The effect of social capital on the performance of technology transfer

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Abstract: In this paper, the social capital was measured based on the social network theory to evaluate effects on the performance of technology transfer. Firstly, the hypotheses were established based on literature review. Secondly, the multi agent model of transforming cooperation was constructed by Netlogo. Then, technology transformation performance was analyzed from macro and micro perspectives. Finally, conclusion was drawn and suggests proposed.

1. Introduction

As scientific and technological innovation is important for social development, how to promote the commercialization of scientific and technological achievements has become significant. Since 2015, Chinese government has revised the Act of Technology Transformation and preferential policies have been introduced in various places. This provides a good political environment for technology transformation. However, there are still many factors affect and restrict the growth of technology transformation performance.

Technology transformation is a complex system, including different agents. Universities and R&D institutions are the mainly suppliers of scientific and technological innovation. Enterprises are the demanders of scientific and technological achievements. Besides, related intermediaries play an indispensable role bridging supply and demand in transformation process. Therefore, technology transformation is a cooperative behavior among multi-agents, which has its own behavioral logic and cooperation criteria. The success or failure of cooperation directly affects the performance of technology transformation.

As an important form of capital, social capital has become a popular research area in many disciplines. Since the 1980s, more and more studies have found that social capital is an important capital affecting economic performance. As the connotation of social capital is complicated, it is worth to explore the impact of different dimensions of social capital on transformation performance.

2. Theoretical Basis

2.1 Social Capital

The concept of social capital was proposed recently. It did not develop rapidly and comprehensively until sociologists such as Bourdieu explored the concept in detail. Bourdieu believes that capital is disguised as three forms: economic capital, cultural capital and social capital. The social capital is composed of social obligations or connections and it is a collection of actual and potential resources [1]. Sandefur and Laumann (1998) concluded that social capital has three main functions: first, social capital is conducive to exchange information between enterprises. Second, social capital makes some actors are more influential than other actors. Thirdly, social capital stimulates the spirit of cooperation by the recognition and trust shared among network members.

The function of social capital makes it play a positive role in social production activities, so there are many studies research on the impact of social capital on performance. Coleman (1998) proposed that social capital, like other capitals, can create value. Social capital promotes cooperation through trust and promotes capital development by regulating people's activities, thus drive the growth of organizational performance [2]. Maskell (2000) Fukuyama (2003) found that the contribution of social capital to the economy is mainly due to the reduction of transaction costs [3]. Wang Ying (2012) found that social capital can promote enterprises to obtain external information, which is beneficial to enhancing the motivation to acquire knowledge and improve performance [4]. Xu Chao (2014) found that entrepreneurs' social capital plays a positive role in enterprise performance through the study of innovation enterprise [5]. Michele Tantardini (2017) analyzed seven years of panel data of Florida and found that social capital had a positive and significant impact on public financial performance [6]. From the perspective of knowledge learning, Zhu Jianmin et al. (2017) found that social capital had a positive impact on innovation performance of enterprises [7].

In summary, as a new form of capital, social capital can influence the innovation performance and public financial performance through building trust, controlling behavior and reducing transaction costs. However, the specific way that social capital affects the technology transformation performance remains to be further studied.

Social capital has multiple dimensions and there are many ways to measure it. P. Wei (2007) summarized the measurement methods of social capital, and divided them into three categories: the measurement based on conceptual level, the measurement based on constituent elements and the comprehensive measurement [8]. Among them, the measurement based on conceptual level can be divided into micro-social capital measurement based on social network characteristics and macro-social capital measurement based on community, regional and national levels. The micro-social capital measurement is divided into local network analysis and global network analysis according to different levels of social network. In addition, if the global network analysis focuses on the impact of individual characteristics on its access to resources and development, it belongs to micro-analysis, which mainly measures individual's degree centrality and betweenness etc. If analyzing characteristics of the global network, it belongs to the macro-analysis, including density, average distance of network and other measurement indicators. In this research, the global network analysis is used to measure social capital from both micro and macro aspects. The micro-measurement indicators are as follows:

Degree centrality. The degree of point i is the number of other points directly connected to point i. In the technology transformation, the higher degree of an agent, the more other agents directly related to it, which is beneficial to transmit of information and cooperation. In order to compare the degree centrality in graphs of different sizes, Freeman (1979) proposed the relative degree centrality, which is generally expressed as CRD, and its calculation formula is as follows:

$$C_{RDi} = \frac{l_i}{2n-2} \quad (1)$$

CRDi represents the relative degree centrality of point□ i, li represents the number of other points directly connected to point i, and n represents the size of the network.

