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Inventor cooperation network effects on technology diversification：

the moderating role of intellectual property protection

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Abstract

Technological diversification can overcome the limitations imposed by an enterprise's single technological capability and enables enterprises to recombine resources, thereby enhancing their competitive advantage. In-house inventor cooperation can improve the

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efficiency of the production factor combination and expand the scope of the enterprise's technology base. This study empirically explores the effect of in-house inventor cooperation network on technology diversification. In addition, this study further investigates the moderating effect of intellectual property protection on the inventor cooperation network and on corporate technology diversification. An enterprise inventor cooperation network is embodied by its network location characteristics. Empirical results show that the difference in the location of the inventor cooperative network exhibits different effects on the diversification of enterprise technology. Moreover, intellectual property protection significantly weakens the incentive effect of the intermediary location of inventor cooperative network on corporate technology diversification.
Keywords: Inventor Cooperation Network, Corporate Technology Diversification, Network Location, Intellectual Property Protection

1. Introduction

Corporate technology diversification refers to the process of continuously expanding the scope of a company's technology foundation and forming new technological capabilities on the basis of maintaining and upgrading relevant core technologies (Cantwell and Vertova, 2004). Corporate technology diversification can improve corporate performance(Gemba and Kodama, 2001), promote corporate technological innovation (Gambardella and Torrisi, 1998), and enhance the competitive advantage of enterprises (Suzuki and Kodama, 2004). In a dynamic and volatile market competition environment, technology diversification requires enterprises to overcome the limitations of single technical capabilities and broaden the scope of their internal technology. Furthermore, this concept helps enterprises create and maintain competitive advantage.

In general, companies can obtain the necessary technical capabilities from the market. To keep up with the current technological frontier, firms in developing countries have been striving to promote technological advancement through exerting internal research and development efforts (in-house R&D) and external technology purchasing. Hou and Mohnen (2013)pointed that several signs of complementarity are evident between the two sources. However, this complementarity is merely viable to companies with 100– 300 employees. Surprisingly, firms that do both do not necessarily achieve the highest productivity performance. However, studies have shown that knowledge on new technologies is mainly produced through internal research (Granstrand et al., 1997). That is, the internal characteristics of an enterprise affect its corporate technology diversification. For example, changes in one component of a product frequently require the adoption of other components or redesign of the system architecture (Henderson and Clark, 1990). Companies' accumulation of technical knowledge is the main path through which most companies diversify their technology (Torrisi et al., 2004), but it also poses challenges for companies. In the process of technological diversification, enterprises should focus on the challenge of how to effectively coordinate the relationships among various departments and promote synergy between the internal and external technologies of different products (Brown and Eisenhardt, 1997).

Therefore, when companies diversify their technology base, they must allocate resources and share the required resources to maintain the diversity of their technology portfolios (Garcia-Vega, 2006b). As one of the most important means through which enterprises improve the efficiency of internal production factor combination (Nahapiet and Ghoshal, 1997), inventor cooperation should be given further attention. The interweaving of many inventor cooperative relations forms the inventor cooperative network. Numerous studies that focus on the measurement of cooperative patents (Chen et al., 2011), the evolution of inventor cooperative networks (Takagi et al., 2009), and inventor collaboration network and innovation performance (Graf et al., 2011) have discussed the importance of inventor cooperation networks. Overall, current research on inventor collaboration networks mainly focuses on team structure, team characteristics, and leadership styles, among other factors (Earley and Mosakowski, 2000). However, few studies have addressed the impact of corporate in-house inventor cooperation networks on corporate technology diversification.

On this basis, this study further explores the boundary conditions of the inventor cooperative network that relates to the diversification of technology. We examine the moderating effects of intellectual property protection on the inventor's network and on technology diversification. This procedure is conducted because intellectual property is a tool for optimizing resource allocation (Arrow et al., 1962) that affects the process of acquiring resources (Sun et al., 2016). The relationship between intellectual property and innovation has been discussed for many years(Allred and Park, 2007; Saxena and Sharma, 2012) because the impact of intellectual property on innovation activities is complex(Long and Wang, 2018). The idea is now supported by more researchers that optimal intellectual property protection is stage-dependent (Chu et al., 2014). As to different types of countries, studies have shown that the impact of intellectual property protection varies greatly. For example, although IPRs policy limits domestic innovation in developing countries, it encourages domestic innovation in developed countries(Kim et al., 2012, Sweet and Maggio, 2015). Furthermore, others suggest that IPR contributes to domestic innovation for developed countries while the results are not as compelling for developing countries (Panda and Sharma, 2019).

