mainly refers to economic effects. For enterprises, it includes reducing costs, strengthening services, enhancing competitive advantage, occupying or entering the market, improving product quality, and utilizing voluntary expansion and diversification strategies. It is possible to change the cooperative attitude between the cooperating entities by improving the expected synergy effect of cooperation and innovation, and to improve the expected synergy coefficient of cooperative innovation. The following measures can be taken: improving the way of cooperation, improving the structure of cooperation, emphasizing communication in the process of cooperation, and strengthening management of the cooperation process[10].

Summary

The knowledge potential difference greatly influences the synergy innovation performance of Industry-University-Research alliance, and the stable and healthy development of the Industry-University-Research alliance. This paper attempts to study the influence of the knowledge potential difference between enterprises and academics in the Industry-University-Research alliance on the collaborative innovation performance of Enterprises and Academics by constructing a collaborative innovation model that considers the knowledge potential difference. This paper analyzes the conditions for Enterprises and Academics to carry out collaborative innovation under the condition of knowledge potential difference, and puts forward a series of suggestions in combination with the game model, such as: avoiding cooperation with Academics with large knowledge potential difference, increasing penalties for disrupting cooperation, increase the number of cooperation, increase the incentive factor, and increase the value of the expected cooperative innovation synergy coefficient, in order to improve the synergy innovation performance of Industry-University-Research.

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