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RESEARCH ON THE IMPACT OF TECHNOLOGICAL DIVERSIFICATION OF INNOVATION NETWORKS ON THE CONTINUOUS INNOVATION OF ENTERPRISES — A PERSPECTIVE BASED ON SOCIAL NETWORK THEORY

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Abstract

Under the new development pattern of the double cycle in the digital economy era and vigorously promoting China's manufacturing power, the key to enterprise development is to comprehensively utilize the new internal and external development dynamics to enhance technological capabilities and strengthen knowledge management. Therefore, it has become a trend for enterprises to form innovation consortiums. Diversified technologies in cooperative innovation networks have become a critical external resource for enterprise i.innervation. However, more research is needed on how technological diversification in innovation networks affects the sustained innovation of enterprises. Existing studies ignore the different combinations of factors in the external environment of enterprises that may have a different impact on the sustained innovation of enterprises. Based on integrating social network, resource-based, and dynamic capability theories, this study constructs a cooperative innovation network based on the data of joint patent applications of listed companies in the information technology industry. It analyzes the intrinsic mechanism and weighting factors of the technological diversification of innovation networks affecting enterprises' continuous innovation from the perspective of individual networks by adopting the panel data random-effects negative binomial regression method. The study results show that technological diversification in innovation networks positively affects firms' continuous innovation, and technical integration capability mediates between the two. The findings of this study will be of great significance in guiding the development of the theory and practice of sustained innovation in enterprises.

Keywords: Technological Diversification of Innovation Networks; Technology Integration Capabilities; Continuous Innovation.

1. INTRODUCTION

In a highly dynamic and uncertain market competitive environment, it has become a consensus among scholars of technology economics and innovation management that continuous innovation is of great value to enterprises in building dynamic competitive advantages (Xiang Gang, 2005). According to the Communist Party of China on the Formulation of the Fourteenth Five-Year Plan （2020）， the dependence of enterprise innovation on external resources continues to strengthen, and collaborative innovation has become an essential way for enterprises to acquire diversified technological knowledge and improve their technological innovation performance. As an essential platform of the innovation network, the patent

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cooperation network has become a powerful means for enterprises to break through the limitation of innovation resources, and the diversified technologies of patent partners provide rich external resources for enterprise innovation (Li-Ying Wang & Di Zhang, 2019). Most studies on technological diversification focus on the internal enterprise (Chen Peizhen et al., 2018; Kim et al., 2016), and fewer studies focus on the technological diversification of the enterprise cooperative innovation network at the social network level.

In recent years, many scholars have emphasized the antecedents of continuous innovation from the perspective of technological diversity in innovation networks (Corradini et al., 2016). It has been found that constant innovation in firms is essentially a knowledge-creation activity using exploration, learning, development, and utilization, with the core of creating, absorbing, integrating, and utilizing diverse technologies, and that firms need to cope with both "creative destruction" (exploratory innovation) and "creative accumulation" (latent innovation) at the same time (Quarterly et al., 2016). Firms need to deal with both "creative destruction" (exploratory innovation) and "creative accumulation" (latent innovation) (Quintana-Garcia & Benavides-Velasco, 2008). The relationship between the technological diversification of innovation networks and continuous innovation is controversial.

Some studies suggest that technological diversification of innovation networks enables firms to engage in "cross-innovation" between different technologies, which can lead to more effective creation of new knowledge and help to break "core rigidities" and "capabilities" (Quintana-Garcia & Benavides-Velasco, 2008). Some studies argue that technological diversification of innovation networks enables firms to engage in "cross-innovation" among different technologies, thus creating new knowledge more efficiently, helping to break the "core rigidity" and "capability trap," and facilitating continuous innovation (Yayavaram S & Chen W R, 2015； Lin M et al., 2015); others point out that technological diversification of innovation networks enables firms to obtain economies of scope of technology while losing the advantage of economies of scale, and that the exploration of emerging technologies leads to a conflict with the core technology.

Exploiting emerging technologies leads to disputes with core technologies and additional coordination costs (including organizational and management expenses of coordinating different technologies, searching for new technologies, etc.), thus inhibiting continuous innovation (Leten et al., 2007). Therefore, it is of great practical significance to clarify the relationship between the level of technological diversification of innovation networks and the continuous innovation of enterprises, as well as the internal mechanism of the role of the innovation network to form enterprise innovation consortiums and strengthen the status of the main body of enterprise innovation.

According to existing studies, fewer researchers have included internal and external resource factors, namely, the firm's technological integration capability and the technological diversification of the innovation network, in the research framework. However, both the increase of technical fields and the evolution of knowledge diversification are dynamic processes of knowledge growth that must be effectively absorbed and utilized to become a source of competitiveness (Yang Y et al., 2021).

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For this reason, this paper introduces the concept of technological integration capability to deeply analyze the role of technological diversification in innovation networks on the path of sustained innovation of enterprises. This study integrates social network theory, resource base theory, and dynamic capability theory, incorporates technological diversification of innovation network, sustained innovation of enterprises, and technical integration capability of enterprises into the research framework, and constructs a cooperative innovation network of listed companies in China's information technology industry from 2012 to 2021 by utilizing the data of joint patent applications between enterprises, examining the weighting factors of technological diversification of innovation network that affect sustained innovation of enterprises and their intrinsic mechanisms, and exploring the role of technical integration capability of enterprises in the process of sustained innovation. The study examines the weighting factors of technological diversification in innovation networks affecting sustained innovation of enterprises and its internal mechanism. It explores the mediated moderating path of enterprises' technical integration capability involving the relationship between technological diversification in innovation networks and innovation performance.