. The levels of intellectual property protection are discrepant in different parts of China (Hasan et al., 2009). Does this difference affect the relationship between inventor cooperative network and diversification of corporate technology? For companies in different regions of China, do stringent intellectual property protection policies affect the relationship between corporate inventor cooperation networks and technological diversification?

This study empirically explores the impact of in-house inventor cooperation network on technology diversification for 87 listed large-scale manufacturing companies using corporate patents and financial data from 2011 to 2015. The results have enriched the research on technology diversification. Most previous literature has discussed the influence of technology diversification, but this paper empirically tests the factors affecting technology diversification. As a moderating variable, the increase of intellectual property protection verifies that the strengthening of intellectual property protection may promote the internal technology flow and thus affect the diversification of enterprise technology.

2. Literature review

2.1 Technology Diversification

The concept of technological diversification began with Nelson's (1959) analysis on the relationship between basic research and diversification strategies. Kodama (1986) introduced and defined the concept of technology diversification as the R&D activities of enterprises in related products other than leading products. Subsequently, scholars defined technological diversification from different perspectives. For example, Breschi et al. (2003)defined technology diversification across various multiple technical fields using technology patents applied by companies. In general, most scholars agree that the essence of enterprise technology diversification is based on maintaining and upgrading the company's core technology, expanding its stock of technical knowledge to new technology fields, and finally developing new technological capabilities (Cantwell and Vertova, 2004).

Different scholars study technology diversification from different perspectives. Barney (1986) took a resource-based view and proved that technological diversification can create scarce technical resources that contribute to the establishment of advantages. Brusoni et al. (2001) followed a knowledge-based perspective and explained that enterprises can gain a unique competitive advantage by constructing knowledge systems in multiple fields. This accomplishment is conducive to the accumulation of knowledge and the creation of new products through cross-integration of multiple fields and products. However, the existing research is primarily concerned with the results and effects of technological diversification (Garcia-Vega, 2006b, Chiu et al., 2008). Moreover, few studies have been conducted on the implementation mechanism of technology diversification and the factors that affect it. Granstrand et al. (1997) studied the effects of internal factors on corporate technology diversification but failed to focus on inventor cooperation network.

2.2 Inventor Cooperation Network

Numerous studies that focus on the measurement of cooperative patents (Swarna et al., 2009), the evolution of inventor cooperative networks (Fleming and Frenken, 2007, Brenner et al., 2013), and Inventor Collaboration Network and Innovation Performance (Graf et al., 2011) have demonstrated the importance of inventor cooperation networks. Overall, current research on inventor collaboration networks focuses on team structure, team characteristics, leadership styles, and other factors (Earley and Mosakowski, 2000). However, few studies have addressed the effect of corporate in-house inventor cooperation networks on corporate technology diversification. Therefore, this study focuses on the mechanism of how corporate inventor cooperation network affects corporate technology diversification.

The structure of social networks mainly includes relationship dimensions and structural dimensions (Granovetter, 1977). In addition, research results on the relationship dimensions in social networks show significant differences. For example, several scholars believe that strong relationships can deepen trust between actors in the network and promote the transmission of tacit knowledge (Rowley et al., 2000). However, strong relationships may also yield problems such as excessive cost and information redundancy (Uzzi, 1996). By contrast, Granovetter (1973) argued that weak relationships are conducive to the transmission of new knowledge, and weak relationships are less expensive to maintain than strong ones. Therefore, this study further explores the effect of network characteristics on corporate technology diversification from the structural dimension. The corporate inventor cooperation network is embodied by network location characteristics. Such characteristics can be divided into two types, namely, central and intermediary. These types are commonly measured using centrality and structural holes, respectively (Junker and Schreiber, 2011). Centrality measures the degree of individual power in the network, while structural holes measure the connections between nodes in the network. These measurements are used because centrality and structural holes can fully reflect the positions of enterprises in social networks and their relationship to other enterprises (Xihong et al., 2010). This study focuses on the degree of centralization of the overall network based on the centrality for measuring the power distribution of the inventor's overall cooperative network (Kim and Shin, 2002). The mediator location of the inventor's cooperative network is measured using structural holes (Burt, 2003).