Closeness. The closeness of a point is the sum of the shortcuts distance between the point and all the other points in the network graph [10]. In the technology transformation situation, the lower value of agent's closeness, the more convenient for the agent to contact with all the other agents in the network. This means it has more chance to obtaining information and building trust. The relative closeness value is marked as CRPi, , and calculation method is:

$$C_{RPi} = (n-1) \Big/ \sum_{j=1}^{n} d_{ij} \quad (2)$$

The dij is the shortcut distance between point i and point j, that is the number of links contained in the shortcut.

Betweenness. If point i is located on shortcuts of many pairs of points, then the point i has a higher betweenness [9]. In the technology transformation, if an agent has a high betweenness value, which indicates that it is the agent that many agents must contact with in the transformation. As a result, it could have a higher ability to control other agents, and obtain more resources and information. The betweenness value of point i is generally expressed as CABi, and the calculation formula is:

$$C_{ABi} = \sum_{j}^{n}\sum_{k}^{n} b_{jk}(i),\ j \neq k \neq i,\ j < k \tag{3}$$

The j and k represent the two random points in the network graph, which means two agents in the technology transformation process. The bjk(i) represents the probability of point i on the shortcut of point j and point k. The calculation formula of relative value of betweenness is:

$$C_{RBi} = \frac{2C_{ABi}}{n^2 - 3n + 2} \tag{4}$$

The macro-measurement indicators are as follows:

Density. The global network density is used to measure the closeness between members [11]. The greater of density value, the more intense connection of members in the global network. In the technology transformation situation, the high density means the market has a high level of cooperation. The calculation of density ND is:

$$N_D = \frac{2m}{n(n-1)} \tag{5}$$

In this formula, m represents the actual links contained in the network, and n(n-1) represents the maximum possible number of links in a network with n points.

Average distance. The distance between two points refers to the length of an optimal path between two points. The average distance of a global network describes the cohesion of members. In the technology transformation situation, a small number of average distances means the communication distance between transformation agents is short, which is conducive to reduce the cost of information exchange. The calculation of average distance NJ is:

$$N_J = 2\sum_{k=1}^{n(n-1)2} \frac{d_{ij}}{n(n-1)} \tag{6}$$

Centralization of betweenness. The betweenness centralization of global network is one of the ways to measure structure holes, which is used to express non-redundant connections. The higher value of centralization, the more probability that existing structure holes in the network. Burt points out that because of the homogeneity of ideas and behaviors within groups, agent which hold a structure hole could have more chance to get different information and resources. The calculation of betweenness centralization NB is:

$$N_B = \frac{\sum_{i=1}^{n}(C_{RB\max} - C_{RBi})}{n-1} \tag{7}$$

C_{RBmax} is the relative betweenness of the point which has the largest betweenness value in the network.

