Advances in Social Science, Education and Humanities Research, volume 505
6th International Conference on Social Science and Higher Education (ICSSHE 2020)

Network Strength, Knowledge Flow and Innovation Performance—an Empirical Study Based on SME Collaborative Innovation Network

Li Wang[1] and Ting Duan[1,*]

[1] *School of Management Science & Engineering, Shanxi University of Finance & Economics, Taiyuan, 030031*
**Corresponding author. Email: 841960581@qq.com*

ABSTRACT
Taking the collaborative innovation network of SMEs in China as the research object, this work collects data through questionnaires, and uses SPSS and AMOS software to demonstrate the relationship of network strength, knowledge spillover, knowledge transfer and innovation performance in collaborative innovation networks. The results show that there is a significant positive correlation of the network strength of SMEs' collaborative innovation network and innovation performance. The more frequent the inter-enterprise linkage, the more helpful the synergy of innovation performance, knowledge spillover and knowledge transfer play a partial mediating effect between "network strength—innovation performance". The research can provide theoretical and practical reference for the development of collaborative innovation networks in China.
***Keywords**: Network strength, Knowledge flow, Innovation performance, Collaborative innovation network*

1. INTRODUCTION

Entering the 21st century, as a new and effective organizational model, collaborative innovation networks have received widespread attention [5]. This organizational model has changed from closed to open. Through the collaboration of multiple innovation entities, it absorbs and utilizes external innovation resources, and ultimately achieves innovation goals and value co-creation, which is a value network. Collaborative innovation network is not only the basic spatial framework that constitutes the world economy today, but also the key to the competitive advantage of a region or country, and this competitive advantage is ultimately evaluated by performance [8]. Therefore, the innovation performance of collaborative innovation networks has always been an important issue for scholars in economics and management[19].

Network strength is a measure of persistent repetitive transaction relationships in a corporate network. It is regarded as "the degree of the frequency of technical cooperation or contact between the innovation network entity and other network entities, or the ability of the organization members to obtain network resources, and the degree of the quality of the resources[2]. It is considered to be "the frequency of technical cooperation or contact between Since Granovetter[18]distinguished network relationships into strong ties and weak ties in the 1970s, the relationship between network strength and innovation performance has been hotly debated by scholars, and different scholars' opinions Not all the same, but broadly can be divided into two factions. In fact, the lack of research on the path between "network strength-innovation performance" will limit the understanding of the relationship between the two in theory and practice, and is not conducive to the formulation and implementation of innovation network development policies.

With the advent of the era of knowledge economy, knowledge has become an important strategic resource for enterprises to cultivate competitiveness and gain competitive advantages [2], and it is also the core resource with the most strategic value for enterprises [11]. Some scholars believe that network strength does not directly affect the performance of collaborative innovation networks, but realizes its indirect effects through the mediation of knowledge. Enterprises access and exchange all kinds of information through the knowledge flow in network activities. The more you connect with network partners, the more opportunities you have to acquire multi-channel knowledge, which can enhance its structural position and learning ability in the network, and ultimately promote its innovation output and performance[23,27].

1.1. Our Contribution

The current academic circles have insufficient research on the relationship between network strength, knowledge flow and collaborative innovation performance, especially in the Chinese context. Therefore, we intend to build a model of the relationship between network strength, knowledge flow and collaborative innovation performance, combining value network theory and knowledge-based view, taking the member companies of the collaborative innovation network of small and medium-sized enterprises in China as the research object. The purpose is to find the specific action path between network strength, knowledge flow and collaborative innovation performance. The research on this issue can not only enrich the collaborative innovation network theory research in the Chinese context, but theoretically promote the development of the collaborative innovation network research field.

1.2. Paper Structure

The follow-up content arrangement of this article: first put forward research hypothesis and theoretical model; secondly, carry out research design, including sample selection and data source, variable measurement and reliability and validity analysis of variables; thirdly, conduct empirical analysis to verify the theoretical model proposed in this article; and the last part is the research conclusion and outlook.