2. LITERATURE REVIEW

When facing a competitive environment and avoiding vulnerability to potential competitors, firms need high-quality products based on diversified technologies, i.e., firms need to extend their innovation activities to multiple technologies (Breschi et al., 2003). Thus, the technological resources available to firms play a vital role in the innovation process, and innovation occurs through the reorganization of existing diverse specialized knowledge (Zeng D et al., 2020).

2.1 Technological Diversity in Innovation Networks and Firms' Continuous Innovation

Technological diversification of innovation networks refers to the variability of the technical domains involved and their familiarity with different firms in the innovation network (Sampson, 2007). Technological diversification is dominant in developing technology-based firms from an economic perspective of scope, space, and speed. When there are differences in the configuration of firms, firms with broad technological domains versus knowledge-intensive firms are more likely to innovate further and are more likely to innovate continuously (Wang Yu et al., 2011). Technological diversification can stimulate firms to generate innovative ideas by combining and reorganizing various technologies (Xu Lei, 2019).

There is also some variation in the findings of existing studies regarding the impact of technological diversification on firms' innovation persistence. He Yubing (2017) and other scholars' study takes the formation and evolution of the technological diversification strategy of Canon Inc. in Japan as a perspective, analyzes the way technological diversification's influence on enterprise innovation continuity, and the existence of the influence mechanism between the two. The results show that different types of technological diversification have other impacts on enterprise-sustained innovation, mainly reflected in the fact that related and irrelevant technological diversification promotes enterprise innovation continuity. In contrast, engaging in both exploratory and exploitative diversification will hurt firms' sustained

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innovation. In Huang and Chen's (2010) study, organizational slack was used to verify the dynamics of technological diversification on firms' innovation, and the results of the study tended to be a non-linear relationship between technological diversification and sustained innovation.

In addition, several studies of technologically diversified firms have found that technology-based firms are often more reliant on their own diversified internal experience and knowledge and refuse to seek out different technologies from external organizations (Guo Runping et al., 2022), which may put firms at risk of falling into a capability trap, as well as the existence of false perceptions of and disregard for external technologies (Lichtenthaler & Ernst, 2010), causing a decline in the willingness of firms that already have a diverse base of technological resources to access external resources (Liu Yan et al., 2022). In addition, due to the complexity and uncertainty of innovation activities, firms' innovation activities usually require the support of a range of resources, technologies, and knowledge from external sources to be accomplished, i.e., inter-organizational knowledge synergy. To achieve sustained innovation, members from different fields of science and technology must work together and develop synergies to challenge the existing product and service delivery system with new approaches. Inter-organizational collaborative innovation networks, strategic alliances, joint ventures, and even collaborations with customers and suppliers can positively impact a firm's ability to innovate (Cao Chang et al., 2020). Of course, these innovation network technological diversification behaviors need to be based on the voluntary basis of enterprises so that the innovation network specialized diversification activities can be carried out steadily and persistently, and the subsequent new products and technologies can be shared and co-developed.

This study focuses on exploring the relationship between technological diversification in innovation networks and firms' innovation persistence, whereby a wide range of technical knowledge enables firms to realize "increasing returns to scale" from knowledge cross-spillovers, which reduces the negative impacts on innovation persistence due to market competition, technological change, imitation, and so on. Therefore, the hypothesis of this study is formulated:

H1: There is a positive effect of technological diversification of innovation networks on firms' continuous innovation, i.e. the more diverse and broader the technological diversification of innovation networks, the better the firms' continuous innovation.

2.2 Innovative Web Technology Diversification and Technology Integration Capabilities

Technology integration is a kind of innovation method in the process of new technology and new product development, in which the enterprise takes the technology and resources it possesses in reality as the basis and utilizes the system integration method to integrate the new and old technologies organically across disciplines and industries, and to develop new technologies and new products. The key lies in the organic fusion of the technologies and the system integration (Zhang et al., 2004). In addition to technological diversification of innovation networks in core domains to acquire core competencies, technical integration between different domains often creates heterogeneous and valuable specialized knowledge

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(Cantwell et al., 2004), and technological diversification of innovation networks can improve technological integration capabilities by expanding technologies in non-core domains to realize cross-innovation across technical boundaries (Yu, Maozhian, & Sun, Yuanxin 2020).

Furthermore, Xiang Gang and Wang Yingluo (2004) researched the driving mechanism of continuous innovation of enterprises and analyzed the mechanism of team spirit, interest drive, the culture of constant innovation, and entrepreneurial innovation consciousness on the continuous innovation of enterprises. Duan Yunlong et al. (2007) constructed a model of enterprises' constant green innovation power based on previous research. Theoretically, they analyzed the role mechanism of the ecological environment, institutional environment, market demand, and political system on enterprises' continuous innovation power, but empirical evidence has not tested these models. Chen Xiaoli (2010) used the gray system correlation method to evaluate the innovation motivation of enterprises from the perspectives of entrepreneurs' innovation spirit and consciousness, the internal incentive mechanism of enterprises, and innovation culture and the study's results. However, they provide some explanations for the sustained innovation motivation, but the perspective of the study is still relatively narrow. Tu Niansong et al. (2018) used the attribute measurement method to evaluate enterprises' green sustained innovation power and verified it with cases. The results found that the innovation incentive mechanism and the innovation incentive culture are important to enterprises' sustained innovation. As a result, this paper proposes hypothesis 2:

H2: There is a positive effect between the technological diversification of innovation networks and technology integration capability, i.e., the broader and more profound the technological diversification of innovation networks, the stronger the firm's technology integration capability.

