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Abstract:

This paper analyzes the relationship between social capital and innovation performance by using structural equation model and Smart PLS software, and discusses the collaborative innovation performance of large coal enterprises based on social capital. The results show that technological innovation network capability, technological cooperation network capability and market innovation network capability can effectively promote innovation performance. External social capital can positively affect innovation performance through the strengthening of internal technological cooperation network capability.

Keywords: Social capital, Collaborative innovation performance, Technology collaborative network capability

Introduction

Under the background of the rise of science and technology economy, the competition of knowledge economy becomes more intense. The academic and industrial circles attach importance to innovation as the core driving force of economic development. As a new and efficient collaborative mechanism for resource integration and optimal allocation, collaborative innovation mechanism, with the advantage of resource sharing brought by corporate social capital, began to emerge and grow in Chinese industry (Baldwin & Von Hippel, 2011; Najafi-Tavani et al., 2018). Enterprises are the main body of innovation, and only by relying on enterprises can collaborative innovation be realized. China's large-scale coal enterprises collaborative innovation is one of the key projects supported by the state, which is the only way for Industry 4.0. In recent years, the collaborative innovation of coal industry has become the focus of national attention and made great progress. However, with the increasing problems of coal enterprises in China, the development of coal enterprises has encountered bottlenecks, the output has been reduced year by year, the resource allocation is unreasonable, the efficiency of collaborative innovation has become low, and the conversion rate of scientific and technological achievements is not high. The evaluation model of collaborative innovation performance of coal enterprises is an important part of collaborative innovation research in China. It is the main way for coal enterprises to improve their market competitiveness and collaborative innovation ability. Innovation and development has become the only way out for this important energy industry, and its model and system need to be continuously developed and optimized. Large coal enterprises mainly refer to large-scale enterprises whose profit-making means are mainly coal mining, processing and sales. The output of raw coal is more than or equal to 10 million tons, and the annual operating revenue is more than or equal to 10 billion yuan. Meanwhile, they are the main suppliers of national coal energy consumption, capital intensive and labor-intensive. In the deepening period of China's economic transformation, large-scale coal enterprises improve their collaborative innovation ability through social capital exchange and optimization of innovation resource allocation, which is of great significance to promote the sound development of coal enterprises, industrial economic development, and even the development of the whole national economy (Tong, 2017).

This paper uses large-scale coal enterprises as samples to analyze the collaborative innovation performance based on the influencing factors of social capital, which can fill in the gaps of related industry research. The main values are as follows: (1) redefining the social capital that directly and indirectly affects innovation performance, and combining quantitative and qualitative measurement methods, which have certain operability And practicability, to overcome the shortcomings of current research on the measurement of corporate social capital; (2) using structural equation analysis method, to analyze the

relationship between social capital and evaluate the collaborative innovation performance of large-scale coal enterprises based on social capital, to find out the internal and external key factors that affect the collaborative innovation performance of large-scale coal enterprises, which can provide feasible construction for coal enterprises to improve innovation performance

Theory Analysis and Research Hypothesis

Corporate Social Capital and Dimensions of Social Capital

Social capital was first put forward by Bourdieu (1986), a French sociologist, in the 1980s. It aims to solve the sharp social contradictions in France, and then becomes one of the front and hot spots in academic research. Bourdieu (1986) thinks that social capital is a combination of real resources that are well known and potential resources that can be recognized, and it is a kind of sustainable network structure connected with each other through social network structure. Burt (1992) thinks that the relationship network within and with other enterprises is the social capital of enterprises, which is the key factor to determine the success of enterprises. This is the earliest research on the social capital of enterprises that can be traced back. Nahapiet & Ghoshal (1997) defined corporate social capital as a collection of existing or potential resources that can be fully utilized by enterprises, which exist in the internal and external social networks of enterprises. Leenders & Gabbay (1999) formally put forward the concept of corporate social capital. After systematic analysis, he believed that corporate social capital is a tangible or intangible resource that can promote the realization of corporate goals and objectives through social networks. So far, the connotation of corporate social capital research has been enriched. Subsequently, many scholars have expounded the concept of corporate social capital from different perspectives. Although they are different, they emphasize that network and norm are a common feature (Durlauf, 2004). All the researches have emphasized the important influence of network on corporate resources. Therefore, this study defines the social capital of large-scale coal enterprises as networks and capabilities based on trust, reciprocity and norms, which can promote enterprises to obtain various resources and innovative development.