2.3 Social capital theory

Social capital theory posits that social networks are valuable, and social capital can generate information and control benefits (McFadyen and Cannella Jr, 2004). Social capital is conducive to helping enterprises achieve their business objectives. Furthermore, various social factors in modern markets have major or decisive effects on economic action (Granovetter, 1985). Human capital is one of the most important types of resources for enterprises (Barney, 1991). In in-house inventor cooperation network, the cooperation of R&D personnel leads to the exchange of key resources such as knowledge, skills, and information. Furthermore, the specific network location occupied by a specific enterprise reflects the company's ability to control resources, such as talent, information, and knowledge. Specific network location also shows the company’s network status and network rights (Wasserman and Faust, 1994). In-house inventor cooperation network can promote the exchange of information, knowledge, and other resources among individuals; improve the combination efficiency of production factors and enable enterprises to control additional heterogeneous resources. The heterogeneous resources of enterprises can exhibit an important effect on the expansion of their technological bases and lead to sustainable competitive advantages of enterprises (Nelson, 1991). Therefore, drawing upon social capital theory, this study explores how in-house inventor cooperation network affects enterprises, enables them to obtain heterogeneous resources, and realizes enterprise technology diversification.

3. Theoretical analysis and research hypothesis

3.1 Inventor cooperation network and corporate technology diversification

Corporate technology diversification is a product of internal production factors and resource combinations. The internal characteristics of an enterprise have an important effect on its technology diversification, particularly when the supply chain is complex (such as in electronic communication equipment manufacturing or the automotive industry) and the ability to accumulate technology related to fields outside a company’s unique capabilities is particularly important (Torrisi et al., 2004). Relevant research on social capital theory shows that social capital associated with relationships within a network is necessary for the development of an enterprise. Trust between employees can improve the quality of relationships within the participating enterprises and influence the cooperation structure (McFadyen and Cannella Jr, 2004). Internal social capital refers to the existence of trust and behavioral norms shared by employees and departments within the enterprise. In addition, internal social capital can enhance the combination efficiency of production factors (Leenders and Gabbay, 2013).

3.1.1 Central location of inventor cooperation network and corporate technology diversification

Social network is embodied by network location characteristics. Network location is divided into central location and intermediary location. Central location analysis is a quantitative analysis of power that measures the individual power in the network and thus the relative importance of each node (Junker and Schreiber, 2011). In corporate inventor cooperation network, the influence of the inventors on technology diversity differs given the different network locations of the inventors (Ibarra, 1993). In general, the superiority and authority of the network's central location enable the actors in such position to dominate a significant amount of information and numerous resources (Koka and Prescott, 2008). The current article focuses on the location of the overall network. Within the in-house inventor cooperation network, the central location describes “who” is the most important inventors by measuring its superiority, privilege, and attributes that represent the possibility of acquiring and controlling resources (Junker and Schreiber, 2011). The existence of a prominent central location means that the power in the network is mainly concentrated on few inventors. The opposite condition would be a uniform distribution of power throughout the network (Freeman, 1978). Cooperation and communication among inventors within the enterprise exhibit a significant effect on team outputs. The inventor’s autonomy of innovation and passion for work considerably depend on his or her position and status in the network. Most members of the network lack interaction with prominent inventors in the central location, and the exchange of relationships is concentrated on extremely limited members. The inventors in the marginal positions are bound to display low morale, thereby affecting their commitment to the organization, particularly in R&D activities that require high synergy. Therefore, this study proposes Hypothesis 1.

Hypothesis 1: The central location of in-house inventor cooperation network exhibits a significant negative effect on the degree of corporate technology diversification.

3.1.2 Intermediary location of inventor cooperation network and corporate technology diversification

If a network is divided into different components, each part can merely be contacted by one or several specific individuals, which forms an intermediary location (Burt, 2003). The intermediary location is equivalent to a bridge that can facilitate communication between two separate groups. Individuals at the intermediary location in the network occupy a position where they can grasp the flow of information and business opportunities and can obtain intermediary benefits including information and control gains (Cook and Emerson, 1978).