2.3 Technology Integration Capability and Continuous Enterprise Innovation

Technology integration capability refers to the behavior of core firms in reorganizing the knowledge of external module suppliers, which is identified and acquired with their original technology to form technology integration innovation (Breschi, 2003). Although technological resources are critical assets for product development in high-technology firms (Jansen et al, 2005), they cannot be used directly to solve the actual problems of the firm but need to be identified, evaluated, combined, and applied by the firm to create value for the firm, and successful technological development relies on the integration between different technologies. Enterprise innovation is developing new technologies or combining and commercializing technologies to meet market needs. In the continuous enterprise innovation process, technology integration capability coordinates and integrates the external sub-module technology of partners and its diversified technology into an operational organic system. It has been shown that the product innovation performance of enterprises with more robust technology integration capability is higher; for example, Kiamehr (2013) proposed in the study of complex product systems in hydroelectric power plants that this ability of complex product enterprises to cross organizational boundaries to integrate the sub-module technologies of module suppliers to form the system as a whole is essential in the process of innovation of complex product systems because the complexity characteristics of complex products dictate that The complexity of complex products dictates that their innovation requires the influential association and

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reconfiguration of a large number of heterogeneous modular technologies to realize the expected functions ultimately.

Resource base theory points out that heterogeneous resources are the source of competitive advantage of enterprises, and technology integration ability can help core enterprises of innovation network integrate heterogeneous resources in a short time, give new functions and competitiveness to innovative products, and make diversified technological modules that were initially produced independently compatible and docked to form a functioning organic whole under unified interface rules and standards, thus accelerating the speed of product innovation innovation speed. （Su， J.et al., 2021）In addition, information technology enterprises can rely on solid technical integration capabilities to reorganize and utilize diversified technologies and eliminate the original fixed path of diversified technologies and inertia to achieve breakthrough innovation.（Gao H.et al., 2022）

When the technology integration capability is low, enterprises cannot better identify and utilize technological resources and thus cannot play a positive role in enterprise-sustained innovation. With the improvement of technology integration capability, enterprises can not only efficiently identify and acquire more valuable technological resources and expand the boundaries of innovation resources (Tang Yuan et al., 2020), which can promote the efficiency of enterprise innovation and the quality of innovation, and further enhance the motivation and sustainability of enterprise innovation. Therefore, the technology integration capability allows information technology enterprises to integrate innovative products more efficiently, promoting continuous innovation behavior. Thus, this paper proposes Hypothesis 3:

H3: There is a positive effect of technology integration capability and firmly sustained innovation; the more substantial the technology integration capability, the longer the firm's firm-supported innovation.

2.4 Mediation Studies of Technology Integration Capabilities

Technological diversification (Granstrand, 1998; Leten et al., 2007) of innovation networks characterized by broader technological domains is the result of firms expanding their knowledge base through internal and external knowledge activities such as internal research and development, external technological cooperation, or technological mergers and acquisitions. Absorptive capacity is an enterprise's ability to acquire and transform external heterogeneous knowledge in order to adapt to its own needs (J.S. Li, & X. Wang, 2022), which is vulnerable to the influence of its own a priori knowledge and falls into the "path dependence" dilemma (Schildt et al., 2012), whereas technological diversification of the innovation network has built up a rich technological knowledge base for enterprises, which contributes to the accumulation of absorptive capacity. On the one hand, a wide range of technological fields becomes the internal foundation of the enterprise's absorptive capacity (Cohen & Levinthal, 1990); on the other hand, the foundation of technological diversification helps to efficiently allocate its own technological resources and improve the efficiency of acquiring external technologies so as to overcome the limitations of "local search" (Schildt et al., 2012). The limitations of "local search" are overcome (Suseno & Ratten, 2007).

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The essence of technology integration capability is the ability of enterprises to acquire, digest, convert, and apply heterogeneous knowledge from the outside, and then the ability to recombine and optimize the allocation of different technology and knowledge resources to produce synergistic and complementary effects, i.e., firstly, it requires the ability of enterprises to acquire and transfer external knowledge, and latterly, it requires the ability of enterprises to reuse and develop the knowledge and further create new knowledge（Guo, Jingjing et al., 2021）. Technological diversification of innovation networks mainly expands technical knowledge in non-core technology fields. This kind of knowledge enriches the technological base capability of enterprises, which in turn affects their ability to acquire more external knowledge. Its primary realization method is external acquisition; therefore, technological diversification of the innovation network mainly involves the continuous innovation of enterprises through the absorption and integration capability of enterprises and expands the knowledge of enterprises in core technology fields; this kind of knowledge has a strong correlation, which contributes to the synergy and complementary effect of each other. The correlation between such knowledge is firm, which contributes to mutual cross-fertilization and interaction effects, and is also the core and foundation of technology integration; in addition, to increase its core competitiveness, most of the enterprise's internal technological knowledge is also related to the enterprise's core specialized fields, and to create new technical knowledge, the enterprise allocates technical resources through reuse development, thus searching for the combination between different knowledge bases of the enterprise's core specialized fields (Dibiaggio et al., 2014), Which is the essence of technical integration. Therefore, innovation network technological diversification influences firms' continuous innovation through technological integration capabilities. As a result, this paper proposes Hypothesis 4:

H4: Technological diversity in innovation networks affects firms' ability to sustain innovation by influencing their ability to integrate technology.