There are many researches on dimensions and measurement of social capital, but they are basically based on the research of Nahapiet & Ghoshal (1997). Nahapiet & Ghoshal (1997) divided the internal dimensions of social capital into three dimensions: structural dimension, relational dimension and cognitive dimension. Among them, the structural dimension refers to the location of enterprises or individuals in the relationship network and the mode of mutual connection, emphasizing close cooperation, interaction of resources, information and knowledge, and division of labor and coordination; Relationship dimension refers to the behavior process in which individuals or enterprises use relationship or relationship means in order to obtain social capital, emphasizing mutual trust and normative obligations; Cognitive dimension refers to the common paradigm, mutual respect of values and mutual understanding of behavior habits of language communication and coding between individuals or enterprises in the relationship network. It emphasizes effective communication. To study collaborative innovation from the perspective of corporate social capital, we should also combine the internal dimensions of social capital, and the relationship and connection ability with each network node should be considered from three aspects: structural dimension, relationship dimension and cognitive dimension.

Corporate Social Capital and Innovation Performance

Collaborative innovation is a process of knowledge capital transformation carried out by multiple network nodes. It is an innovation organization (Chen, 2012) including enterprises, government departments, knowledge and R & D organizations, intermediaries and users. In order to achieve the common goal, collaborative innovation is carried out to achieve the effect of $1 + 1 > 2$. Yli-Renko et al. (2001) pointed out that the impact of social networks on the process of collaborative innovation of enterprises should not be ignored. The research of Zhao and Chen (2012) divides enterprise collaborative innovation network nodes into three types: R & D network nodes (universities, scientific research institutes, etc.), service network nodes (government departments, banks and other financial institutions and intermediary organizations), and business network nodes (competitors, suppliers, customers, customers, etc.). Nowadays, the external capital that influences the performance of collaborative innovation mainly includes government policy, industry development level and technological

progress, while the internal capital mainly includes knowledge absorption capacity, enterprise innovation culture and internal capital structure network. Collaborative innovation is a multi-dimensional and complex system. According to the concept of collaborative innovation, the performance of collaborative innovation and social capital are inseparable complexes (Tong, 2017). Based on the above analysis, this study constructs a theoretical system of collaborative innovation for large-scale coal enterprises, in which the degree of collaboration is higher than that of cooperation, and each subject of collaborative innovation drives the innovation within the alliance with a common goal.

In this paper, the collaborative innovation ability of large-scale coal enterprises based on social capital is summarized into four categories: first, technological innovation network ability, including technical dimensions such as schools and research institutions; second, System innovation network ability, which refers to institutional dimensions such as government departments, banks and other financial institutions, as well as intermediary organizations; third, market innovation network ability, which means suppliers, customers and competitors Other enterprise and market dimensions; internal technology collaboration capability is also a key element of collaborative innovation performance, including R & D technology, management, shareholders and employees (Wang, 2017). The above four dimensions together constitute the social capital elements of collaborative innovation performance, which are indispensable.

Most studies show that through the exchange of internal networks and the effective cooperation between enterprises and external networks, enterprises can make use of external network technology and knowledge to flow into enterprises and realize internal absorption and flow, so as to improve the innovation performance and innovation ability of enterprises (Nuryani, 2018). Lins et al. (2017) confirmed that when the overall trust level of enterprises and the market is negatively impacted, the trust established between enterprises and their stakeholders and investors through social capital investment will be rewarded. Nuryani et al. (2018) empirical analysis shows that social capital has a certain impact on financial performance. The research results of Wang (2017) show that there is a curve correlation between internal social capital and enterprise innovation. Rass et al. (2013) proposed that the implementation of open innovation tools strengthened the organization's social capital, which was positively related to the enterprise performance.

In the working environment of national collaborative innovation, the resource input of enterprises is the basic condition for collaborative innovation. The essence of corporate collaborative innovation is to promote intellectual innovation by internalization of social capital so as to improve the performance of collaborative innovation. The four dimensions of social capital have a positive effect on collaborative innovation. Large coal enterprises can achieve collaborative innovation and change the existing inefficiency only if they work closely with the stakeholders of R & D node, service node and operation node in the structural dimension, relationship dimension and cognitive dimension, interact resources, information and knowledge and coordinate their work division, communicate effectively, trust each other and standardize their obligations Rate the transformation of achievements and promote sustainable development. Based on the above analysis, this paper proposes the following assumptions:

H1: technological innovation network capacity of large coal enterprises has a positive impact on innovation performance;

H2: the system innovation network capacity of large coal enterprises has a positive impact on innovation performance;