2.2 Performance

The definition of performance in existing researches can be divided into four categories: first, focus on result; second, focus on behavior; third, take both behavior and result into consideration; fourth, estimate the things it constructs (Bemardin, 1992; Campbell, 1990; Kaplan, et al, 1993) [12]. The development of organizational performance has gone through five stages. The first stage takes the realization of organizational goals as the main measurement standard, which is based on the goal theory. Organizations have different goals at different stages of development and its performance is measured by the level of achievement (Etzioni, 1964). The second stage takes the resources owned by the organization as the main measurement standard, which is based on the theory of system resources. As a social organization, it needs to acquire development resources from environment. Organizational performance is closely related to its surrounding environment. Therefore, the main measurement criteria are valuable resources that organizations can acquire and hold (Yuchtman, Seashore, 1967). The third stage takes stakeholder satisfaction as the main measurement standard. Organizational goals must be achieved on the basis of meeting the stakeholders' demand, so the satisfaction of investors, managers, customers and other stakeholders should be taken as the measurement standard of organizational performance. In the fourth stage, the behavior of organizational members is taken as the main measurement standard of performance, and its theoretical basis is process theory. The process theory holds that the performance evaluation criteria are based on behavior, and its main view is that the employee's behavior level is the embodiment of organizational performance (Camp-bell, 1987). The fifth stage is to take the achievement of organizational goals and the satisfaction of relevant stakeholders as the main measurement criteria at the same time. At this stage, organizational performance will pay attention to the realization of organizational and individual goals at the same time, and try to achieve a win-win situation between organizations and stakeholders through such a combination (Rogers, Wright, 1998).

The purpose of technology transformation is to enhance the competitiveness of enterprises, promote social development, and bring benefits to organizations. Under the influence of risk and transaction cost, the benefits of successful technology transformation are the direct manifestation of technology transformation performance. Taking time in to consideration, the profits accumulated by the organization after a period of times of transformation reflects the performance of technology transformation. The expression of individual performance in technology transformation E is:

$$E = \sum_{t=1}^{n} (\beta R - C) \tag{8}$$

In this calculation, β represents the risk coefficient, R represents the income of technology transformation, and C represents the cost of technology transformation.

3. Hypothesis Presentation

Technology transformation is a complex system involving cooperation among research institutions, intermediaries and enterprises. Therefore, technology transformation is embedded in the social network established by the relevant agents. Social capital based on individual network and global network affects the performance of technology transformation.

Ahuja et al. (2003) found that individual network centrality has a direct impact on individual performance through the research of online virtual R&D team [13]. Wang Zeyu (2014) based on a questionnaire survey of 87 scientific research teams, studied the relationship between social network connections and team performance of scientific research team leaders, and found that the internal degree centrality of scientific research team leaders has a significant positive impact on team performance [14]. By using the method of social network analysis, Alarcão et al. (2016) studied the relationship between network centrality and scientific productivity, and found that the stronger the centrality, the more likely it is to achieve the goal [15]. Based on this, the hypothesis is put forward:

H1: individual degree centrality is positively correlated with technology transformation performance.

H2: individual closeness is negatively correlated with technology transformation performance.

H3: individual betweenness is positively correlated with technology transformation performance.

Burt (1992) thought that high network density increases network closeness and homogeneity, which is not conducive to knowledge transfer [16]. However, Xie Hongming (2011) found that network density had a significant positive impact on technological innovation performance of learning ability through empirical research on high-tech enterprises in Guangdong Province [17]. Luo Jia De (2003) thought that distance is more conducive to avoiding knowledge redundancy and making communication more valuable [18]. Li Jinghua (2013) believed that the smaller the network distance, the more conducive to the transmission of tacit knowledge [19]. Burt (1992) structural hole can provide opportunities for its occupants to gain "information benefits" and "control benefits", thus having more competitive advantages than other members in the network [16]. Ying Hongbin (2016) empirically tested the impact of structural holes on innovation performance, and found that structural holes are beneficial to information collection but not to knowledge transfer, so there is an inverted "U" relationship between structural holes and innovation performance [20]. Based on this, the hypothesis is put forward:

H4: global network’s density and technology transformation performance have an inverted “U” correlation.

H5: global network’s average distance and technology transformation performance have an inverted “U” correlation.

H6: global network’s betweenness centralization and technology transformation performance have an inverted “U” correlation.

4. Simulation Process

Netlogo is a simulation software programmed with logo language. It is suitable for studying complex systems by manipulating agents and observing the rules or characteristics emerging from the macro-level.

