Influencing Factors of Dynamics of Industry-University Cooperative Network in New Energy Industry on the Performance of Industry-University Cooperative Innovation

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Abstract. Based on the social network analysis method, by utilizing the patent data jointly applied by the industry and universities under the new energy industry, this paper will construct the industry-university cooperation network and the knowledge network of colleges and universities, as well as study the influencing factors of the dynamics of the cooperation network on the performance of industry-university collaborative innovation. Meanwhile, the moderating effect of structural attribute of knowledge network will be considered. It is found that the expansion and stability of cooperative network have a significant positive impact on collaborative innovation performance. Knowledge diversity in colleges and universities positively regulates the relationship between the dynamics of industry-university cooperative network and the performance of industry-university cooperative innovation.

1. Introduction
The 21st century is an era dominated by innovation. In order to improve the overall innovation capacity of the country, the government clearly pointed out in the reports of the 19th National Congress of the Communist Party of China and the 13th Five-Year Plan that a national technological innovation system should be established with enterprises as the main body, market as the orientation and production, education and research deeply integrated. Therefore, many scholars have conducted extensive research on industry-university-research cooperative innovation and found that organizational innovation performance is affected by network scale, relationship, structure and location in the network [1]. Most existing researches start from a static perspective; however, the environment is changeable, and the demand for knowledge will change as time goes by. These changes encourage organizations to change their existing partnerships and continually seek new partners to exchange and reorganize their knowledge resources in order to adapt to the dynamic environment [2].

And with the continuous deterioration of the environment, new energy replacing coal and oil has become the focus of Chinese society. Many scholars have studied how to optimize the environment from government, enterprises, society and other subjects. However, there are relatively few researches on the impact of the changes of industry-university cooperation network on the performance of industry-university cooperative innovation in the field of new energy from the perspective of industry-university cooperation. Therefore, it is necessary to use social network analysis method to construct
industry-university cooperative network and analyze the influencing factors of the dynamic change of cooperative relationship on the performance of industry-university cooperative innovation.

Therefore, this paper studies how the cooperative network between universities and enterprises changes over time, and how the change of cooperative network affects the collaborative innovation between universities and industry. In view of the dynamic change of cooperative network, this paper studies two dimensions: the expansiveness of cooperative network and the stability of cooperative network. In addition, colleges and universities need at least two networks to carry out innovation activities: one is the industry-university cooperation network, and the other is the knowledge network owned by colleges and universities. Therefore, in the process of innovation, colleges and universities will not only be influenced by their partners, but also have a knowledge reserve that will have an impact on their performance.

2. Theoretical Basis and Research Hypothesis

2.1. Influence of the Stability of Cooperative Network on the Performance of Industry-University Cooperative Innovation

The stability of cooperative network refers to the tendency of colleges and universities to cooperate with familiar enterprises in the collaborative process of production and learning [3]. In the long-term communication and cooperation process of industry-university alliance, the knowledge reserve tends to be consistent, which makes the communication and cooperation between universities and enterprises more convenient. In addition, cooperation between universities and familiar enterprises will greatly reduce the risk of innovation.

Based on this, this paper proposes the following hypothesis:

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

2.2. Influence of the Expansion of Cooperative Network on the Performance of Industry-University Cooperative Innovation

In the process of industry-university cooperation, although maintaining cooperative relationship can bring lower innovation risk, long-term cooperation will bring repetitive and homogenized knowledge to colleges and universities. Such knowledge can hardly help the innovation of colleges and universities, and may even hinder their innovation. Therefore, universities need to cooperate with new cooperative enterprises to acquire heterogeneous knowledge [4].

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 cooperative innovation.

2.3. Regulating Effect of Knowledge Diversity between Network Dynamics and Performance of Industry-University Cooperative Innovation

There are usually different knowledge reserves among different parties in a cooperative network. In order to collaborate with other members, the university or enterprise must have the ability to identify, evaluate, transform and utilize the knowledge of others [5]. And for those members with diverse knowledge, they will also gain many innovative capabilities. For example, extensive knowledge reserves will enable them to reuse existing knowledge from a new perspective, and a wide range of knowledge allows them to combine knowledge from different fields. Therefore, the diversity of knowledge enables organizations to innovate based on existing or heterogeneous knowledge, regardless of the stability or expansion of the cooperative network.

Based on this, this paper proposes the following hypothesis:

H3a: The diversity of knowledge positively regulates the influence of the stability of cooperative network on the performance of industry-university cooperative innovation.
H3b: The diversity of knowledge positively regulates the influence of the expansion of cooperative network on the performance of industry-university cooperative innovation.

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 finding more increasing apply to the research of innovation network. Therefore, this paper selects the patent application jointly applied by industry and universities in the field of new energy as the research sample and data retrieval as the method to search in pairs with key words “university”, and “company”, “enterprise”, “group” or “factory” in the state intellectual property office of patent retrieval and analysis of website (http://pss-system.cnipa.gov.cn/sipopublicsearch/portal/uiIndex.shtml). A total of 18,971 patents applied for by industry-university cooperation in new energy fields from 1985 to 2017 were finally obtained. Data were collected from November 1, 2017 to January 31, 2018.

3.2. Variable Measurement
(1) Dependent Variable
Performance of industry-university cooperative innovation: the number of invention patents is often used to measure the innovation output of an institution [6]. The dependent variable of this paper is the performance of industry-university cooperative innovation, which is measured by the total number of invention patents jointly applied by universities and enterprises in the field of new energy every year.