3. RESEARCH MODEL

Based on the above research review, this study shows that the dependence of enterprise innovation on external resources continues to strengthen, and cooperative innovation has become an essential way for enterprises to acquire diversified technological knowledge and reinforce their technical integration capacity has become a meaningful way to enhance innovation performance. This research elaborates on the positive hypothesis of the main effect of innovation network technology diversification and enterprise continuous innovation, as well as the positive mediating effect of technology integration capacity. Therefore, the research model is as follows:

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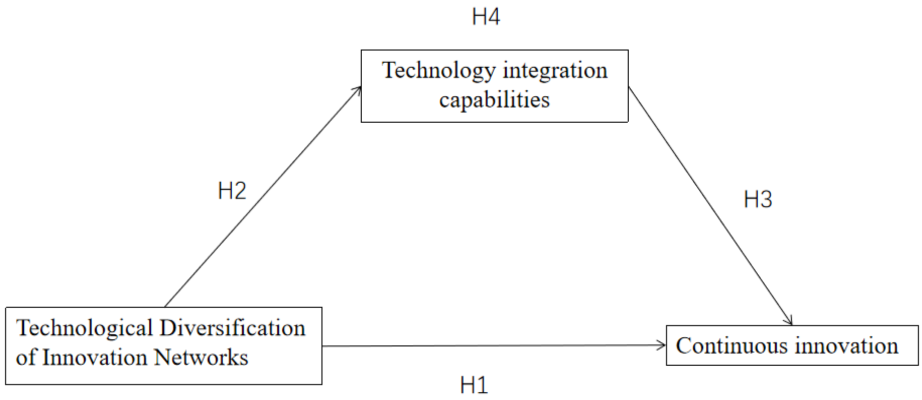

4. DATA SOURCES AND RESEARCH METHODOLOGY

4.1 Data Sources

This study takes listed companies in China's information technology industry as the object of analysis, whose financial data have been strictly audited and disclosed to the public and whose data availability and authenticity have been recognized by the industry. Following the practice of most of the previous literature (Yang Chunbaixue et al., 2020), we adopt the data of joint patent applications as the basis for constructing the cooperative innovation network of enterprises. To select the collaborative patent application data of listed companies in the information technology industry from 2011 to 2020, we obtained the list of all listed companies from 2011 to 2020 from the Cathay Pacific database. We queried and got the basic information such as the full name of the enterprise, the history of name change, the year of establishment, the number of employees, and other essential information and financial data. Verify the above enterprise information in the patent search website of the State Intellectual Property Office, i.e., joint application entries between enterprises, and get patent data totaling 6,594. In addition, taking three years as the time moving window, based on the individual network perspective, the overall network under each time window is regarded as composed of the particular network of each listed company, with the listed company as the core node, the other cooperating enterprises as the member nodes, and the number of joint patent applications as the linkage edge. Use UCINET6.0 software to derive the values of each network index. Finally, the sample data with serious missing information are excluded, and the unbalanced panel data containing 315 observations from 2011 to 2020, involving 82 listed companies and 677 related cooperative enterprises, are obtained and analyzed using stata econometrics software.

4.2 Variable Measurement Methods

4.2.1 Measurement of Continuous Innovation in Firms

Enterprise sustained innovation (OIP): that is, the knowledge accumulation, technological progress, and economic benefits obtained by enterprises based on long-term investment in innovation continuity, thus motivating enterprises to carry out sustained innovation activities, so this study uses the output latitude of the innovation continuity to indicate enterprise

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continuous innovation, drawing on the study of He Yubing et al. (2017), considering the lag in enterprise sustained innovation in the innovation network established in the current period, and equating enterprise continuous innovation in the innovation network with enterprise continuous innovation in the t year, and the chain growth rate of the sum of patent applications of enterprises in the $t+2$ and $t+1$years compared to the sum of patent applications in the $t+1$ and t years, and multiplying by the ring growth rate in the $t+2$ and $t+1$ years. The formula is as follows:

$$OIP_t = \frac{OIN_{t+2} + OIN_{t+1}}{OIN_{t+1} + OIN_t} * (OIN_{t+2} + OIN_{t+1})$$

where OIP_t denotes the firm's performance in the first t year of continuous innovation, the OIN_{t+2} 、 OIN_{t+1}、 OIN_t denote the firm's continuous innovation in the first $t+2$ 、 $t+1$ ，*and* t the number of patent applications in the year.

4.2.2 Measurement of Diversity in Innovative Web Technologies

Innovation network technological diversification (NTD): construct an indicator of individual innovation network technological diversification of listed companies by drawing on Chen, Li-Yong et al. (2015), and Zhao, Yan et al. (2022). First construct the firm i patent vector $F_i = (F_{i1}, F_{i2}, \ldots, F_{is})$, which$F_{is}$ represents the enterprise i in the first$s$ number of patents in the category; then calculate the level of technological diversification between the listed company and its partners, and between the two partners and partners:

$TD_{ij} = 1 - F_i F_j' / [(F_i F_i')(F_j F_j')]^{1/2}$, of which $i \neq j$.;

Finally: averaging the above indicators yields.

$NTD = \frac{2}{n(n-1)} \sum_i \sum_j TD_{ij}$ where n refers to the number of network members;

NTD is the indicator of technological diversification at the level of the individual network of the listed company, and the larger the value of the indicator, the greater the technical differences among the network members and the higher the level of technological diversification of the innovation network.

4.2.3 Measurement of Technology Integration Capacity

Technology Integration Capability (TIC): i.e., the ability of enterprises to recombine and optimize the allocation of different technologies and knowledge resources based on previous investment, learning, and accumulation, reflecting the ability of enterprises to identify, digest, integrate, and utilize technological resources. Drawing on the indicator selection method of Zhao Yan et al. (2022), this paper adopts R&D investment intensity, i.e., the proportion of R&D investment to operating revenue, to measure technology integration capability.

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4.2.4 Measurement of Control Variables

The indicators of control variables refer to Zhao Yan et al. (2022) and He Yubing et al. (2017) selected from the aspect of firm characteristics; gearing ratio (DAR) is measured using the ratio of total liabilities to total assets; strong profitability (FP) is calculated using the ratio of net profit to the balance of total assets; firm size (Size) is measured using the natural logarithm of the total assets as a measure by the research convention; and the age of the firm (Age) is calculated using the difference between the year in which the firm joins the innovation network and the year of the firm's establishment.

4.3 Selection of Econometric Models

The dependent variable of this study is the continuous innovation of enterprises, which is expressed by using the ring of the number of patents, and considering the large degree of discrete data of the dependent variable, the negative binomial regression model is chosen. At the same time, the sample data is unbalanced panel data; using the fixed-effects model will automatically delete the enterprise sample with only one year of data, resulting in the loss of sample size, so the negative binomial regression model with random effects is used.