Before the technology transformation, each agent needs primitive capital to start up. In this study, the initial asset value of each agent is set as 30. In addition, technology transformation requires the cooperation of different organization, such as suppliers, demanders and intermediaries. In this simulation, there are three agents to cooperate at each time. If the scientific and technological achievements can be successfully transformed, the participants in the cooperation can obtain benefits. Because this study focuses on the impact of social capital from reducing cost and risk, it ignores the difference of income caused by different projects and sets the profit value of the successful technology transformation as 20. Technology transformation needs to pay the transaction cost. Because of social capital among these agents, they have different levels of trust, and their ability of obtain information are different which influence the transaction cost. In this simulation, the transaction cost among agents which have cooperated before is C1. And the transaction cost among agents do not have cooperation experience before is C2, C2 > C1. There are also risks in the process of technology transformation. Referring to the risk measurement tools of the securities market, the formula for calculating the risk coefficient β is as follows:

$$\beta_i = \frac{Cov(r_{i,} r_m)}{\sigma_m^2} \tag{9}$$

Cov (r_i, r_m) is the covariance of the profit of point i and the profit of market, and σm is the standard deviation of the market. Besides, every agent in the market has a life cycle. Agent lacking sufficient competitiveness will be eliminated by market. In this simulation there are two elimination conditions.

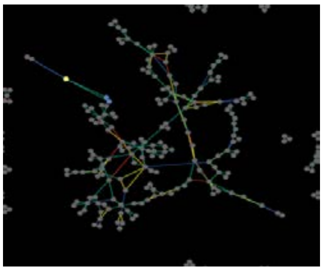

Figure.1. The global network of a simulation.

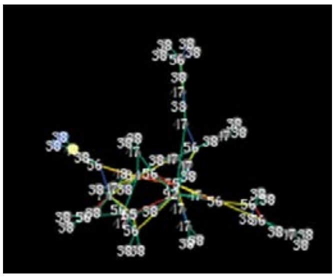

Figure.2. The energy value of each agent in a simulation.

First, when the value of the performances is less than zero, the agent will disappear. Second, when the agent has not participated in any cooperation for a long time, set as 100 footsteps in this simulation, it will be eliminated.

5. Result

Through multi-agent simulation, 4000 individual data of 20 network graphs and 200 global network data are generated. The data generated are calculated through UCINET, a kind of network analysis software, and regression analyses were made from micro and macro perspectives.

5.1 Micro Analysis

Micro analysis aims at the relationship between the individual transformation performance and individual characteristic at network. Table 1 shows the regression relationship of the degree centrality, the relative closeness and the relative betweenness of a point and the individual technology transformation performance. From model 1, it can be seen that the regression coefficient between degree centrality and performance is 14.271, and the square value of it is 0.243. It shows the positive relationship between individual performance and individual degree centrality. Besides, the P value is less than 0.05, which means the relationship is significant. In addition, R^2 is 0.54, which means degree centrality could explain more than half of the performance. On the basis of model 1, the variable closeness was added into the model. From model 2, it could be found that the degree centrality still maintains a significant positive correlation, but the relationship with closeness is different. Relative closeness regression coefficient is -5.825, while the square value of it is 0.891, besides P value is less than 0.05, which means that the individual performance and closeness has a significant "U" type relationship. When an agent has a high closeness value, indicating it has a large distance with other agents. That is to say, the closeness value has a critical point. Before the critical point, the agent has an over intimate social network, while after the point the agent is over isolated.

Table.1. The correlation coefficients for individual network characterize and performance

Variable	Performance		
	M1	***M2***	***M3***
Degree centrality (C_{RD})	14.271**	14.835**	15.397**
C^2_{RD}	0.243**	0.143	0.122
Closeness (C_{RP})		-5.825**	-5.414**
C^2_{RP}		0.891**	0.785**
Betweenness (C_{RB})			0.855*
C^2_{RB}			0.06
R^2	0.54	0.546	0.547

** means the difference is significant at the 0.05 level.

* means the difference is significant at the 0.1 level.

Table.2. The correlation coefficients for global network characterize and performance

Variable	Performance		
	M4	***M5***	***M6***
Density (N_D)	223.101**	171.148**	179.676**
N^2_D	-11.483**	-1.454**	-3.535**
Average distance(N_J)		221.772**	197.440**
N^2_J		-38.027**	-27.818**
Centralization of betweenness (N_B)			9.923*
N^2_B			-23.606**
R^2	0.516	0.695	0.707

** means the difference is significant at the 0.05 level.

* means the difference is significant at the 0.1 level.