2. RESEARCH HYPOTHESIS AND THEORETICAL MODEL CONSTRUCTION

2.1. Network Strength and Innovation Performance

Exploring the influence of the strength of the collaborative innovation network of SMEs on the performance of network innovation can essentially show the value of the network where the innovative enterprise is located to the individual enterprise. The strength of the network mainly examines the frequency of interaction between enterprises, the depth of feelings, the closeness of relationships, and the frequency of reciprocal exchanges [26]. Moreover, network relationships of different intensities play a completely different role in information transmission and cooperation and communication, and have different significant effects on technological innovation performance [3]. Most early scholars believed that the more closely the nodes of the network are connected to their network, the more they will be able to obtain external information and knowledge that are essential for innovation, and dig out hidden innovations and ideas, thereby greatly stimulating the innovation activities of the enterprise [15]. However, with the deepening of network research, many scholars have noticed the hindering effect of network strength on network innovation performance, believing that too frequent corporate contacts will cause companies to be confined to a fixed network range, leading to duplication or similarity of information acquisition. Enterprises cannot understand the market in time, nor can they obtain relevant information about product innovation, which makes the network gradually closed and rigid, with a "lock-in effect", which inhibits innovation within the network and ultimately affects innovation performance [12].

The above analysis shows that scholars have great differences on the relationship between network strength and innovation performance. With the deepening of research, many scholars have tried to use an inverted U-shaped model to explain the relationship between the two [10,21], but in fact the relationship is difficult to prove. On the one hand, with the extension of time, the collaborative innovation network will inevitably experience a long process of prosperity, stability and decline, and it is difficult to obtain empirical data; on the other hand, the research is of little significance for guiding the development of small and medium-sized enterprises and government policy formulation at this stage. So what is the relationship between collaborative innovation network, network strength and collaborative innovation performance in the Chinese context? We believe that the development of collaborative innovation networks in China has not been long, and the development of my country's innovation networks is not yet mature due to China's humanistic environment and imperfect policies and systems. Enterprises have a strong willingness to exchange knowledge to improve their learning ability, and their interactions are not saturated. The heterogeneous knowledge in the network resource pool is crucial to the development of network members. Therefore, the frequent interaction of enterprises will not produce a "lock-in effect". In view of this, we propose the following hypotheses:

H1: In the collaborative innovation network of my country's SMEs, network strength and innovation performance are positively correlated.

2.2. Network Strength, Knowledge Flow and Innovation Performance

Due to the increasingly complex nature of innovation tasks, it is difficult for companies to complete the entire innovation process independently, requiring cross-boundary acquisition of external knowledge. According to the degree of initiative of knowledge flow, we divide it into two dimensions: conscious and unconscious. Knowledge spillover is the unconscious sharing of knowledge, while knowledge transfer is the conscious output of knowledge between enterprises.

The knowledge-based view believes that the source of the core competence of an enterprise is the tacit knowledge of the enterprise. The collaborative innovation network provides channels for the exchange and sharing of information, knowledge and other resources between enterprises. The higher the network strength, the network often means that between enterprises. Effective norms and mechanisms for knowledge transfer have been constructed, which in turn provide a platform for enterprises to obtain tacit knowledge and heterogeneous knowledge [9]. Compared with knowledge transfer, the knowledge spillover generated by the friendly interaction of network enterprises usually conveys tacit knowledge that is difficult to form but is conducive to innovation [1]. Moreover, there are often high-level trust relationships between frequently interacting companies. This trust relationship can not only further promote the exchange and

communication of knowledge, but also lay a solid foundation for good cooperation in the future and simplify information search [7]. We propose the following hypotheses:
H2a: There is a positive correlation between network strength and knowledge spillover.
H2b: There is a positive correlation between knowledge spillover and innovation performance.
H2c: Knowledge spillover plays a mediating role between network strength and innovation performance
Compared with knowledge spillover, knowledge transfer consciously transfers knowledge to other enterprises. Therefore, knowledge transfer often transfers specific technology and explicit knowledge of the enterprise. In the case of incomplete development of the innovation network, the knowledge held by the enterprise needs to be exchanged and communicated, and the learning path needs to be expanded, which requires the promotion of strong relationships within the network. The essential purpose of knowledge transfer is to promote the improvement of the knowledge level and ability of the knowledge recipient. Similarly, this improvement also requires the promotion of strong relationships [13]. In view of this, we propose the following hypotheses for the collaborative innovation network of SMEs in the Chinese context:
H3a: There is a positive correlation between network strength and knowledge transfer.
H3b: There is a positive correlation between knowledge transfer and innovation performance.
H3c: Knowledge transfer plays an intermediary role between network strength and innovation performance.
In summary, there are two paths for the influence of network strength on innovation performance, Based on this, this paper establishes an empirical research theoretical model, as shown in Figure 1.