5. EMPIRICAL TESTS AND ANALLYSIS OF RESULTS

5.1 Descriptive Statistics

Table 5-1 shows the results of descriptive statistical analysis of the main variables. It can be seen that the mean value of enterprise sustained innovation (OIP) in the overall sample is 644.7405, and the standard deviation greater than the mean is taken as 841.3510, indicating that the sample enterprises have a high level of sustained innovation, but the gap between enterprises is large. The mean value of innovation network technological diversification (NTD) is 0.4631, and the median is 0.4752, indicating the overall technical diversification level of the innovation network where the sample enterprises are generally located, and the comprehensive distribution tends to be symmetrical. Technology Integration Capability (TIC) is used to measure the ability to organize and configure technology and knowledge within the enterprise, with an overall mean value of 14.2771, minimum and maximum values of 0.9700 and 41.2000 respectively, and a standard deviation of 9.3751, which shows that there is a significant gap in the internal knowledge and technology transformation ability of listed companies in the information technology industry and that the sample enterprises' technological integration capability needs to be overall Improvement.

From the point of view of internal governance-related indicators, the average value of corporate gearing ratio (DAR) is 0.3347, the minimum and maximum value of 0.0487 and 1.2855, respectively, indicating that the overall level of corporate indebtedness is reasonable, but the difference in debt between enterprises is still significant; corporate profitability (FP) average level of 0.0331, the minimum value of -0.8314, the maximum value of 0.3019, reflecting a more obvious gap in the business situation; reflecting the size of the enterprise (Size) is the

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natural logarithm of the total assets, the maximum value of 24.9123, the minimum value of 19.5062, there is still a particular gap after the logarithmic processing, the median is 21.7142, the mean and median are very close to show that the size of the assets of the listed enterprises under study presents a symmetrical distribution; age (Age) is the difference between the year when the enterprise joined the innovation network and the year of its establishment, and its mean value is 16.3502, with the minimum and maximum values of 1 and 31 respectively, indicating that there is a significant gap in the timeframe of the enterprise's integration into the innovation network to carry out innovation and development, and that the majority of the sample enterprises have joined the innovation network for a shorter period of time.

Table 5.1: Results of Descriptive Statistics for Sample Variables (N=315)

variable name	average value	(statistics) standard deviation	upper quartile	minimum value	maximum values
OIP	644.7405	841.3510	602.7618	100.1477	1390.8937
NTD	0.4631	0.3885	0.4752	0.1022	0.8014
TIC	14.2771	9.3751	12.1700	0.9700	41.2000
DAR	0.3347	0.1881	0.2939	0.0487	1.2855
FP	0.0331	0.0955	0.0452	-0.8314	0.3019
Size	21.8151	0.9488	21.7142	19.5062	24.9123
Age	16.3502	5.7726	17.0000	1.0000	31.0000

Note: Data sources are compiled for this study.

5.2 Correlation Analysis

Table 5-2 is the Pearson correlation coefficient table between variables. According to the correlation coefficient table, technological diversification of the innovation network is positively correlated with sustained innovation of enterprises at 5% significance level, which is consistent with hypothesis 1; technological diversification of innovation network is significantly negatively correlated with technical integration capability with a correlation coefficient of 0.118, which is not in line with the description of hypothesis 2, but the correlation analysis only indicates the relationship between the variables in a certain way, and the actual impact effects need to be discussed later in a more rigorous regression analysis for discussion; technology integration capability is positively correlated with enterprise continuity innovation at 1% significance level, which is in line with the hypothesis inference. In the part of control variables, there is a significant correlation between them and the explanatory variable enterprise continuity innovation, which somehow explains the rationality of the control variables selected in this paper. Further diagnostic tests for multicollinearity show that the variance inflation factor (VIF) of each variable is less than 2, indicating no multicollinearity problem among the variables.

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Table 5.2: Correlation Coefficients and Variance Inflation Factors among Variables

	OIP	NTD	TIC	KF	MKT	DAR	FP	Size	Age	VIF
OIP	1.000									
NTD	0.086**	1.000								1.05
TIC	0.04***	-0.118**	1.000							1.36
KF	-0.003*	0.033*	-0.134**	1.000						1.27
MKT	0.029**	0.080***	0.112**	-0.135**	1.000					1.08
DAR	0.008***	-0.080	-0.390***	0.196***	-0.075*	1.000				1.63
FP	0.032**	0.120**	-0.057**	-0.014**	0.039***	-0.355***	1.000			1.26
Size	0.034***	0.079***	-0.253***	0.435***	0.002***	0.390***	0.016***	1.000		1.55
Age	0.068*	-0.058***	-0.283***	0.075***	0.148***	0.180***	-0.057**	0.280***	1.000	1.20

Note: * represents p < 0. 1, ** represents p < 0. 05, and *** represents p < 0. 01.

5.3 Regression Analysis

5.3.1 Benchmark Regression

This paper is based on the empirical analysis of unbalanced panel data; the model selection needs to use the Hausman test to determine the use of fixed effects or random effects, the chi-square test statistic takes the value of 11.94, the p-value of 0.5328 is much more significant than 0.05, that is, it cannot be rejected the original hypothesis that should be used in the random effects model. On the other hand, considering the dependent variable's characteristics, its standard deviation is larger than the mean, and the value is more discrete, so the negative binomial regression model is used. In summary, this paper uses the random effects adverse binomial regression model controlling for time variables for the empirical testing part of the hypothesis.

Table 5-3 reports the regression results of innovation network technological diversification, technological integration capability, and firms' sustained innovation. Column (1) in the table is a control model, considering the effect of year, at which time the adjusted R2 is 0.2240. Column (2) adds the explanatory variable innovation network technological diversification based on the control model.