Numerous intermediary locations in in-house inventor cooperation network indicate high information heterogeneity among inventors within the enterprise. Hoskisson et al. (1993) argued that the exchange of knowledge and information between actors in the network is conducive to the diversification of corporate technology. Inventors in intermediary positions can effectively integrate nonredundant information and knowledge acquired from different inventors by “information benefits” and “control interests” brought by their intermediary locations. Technological diversification arises from the creative combination of different resources. Therefore, this study proposes Hypothesis 2:

Hypothesis 2: An intermediary location of in-house inventor cooperation network exhibits a significant positive effect on the degree of corporate technology diversification.

3.2 Moderating effect of intellectual property protection

Intellectual property optimizes resource allocation (Arrow et al., 1962) that affects the process of acquiring external resources (Sun et al., 2016). In order to utilize monopoly position to earn more rewards, inventors pay more attention to the incentive effect of intellectual property protection(Penin, 2005). However, most inventors are employed by some organization, and the majority of the bonus generated by the invention does not allocated to the inventor, which may result in their unwillingness to pay more efforts. So enterprises began to stimulate inventors by increasing inventors' salary and incentives.

However, the number of proposed projects implemented is constrained by limited resources(Foss, 2003), and companies worry that too many incentives will generate redundant ideas that cannot be funded (Baumann and Stieglitz, 2014). Enterprises have to adopt different incentives according to patent quality and competitiveness(Giarratana et al., 2018). Therefore, inventors in enterprises, especially those with core technologies, are reluctant to share information for the reasons, like lack of willingness to share in pursuit of rewards (Lin et al., 2008), fear of losing ownership of knowledge or technology(Shaw and Edwards, 2005),etc. All these factors will affect the flow of knowledge and technology within enterprises.

Considerable controversy concerning the optimal intellectual property strengths arises in different countries and regions (Branstetter et al., 2011). Lerner (2002) noted that efforts to streamline and optimize legal procedures have unleashed additional litigation, which is not conducive to a virtuous cycle of technological innovation but harmful to social welfare. When faced with strict legal and regulatory constraints, companies in areas with high levels of intellectual property protection will exhibit limited ability to innovate by imitating the best companies in their vicinity (Glass and Saggi, 2002). This situation is not conducive to the expansion of the company's technology base. Although the legal and regulatory framework in China is consistent, differences are evident in the implementation of laws and policies in various places (Sun et al., 2016).Therefore, this study proposes the following hypotheses:

Hypothesis 3a: The strong level of intellectual property protection weakens the effect of the inventor cooperation network’s central location on corporate technology diversification.

Hypothesis 3b: The strong level of intellectual property protection weakens the effect of the inventor cooperation network’ intermediary location on corporate technology diversification.

4. Research design

4.1 Samples and data

This paper used samples from manufacturing enterprises listed on the Shanghai and Shenzhen stock exchanges. To ensure the validity and reliability of conclusions, this study limits the study period from 2011 to 2015 given the completeness and availability of the data. Furthermore, we merely selected A-share listed companies as samples to avoid complications due to the differences among different types of stocks. A-shares are the predominant type of shares issued by publicly traded Chinese companies listed in China, denominated in RMB, and sold solely to domestic investors (Wang et al., 2004). We also eliminated *ST* and **ST* ("*ST*" represents special treatment stocks that have had two consecutive years of losses; "**ST*" represents stocks with three consecutive years of losses and faced with risks of being unlisted) shares given several deviations that were observed(Song et al., 2015). The independent and dependent variables of this paper study are based on patents, which is an approach consistent with previous scholars' research methods (Cantwell and Vertova, 2004). Therefore, this study empirically explores the effect of in-house inventor cooperation network on technology diversification by using corporate patents and financial panel data from 2011 to 2015 for 87 listed large-scale manufacturing companies.

We selected the cooperation among patent inventors for patent application to express the cooperative relationship among them. The patent inventor cooperative network was generated by UCINET.6. (see Appendix, Section 1,2).

