Study on the Impact of Digital Technology on Enterprise Innovation Performance—Based on the Structural Hole Theory

Wen Li[*], Tianwei Huang, Haibing Liu

[*]2668055440@qq.com

huangtianwei@wust.edu.cn

habliu@zju.edu.cn

School of Management, Wuhan University of Science and Technology, Research Center of Hubei Industrial Policy and Management, Wuhan, China

Abstract—Based on the structural hole theory, this paper takes China's A-share automobile manufacturing listed companies in 2021 as the research object, builds a mediation effect model, and explores the impact mechanism of digital technology on enterprise innovation performance. The results show that, first, Digital technology has a significant positive impact on enterprise innovation performance; second, structural holes have a positive impact on enterprise innovation performance; third, structural holes play a part of the intermediary role in the role of digital technology on enterprise innovation performance. This research conclusion expands the discussion boundary between digital technology and enterprise innovation performance, enriches the element analysis of the internal mechanism, and provides guidance and reference for the innovation of manufacturing enterprises.

Keywords—Digital technology; Enterprise innovation performance; Structural hole theory

1. Introduction

According to the report to the 20th National Congress of the CPC, we must continue to implement the strategy of innovation-driven development, create new drivers and advantages for development, and accelerate efforts to achieve self-reliance in high-level science and technology. With the rapid development of digital technology, enterprises should fully grasp the opportunity of digital transformation, and actively use digital technology to enhance the creation of data value to stimulate the innovation power of enterprises. Therefore, how to apply digital technology to improve innovation performance has become a hot issue for enterprise managers and academic circles. For example, Ye Dan et al. (2022)[1], based on the Resource-based view and Theory of institution, believes that the acquisition of digital technology is the premise of enterprise innovation.

In recent years, Chinese automobile industry has been making continuous progress in self-research and innovation in technology, products, supply chain and other aspects, and its position in the global automobile industry chain becomes more and more prominent. As an important

means to optimize the development mode of enterprises and industries, digital-technology-driven innovation has become the key to the transformation and upgrading of the global automobile manufacturing industry.

Individuals are fragile, but networks are robust. When there is no direct connection between two or more entities, there will be structural loopholes in the social network[5]. Enterprises occupying the structural holes can master more abundant information resources than other enterprises and obtain information advantages in business communication, thus affecting the improvement of enterprise innovation performance (EIP). Therefore, the discussion on improving the innovation performance of enterprises from the perspective of structural holes has gradually attracted the attention of the academic circle. One view holds that enterprises occupying more structural holes can access different types of information, which is conducive to the innovation activities of enterprises[10]. However, another view holds that there is an inverted U-shaped relationship between structural holes and enterprise innovation performance, that is, when an enterprise occupies too many structural holes, other network members will become too dependent on them, which will inhibit enterprise innovation output[8].

2.   Theoretical basis and research hypothesis

2.1   Digital technology and enterprise innovation performance

The reason for the uneven innovation capability among enterprises is that tangible resources, intangible resources and accumulated knowledge are different among enterprises, and these resources are usually of high value, scarcity and unrepeatability[1]. Digital technology is characterized by editability, expansibility, openness and relevance[3]. Among them, openness refers to the degree to which exponential word technology allows other enterprises to participate in and share, while relevance refers to the function of exponential word technology to promote the realization of functions through multi-subject link and interaction. Therefore, digital technology can make up for the deficiency of enterprises' ability to obtain resources and contribute to the improvement of EIP.

H1: Digital technology has a significant positive impact on enterprise innovation performance.

2.2   Digital technology and enterprise structure hole

Structural hole refers to the gap between two groups with complementary resources and knowledge. If the third-party intermediary can connect the two groups to fill the gap, it can gain a competitive advantage. Structural holes exist in a large number of social networks, innovation networks, knowledge networks and other networks[4]. In the Internet information age, with the development of digital technologies, Resource interaction is gradually transferred from the real interaction to the network exchange, and the social network presents the characteristics of digitalization [6]. The application of digital technology promotes the enrichment of social networks and helps enterprises to occupy structural holes and gain competitive advantages.

H2: Digital technology has a significant positive impact on enterprise structural holes.

2.3 Structural holes and enterprise innovation performance

Structural hole theory is often applied to the analysis of relationships among individuals, organizations or other entities occupying social networks[5]. People who are familiar with the opinions and behaviors of different groups are more likely to be the ones who approach the structural hole. These people will have more opportunities to choose and synthesize different opinions and behaviors, so that good ideas and innovative thinking will emerge[4]. Therefore, only enterprises with more structural holes in the market transaction network can have a strong social network, and obtain abundant resources from the social network for the development of innovative thinking and capability, so as to improve the innovation performance of enterprises.