Also, it takes into account the effect of the year, and the estimated coefficient of NTD is 0.3556, which is significant at the 5% level is substantial; at this time, the adjusted R2 increases to 0.3314, the explanatory strength of the model has a significant increase, indicating that the

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innovation network technology diversification significantly positively affects the continuous innovation of enterprises, so hypothesis 1 is verified.

The regression results of the control variables are also basically in line with the expectation: the estimated coefficient of FP is significantly positive, indicating that the higher the profitability of an enterprise, the more positively its level of continuous innovation will be affected; the regression coefficient of Size is significantly positive, indicating that the higher the total assets, the more resources and funds an organization can mobilize, and the more positively the continuous innovation of the enterprise will be affected; and the regression coefficient of Age is significantly positive, indicating that the longer the enterprise joins in the innovation network, the more it can connect with the other enterprises or organizations in the network and the more positively it will be affected on the continuous innovation.

Table 5-3: Main and Mediating Effects Regression Results (N=315)

	OIP(1)	OIP(2)	TIC(3)	OIP (4)	OIP (5)
NTD		0.3556** (0.1912)	0.9121*** (1.0046)	0.1081*** (0.0002)	
TIC				0.0475 (0.0322)	0.0018** (0.0052)
DAR	0.0184 (0.2466)	0.0472 (0.2446)	-0.1660** (1.7168)	0.0236* (0.0117)	0.0476** (0.2606)
FP	0.0824*** (0.4230)	0.0345*** (0.4210)	-8.9964*** (2.4859)	0.0675*** (0.0090)	0.1075** (0.4328)
Size	0.0300** (0.0475)	0.0236** (0.0471)	-0.7435** (0.3477)	0.0201*** (0.0033)	0.0309*** (0.0478)
Age	0.0050*** (0.0081)	0.0061*** (0.0080)	-0.4077*** (0.1535)	0.0291*** (0.0069)	0.0056*** (0.0084)
Year	containment	containment	containment	containment	containment
Constant	5.6584*** (0.9801)	4.6380*** (0.9684)	33.5762*** (7.5027)	5.3561** (0.6792)	5.5971*** (1.0045)
Wald chi2	37.11	40.61	41.12	45.13	47.21
Prob > chi2	0.0078	0.0000	0.0000	0.0003	0.0000
Adj-R^2	0.2240	0.3314	0.1212	0.3360	0.2348
sobel Z-p value			Z=2.364 (p=0.029<0.05)		

Note: Standard errors are in parentheses, * represents p < 0. 1, ** represents p < 0. 05, and *** represents p < 0. 01.

5.3.2 Brokering Effects

The mediation effect test refers to the classic three-step mediation test of Wen Zhonglin et al. (2004): the first step is to test whether technological diversification of the innovation network can significantly enhance firms' sustained innovation, which has been verified in the previous section; the second step is to test whether technological diversification of the innovation network can significantly enhance technical integration capability; the third step is to try

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whether technological diversification of the innovation network and technological integration capability has a significant effect on the sustained innovation of the firms at the same time. Innovation. Among them, technology integration capability (TIC) is the mediating variable, and other variables are consistent with the previous section. Columns (2) - (5) of Table 5-3 show the results of the stepwise test of mediating effect. Column (3) tests the impact of innovation network technological diversification on technological integration capability, and the regression coefficient of enterprise innovation network technological diversification (NTD) is significantly positive at the level of 0.01, taking the value of 0.9121, which indicates that innovation network technological diversification significantly and positively affects enterprise's technical integration capability, and Hypothesis 2 has been verified. Column (4) examines the role of innovation network technology diversification and technology integration capability on enterprise continuous innovation, and the results show that innovation network technology diversification still has a significant positive impact on enterprise continuous innovation. However, the positive effect of technology integration capability is no longer critical, and the mediating effect needs to be further tested.

The mediating effect is further analyzed by calculating the test statistic Z performing the Sobel test, the test strength of which is superior to the stepwise regression method. Calculating the product of the estimated quantities of column (3) technological diversification of innovation networks and column (5) technical integration capabilities divided by their standard errors to obtain the value of the test statistic is judged. Table 5-3 reports the results of the Sobel test, with a Sobel Z value of 2.364 and a p-value of 0.029 less than 0.05, which proves that the partial mediating effect of technological integration capability is valid, i.e., technological diversification of the innovation network can enhance the level of sustained innovation of firms by promoting technical integration capability, and Hypothesis 4 is verified.

5.4 Robustness Tests

To ensure the reliability of the research conclusions, this paper carries out a deeper regression analysis of the above model by adjusting the characterization of variables while keeping other variables unchanged.

Change the proxy variable measurement method. Referring to the indicator selection method of Wang Wenhua et al. (2015), the proxy variable enterprise internal R&D personnel proportion is applied to measure the technology integration capacity; R&D personnel with heterogeneous characteristics are the most creative human capital in the enterprise, and their innovative behavior and innovative performance fundamentally determine the level of enterprise integration and utilization of new and old technologies, i.e., they show the enterprise technology integration capacity. Utilizing the measurement criteria of adjusted mediating variables, the influence effect of innovation network technology diversification on enterprise sustained innovation and the mediating role of technology integration capability (TIC_2) in the relationship between innovation network technology diversification and enterprise sustained innovation were further tested. The effect of innovation network technology diversification on technology integration capability is shown in column (3) of Table 5-4, and the regression coefficient of NTD is significantly positive at the 5% level, indicating that Hypothesis 2 is

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robustly established; column (4) of Table 5-4 illustrates that the positive effect of technology integration capability on firms' sustained innovation is significantly positive at the 10% level, and the regression coefficient of innovation network technology diversification is significantly positive, indicating that Hypothesis 4 passes the test, i.e., the mediating effect of technology integration capability between technological diversification of innovation networks and firms' continuous innovation remains robustly established.