4.2 Variable definition

4.2.1 Corporate technology diversification

This paper follows the methods described by Garcia-Vega (2006b) to measure enterprise technology diversification (*TD*). Patent data were extracted from the China National Intellectual Property Administration database (see www.sipo.gov.cn/zljs/) using a search algorithm based on a selection of IPC classes from OECD, which targets specific areas of environment-related technology (see http://www.oecd.org/environment/consumption-innovation).

Subsequently, this paper uses the Herfindahl index to measure the degree of diversity of technology (Hidalgo and Hausmann, 2009).

$$\mathrm{TD} = \frac{1}{\sum_{i=1}^{n} P_i^{2}} \tag{1}$$

In (1), P_i represents the ratio of the number of patents owned by a certain enterprise in the technical field i to the total number of patents. A close TD value to 1 indicates that the company's numerous patents are dispersed across a wide range of technical fields. This representation means that the level of technological diversification of enterprises is relatively high. By contrast, a close TD value to 0 indicates that the enterprises' patent distribution is concentrated and their level of technological diversification is low.

4.2.2 Inventor cooperation network

The central location of the inventor's collaborative network is measured as centrality (Junker and Schreiber, 2011). Given that this paper regards in-house inventor cooperation network as an overall network by focusing on the overall power distribution of the network, it uses overall network degree centralization (*NDC*) indicators for measurement. The centralization index is a measurement of the overall power of the network. A high degree of centralization means that the power in the network is mainly concentrated on a few inventors, and the opposite means an even distribution of power throughout the network. The formula used in the calculation is as follows (Wasserman and Faust, 1994):

$$\mathrm{NDC} = C_{RD} = \frac{C_{AD}}{n-1} = \frac{\sum_{i=1}^{n}(C_{RD_{\max}} - C_{RD_i})}{n-2} \tag{2}$$

$$C_{AD} = \frac{\sum_{i=1}^{n}(C_{AD_{\max}} - C_{AD_i})}{\max[\sum_{i=1}^{n}(C_{AD_{\max}} - C_{AD_i})]} = \frac{\sum_{i=1}^{n}(C_{AD_{\max}} - C_{AD_i})}{n^2 - 3n + 2} \tag{3}$$

where n is the number of nodes (the number of cooperation events among the inventors), CAD_i represents the absolute degree of i, CAD_{max} represents the maximum value of the absolute degree in the network, CRD_i represents the relative degree of i, and CRD_{max} represents the maximum value of the relative degree of centrality in the network.

The inventor cooperative network mediation location is measured using the structural hole indicator, because structural holes are an indicator of the location of network intermediaries (Burt, 2003). Numerous methods for measuring the Structure Hole Degree (*SH*), including effective scale, efficiency, constraint coefficient, and grade are available (Burt, 1992). In this paper, the widely used "constraint index" measures the richness of the structural hole. High constraint degree yields few structural holes in the network. The quantitative relationship between the degree of constraint and the structural hole is as follows: assuming that the maximum degree of constraint is 1, then the difference between 1 and the constraint is often used to measure the richness of the structural hole (Bell and Zaheer, 2007). The formulas used in the calculation of structural holes in this paper are shown in equations (4), (5), and (6).

$$SH = 1 - C_i \quad (4)$$

$$C_i = \sum_{j=1}^{n} C_{ij}, i \neq j \quad (5)$$

$$C_{ij} = (p_{ij} + \sum_q p_{iq} p_{qj})^2 \quad (6)$$

In these equations, i, j, and q represent three different inventors. If two inventors i and j are connected with q, then q acts as a bridge between i and j. P_{ij}, P_{iq}, and P_{qj} represent the proportion of direct contact in all indirect connections between i and j, i and q, and q and i, respectively. C_{ij} represents the degree of dependence of i on j, and C_i represents the degree of dependence of i on all other nodes.

4.2.3 Intellectual property protection

The GP index proposed by Park and Ginarte (1996) is the most widely used method to measure the intensity of intellectual property protection. In 2005, Park updated and revised the substitute variables of the GP index based on actual conditions (Park, 2005). However, the GP index remains an evaluation of whether a country has sound intellectual property protection laws without the consideration of the actual effects of implementing the laws. Sun et al. (2016) mentioned that although the legal and regulatory framework in China is uniform, differences in the interpretation and enforcement of local laws and policies are evident. Therefore, this study introduces the intellectual property enforcement intensity index based on the GP index to comprehensively evaluate the Intellectual property protection level (see Appendix, Section 3).