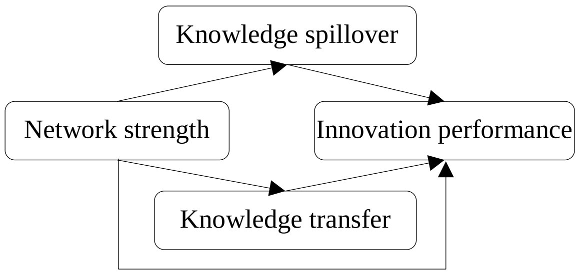

Figure 1. Research model diagram

3. RESEARCH DESIGN

3.1. Data Sources

This paper uses a questionnaire survey method to collect the network strength, knowledge flow and innovation performance data of the SME collaborative innovation network. The reason is that the measurement of these variables is relatively subjective, and it is difficult to obtain first-hand objective data, which requires subjective judgments by enterprise managers. The questionnaire used mainly refers to the existing mature scales of domestic and foreign scholars, and is distributed to enterprises in the collaborative innovation network of SMEs in Shanxi, Shaanxi, Hebei, Tianjin, Beijing, Shanghai and other places. The questionnaire is issued from January 16, 2019 to February 13, 2019. A total of 450 copies were issued and 392 copies were eventually recovered, with a recovery rate of 87.11%. Finally, 363 valid questionnaires were obtained, and the data validity rate was 92.60%. . The basic information of the survey object is shown in Table 1:

Table 1. Sensor network experimental results

Question	Options	Number	percentage
High-tech enterprise	Yes No	102 261	28.10% 71.90%
Established	<10 10～20 21～30 >30	99 129 59 76	27.27% 35.54% 16.25% 20.94%
Scale	<100 100～1000 1001～10000 >10000	82 123 82 76	22.59% 33.88% 22.59% 20.94%
Stage	Entrepreneurial period Growth period Maturity Recession	35 76 222 30	9.64% 20.94% 61.16% 8.26%
Sum		**363**	**100%**

3.2. Variable Measure

The measurement items of the variables selected in this article all use Likert 5-point scale. Among them, 1 to 5 of the explained variable, explanatory variable and intermediate variable respectively represent "very non-conforming", "less conforming", "general", "relatively conforming" and "very consistent". The Likert5 subscale of the control variable has a slightly different meaning. The operational definition and measurement method of each variable are described below.
The explained variable is innovation performance, and the measurement of innovation performance refers to the survey scale of Yang Jiaoping [12]. The explanatory variable is network strength, that is, the frequency and closeness of connections between collaborative innovation network companies. By integrating the research of Levin et al. (2004) and Pan Songting et al. (2010), the network strength is divided into 4 dimensions and a total of 9 question items are measured. And according to the actual situation of the subjects surveyed by the author, the item design of the questionnaire was appropriately revised and integrated. The measurement index of knowledge spillover draws on the literature of Kesidou and Romijn [20] and

Tao Feng [6]. The knowledge transfer scale mainly refers to the research of Zahra et al. [28]. This paper chooses the innovation ability("1" means "innovative ability is very weak", "3" means "innovative ability is moderate", and "5" means "the ability to innovate is very strong"), enterprise scale("1" means "the enterprise is small in scale", "3" means "the enterprise scale is moderate", and "5" means "the enterprise scale is very large") and development stage of the enterprise("1" means "initial stage of enterprise development", "3" means "mid-term enterprise development", and "5" means "mature period of enterprise development") in the collaborative innovation network as the control variables.

3.3. Reliability and Validity Analysis

First, SPSS22.0 software uses Cronbach'sα coefficient to test the reliability of the scale (Table 2). The results show that the Cronbach's α coefficient of innovation performance is 0.943, the Cronbach's α coefficient of network strength is 0.807, the Cronbach's α coefficient of knowledge spillover is 0.927, and the Cronbach's α coefficient of knowledge transfer is 0.820, both of which are greater than the threshold of 0.7. And the CITC coefficients of each question type measuring innovation performance, network strength, knowledge spillover and knowledge transfer are far greater than the threshold 0.35.The table meets the reliability requirements. Therefore, the scale used in this article is reliable, with good internal consistency among the items.

The SPSS22.0 software was also used to test the validity of the scale. The Kaiser-Meyer-Olkin (KMO) statistic of collaborative innovation performance, network strength, knowledge spillover, and knowledge transfer is 0.836, which exceeds the minimum standard of 0.6. The Bartlett sphere test value is 534.076, which passed the significance test ($p<0.01$) . It can be seen that the data is more suitable for exploratory factor analysis. The result of factor analysis shows that four factors can be extracted, and the initial 15 items of the scale are all retained. The cumulative explanatory variance of the four factors of innovation performance, network strength, knowledge spillover, and knowledge transfer is 79.104%. The specific results are shown in Table 3.