Table 5.4: Main and Mediated Effects Robustness Regression Results (Replacing Mediating Variables) (N=315)

	OIP(1)	OIP(2)	TIC_2(3)	OIP (4)
NTD		0.3556** (0.1912)	5.6327** (3.5473)	0.3439* (0.1909)
TIC_2				0.0031* (0.0020)
DAR	0.0184 (0.2466)	0.0472 (0.2446)	-9.9496* (5.8893)	0.0747* (0.2429)
FP	0.0824*** (0.4230)	0.0345*** (0.4210)	12.3702* (8.6948)	0.0733** (0.4188)
Size	0.0300** (0.0475)	0.0236** (0.0471)	-3.7394*** (1.1811)	0.0256** (0.0466)
Age	0.0050*** (0.0081)	0.0061*** (0.0080)	0.4998 (0.3879)	0.0043** (0.0079)
Year	containment	containment	containment	containme
Constant	5.6584*** (0.9801)	4.6380*** (0.9684)	108.8215*** (24.9894)	5.4943*** (0.9613)
Wald chi2	37.11	40.61	45.24	43.13
Prob > chi2	0.0078	0.0000	0.0000	0.0000
Adj-R^2	0.2240	0.3314	0.1445	0.4012

Note: Standard errors are in parentheses, * represents p < 0. 1, ** represents p < 0. 05, and *** represents p < 0. 01.

Adjusting the dependent variable measurement standard. Referring to the indicator selection method of Zhao Yan et al. (2022), in view of the fact that the patent grant is an important indicator to characterize the innovation ability of enterprises, this paper takes the chain growth rate of the sum of patent grants of enterprises in the t+2nd and t+1st years over the sum of patent grants in the t+1st and the years and then multiplies it by the sum of patent grants of the t+2nd and t+1th years to measure the sustained innovation of enterprises. After replacing the dependent variable of sustained innovation, we continue to test the relationship between technological diversification in innovation networks and sustained innovation, as well as the mediating effect of technological integration capacity and the moderating effect of knowledge flow and marketization level. The results in Tables 5-5 show that column (1) is the control model, the positive effect of technological diversification of innovation networks in column (2) is significantly established, so hypothesis 1 is robust; column (3) verifies the effect of technological diversification of innovation networks on technological integration capabilities, and according to the regression results, hypothesis 2 is robustly established; the results in

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columns (4)-(5) also confirm the establishment of mediating effect of technological integration capabilities.

Table 5-5: Main and Mediating Effects Robustness Regression Results (Replacing the Dependent Variable) (N=315)

	OIP_2 (1)	OIP_2 (2)	TIC(3)	OIP_2 (4)	OIP (5)
NTD		0.2574* (0.1985)	0.9121*** (1.0046)	0.2391* (0.1977)	
TIC				0.0142 (0.0102)	0.0149* (0.0102)
DAR	0.6303* (0.3310)	0.6322* (0.3307)	-0.1660** (1.7168)	0.6509** (0.3297)	0.6504** (0.2606)
FP	0.5634 (0.4846)	0.4932 (0.4871)	-8.9964*** (2.4859)	0.6351 (0.4949)	0.7076 (0.4917)
Size	0.1771** (0.0664)	0.1750** (0.0664)	-0.7435** (0.3477)	0.1821*** (0.0667)	0.1847*** (0.0667)
Age	0.0385* (0.0224)	0.0394* (0.0223)	-0.4077*** (0.1535)	0.0450** (0.0229)	0.0446* (0.0084)
Year	containment	containment	containment	containment	containment
Constant	-2.3395* (1.4073)	-2.3948* (1.4064)	33.5762*** (7.5027)	-2.8049** (0.6792)	-2.7796 (1.4496)
Wald chi2	45.42	40.61	41.12	49.13	47.60
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000
Adj-R^2	0.2577	0.2651	0.1212	0.2698	0.2521
sobel Z-p value			Z=4.982 (p=0.011<0.05)		

Note: Data sources are compiled for this study.

6. SUMMARY AND DISCUSSION

6.1 Summary

The results of empirical research in this chapter verify the significant positive correlation between the technological diversity of innovation networks and the continuous innovation of enterprises, and the results of the analysis of main effects confirm hypothesis 1, that is, the richer the technological diversity of the innovation network of individual enterprises, the more it can promote the continuous innovation of enterprises. Under the background of high-quality development, innovation has become a critical factor in promoting China's economic growth; due to the increase of innovation risk and the acceleration of technological upgrading speed, enterprise to enterprise, cross-regional organizations to carry out collaborative innovation has become a "general trend," the entire network can be different innovation subject aggregation, to complete the individual innovation subject can not do. The network can aggregate other innovation subjects to accomplish what a single innovation subject cannot. Most domestic and international studies on technological diversification focus on internal enterprises, but fewer studies focus on the technological diversification of enterprises' cooperative innovation

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networks from the social network level. This paper constructs an innovation network through the joint patent application data of listed companies in the information technology industry in China during the decade from 2011 to 2020. It conducts empirical research by combining relevant patents and financial data and finds that as the level of technological diversification in the innovation network improves, the sustained innovation of the enterprises will also be promoted accordingly. It shows that under the current cruel competition situation, the external diversified technical knowledge contacted by enterprises has indeed become an indispensable resource for enterprise innovation, and enterprises should strengthen open innovation, actively seek external cooperation, especially seek partners with heterogeneous technical knowledge, and build a technologically diversified cooperative innovation network.