H3: Corporate structural holes have a significant positive impact on corporate innovation performance.

2.4 The mediating role of structural holes

According to the structural hole theory, two enterprises without direct connection must exchange information, resources and technologies through the enterprises in the position of structural holes. Therefore, enterprises with more structural holes in the network have more advantages in terms of information and resources than other enterprises[7]. On the one hand, digital technology has realized data visualization, promoted the transparency of information resources between enterprises, improved the speed and efficiency of information resource exchange, and promoted the perfection and extension of social network. Therefore, enterprises in marginal positions can obtain rich resources through connection after other enterprises fill the gaps in the structure, thus facilitating enterprise innovation[3]. On the other hand, digital technology has improved enterprises' capability to obtain and screen resources, and promoted enterprises to acquire more key resources.

H4: Corporate structure hole plays an intermediary role in the relationship between digital technology and corporate innovation performance.
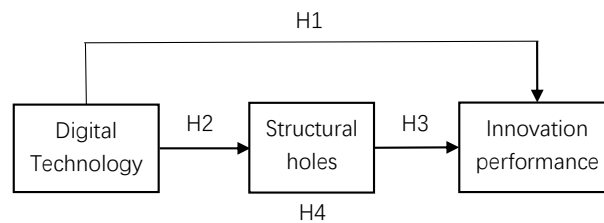

FIGURE 1 Theoretical model

3. Research design

3.1 Sample selection and data sources

This paper selects Chinese A-share automobile manufacturing listed companies in 2021 as research samples. In order to further improve the quality of research data, samples were screened according to the following criteria: (1) samples of listed companies with less than one year of

listing and delisted companies were excluded; (2) samples with missing or ambiguous data of important variables were excluded. (3) Samples of companies with major business changes during the study period were excluded. Finally, a total of 1310 cross-sectional samples of 100 listed manufacturing companies were obtained. Relevant sample data mainly came from the annual reports of listed companies, supplemented by the CSMAR Database.

3.2 Variable measurement

3.2.1 Dependent variable: Enterprise Innovation Performance (EIP)

Referring to the innovation performance measurement method adopted by FANG et al.[9], this paper uses the number of new Patents applied for each year to measure the innovation performance of enterprises.

3.2.2 Independent variable: Digital Technology (DT)

Referring to the research of Haihua Wang et al.[3], the relevant expressions of digital components, digital platforms and digital infrastructure disclosed in corporate annual reports and corporate social responsibility reports are used to measure the application degree of enterprises' digital technologies. If any of the three occurs, the digital technique is assigned a value of 1; If any two of the three are present, the digital technology value is 2; If all three are present, the digital technique is assigned the value 3; If none of the three appear, the digital technique is assigned a value of 0.

3.2.3 Mediating variable: Structural Hole (SH))

According to Burt's structural hole theory, the executive team must keep its network rich in structural holes, so that the team is in a position of structural autonomy in the network. So that enterprises have more abundant social capital conducive to the improvement of innovation performance[11]. Executive members play an important role in enterprise decision making. The executive social network structure can increase or overlap the structural holes in the enterprise value network. Therefore, the strength of corporate structural holes is measured by the number of part-time executive members of sample enterprises in government, enterprises, industries and social organizations.

3.2.4 Control variable (Con)

Referring to relevant research[3], the control variables selected in this paper include: ① Enterprise size(SIZE), namely the total assets of the enterprise; ②Ownership structure (OS), that is, the shareholding ratio of corporate executives; ③Asset-liability ratio (AIR), that is, the ratio of total liabilities to total assets; ④Establishment years (AGE), that is, the period from the establishment of the enterprise to the current year; ⑤The size of the senior management team (TMTS) refers to the total number of the senior management team. All relevant data comes from CSMAR database and corporate annual reports.