H3: the technological cooperation network capacity of large coal enterprises has a positive impact on innovation performance;

H4: the market innovation network capacity of large coal enterprises has a positive impact on innovation performance;

Social capital under the framework of collaborative innovation performance needs to consider the relationship between the enterprise and the external social network, and more importantly, the internal technology cooperation ability of the enterprise. If it is only closely connected with external social capital, but there are problems in internal management and technology investment, and it does not have strong knowledge absorption and transformation ability, it cannot make collaborative innovation process smooth, and then achieve the improvement of performance. So how does social capital affect the exchange of productive resources? Moran (2005) holds that the exchange of resources within an enterprise is the key to its value creation. Yli-Renko et al. (2001) conducted an empirical study on 180 British high-tech enterprises, and found that all aspects of social capital (social interaction, relationship characteristics and network connection) make the knowledge transfer between

emerging technology enterprises and key customers easier, and the acquisition of knowledge promotes the development of new products and the improvement of performance. Maurer et al. (2011) believed that the impact of social capital on organizational performance was positive, and knowledge transfer played an intermediary role between social capital and organizational performance within the organization. In order to realize the exchange of internal and external resources of innovation performance and the transformation of knowledge capital, it is necessary to rely on the social capital of the enterprise's own management, the cohesion of employees, the relationship between shareholders and the R & D technology input, that is, the internal technology cooperation ability plays an intermediary role in the external social capital and innovation performance. Therefore, this paper assumes that:

H5: the technological cooperation network capability of large-scale coal enterprises plays an intermediary role in technological innovation network capability and innovation performance;

H6: the technological cooperation network capability of large coal enterprises plays an intermediary role in the system innovation network capability and innovation performance;

H7: the technological cooperation network capability of large coal enterprises plays an intermediary role in market innovation network capability and innovation performance.

From the previous studies, the relationship between corporate social capital and innovation performance has been an important research field in the management field, and the positive correlation between them has also been confirmed by more and more scholars. However, with the importance of social capital in the new era and the urgent need of enterprise innovation and development, collaborative innovation performance itself is an innovation system integrating social capital, and should not be separated from the two for analysis. Therefore, it is more academic and practical significance to build a performance evaluation model of Collaborative Innovation Based on social capital. This study is based on the mechanism research of corporate social capital and innovation performance, and finds that collaborative innovation performance must be based on the theoretical basis of collaboration, and social capital should be included, which is in line with the future development direction of the research of social capital and performance mechanism to a certain extent.

Hypothesis Development

Definition and Setting of Variables

The variables involved in this study are exogenous latent variables (three dimensions of external social capital of enterprises), intermediary variables (technological collaboration network capacity) and endogenous latent variables (innovation performance). Refer to the research of Yli-Renko et al. (2001), Rass et al. (2013), Xie (2016) and Wang & Hu (2017) to construct the observation variable index of innovation performance. Refer to the research of Zhao et al. (2012), Wang (2017) and Najafi-Tavani (2018) to establish the observation variable indexes of four dimensions of social capital. As shown in Table 1.

Table 1.

Structured performance variables of collaborative innovation

Latent Variable	Index Meaning or Calculation	Remarks
Innovation performance (INPE)	Number of patents authorized in the current year (INPE1)	Quantitative
	Whether the number of new product development increases (INPE2)	Qualitative
	Whether the speed of new product development is accelerated (INPE3)	Qualitative
	Whether the success rate of innovative products is improved	Qualitative

		(INPE4)	
Corporate Social Capital (CSC)	Technological innovation network capability (TEIN)	Collaboration with universities (TEIN1)	Qualitative
		Cooperation with the College (TEIN2)	Qualitative
		Cooperation with technical school (TEIN3)	Qualitative
		Proportion of R & D institution funds from large coal enterprises (TEIN4)	Qualitative
	System innovation network capability (SYIN)	Natural logarithm of government subsidy income (SYIN1)	Quantitative
		Cooperation degree between enterprises and Industry Alliance and Industry Association (SYIN2)	Qualitative
		Cooperation between enterprises and science and technology intermediary service agencies (SYIN3)	Qualitative
		Short term borrowings / current assets (SYIN4)	Quantitative
	Technical cooperation network capability (TECO)	Background of management's Government Relations (TECO1)	Qualitative
		Management experience in other enterprises (TECO2)	Qualitative
		Proportion of total R & D expenditure to operating revenue (TECO3)	Quantitative
		Proportion of R & D personnel (TECO4)	Quantitative
	Market innovation network capability (MAIN)	Proportion of top 5 suppliers in total purchase amount (MAIN1)	Quantitative
		Sales amount of top 5 customers as a proportion of total sales(MAIN2)	Quantitative
		Natural logarithm of main business income (MAIN3)	Quantitative
		Natural logarithm of marketing cost input (MAIN4)	Quantitative