4. EMPIRICAL RESEARCH

4.1. Regression Analysis Process

In order to verify whether the network strength has an impact on the innovation performance of the collaborative innovation network through knowledge flow, this paper adopts a regression analysis method. First, the principal component analysis method is used to combine the items under each variable into one, and then perform regression analysis. In order to ensure the rigor of the regression analysis, the collinearity and autocorrelation issues between variables were verified. The results showed that the maximum expansion factor of the regression model constructed was 1.446 and the minimum was 1.245, both of which were below the threshold 10. Moreover, the Durbin-Watson (DW) value of the regression model test sample data is close to 2, indicating that the regression model constructed in this paper does not have serious multicollinearity and autocorrelation problems.

Table 2. Analysis of CITC Coefficient and Reliability of Variable Items

Variable	Item Code	CITC	Alpha if Item deleted	Cronbach's α
Innovation Performance	The number of new products or patents is increasing	0.831	0.936	
	Product output value/total sales are increasing	0.878	0.921	0.943
	Product development speed is accelerating	0.869	0.924	
	Product success rate is gradually increasing	0.878	0.921	
	Business communication is frequent and lasting	0.463	0.836	
Network Strength	Spend a lot on connections between companies	0.729	0.702	0.807
	Employees are highly dependent on the Internet	0.728	0.710	
	Adhering to the concept of mutual benefit and win-win	0.601	0.770	
Knowledge Spillover	Obtaining new technology from within the corporate network is cheap	0.863	0.897	
	Frequently introduce new products from the Internet for free or at low cost	0.874	0.890	
	Often get information from the Internet for free or low cost	0.786	0.920	0.927
	Often get management skills and experience from the Internet for free or at low cost	0.812	0.911	
	Knowledge exchange and transfer activities are more	0.569	0.878	

Knowledge Transfer	frequent			
	It is easier to obtain information and knowledge about innovation from within the cluster network	0.766	0.659	0.820
	Ability to effectively integrate external resources and information	0.715	0.720	

Table 3. Exploratory factor analysis results

Measurement item	Factor structure			
	Factor1	Factor2	Factor3	Factor4
Innovation performance				
The number of new products or patents is increasing	0.787			
Product output value/total sales are increasing	0.898			
Product development speed is accelerating	0.811			
Product success rate is gradually increasing	0.844			
Network strength				
Spend a lot on connections between companies		0.505		
Employees are highly dependent on the Internet		0.709		
Adhering to the concept of mutual benefit and win-win		0.808		
Spend a lot on connections between companies		0.776		
Knowledge spillover				
Obtaining new technology from within the corporate network is cheap			0.889	
Frequently introduce new products from the Internet for free or at low cost			0.910	
Often get information from the Internet for free or low cost			0.828	
Often get management skills and experience from the Internet for free or at low cost			0.835	
Knowledge transfer				
Knowledge exchange and transfer activities are more frequent				0.635
It is easier to obtain information and knowledge about innovation from within the cluster network				0.896
Ability to effectively integrate external resources and information				0.856
Eigenvalues of factors	7.147	2.080	1.566	1.073
Explained variation%	47.646	13.868	10.438	7.153
Cumulative explained variation%	47.646	61.513	71.951	79.104

Table 4. Regression analysis results

Variable	**model1**	**model2**	**model3**	**model4**	**model5**
	Performance	**Performance**	**Spillover**	**Spillover**	**Transfer**
Independent and intermediate variables					
Network Strength		0.685***		0.497**	
Knowledge Spillover					
Knowledge Transfer					
Control variable					
Innovation Capacity	0.252	0.015	-0.137	-0.309	-0.062
Scale	0.595	0.287	0.251	0.028	-0.390
Stage	0.533	0.403	-0.443	-0.537	-0.647
R^2	0.075	0.385	0.031	0.184	0.027
$AdjR^2$	0.010	0.326	-0.036	0.106	-0.041
$\triangle R^2$		0.310		0.153	
F	1.157	6.561***	1.194	2.361*	0.402
Variable	**model6**	**model7**	**model8**	**model9**	**model10**
	Transfer	**Performance**	**Performance**	**Performance**	**Performance**
Independent and intermediate variables					
Network Strength	0.410***			0.540**	0.597**