4.2.4 Control variables

By drawing on recent literature on corporate technology diversification (Said et al., 2003), this study selects the natural logarithm of the total number of employees at the end of the year to control the impact of firm size (Ahuja, 2000). The company's length of establishment indicates the number of technology and resources it accumulates. In addition, this paper uses age of establishment (*AGE*) as one control variable (Huergo and Jaumandreu, 2004). Many companies also use the debt of innovation to obtain the excess return of profits after innovation success. The form acquires innovation input; hence, the asset–liability ratio (DAR) also affects the technological innovation of the enterprise to a certain extent. Given that the sample companies in this study are from different manufacturing sectors and companies in various industries exhibit specific industry characteristics, this study sets five industry dummy variables to control industry differences. Table 1 presents the definitions used in this study.

5. Results and analysis

5.1. Descriptive statistics analysis

Table 3 presents the descriptive statistics for the characteristics of the major variables. Table 4 shows the Pearson correlation coefficients Tables 2 and 3 present the data, such as the mean, standard deviation, and correlation. These data are calculated based on nonstandardized variables. In the subsequent hypothesis test, normalized data are used as independent variables and mediation variables. Data normalization can reduce the problem of multicollinearity and increase the degree of interpretation of product terms (Aiken et al., 1991). Table 3 shows that the correlation coefficient between the degree centralization and the structural hole of the inventor cooperation network are below the critical value 0.6, as well as the independent and the adjustment variables. A value larger than this threshold indicates that multicollinearity is likely to exist.

We also computed the VIFs (Table 4) and found that most of the values are close to 1 and lower than the conservative threshold of 5 (Neter et al., 1996). Therefore, no serious multicollinearity exists.

5.2. Regression analysis

We conducted a hierarchical regression analysis to test the moderating effect. Table 5 reports the results. In terms of the control variables, the results reach a significant level ($F=2.93$, $p<0.05$). Model 1 only contains the baseline model of the control variables. Moreover, the result of the Hausman test shows that a fixed effect model is suitable. We subsequently added the independent variables to test the linear relationship between inventor cooperation network and corporate technology diversification. Model 2 adds two main effects of the inventor's collaborative network center location and mediation location. Model 3 adds a moderating variable. Model 4 provides the product term of the independent and mediator variables.

5.3 Hypothetical test

In Table 5, Model 2 provides strong support for Hypothesis 1 and Hypothesis 2. In Model 1, the influence of the central location of the inventor cooperative network on corporate technology diversification is negative and highly significant ($\beta=-0.374$, $P<0.001$). Therefore, Hypothesis 1 is established. The influence of the intermediary location of the inventor cooperative network on corporate technology diversification is positive and highly significant ($\beta=0.263$, $P < 0.001$), thereby indicating that Hypothesis 2 is accepted. The results of Model 4 reveal that the coefficient of the interaction term between central location and intellectual property protection intensity is positive but not significant. ($\beta=0.033$, $P>0.1$). Therefore, Hypothesis 3a is not supported. The coefficient of the interaction term between intermediary location and intellectual property protection intensity is positive and significant. (β=-0.145, P<0.001), thereby accepting Hypothesis 3b.

To explicitly express how the moderating effect of intellectual property protection works, this paper uses the mean values of the regulatory variables as a benchmark. Samples with values greater than or equal to the mean are classified as high, whereas samples with values smaller than the mean are classified as low. Thus, a regression adjustment effect map is created (see Figure 1). Figure 1 compares the relationship between the intermediary location of the cooperative network and corporate technology diversification at different intellectual property protection levels.

Previous literature has shown that entropy index method is another commonly used method to measure technical diversity(Garcia-Vega, 2006a, Hidalgo and Hausmann, 2009). To prove the validity of the study, we added the robustness test. We found that the results of the two methods were consistent (see Appendix, Section 4).

6. Discussion

Central location and corporate technology diversification: within the in-house inventor cooperation network, a prominent central location, indicates relative concentration of power on the hands of several people. Two negative effects are made on the diversification of enterprise technology. First, a small number of people control the resources and information, but their own innovation and mobility are limited. A substantial number of resources are collected around them, but these resources can merely be used in an extremely limited manner and consequently produce considerable waste. Second, the morale of the majority of members at the edge of power is low owing to the concentration of power, thereby reducing their organizational commitment and work enthusiasm. Substantial results that lack good communication and cooperation among internal members can hardly be achieved because technological diversification is a highly collaborative and complex process.