Research Samples and Data Collection

The industry classification standard of this paper adopts the industry classification guidelines for listed companies (revised in 2019) issued by the CSRC, and selects 27 listed companies in the first category of coal mining and washing industry in category B. Because PLS-SEM requires the sample size to be as large as possible, this study decided to use panel data for analysis (Michael, 2004). Taking the coal listed companies listed in Shanghai and Shenzhen from 2014 to 2018 as samples, 5 samples that were rejected by * ST or ST, audit denial, lack of financial data, etc. were excluded. Finally, the number of coal listed companies that meet the requirements is the balance panel data of 21 companies, with 105 effective observations. The data are mainly from WIND, CMSR, SIPO and CNINFO. In this paper, SPSS19.0 software is used for data pre-processing, and Smart PLS2.0 software is used for structural equation model analysis.

In the empirical study, because the research object of this study is enterprises, in order to ensure the authenticity and availability of data and

improve the reliability and validity of each potential variable, this study uses the combination of open financial statement data and questionnaire to obtain basic sample data. In order to verify the relevant assumptions of the framework model in this paper, on the basis of combing a large number of previous relevant studies, combined with the actual situation of the survey, using mature research scales for reference, and drawing on the opinions of experts in relevant fields to design and modify the questionnaire, finally determining the questionnaire in this paper, and measuring some observation variables in the study through multiple items (Farooq, 2017). The questionnaire consists of blank filling questions and multiple choice questions. The multiple choice questions are designed with medium length sentences (16-24 words), and the scores are expressed by Likert seven point scale (totally disagree - totally agree) (Bedford & speklé, 2018).

Model Design

Structural Equation Model (SEM) based on Partial Least Square Method (PLS) is the second generation of statistical analysis method combining principal component analysis and multiple regression analysis, which is suitable for small sample prediction analysis without sample data conforming to normal distribution, and suitable for the prediction model proposed in this paper based on Theory (Xie et al, 2016). According to the hypothesis and variable selection of social capital and collaborative innovation performance, the structural equation analysis model is constructed, as shown in Figure 1. The model reflects the evaluation mechanism of collaborative innovation performance based on social capital, and the intermediary role of technological collaboration network capability in technological innovation network capability and innovation performance, institutional innovation network capability and innovation performance, and market innovation network capability and innovation performance.

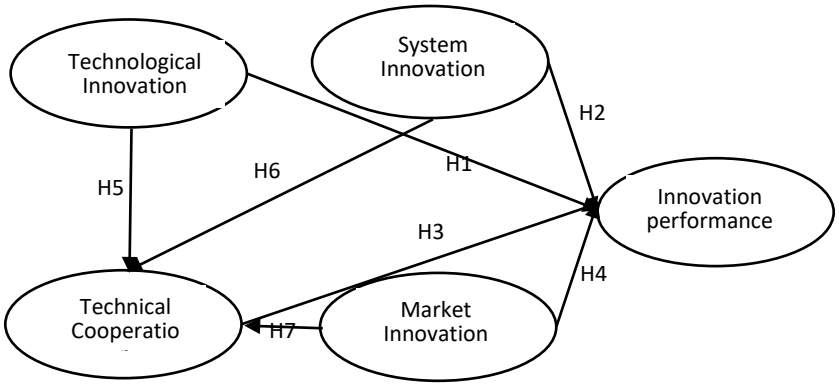

Figure 1. Performance evaluation model of collaborative innovation of large coal enterprises based on social capital

Empirical Test

Measurement Model

The measurement model can examine the effect weight of observation variables on structural latent variables. According to the literature review, the main test contents are: construction reliability, convergence validity and discrimination validity. Through the measurement model, we can test the adequacy and appropriateness of the description (capture) of each observation variable item to the specific concept connotation, and then investigate the reliability and validity of the observation variable to the latent variable of the external model, and obtain the weight of the observation variable to the structural variable. Only when the external model passes the test can the further test of the structural model be meaningful (Nic & Lorne, 2007).