Knowledge Spillover		0.541***		0.361**	
Knowledge Transfer			0.664***		0.295
Control variable					
Innovation Capacity	-0.254	0.847	0.444	0.446	0.142
Scale	-0.177	-0.813	-0.077	-0.372	0.088
Stage	-0.271	-0.089	-0.181	0.232	0.127
R^2	0.274	0.306	0.213	0.469	0.391
AdjR^2	0.205	0.240	0.138	0.404	0.316
$\triangle R^2$	0.247	0.231	0.138	0.394	0.316
F	3.962***	4.631***	2.834***	7.246***	5.256**

Note: *** p<0.01; ** p<0.05; * p<0.1.

In order to test the influence of network strength on collaborative innovation performance, firstly, three control variables of enterprise innovation capability, enterprise scale, and enterprise development stage are added to Model 1. According to the results of Model 1, it is found that its explanation of innovation performance is low (R2 =0.075). The independent variable network strength is added to Model 2, and compared with Model 1, it is found that the overall explanatory power of the model is significantly improved after the network strength is added (R2=0.385), and the explanatory power increases by 31.0%. The coefficient of network strength is a significant positive number (β=0.685, p<0.01), indicating that network strength has a significant positive correlation with innovation performance, that is, the more frequent the connections between nodes in the innovation network, the higher the performance of the innovation network. That is, H1 is established. In order to further reveal the mechanism of "network strength-innovation performance", that is, how network strength affects the flow of knowledge and then affects innovation performance, this article refers to the sequential inspection method proposed by Baron and Kenny [16]. To examine the relationship between network strength, knowledge flow and innovation performance, so as to clarify the role of network strength on innovation performance, the specific methods are as follows:

(1) In order to verify the influence of network strength on knowledge spillover, taking knowledge spillover as the explained variable, three control variables of enterprise innovation capability, enterprise scale and enterprise development stage are added to Model 3, and it is found that the overall explanatory power of Model 3 is low (R2=0.031). Secondly, the variable network strength is added to Model 4. The result shows that the overall explanatory power of Model 4 (R2=0.184) is 15.3% higher than that of Model 3, and the network strength coefficient is positive (β=0.497), P<0.05), indicating that there is a significant positive relationship between network strength and knowledge spillover, that is, the more frequent the connections between nodes in the innovation network, the higher the efficiency of knowledge spillover, that is, H2a is verified.

(2) In order to test the influence of network strength on the efficiency of knowledge transfer, first, only control variables were added to Model 5, which is similar to the results of Model 3, and the overall explanatory power of this model is low (R2=0.027). Secondly, the variable network strength is added to Model 6, and it is found that the overall explanatory power of Model 6 (R2=0.274) is 24.7% higher than that of Model 5, and the coefficient of network strength is positive (β=0.410, p<0.01). The results of this study mean that the more frequent the contacts between enterprises, the higher the efficiency of knowledge transfer, that is, the strength of connections between nodes in the innovation network and the knowledge transfer have a significant positive correlation, that is, H3a is established.

(3) In order to reveal the impact of knowledge flow between innovation networks on innovation performance, we take innovation performance as the explained variable, and add variable knowledge spillover to Model 7. It is found that the overall explanatory power of Model 7 (R2=0.306) is 23.1% higher than that of Model 1, and the coefficient of variable knowledge spillover is positive (β=0.541, p<0.01). This shows that the knowledge spillover generated by frequent interaction between enterprises can help improve the innovation performance of the network, that is, there is a significant positive correlation between knowledge spillover and innovation performance, that is, H2b is established. Next, to verify the relationship between the efficiency of knowledge transfer and innovation performance, first add variable knowledge transfer to Model 8. The results show that the overall explanatory power of Model 8 (R2=0.213) is 13.8% higher than that of Model 1. And the coefficient of knowledge transfer is positive (β=0.664, p<0.01), which means that the higher the efficiency of knowledge spillover of enterprises in the network, the more helpful the improvement of innovation performance. That is, there is a significant positive correlation between innovation performance and knowledge transfer efficiency, that is, H3b is established.

