Research on Enterprise Innovation Performance

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ABSTRACT. *Starting from the social network analysis method, based on the patent data of 42 double-first-class universities' industry-university-research institute joint applications, establish a production university research cooperation network and a university knowledge network. Analyze the factors affecting the performance of industry-university-research collaborative innovation, and at the same time determine the moderating role of knowledge networks in this process. The research results show that the performance of industry-university-research collaborative innovation is positively affected by the stability and expansion of the cooperation network; in the path of the dynamics of the industry-university cooperation network on the performance of industry-university collaborative innovation, the diversity of university knowledge plays a positive role in moderating.*

KEYWORDS: *cooperation network network, university knowledge network, industry-university collaborative innovation*

1. The introductionInnovation

Leading is another name for the 21st century, as to upgrade the overall innovation country, the Chinese government in 19 report, much starker choices-and graver consequences-in planning explicitly pointed out that to establish enterprises as the main body, market oriented, the depth of the fusion of national technology innovation system, led many scholars to study the collaborative innovation thinking. In recent years, with the development and improvement of social network analysis, social network analysis has become a new focus of innovative research.

The essence of industry-university cooperation is the process of knowledge sharing based on the social network relationships established between companies and universities. The purpose is to obtain knowledge spillover effects through cooperation, so as to avoid risks and reduce r&d and transaction costs [1-2]. In the process of establishing the industry-University-Research cooperation innovation network, enterprises need to maintain the stability of existing cooperative relations so as to establish deeply integrated and highly trusted cooperative relations. At the same time, we must actively seek new partners and expand the scope of cooperation.

The source obtains non-redundant innovation resources and keeps the network dynamic to obtain continuous competitive advantage [3]. Therefore, from the perspective of enterprises, the influence of the dynamic characteristics of industry-university cooperative network -- expansibility and stability on innovation performance cannot be ignored [4]. However, based on the existing literature, it is found that most scholars focus on the static characteristics of the network:

The existing researches are mainly carried out from two aspects. One is the description of the evolution of industry-university-Research collaborative innovation network. Through the evolution of network indexes, the development rules of each subject of industry-university-research collaborative innovation are found. The second is qualitative research on industry-university collaborative innovation. Scholars mainly discuss the impact of network structure on innovation activities from the perspectives of network scale, connection duration and centrality. For example, Elfring et al [5]. pointed out that a strong connection within a network is very conducive to the exchange of tacit knowledge, while a weak connection is more conducive to the exchange of explicit knowledge. The research of Li-Renko et al. found that the knowledge acquired from the external relations of the organization would be conducive to the development of new products. Daghfous [15] believes that this knowledge may be a kind of innovative ability, which can improve the ability of enterprises to obtain information, knowledge and technology.

However, most existing research from the perspective of the static, innovation main body of the external environment is variable, with the passage of time, knowledge, technology, the demand of scientific research will also continue to change, when existing partners can't together to solve these problems, the motivation of external knowledge acquisition from existing cooperation network is created. Therefore, universities and other innovation subjects will maintain some partners beneficial to their own innovation in the process of development, and constantly add new partners to meet their own innovation needs. Therefore, it is more suitable to study the effect of industry-university cooperative network on the performance of industry-university collaborative innovation from a dynamic perspective.

In addition, in terms of the use of research methods, although many scholars find that it is very important to use multi-layer network analysis method to study network components, few achievements have been made [10]. In the previous processing, data is often converted to a single analysis level, which leads to the impact of data richness and integrity; In other studies, data at different analysis levels are analyzed separately, ignoring the interaction between different networks [6]. Therefore, it is very necessary to use the method of multi-layer network analysis to put different levels of networks into a whole for research [7], and to analyze the interaction between network relationship structures at different levels [13].

Therefore, this paper studies how the industry-university cooperative network changes with time and the influence of the evolution of the cooperative network on the performance of industry-university collaborative innovation. In view of the dynamic changes of cooperative networks, this paper studies two dimensions: the expansiveness of cooperative networks and the stability of cooperative networks. In

addition, based on the patent data of the joint application of industry and university, the knowledge network of colleges and universities is constructed to study the interaction effect of dual networks.