It is found that the relationship between technological diversification in the innovation network and sustained innovation of enterprises is not purely direct. However, the technical integration capability of enterprises plays a critical intermediary role, i.e., the diversified technological knowledge that enterprises are exposed to externally not only directly provides enterprises with a steady stream of knowledge resources and technical opportunities for innovation, but also indirectly promotes the improvement of enterprises' sustained innovation performance through the enhancement of the technological integration capability of enterprises. Based on the dynamic capability theory and resource base theory, technology integration capability, a vital indicator of an enterprise's ability to identify, digest, integrate, and utilize technological resources, has long been an essential source of enterprise competitiveness. As a critical dynamic capability, technology integration capability affects the quality and efficiency of enterprises in transforming external knowledge and technology into internal innovations (Yuan Bo et al., 2014), as well as the degree of synergy and complementarity between enterprises' technology and expertise, which then positively affects enterprises' continuous innovation.

6.2 Discussion

6.2.1 Building Diversified Collaborative Innovation Networks

Sustainable innovation emphasizes that enterprises should break through technological and organizational boundaries, track and absorb knowledge in cutting-edge technical fields, and then enhance their sustainable development level. Theoretical and empirical studies show that the technological diversity of the innovation network is conducive to improving the performance of enterprises in sustainable innovation. In selecting collaborative innovation partners, enterprises need to focus on knowledge heterogeneity and accessibility, and choosing partners that can bring technological diversity will help them fully benefit from different partners. Enterprises build diverse co-innovation networks; enterprises establish cooperative relationships with multiple types of innovation entities, and the diversity of co-innovation network members and technological diversity. Collaborative innovation network members should include innovation subjects of different kinds, such as higher education institutions, research institutes, industrial sectors, and government departments. Enterprises should actively adopt an open mode in their technological innovation activities, cooperate with different innovation body network members, integrate internal and external advantageous innovation resources, and improve enterprise continuous innovation. Specifically, enterprises need to

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strengthen cooperation with varying subjects of innovation in resource sharing, technology research, and development, information communication, etc., to realize the sharing and overflow of complementary innovation elements among subjects, thus contributing to the synergistic effect. In short, enterprises should build a diversified collaborative innovation network, give full play to the knowledge sharing and knowledge spillover effect of innovation subjects from different fields, and continuously improve the sustainable innovation capability of enterprises.

6.2.2 Emphasis on Improving Technology Integration Capability

As a critical indicator of an enterprise's ability to identify, digest, integrate, and utilize technological resources, technology integration capability has become an essential source of enterprise competitiveness and is closely related to its innovation activities. This study shows that technical diversity in innovation networks affects enterprise technology integration capability, promotes the transfer and integration of differentiated knowledge, stimulates the technological innovation vitality of the main body of the innovation network, and then enhances the sustained innovation of enterprises. Enterprise technology integration capability is essential to realizing product innovation and technological diversification, which makes the organization more flexible. In the face of resources that need to be integrated, enterprises need to optimize their structure and overcome operational inertia through technological diversification, and articulating the various phases of resource integration is the fundamental problem they need to solve. Information technology enterprises should actively integrate into the regional innovation system, build a wide range of cooperative relationships, focus on matching the technological diversification of the innovation network with their capabilities, and effectively improve the quality of the role of technological diversification. While expanding their technical knowledge base, they need to choose different knowledge behaviors according to the characteristics of the technological diversification of the external network to build the absorption capacity and technological integration capacity and reasonably absorb and integrate the knowledge of the different fields to acquire the knowledge of the other fields. At the same time, it should choose different knowledge behaviors based on the characteristics of technological diversification of external networks to build up absorption and technical integration capacity and reasonably absorb and integrate knowledge in various fields to obtain a higher level of continuous innovation.

6.3 Research Limitations and Research Recommendations

This paper explores the relationship between technological diversification of innovation networks, technical integration capabilities, and enterprises' sustained innovation from theoretical and empirical perspectives. It draws some meaningful conclusions, but there are still some limitations in the study that need to be perfected in the subsequent research.

Firstly, this paper analyzes the influence mechanism of technological diversification of innovation networks on enterprise innovation sustainability based on social network theory. However, the division of technological diversification of innovation networks needs to be more comprehensive from the theoretical point of view. In this paper, we have yet to distinguish

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whether there is any difference between the different divisions of these technological synergies in analyzing the relationship between innovation networks' technological diversification and enterprises' innovation sustainability. In future research, we can consider the division of specialized synergistic behavior from a more comprehensive perspective and compare and analyze the effects of different technological synergistic modes of technological diversification on the sustainability of enterprise innovation and the operation mechanism in order to improve the relevant theoretical system.

Secondly, the sample of this study comes from the unbalanced panel data of 315 observations from 2011 to 2020, with 82 listed information technology industry companies and 677 related cooperative companies; the sample size and sample industry types are relatively limited. Future research needs to expand the sample size further and broaden the types of industries in which the sample companies are located to improve the stability, applicability, and generalizability of the empirical research results by analyzing broader and more representative sample data. In addition, this study is mainly based on patent data, which has certain limitations. On the one hand, the research object is a listed information technology company.

The industry to which it belongs is characterized by rapid technological innovation and change, while the patent indicator represents to some extent the actual output of innovation results in the given year, which does not fully reflect the technological innovation activities and innovation results; on the other hand, due to the discontinuity and uncertainty of the R&D activities, it may result in the lack of data on the cooperation between the innovation subjects in the early stage and the patent output in the later stage.

This paper measures by a three-year moving time window to obtain more observations, which may not fully reveal the dynamic behavior of innovation activities. Future studies may consider combining scientific papers to get more observations on inter-innovator cooperation and innovation output from scientific papers.

Thirdly, industry limitations: the study, as long as the listed information technology industry companies and their partner companies, the conclusions can only guide the industry; future research can be aimed at more industries and types of companies to expand the applicability of the findings and the correctness of the paper.

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