(4) On the basis of Model 2, variable knowledge spillover and knowledge transfer are sequentially added. Model 9 adds knowledge spillover to model 2, and finds that the coefficients of variable network strength (β=0.540, p<0.05) and knowledge spillover (β=0.361, p<0.05) are both significant positive numbers. In other words, knowledge spillover presents a partial mediating effect between network strength and innovation performance, and H2c is established. From the empirical results, the coefficient of variable network strength is positive (β=0.597, p<0.05), but the coefficient of variable knowledge transfer is not significant, indicating that knowledge transfer may not

have a mediating effect between network strength and innovation performance. Therefore, H3c does not hold.

4.2. Mediation Effect Test and Hypothesis Test

For the rigor of the empirical results, this paper further uses the Sobel robustness test to verify the mediation effect. The mediating effects of knowledge spillover and knowledge transfer have z values of 1.976 and 1.650, respectively. The mediating effects of knowledge spillover and knowledge transfer both pass the test at a significance level of 0.1. The mediating effect of knowledge spillover accounted for 21.5% of the total effect, and the mediating effect of knowledge transfer accounted for 16.7% of the total effect. This shows that 21.5% of the influence of network strength on innovation performance is realized through knowledge spillover, and 16.7% is realized through knowledge transfer. In other words, knowledge spillover and knowledge transfer are part of the mediating role in the influence of network strength on innovation performance, that is, H3c has been verified. Network strength has a positive impact on knowledge spillovers, and knowledge spillovers also have a positive impact on network innovation performance; similarly, the effect of knowledge transfer in the influence of network strength on innovation performance is similar to that of knowledge spillovers, and knowledge transfer between enterprises is affected by network strength. The positive impact on innovation performance has a positive impact on innovation performance.

5. CONCLUSION

5.1. Research Conclusion and Inspiration

This paper integrates the value network theory and knowledge base view, takes the collaborative innovation network of small and medium-sized enterprises as the research object, and uses the knowledge flow as an intermediary to explore the role of network strength on the performance of collaborative innovation. The results found that there is a significant positive correlation between the network strength and performance of the SME collaborative innovation network in the Chinese context. It shows that my country's small and medium-sized enterprise collaborative innovation network has not yet shown a "lock-in effect", and the frequent interaction between nodes of the network is conducive to the improvement of innovation network performance. Therefore, strengthening the relationship between enterprises can have a positive effect on the improvement of innovation performance. Similarly, there is a significant positive correlation between knowledge flow and innovation performance, that is, the more frequent the contacts between enterprises, the more conducive to the flow of knowledge, and the promotion of knowledge flow within the network can effectively improve innovation performance. At the same time, knowledge spillover and knowledge transfer play an important intermediary role between "network strength-innovation performance", that is, there are two paths of action between the frequency of collaborative innovation network enterprise contact and innovation performance. To a certain extent, the research results reflect the reality of the collaborative innovation network of SMEs in my country. The following enlightenment can be obtained through the research conclusions:

(1) For network members, a knowledge-intensive collaborative innovation network should be constructed to speed up the flow of knowledge within the network. Based on the importance of heterogeneous knowledge to the development of my country's collaborative innovation network, companies should attach importance to external cooperation and knowledge exchange, and improve cross-departmental, cross-enterprise, and cross-regional exchange and cooperation mechanisms. Strengthen corporate training, send corporate members to receive high-quality training, improve knowledge absorption and learning capabilities, and promote knowledge conversion efficiency. Strengthen formal and informal communication with upstream companies, downstream companies, partners, suppliers and customers to ensure the abundance of corporate information and resources. Expand the scope of network contact, actively seek partners and competitors and continuously improve trust, and establish a large-scale collaborative innovation network based on trust.

(2) For government departments, it is necessary to pay attention to the establishment of an innovation environment, create a relaxed innovation environment, and focus on improving the sense of innovation efficiency of network members; it is necessary to accelerate the improvement of innovation incentive policies, provide policy and financial support for innovation activities, and strengthen network members' innovation awareness and spirit. Attract outstanding enterprises and innovative talents to gather.

5.2. Insufficient Research

There are still some shortcomings in this article: (1) Based on the degree of initiative of knowledge flow, it can be divided into conscious knowledge transfer and unconscious knowledge spillover. Is it possible to divide knowledge flow from more dimensions and study the relationship between them? The relationship between the two also needs further study. (2) Only the network strength in the network structure is selected as a factor affecting innovation performance. Future research can further explore the impact of network density and network centrality on performance through knowledge flow.

ACKNOWLEDGMENT

This work was supported by National Natural Science Foundation of China (71872014), Humanities and Social Sciences Planning Project of the Ministry of Education (16YJA630047), and Shanxi Province Graduate Education Innovation Project (2017BY091).

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