2. Theoretical basis and research hypothesis

It is the foundation of network dynamics to study the changes of network relations. The change of network relationship is the basic element of network change, which is easy to be observed and detected. The change of network relationship is mainly reflected in three aspects: the establishment, persistence and disintegration of network relationship. The establishment of network relationship can bring new resources and values to the organization, and it has the most important influence on the organization. It is the first action taken by the organization in pursuit of social capital [8]. Therefore, how to effectively establish network relationship is the primary concern of organizations and the most concerned issue of scholars. However, while establishing new contacts is a necessary condition for acquiring new resources, in many cases, maintaining and strengthening existing relationships can bring more benefits [4].

Long-term and frequent cooperation can reduce costs, save resources, enhance effective information exchange, with high certainty and low risk. As a result, people tend to be more interested in how relationships are maintained. Network changes are also partly caused by the breakdown of relationships. The disintegration of network relationships means that some relationships cannot bring the required resources and benefits to the organization, and such relationships are difficult to sustain and eventually collapse [5].

2.1 Influence of the stability of industry-university cooperative network on the performance of industry-university collaborative innovation

Co-operative network refers to the stability of colleges and universities in the process of cooperative innovation between production, more inclined to cooperate with known enterprises (Guan et al, 2017), because the alliance between production in the process of long-term exchanges and cooperation, knowledge base to converge between different subjects, this will make more convenient for communication and cooperation between universities and enterprises (Baum, etc., 2000; March 1991). In addition, cooperation between universities and familiar enterprises will also have higher certainty and lower risk.

This paper believes that the cooperation between universities and familiar enterprises will have higher innovation performance, because the familiar partners will have higher trust and willingness to cooperate, and the partners will take the initiative to share their own knowledge, technology and other resources, and on this basis will also have higher innovation performance.Based on this, this paper proposes the following hypothesis:

H1: The stability of industry-university collaborative network has a significant positive impact on the performance of industry-university collaborative innovation.

2.2 Influence of the expansion of industry-university cooperative network on the performance of industry-university collaborative innovation

In the process of industry-university cooperation, although maintaining the existing cooperative relationship can bring lower innovation risks, long-term cooperation will bring homogeneous and redundant knowledge to colleges and universities, which is difficult to help the innovation of colleges and universities, and even becomes an obstacle to their innovation. Therefore, in the process of innovation, universities need to constantly cooperate with new cooperative enterprises to acquire heterogeneous knowledge (Bouty 2000).

In this paper, it is believed that adding new partners is very beneficial to the industry-university collaborative innovation performance of universities, because the heterogeneous knowledge brought by new partners will bring more innovative possibilities to universities, and social network theory generally believes that unique knowledge is more valuable in long-term studies [7]. Based on this, this paper proposes the following hypothesis:

H2: The expansion of cooperative network has a significant positive impact on the performance of industry-university collaborative innovation.

2.3 The regulating effect of knowledge diversity on network dynamics and collaborative innovation performance of production

An organization needs at least two networks for innovation: one is the industry-university collaborative network where the organization is located [5], and the other is the knowledge network owned by the organization. In the process of innovation, organizations will not only be affected by the dynamic nature of their industry-science cooperation network, but also by the structural attributes of their knowledge network [25]. Therefore, while considering the influence factors of the dynamics of industry-university cooperation on performance, we should also consider the influence of the knowledge base on the performance of colleges and universities.

In cooperative networks, different subjects usually have different knowledge reserves, and in order to cooperate with other members, universities must have the ability to identify, evaluate, transform and utilize the knowledge of other enterprises (Buchmann and Pyka 2013). Diversity and for those who have knowledge of colleges and universities, they will also get a variety of useful innovation ability, such as a wide range of knowledge reserves will make colleges and universities have more unique thinking and ideas, make them from the Angle of novel to rearrange use of knowledge, but also makes them a wide range of knowledge to different areas of knowledge integration. Therefore, whether the cooperative network remains stable or expands, the diversity of knowledge enables organizations to innovate based on existing or heterogeneous knowledge.

This paper argues that the higher the degree of diversification of knowledge reserve in colleges and universities, the greater the positive effect of the dynamic of industry-university cooperative network on the performance of industry-university collaborative innovation.Based on this, this paper proposes the following hypothesis:

H3a: The diversity of knowledge positively moderates the influence of the stability of cooperative network on the performance of industry-university collaborative innovation.

H3b: Knowledge diversity positively moderates the influence of cooperative network expansion on industry-university collaborative innovation performance.