3.3 Model selection

This paper establishes a multiple regression model to examine the relationship between digital technology, structural holes and EIP. Model (1) and Model (2) are the relationship models between digital technology, structural hole and EIP, Model (3) is the relationship model between

digital technology and structural hole, and Model (4) is the mediating effect model of structural hole in the relationship between digital technology and EIP.

$$EIP_{i,t+1} = \beta_0 + \beta_1 DT_{i,t} + \beta_2 \sum Con_{i,t} + \varepsilon_{i,t} \qquad (1)$$

$$EIP_{i,t+1} = \beta_0 + \beta_3 SH_{i,t} + \beta_4 \sum Con_{i,t} + \varepsilon_{i,t} \qquad (2)$$

$$SH_{i,t} = \beta_0 + \beta_5 DT_{i,t} + \beta_6 \sum Con_{i,t} + \varepsilon_{i,t} \qquad (3)$$

$$EIP_{i,t+1} = \beta_0 + \beta_7 DT_{i,t} + \beta_8 SH_{i,t} + \beta_9 \sum Con_{i,t} + \varepsilon_{i,t} \qquad (4)$$

EIP is enterprise innovation performance; DT is digital technology; SH is structural hole; Con is control variable, including enterprise size (SIZE), equity structure (OS), asset-liability ratio (AIR), age of establishment (AGE), size of senior management team (TMTS), β0 is constant term, ε is error term, i represents enterprise, t represents year.

4.   Empirical Analysis

4.1   Descriptive statistics and correlation analysis

In this paper, correlation analysis of variables was carried out by Pearson correlation analysis method, and the mean value, standard deviation and correlation coefficient of research variables were obtained as shown in Table 1. It can be seen from the table that the standard deviations of the richness of structural holes and the degree of digital technology are 3.992 and 0.927 respectively, indicating that there are differences between structural holes and digital technology among enterprises. There is a significant correlation between digital technology and enterprise structure hole and enterprise innovation performance.

Table 1 Mean, standard deviation and correlation coefficient of variables

Variable	$\bar{X}$	σ	1	2	3	4	5	6	7	8
1.EIP	4.430	1.615	1							
2.DT	1.010	0.927	0.327***	1						
3.SH	10.400	3.992	0.197**	-0.012	1					
4.OS	0.104	0.154	-0.177*	-0.039	-0.019	1				
5.SIZE	22.749	1.477	-0.177***	-0.039**	-0.019*	1***	1			
6.AIR	0.437	0.194	0.237**	0.117	-0.06	-0.395***	0.490***	1		
7.TMTS	13.990	4.451	0.094	-0.125	0.815***	0.012	0.153	-0.133	1	
8.AGE	20.760	7.619	0.002	-0.053	0.319***	-0.229**	0.228**	0.198**	0.401***	1

Note: N=100, *, ** and *** are significant at the level of 10%, 5% and 1% respectively.

4.2   Direct and intermediate effect tests

This paper uses SPSS23.0 to test the relationship between digital technology, structural holes and EIP, and the results are shown in Table 2. Model (1) shows that the regression coefficient of digital technology on EIP is positive (β=0.238, p<0.01), H1 has been verified. Model (2) shows that the regression coefficient of structural holes on EIP is positive (β=0.259, p<0.1), i, H3 is verified. Model (3) shows that the regression coefficient of digital technology on structural holes is positive (β=0.08, p<0.2), indicating that digital technology provides a wider range of

information resources and sharing exchange platform for enterprise executives, which is conducive to enterprises occupying more structural holes, and H2 is verified. Model (4) shows that the regression coefficients of digital technology and structural holes on EIP are both positive. Among them, the regression coefficient of digital technology on innovation performance in model (4) is 0.221, which is greater than that of digital technology on innovation performance in model (1), and the regression coefficient of structural hole on EIP in model (4) is positive, indicating that structural hole plays a partial mediating effect in the influence of digital technology on EIP.

Table 2 Regression analysis of DT, SH and EIP

Variable	EIP		SH	EIP
	Model (1)	Model (2)	Model (3)	Model (4)
DT	0.238***		0.08	0.221**
	(2.638)		(1.299)	(2.443)
SH		0.259*		0.209*
		(1.681)		(1.384)
OS	-0.027	-0.012	0.08	-0.025
	(-0.272)	(-0.123)	(-0.123)	(-0.256)
SIZE	0.412***	0.465***	0.033	0.405***
	(3.793)	(4.294)	(0.45)	(3.743)
AIR	0.042	0.033	0.027	0.036
	(0.393)	(0.297)	(0.376)	(0.341)
TMTS	0.125	-0.125	0.835***	-0.05
	(1.236)	(-0.769)	(12.152)	(-0.312)
AGE	-0.144	-0.146	-0.027	-0.138
	(-1.442)	(-1.427)	(-0.397)	(-1.391)
R^2	0.303	0.273	0.676	0.317
Adj.R^2	0.258	0.226	0.655	0.265
Durbin Watson	1.796	1.791	1.969	1.808

Note: N=100, *, ** and *** are significant at the level of 10%, 5% and 1% respectively.