(1) Validity analysis of the basic structure of the model

The validity analysis of the basic structure of the model is mainly the analysis of the basic structure of PLS: cross load. Validity analysis is a powerful tool to measure the structure that the paper research wants to measure

correctly. With the help of Smart PLS software, the standardized load coefficient of the item can be obtained. The structural equation analysis can be carried out by using Smart PLS software, and the index with external factor load coefficient lower than 0.6 can be deleted (Nick & Lorne, 2007). In order to calculate the cross load, the factor score of each structure is calculated according to the weighted sum of the standardized and standardized indexes of the factor provided in the PLS result table, and the factor score is related to each item of cross load calculation. The bold figure is the load (correlation) between each index and its own structure, and the other figures are the cross load. The bold item load should be greater than the cross load. See Table 2 for score coefficient of each factor.

Table 2.
PLS Component-Based Analysis: Cross-Loadings

Items	TEIN	SYIN	TECO	MAIN	INPE
TEIN1	**0.9567**	0.1132	0.2736	0.3327	0.5425
TEIN2	**0.9476**	0.0968	0.2468	0.3074	0.5623
TEIN3	**0.9768**	0.1222	0.2858	0.3425	0.5644
TEIN4	**0.9494**	0.0861	0.1920	0.2657	0.4721
SYIN1	0.2479	**0.6111**	0.2632	0.3802	0.2264
SYIN2	-0.0510	**0.7757**	0.2807	0.1345	-0.0075
SYIN3	-0.0564	**0.6166**	0.1738	-0.1942	-0.0940
SYIN4	0.0419	**0.7267**	0.1961	-0.0498	0.0133
TECO1	0.0932	0.1821	**0.6511**	0.1395	0.2885
TECO2	0.3140	0.3560	**0.8651**	0.3627	0.3810
TECO3	0.0000	0.1279	**0.6409**	0.1587	0.2535
TECO4	0.2640	0.3989	**0.8723**	0.2890	0.4400
MAIN1	0.1328	0.0879	0.2831	**0.7786**	0.3349
MAIN2	0.1111	0.0953	0.2208	**0.7381**	0.2706
MAIN3	0.4389	0.1908	0.2144	**0.6232**	0.3161
MAIN4	0.2618	0.2461	0.2077	**0.6581**	0.1227
INPE1	0.5384	0.1347	0.4226	0.4053	**0.9598**
INPE2	0.5092	0.0852	0.4855	0.3948	**0.9511**
INPE3	0.5675	0.1098	0.4381	0.3315	**0.9604**
INPE4	0.5146	0.0469	0.3919	0.3659	**0.9189**

(2) Convergence validity analysis

The criterion of convergence validity analysis is the standardized factor load coefficient of the item and the average variation extraction (AVE) of each latent variable (dimension). With the help of Smart PLS software, the standardized load coefficient of the item can be obtained. With the help of Smart PLS software, the structural equation analysis can be carried out, and the index with external factor load coefficient lower than 0.6 can be deleted. The measurement results of structural variables of all levels of Corporate Social Capital (CSC) and Innovation Performance (INPE) of coal enterprises are shown in Table 3. The load coefficient represents that the common variance between the item and its latent variable is greater than that between the item and the error variance. It is generally considered that when the load coefficient and AVE value are greater than 0.5, and the T value is greater than 1.96 (described in the structural model), it means that each construction of the questionnaire has an introverted effect (Michae, 2004).

Table 3.
Measurement results of dimensions of corporate social capital and innovation performance

Latent variables	Inspection index	Observation item	Loading	Means	Standard deviation
TEIN	Cronbach's Alpha=0.969916 CR=0.977918 AVE=0.917172	TEIN1	0.9567	3.5407	1.5100
		TEIN2	0.9476	3.3556	1.6366
		TEIN3	0.9768	3.4963	1.6294
		TEIN4	0.9494	3.2296	1.6297
SYIN	Cronbach's Alpha=0.642314 CR=0.726516 AVE=0.522317	SYIN1	0.6111	16.9092	1.8416
		SYIN2	0.7757	3.5778	1.4324
		SYIN3	0.6166	4.4667	1.3203
		SYIN4	0.7267	0.3608	0.4001
TECO	Cronbach's Alpha=0.785974 CR=0.849118 AVE=0.615975	TECO1	0.6511	3.7481	1.9421
		TECO2	0.8651	4.2593	1.8160
		TECO3	0.6409	0.0087	0.0132
		TECO4	0.8723	4.1270	3.5744
MAIN	Cronbach's Alpha=0.693136 CR=0.774303 AVE=0.593136	MAIN1	0.7786	0.1983	0.2246
		MAIN2	0.7381	0.2013	0.2399
		MAIN3	0.6232	22.9987	1.4443
		MAIN4	0.6581	19.0533	2.4413