3. Research design

3.1 Data collection and processing

As the most intuitive way to study knowledge sharing and knowledge combination, cooperative invention patent is more and more applied to the research of innovation network. Therefore this article selects the new field of energy production joint patent as the research sample, data retrieval for the way in which the state intellectual property office of the patent retrieval and analysis of website (http://pss-system.cnipa.gov.cn/sipopublicsearch/portal/uiIndex.shtml) to "university" and "company", "enterprise", "group" or "factory" retrieved two combinations, received after the first retrieval patent cooperation between 1985-2017 annual data, 54643, Subsequently, the patent data of non-new energy fields were excluded, and 18,971 patents were finally applied for by industry-university cooperation in new energy fields from 1985 to 2017. The data will be collected from November 1, 2017 to January 31, 2018.

3.2 Measurement of variables

3.2.1 The dependent variable

Industry-university collaborative innovation performance: The number of invention patents is often used to measure the innovation output of an institution [7]. The dependent variable of this paper is industry-university collaborative innovation performance, and the total number of invention patents jointly applied by universities and enterprises in the field of new energy each year is adopted as the measurement standard.

3.2.2 The independent variable

Expansion of the industry-University Network, Stability of the industry-University Network.

This paper compares the cooperative enterprises of each university in each period with those in the previous period. For example, an enterprise does not appear in the T-1 period, but in the Observation period Of T. Therefore, it is considered that the cooperative network of industry and education expands in the T period (Guan 2018). For enterprises appearing in cooperative networks during t-1 and T, colleges and universities should maintain stable networks during T (Dahlander and McFarland, 2013).

3.2.3 Regulating variables

The diversity of knowledge in colleges and universities refers to the research of Wang [7] to calculate the total number of knowledge elements owned by colleges and universities.

3.2.4 Control variables

Length of establishment of a university: The longer the history of a university is, the more conducive it is to acquire knowledge, resources and information for innovation. Therefore, the length of establishment of a university is selected as the control variable.

Number of double first-class disciplines: Universities with double first-class disciplines usually have more complete research teams, more scientific research achievements, better student quality and better academic reputation. Therefore, the number of double first-class disciplines is selected as the control variable of this paper.

The number of enterprises cooperating with colleges and universities: Cooperation with enterprises can make the research conducted by colleges and universities closer to reality and more targeted. Therefore, the number of enterprises cooperating with colleges and universities is selected as the control variable of this paper.

4. Empirical Analysis

4.1 Model Setting

The dependent variable in this paper is the number of patents, which are discrete, discontinuous, non-negative integers, with unequal expectations and variances. Therefore, the negative binomial regression model is selected to explore the factors affecting the innovation performance of industry-University-Research cooperation. In the process of innovation, there is a lag between innovation input and output performance, so the dependent variable is treated with a 2-year lag. Therefore, the number of patents from 1987 to 2017 correspond to network characteristics and other indicators from 1985 to 2015.

The results of correlation analysis (see Table 1) show that there is a significant correlation between the number of patents applied by both parties and other variables, and there is a certain correlation between most independent variables. It reflects that in China's industry-university collaborative innovation network, there is an obvious correlation between the characteristics of the network and the dynamics of the cooperative network and the performance of production-university collaborative innovation. The change of each index will directly or indirectly affect the innovation performance of universities.

4.2 Analysis of empirical results

Table 1 Correlation analysis

	1	2	3	4	5	6	7
1.Length of university establishment	1						
2.Number of double first-class disciplines	0.391***	1					
3.Number of cooperative enterprises	0.280***	0.254***	1				
4.Stability of the network	0.312***	0.277***	0.347***	1			
5.Network expansiveness	0.006	0.349***	-0.079**	-0.082**	1		
6.Diversity of knowledge	0.266***	0.110***	0.373***	0.432***	-0.070*	1	
7.Industry-university collaborative innovation performance	0.220***	0.036	0.218***	0.232***	-0.13***	0.259***	0.361***
The mean	75.195	7.79	6.47	1.3319	0.19	9.52	262.65
The standard deviation	27.066	8.222	13.579	3.1339	0.273	17.745	468.597