On the basis of model 2, the variable betweenness was added into the model, which composed model 3. It could be found that the degree centrality and betweenness still maintain the same relationship with performance. In addition, the regression coefficient between betweenness and performance is 0.855, and the square value of it is still positive. Besides, the P value is less than 0.1 and R^2 has risen. This means there is a significant positive correlation between the betweenness and the performance.

5.2 Macro Analysis

Macro analysis is aimed at the relationship between the characteristics of global network and the performance of the whole technology transfer market and Table 2 shows the regression coefficients of them.

From model 4 to model 5, the value of R2 increased from 0.516 to 0.707, it indicates the explanatory of the model is gradually increased. From model 4, it could be fund that the regression coefficient of the global network density is 223.101 and the square value of it is - 11.483. Besides, the P value is less than 0.05. This means there is a significant inverted "U" correlation between the global network density and the global network technology transformation performance. That is to say, there is a critical point of the global network density. Before the critical point, the greater of global network density, the greater the impact of the network on each agent, which is conducive to connect of each other. However, if the density is too high, it could have information redundancy which restricts technology transfer in the market. On the basis of model 4, average distance was added into the model, which composed of model 5. It can be found that the regression coefficient of average distance and performance is 221.772, and the regression coefficient of its square value is -38.027. Besides, both have a P value less than 0.05. It means the regression relationship between average distance and performance is an inverted "U" type. Average distance reflects the cohesion of the global network. If average distance is large, it will increase the cost of transferring resources and information. If average distance is small, it will increase the possibility of information homogeneity, which limits the transformation performance of the whole market. On the basis of model 5, centralization of betweenness was added into the model, which composed of model 6. It could be found that the degree centrality and betweenness still maintain the same relationship with performance. The regression coefficient between betweenness centralization and performance is 9.923, and regression coefficient of its square value is -23.606, and both has a significant P value. This indicates that there is a significant inverse "U" regression relationship between centralization of betweenness and transformation performance. Because the betweenness used to express the tendency of centralization to a certain point in a global network. A high value of betweenness centralization means that a few strong agents control the global network, which probably drives the development of the whole market. However, the excessive betweenness centralization indicates that the market is too monopolistic. Few agents occupy the development opportunities of other individuals, which makes the number of individuals in the whole market decrease.

6. Conclusion

In order to explore the relationship between social capital and technology transformation performance, this study establishes research hypothesis through literature research, simulates the cooperation of technology transformation through Netlogo, and finally analyses the relationship between social capital and transformation performance from macro and micro perspectives. Through the micro-level analysis of social capital, it is found that individual technology transformation performance has a positive relationship with degree centrality and betweenness, which means H1 and H2 are valid. The individual performance and closeness have a U type relationship, which means H3 is not valid. Because when the point has a high value of closeness means more likely far away from the network center and inconvenient to contact with other points or exchange information. However, if the value of closeness is too small, which means it has tight links with other points. And there will be redundancy of information and is not conducive to the technology transformation. Through the macro-level analysis of social capital, it is found that global network's density, average distance and betweenness centralization all have an inverted "U" type correlation with technology transformation performance. This indicates H3, H4 and H5 are all valid.

Based on these, suggestions are proposed. First, building more relationships with other transforming agents are conducive to the technology transformation. As degree centrality is positive with technology transformation performance, an extensive social relationship could improve the capability of transformation. Second, occupy or close to the "bridge" position. As individuals located in the "bridge" position in the network are more convenient to gather more valuable information and resources, approaching to the "bridge" is beneficial to obtain resources. Third, do not forget to jump out of the intimate circle to obtain heterogeneous information. As closeness should not be an extreme value, agents should also contact with other agents which outside the intimate circle. Forth, from the macro-level of social capital, the market for the technology transformation should be maintained at an appropriate level, and agents should not be too dense or isolated, and avoiding a few agents have too much resources to control the technology transformation market.

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