INPE	Cronbach's Alpha=0.962103 CR=0.972427 AVE=0.898165	INPE1	0.9598	1.4309	1.7690
		INPE2	0.9511	3.8963	1.9133
		INPE3	0.9604	3.6370	2.2580
		INPE4	0.9189	3.8222	2.0511

It can be seen from Table 3 that from the perspective of reliability analysis of the observation model, the four structural variables of corporate social capital are technological innovation network capability TEIN and institutional innovation network capability SYIN, technical cooperation network capability TECO and market innovation network capability main, the combination reliability CR is between 0.726516 and 0.972427, which is higher than the basic requirement of 0.7, indicating that the internal observation items of each structural variable of each dimension of corporate social capital and innovation performance have strong internal consistency. From the perspective of validity analysis of the observation model, the standardized load coefficient of each dimension concept of the observation project is between 0.6111 and 0.9768. Although there is no minimum requirement of greater than 0.7, it is also acceptable to be greater than 0.6 without affecting the overall results of the model. It shows that the measurement model has good convergence validity in a single dimension. The minimum value of AVE of each structure variable is 0.522317, which meets the minimum standard that AVE must be higher than 0.5 proposed by Fornell in the literature, indicating that the measurement of each structure has good differentiated validity (Nic & Lorne, 2007).

(3) Discriminant validity analysis

The overall discriminant validity test of the structural model is mainly to compare the absolute value of the correlation coefficient between the square root of AVE of potential variable and other potential variables. The test table of discriminant validity is shown in Table 4.

Table 4.
Correlation coefficient matrix, AVE and square root of model structural variables

Latent variable	INPE	MAIN	SYIN	TECO	TEIN
INPE	0.9577				
MAIN	0.1101	0.7848			
SYIN	0.2634	0.383	0.7227		
TECO	0.328	0.2032	0.3348	0.7702	
TEIN	0.5619	0.0998	0.4592	0.395	0.9477
AVE	0.9172	0.5223	0.616	0.5931	0.8982

Note: the last line is the value of AVE, the lower half of the matrix is Pearson correlation coefficient, and the diagonal is the square root of AVE.

According to the calculation results in Table 4 above, the correlation coefficient between each latent variable and other latent variables is less than the square root of AVE of the latent variable, so it can be seen that the

difference validity of the modified model has passed the test.

Structural Model

Using Bootstrapping algorithm in Smart PLS software, set sub samples 1000 times to calculate the t-test value of the structural model, and deleted the indexes whose t-test value is less than 1.96 in the scale of external measurement model (Michael, 2004; Nick & Lorne, 2007), which is used to evaluate the collaborative innovation performance of coal listed companies based on social capital, as well as the influence process and mechanism of the intermediary role of technological collaboration network capability. It can be seen from Table 5 that all the measured variables of the adjusted model have passed the t-value test.

Table 5.
External model loadings of structural equation

Items	Original Sample	Mean	STDEV	T-Values
TEIN: TEIN1	0.9567	0.9568	0.0054	175.8774
TEIN2	0.9476	0.9479	0.0076	124.4394
TEIN3	0.9768	0.9768	0.0036	270.4343
TEIN4	0.9494	0.9499	0.0078	122.1689
SYIN: SYIN1	0.5511	0.5324	0.1138	1.9631
SYIN2	0.7757	0.7189	0.1881	4.1233
SYIN3	0.5966	0.5284	0.2749	2.1701
SYIN4	0.7267	0.6648	0.2731	2.6606
TECO: TECO1	0.6511	0.6525	0.0958	6.7932
TECO2	0.8651	0.8578	0.0392	22.0488
TECO3	0.6409	0.6472	0.1173	5.4625
TECO4	0.8723	0.8652	0.0345	25.2669
MAIN: MAIN1	0.7786	0.7752	0.0649	11.9995
MAIN2	0.7381	0.7351	0.0935	7.8944
MAIN3	0.6232	0.6129	0.1158	5.3817
MAIN4	0.6581	0.6631	0.0877	7.5019
INPE: INPE1	0.9598	0.9606	0.0059	162.6247
INPE2	0.9511	0.9512	0.0094	100.9969
INPE3	0.9604	0.9606	0.0066	144.6070

INPE4	0.9189	0.9197	0.0195	47.2111

The results of structural model estimation show that all dimensions of corporate social capital have different degrees of impact on innovation performance (INPE) of coal listed companies. Three external social capital have a certain effect transmission relationship on innovation performance (INPE) through internal technical cooperation network capability (TECO). The specific results are shown in Table 6.