(2) Independent Variable
The expansion of production network, the stability of production network.
This paper compares the cooperative enterprises of each university in each period with those of the previous period. For example, when an enterprise does not appear in the t-1 period, but appears in the observation of the t period, it is believed that the industry-university cooperation network expands in the t period [7]. For enterprises that appear in the cooperative network in both t-1 and t periods, it is believed that the network of colleges and universities remained stable in t period.

(3) Regulated Variable
The diversity of knowledge in colleges and universities refers to Wang’s [8] research to calculate the total number of knowledge elements possessed by colleges and universities

(4) Control Variable
This paper chose Duration of establishment of colleges and universities, number of double first-class disciplines, number of enterprises cooperating with colleges and universities as control variable.

4. Empirical Analysis

4.1. Model Specification
The dependent variables in this paper are the number of patents, which are discrete, non-continuous, non-negative integers, and unequal expectation and variance. A negative binomial regression model is selected to establish to explore the influencing factors of collaborative innovation performance. Due to the lag period between innovation input and output performance in the innovation process, the dependent variable is handled with a lag of 2 years. Therefore, the number of patents from 1987 to 2017 corresponds to the network characteristics from 1985 to 2015.
4.2. Analysis of Empirical Results

Table 1. Negative binomial regression results

|                                | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|--------------------------------|---------|---------|---------|---------|---------|
| constant                       | -2.234**| -2.157**| -1.840**| -2.210* | -1.862* |
| The stability of cooperation network |   0.203* |         |         |         |         |
| The expansion of cooperation network | 4.463***|         |         |         |         |
| Diversity of knowledge         |         | 0.028*  | 0.058** |         |         |
| Stability of network * Diversity of knowledge |         | 0.019***|         |         |         |
| expansion of network * Diversity of knowledge |         |         |         |         | 0.049** |
| Duration of establishment of colleges and universities | -0.041**| -0.044**| -0.035**| -0.041**| -0.033* |
| number of double first-class disciplines | 0.130** | 0.131** | 0.127***| 0.123** | 0.126** |
| number of enterprises cooperating with colleges | 2.482***| 2.329***| 1.410***| 2.272***| 1.401***|

Remarks: *, **, *** represent the parameter estimates at the confidence levels of 5%, 1% and 0.1% respectively.

In model 1, only the control variable is added as the explanatory variable, and the results show that the duration of school construction (β = -0.041, p<0.01) has a significant negative influence. The number of double-first-class disciplines (β = 0.130, p<0.01) and the number of cooperative enterprises (β = 2.482, p<0.001) have a significant impact on innovation performance.

Models 2 and 3 are tests of the direct influence of the dynamics of industry-university cooperative network on the performance of industry-university cooperative innovation. The results show that the stability of cooperative network (β = 0.203, p<0.05) and the expansion of cooperative network (β = 4.463, p<0.001) have significant positive effects, and hypothesis H1 and H2 are verified.

Models 4 and 5 are established to test the regulating effect of college knowledge diversity. The results show that knowledge diversity positively regulates the effect of cooperative network stability on performance (β = 0.019, p>0.001), and H3a is verified. The diversity of knowledge positively regulates the influence of cooperative network expansion on performance (β = 0.049, p<0.01), and hypothesis H3b is verified.

5. Research Conclusion and Enlightenment

Based on patent data jointly applied by industry and universities in the field of new energy from 1985 to 2017, this paper constructs the industry-university cooperation network and knowledge network with the method of social network analysis. The negative binomial regression model is used to test the direct effect of the dynamic nature of the industry-university cooperative network and the interaction between the industry-university knowledge network and the cooperative network. It is found that the expansion and stability of the industry-university cooperative network have a positive impact on the performance of industry-university collaborative innovation. Moreover, the diversity of knowledge positively regulates the expansion and stability of cooperative network. The main conclusions and implications are as follows:

The relationship between the new and the old is alternated and the best is selected to maintain the relationship.

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 cooperative innovation. Therefore, in the process of cooperation, it is improper to stick to the existing relationship or focus too much on seeking new
cooperative enterprises. Colleges and universities should do the following three things: ① Existing cooperative relationships among enterprises that are beneficial to the innovation of universities themselves shall be maintained. ② Existing cooperative relations of enterprises are not conducive to the innovation of colleges and universities should be timely eliminated. ③ Exploring more helpful enterprises to carry out industry-university cooperation activities actively.

Colleges and universities are actively engaged in industry-learning activities to enhance their knowledge reserves
As can be seen from the relationship between the significant positive adjustment of the diversity of university knowledge and the dynamics of cooperative network on the performance of industry-university cooperative innovation, when universities have extensive knowledge reserves, they will actively promote the output of innovation and performance. Whether it is maintaining existing partnerships and using existing knowledge to innovate, or cooperating with new cooperative enterprises based on heterogeneous knowledge, colleges and universities can cope with it easily. And for universities, self-exploration can certainly improve their own knowledge field, but it is more effective and convenient 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 own knowledge reserves more quickly and efficiently.

(3) The government plays an active role in promoting industry-university cooperation
It can be seen from the existing research that the participation of universities and enterprises in industry-university cooperative innovation can greatly help the improvement of their innovation ability. However, at present, the proportion of patents filed by Chinese industry-university cooperation accounts for about 30% of all patents. There is no doubt that it is beneficial to both sides, but the partnership is usually established with difficulties. Therefore, the government should actively promote the production of industry-university cooperation and release policies to encourage the establishment of cooperation, which will be extremely beneficial to the development of China’s innovation cause.

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