Table 2 Negative binomial regression results

	Model1	Model 2	Model 3	Model 4	Model 5
Constant term	-2.234**	-2.157**	-1.840**	-2.210*	-1.862*
The independent variables					
Stability of cooperative network		0.203*		0.375**	
The expansiveness of the cooperative network			4.463***		4.851***
Adjust the variable					
Diversity of knowledge				0.028*	0.058**
Interactive items					
Stability of cooperative networks * diversity of knowledge				0.019***	
The expansive nature of cooperative networks * the diversity of knowledge					0.049**
Control variables					
The length of time a university is built	-0.041**	-0.044**	-0.035**	-0.041**	-0.033*
Number of two first-class disciplines	0.130**	0.131**	0.127***	0.123**	0.126**
Number of cooperative enterprises	2.482***	2.329***	1.410***	2.272***	1.401***

Note: *, **, and *** respectively represent that the parameter estimation value is significant at the confidence level of 5%, 1%, and 0.1%

In model 1, only the control variable was added as the explanatory variable, and the results showed that the duration of school establishment (= -0.041, P <0.01) had a significant negative impact, while the number of two first-class disciplines (= 0.130, P <0.01) and the number of cooperating enterprises (= 2.482, P <0.001) had a significant impact on innovation performance.

Model 2 and model 3 are the tests of the direct influence of the dynamics of the industry-university cooperative network on the performance of the industry-university collaborative innovation. The regression results showed that the stability of the cooperative network (= 0.203, P <0.05) and the expansion of the cooperative network (= 4.463, P <0.001) had significant positive effects, and hypothesis H1 and H2 were verified.

Model 4 and 5 test the regulating effect of knowledge diversity in colleges and universities. The results showed that the diversity of knowledge positively moderated the effect of the stability of the cooperative network on performance (= 0.019, p>0.001), and H3a was verified. Knowledge diversity positively moderates the effect of cooperative network expansion on performance (= 0.049, P <0.01), and hypothesis H3b is verified.

5. Research conclusions and implications

Based on the new energy sector in 1985-2017 and jointly apply for the patent data of production as the foundation, social network analysis method was used to construct the industry-academic cooperation network and knowledge network, and the negative binomial regression model of co-operative network dynamic knowledge of direct action and production test in the interaction and cooperation network, find co-operative network expansion, stable positive influence university-industry cooperative innovation performance, and the diversity of knowledge is to adjust cooperation network expansion, stable effect. The main research conclusions and implications are as follows:

(1) Replace the old relationship with the new one, and maintain the relationship according to the best.

It can be seen from the dynamic nature of the industry-university cooperative relationship that the stability and expansion of the industry-university cooperative network have a significant positive impact on the performance of industry-university collaborative innovation. Therefore, in the process of cooperation, it is inappropriate to stick too much to the existing relationship or focus too much on seeking new cooperative enterprises. Colleges and universities should do the following three things: (1) Those enterprises that have existing cooperative relations are beneficial to the innovation of colleges and universities, and continue to maintain them; (2) Those enterprises that have existing cooperative relations are of no benefit to the innovation of colleges and universities, which should be eliminated in time; (3) actively explore more helpful enterprises to carry out industry-university cooperation activities.

(2) Colleges and universities actively participate in industry-university activities to improve their knowledge reserve.

It can be seen from the knowledge diversity of colleges and universities that the relationship between the dynamics of cooperative network and the performance of collaborative innovation can be positively adjusted. When colleges and universities have extensive knowledge reserves, they will actively promote the output of innovation and performance. Whether it is to maintain existing partnerships and innovate with existing knowledge, or to collaborate with new partners based on heterogeneous knowledge, universities can take it in stride. In addition, for colleges and universities, self-exploration can certainly improve their knowledge field, but it is more effective and convenient for them to participate in industry-university cooperation and obtain heterogeneous knowledge from cooperative enterprises. Therefore, colleges and universities should actively participate in industry-university cooperation activities to improve their knowledge reserve more quickly and efficiently.

(3) The government plays an active role in promoting industry-university cooperation.

By the existing research as you can see, universities and enterprises to participate in co-operative innovation can greatly help the innovation ability of ascension, but the proportion of present Chinese co-operative patent about 30% of all patents, production activities of cooperation benefits on both sides, but the difficulties on the establishment of cooperative relations, so the government should actively promote co-operative, issued a policy to encourage the establishment of cooperation, it is highly advantageous for the development of the innovation in China.

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