Table 6.
PLS analysis results of collaborative innovation performance based on social capital

Variable relation	Path Coefficients	Mean	STDEV	T-Statistic	Hypothesis	Result
TEIN→INPE	0.4326	0.4286	0.0737	5.8697	H1	Support
SYIN→INPE	-0.1082	-0.0988	0.0827	1.3084	H2	Unsupported
TECO→INPE	0.3319	0.3355	0.0685	4.8434	H3	Support
MAIN→INPE	0.1639	0.1574	0.0669	2.4505	H4	Support
TEIN→TECO→INPE	0.0519	0.0539	0.0268	1.9760	H5	Support
SYIN→TECO→INPE	0.1067	0.1068	0.0356	3.0011	H6	Support
MAIN→TECO→INPE	0.0724	0.0778	0.0280	2.5851	H7	Support

(1) Test results of the impact of various dimensions of corporate social capital on innovation performance

The standard path coefficients of technological innovation network capability, technological collaboration network capability and market innovation network capability to innovation performance are 0.4326 (t = 5.8697 > 1.96), 0.3319 (t = 4.8434 > 1.96) and 0.1639 (t = 2.4505 > 1.96), respectively, and the path coefficients are significant. Therefore, suppose H1, H3 and H4 are verified. That is to say, the technological innovation network ability, technological cooperation network ability and market innovation network ability of coal listed companies can effectively promote the improvement of collaborative innovation performance; The standard path coefficient of institutional innovation network capability on innovation performance is -0.1082 (t =1.3084 < 1.96), so if H3 fails to pass the verification, that is, institutional innovation network capability has no significant effect on innovation performance.

(2) Test results of intermediary effect of technical cooperation network capability

The path coefficient of the intermediary effect of technological collaboration network capability on technological innovation network capability and innovation performance is 0.0519(t=1.9760 > 1.96), the path coefficient of the intermediary effect of technological collaboration network capability on institutional innovation network capability and innovation performance is 0.1067 (t=3.0011 > 1.96), and the path coefficient of the intermediary effect of technological collaboration network capability on market innovation network capability and innovation

performance is 0.0724 (t=2.5851 > 1.96), the path coefficients are significant, so it is assumed that H5, H6 and H7 are all verified. It means that the external technology, system and market innovation network capacity of coal listed companies can positively affect the innovation performance of coal listed companies through the strengthening of internal technology cooperation network capacity.

To sum up, through the construction of PLS structural equation model of innovation performance of coal listed companies based on social capital, the hypothesis of the path and mechanism of external and internal social capital's impact on innovation performance is verified. The results show that most of the research hypotheses have passed the test, reflecting the evaluation of collaborative innovation performance.

Path Correction and Construct score

Based on the above hypotheses test results, paths were deleted that were not supported or weakly supported, re run the path estimation of PLS structure model, and get the impact transfer process and mechanism between the social capital and innovation performance of coal listed companies as shown in **Figure 2**. As can be seen from **Figure 2**, after deleting the non-significant hypothesis relations, the remaining six hypothesis relations are all supported.

By testing the explanatory variance R^2 of structural variables, we can see that the two structural variables' R^2 of innovation performance and technological collaboration network capability are 0.440 and 0.237 respectively. It shows that the innovation performance is more than 0.33, reaching a medium level, and the explanation effect of technical cooperation network capability is slightly poor, indicating that the model fitting degree is good 20(Michael, 2004).

In addition, it can be seen that among the four dimensions of social capital of coal listed companies, there are significant differences in the impact of innovation performance dimensions. Among them, the path coefficient of the influence of technological innovation network capacity on innovation performance of coal listed companies is the highest, which is 0.434, indicating that the relationship between coal enterprises and universities and scientific research institutes plays the most significant role in improving innovation performance; Secondly, technological cooperation network capability and market innovation network capability, with path coefficients of 0.293 and 0.155 respectively; Institutional innovation network capability has no significant impact on innovation performance, which shows that the social capital of the relationship between coal listed companies and governments, intermediaries and banks can not directly promote the improvement of innovation performance, but it can indirectly promote the improvement of innovation performance through the intermediary transmission of internal technology cooperation network capability. The improvement of technical cooperation network capabilities of shareholders, management, employees and innovation input in coal listed companies has significant intermediary effects on the three external social capital and innovation performance, among which the most obvious intermediary effect is institutional innovation and innovation performance, followed by market innovation, and finally technological innovation.