Intermediary location and corporate technology diversity: the substantial number of intermediary locations presented in an in-house inventor cooperation network indicate qualitative information possessed by actors in the intermediary location contributes to diversity. Furthermore, other inventors are willing to work with inventors at intermediary locations to further recognize and exploit new opportunities. An increase in intermediary location within the enterprise means the accruement of heterogeneous knowledge and information. The inventors occupying other locations actively cooperate with inventors who occupy the intermediary. This condition is also conducive to generating new technology and promoting the degree of corporate technology diversification.

Moderating effect of intellectual property protection: compared with areas with weak degree of intellectual property protection, the intermediary location of inventor's cooperative network in areas with strong degree has a weaker impact on corporate technology diversification, which shows that stringent intellectual property protection will result in resistance to the improvement of corporate technology diversification. Different regions should adopt intellectual property protection policies congruent to the realistic development level of enterprises. Results also show that enterprises in different regions should continually adjust their business strategies to reflect changes in the institutional environment. In addition, intellectual property protection lacks a moderating effect on central location and corporate technology diversification, which is caused byseveral factors in the distribution of individual rights in the inventors' cooperative network, such as corporate organizational culture, internal resource input, and technical learning. This analysis is consistent with the work of previous scholars (Osterloff, 2003).

7. Conclusions and implications

Several theoretical conclusions are drawn in this study. (1) First, this paper constructs an analytical framework on the relationship between in-house inventor cooperation networks and corporate technology diversification. Moreover, this study introduces the method of social network analysis into the process of technology diversification research. This paper also adopts the perspective of social capital theory and explores its relationship with technology diversification by focusing on several key factors that affect corporate technology diversification. Most existing research is concerned with the results of diversification of enterprise technology, and research on the factors that lead to such diversification is relatively sparse. These instances happen because the promotion of enterprise technology diversification strategy must be realized through enterprise employees, particularly inventors. Second, this study further examines the moderating effect of intellectual property protection on inventor cooperation networks and corporate technology diversification and clarifies the boundary conditions of the inventor cooperation network's effects on corporate technology diversification. Third, based on the actual protection of intellectual property rights in China, this study constructs an intellectual property protection intensity index. In previous studies, the intensity of patent protection is used to characterize the intensity of intellectual property protection (Park, 2005). Intellectual property mainly includes patents, trademarks, and copyrights (Cornish et al., 2003). Therefore, this paper adds the contents of trademark protection and copyright protection. Furthermore, previous studies have merely concentrated on the strength of intellectual property legislation. However, the effectiveness of law enforcement should be taken into consideration (Lesser, 2005).

Several management implications are also enumerated. First, companies must focus on the "democracy" within the organization. In particular, companies should attempt to achieve a relatively even distribution of power to break the monopoly of cooperative networks and to amplify the voice to internal enterprises inventors with innovation and execution capabilities. Second, all inventors in the enterprise should exert their enthusiasm and initiative for innovation, while each intermediary node is a source of innovation. Converging these different sources provides continuous locomotive for corporate technology diversification. Therefore, enterprises should pay attention to structuring a reasonable inventor cooperation network and increasing the number of network structural holes. Third, enterprises should focus on the institutional environment, including intellectual property protection, and adjust their business policies in a timely manner.

Several limitations are recognized in the current study. First, we employed a merely limited panel dataset covering 2011 to 2015 and included 87 sample firms in the manufacturing industry owing to our choice of data and samples. Future study should consider data screening. Furthermore, the range of sample companies should be enlarged to enhance the representativeness of results. Second, patent data are used to measure corporate technology diversification. Although patent data are easily accessible and show good continuity, they cannot fully reflect the deep motivation of technology diversification. Therefore, our follow-up study will employ a broader context than the present and adopt other index to reflect corporate technology diversification. Third, in view of the complex relationship between in-house inventor cooperation networks and technology diversification, the possible non-linear relationships among variables should be explored for the enhanced understanding of these variables.

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