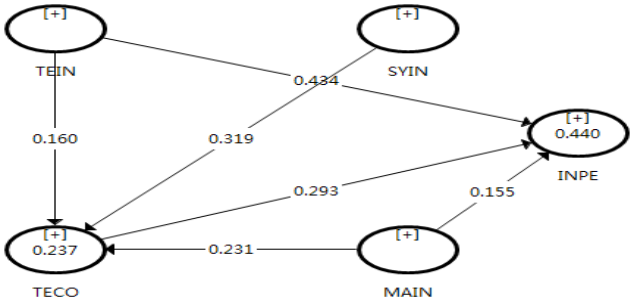

Figure 2. Modified influence mechanism model

Discussion

(1) The contribution of social capital to innovation performance

Collaboration with universities, Cooperation with the College, Cooperation with technical school and Proportion of R & D institution funds from large coal enterprises all have large influence coefficients and T statistics. It shows that each index of the relationship between coal listed companies and universities and R & D institutions has a significant direct impact on innovation performance, so coal listed companies should continue to strengthen the relationship with technology innovation departments.

The influence coefficients of the four indicators of Natural logarithm of government subsidy income, Cooperation degree between enterprises and Industry Alliance and Industry Association, Cooperation between enterprises and science and technology intermediary service agencies, and Short term borrowings / current assets are 0.6111, 0.7757, 0.6166 and 0.7267, respectively, and the T statistics are 1.9631,4.1233,2.1701 and 2.6606, respectively. It can be seen that the relationship between the coal enterprises and the government has the least contribution to the system innovation network capacity, and the largest contribution to the relationship between the coal enterprises and the industry alliance and the industry association. The external institutional innovation network capacity of coal listed companies has no significant negative impact on innovation performance, which shows that increasing government subsidies, strengthening the relationship with intermediaries and optimizing the relationship between banks and enterprises can't directly have a positive impact on innovation performance.

The path coefficients of the four indicators are 0.6511, 0.8651, 0.6409 and 0.8723 respectively, and the T statistics are 6.7932,22.0488,5.4625 and 25.2669 respectively. In the process of analysis, Loyalty variable of employees is not significantly deleted. Therefore, Proportion of R & D personnel and Management experience in other enterprises are the main contribution indicators of technical cooperation network capability. Relationship between management and government and Proportion of R & D expenditure are relatively weak compared with the contribution of internal social capital.

Depending on the strengthening of the relationship between the management and the government or other enterprises, increasing the R & D investment and the proportion of R & D personnel in the coal listed companies can promote the collaborative innovation performance. We should improve the salary and welfare of employees, enha]nce the loyalty of employees, and then improve the collaborative innovation ability and innovation performance of internal social capital.

Four indexes' loadings of Proportion of top 5 suppliers in total purchase amount, Sales amount of top 5 customers as a proportion of

total sales, Main business income and Marketing cost input are 0.7786, 0.7381, 0.6232 and 0.6581, respectively, with T values of 11.9995,7.8944,5.3817 and 7.5019. Proportion of top 5 suppliers in total purchase amount contributes the most to the social capital dimension of market innovation, followed by Marketing cost input and Sales amount of top 5 customers as a proportion of total sales, and finally Main business income reflecting the relationship between competitors. In the analysis process, the two indicators of Proportion of top 5 suppliers in total purchase amount and Sales amount of top 5 customers as a proportion of total sales are treated as negative because the influence coefficient is negative. Therefore, the social capital of suppliers and customers of coal listed companies has a significant negative impact on collaborative innovation performance. The closer the relationship between enterprises and major suppliers and customers, the less conducive to the improvement of innovation performance. Market innovation mainly depends on reflecting the superiority of the market and competitors. The larger the marketing cost input and the higher the market share, the higher the collaborative innovation performance of coal listed companies.

Conclusion

Internal technical cooperation network capability plays an active role in the process of the influence of three external social capital dimensions on innovation performance. The intermediary effect of internal cooperation network capacity on social capital of institutional innovation is the most obvious, and its intermediary effect on institutional innovation and innovation performance is greater than the direct effect. Therefore, coal listed companies should strengthen the close degree of internal social capital relations, and work hard in the management ability of management and shareholders, the loyalty of internal employees, and the increase of R & D investment, so as to enhance the internal technology cooperation ability, so as to better play the role of external technology innovation, system innovation and market innovation, and promote collaborative innovation Performance improvement.

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