5. Discussion and Conclusion

5.1 Conclusion

Using the theory of structural holes, this paper takes China's A-share listed automobile manufacturing enterprises in 2021 as research samples, analyzes the relationship between digital technology, structural holes and enterprise innovation performance, and draws the following research conclusions. The results are as follows:

(1) Digital technology has a significant positive impact on enterprise innovation performance. Similarly, it shows that manufacturing enterprises can further transform and upgrade their digital technology application by making efforts in digital infrastructure, digital components and digital platforms.

(2) Structural holes have a positive effect on EIP. The conclusion of this paper responds to Burt's structural hole theory, demonstrating that enterprises occupying more structural holes can help improve their centrality in social networks, improve their capability to build information

resource platforms with larger scale and higher freedom, and involve users and partners in the network.

(3) After further considering the mediating effect of structural holes, part of the reason why digital technology can improve innovation capability is that digital technology enables enterprises to have more convenient channels and communication tools, and can form more abundant innovation ecological network system, which confirms the mechanism of digital technology driving enterprises to occupy more structural holes and thus drive innovation capability.

Digital technology includes a variety of technical layers, involving the resource management of each link of technological innovation, and can empower the whole process of enterprise technological innovation. For example, for the intangible resources of structural holes, enterprises can use digital identification and other technologies to carry out information processing and processing, so as to make the intangible resources that have not been fully utilized in the past structured and explicit. Thus, the dynamic updating of resources can be realized and the technological innovation of enterprises can be enabled.

5.2 Limitations and Future Study Directions

This paper studies the mediating effect of structural holes in the influence of digital technology on innovation performance, which enricfies the existing theoretical researches, but there are still some research limitations and shortcomings:

① In this paper, listed companies in the automobile manufacturing industry are selected as research samples and the number of samples is relatively small. Although industry differences and enterprise size differences are controlled to a certain extent, the applicability to other industries has yet to be tested. Future research is not limited to this field, and whether structural holes in various fields produce mediating effects will be explored to enhance the universality of research conclusions.

②This paper selects the number of patents obtained as the standard to measure the innovation performance of enterprises, but does not measure the value of each patent innovation in detail. Moreover, the innovation of enterprises is not only reflected in patents, but also may include other aspects such as papers. In the future, the innovation performance of enterprises will be measured in a more detailed and accurate way to make the research results more accurate.

References

[1]   Dan Ye, Meifang Yao, Baoshan Ge, Liyi Zhao. The Mechanism of Digital Technology Driving Digital Innovation Performance in Non-Internet Enterprises: The Moderating Effect of Organizational Legitimacy [J/OL]. Science & Technology Progress and Policy:1-8[2022-11-27]. http://kns.cnki.net/kcms/detail/42.1224.G3.20220725.1120. 012.html

[2]   Grant, R. M. Toward a Knowledge-based Theory of the Firm [J]. Strategic Management Journal, 1996, 17(2):109-122.

[3]   Hai-hua WANG, Mei DU. Digital Technology, Employee Participation and Enterprise Innovation Performance[J]. R&D Management,2021,33(01):138-148. DOI:10.13581/j.cnki. rdm.20200757.

[4]   Yalan Yan, Yong Zhang, Xianjin Zha. Research Progress of Structural Holes Theory Application Abroad [J].   Documentation,   Information   &   Knowledge,2019(4):104-112. DOI:10.13366/j.dik.2019.04.104.

[5]   Lingyan Yan, Yao Zhang. Analysis of Brokerage Roles of Online Academic Social Users Based on Structural Hole theory [J/OL]. Journal of Intelligence:1-7[2022-11-17].http://kns.cnki.net/ kcms/detail/61.1167.g3.20220915.0932.002.html

[6]   Hongwei Zhang, Guanlin He. The Mechanism and Effects of Social Network Digitalization on Household Risk Asset Allocation[J]. Journal of Sichuan University (Philosophy and Social Science Edition), 2022(2):173-181. DOI:10.3969/j.issn.1006-0766.2022.02.017.

[7]   Zhong-hui Jiang, Junmei Luo, Chaoyue Meng. Dynamic Capability, Structure Hole Status and Sustained Competitive Advantage——A Longitudinal Case Study of Qingdao Redcollar from 1995 to 2018[J]. R&D Management, 2020, 32(3):152-164.

[8]   Peizhe Li, Lirong Jian. Network Structure, Knowledge Base and Enterprise Innovation Performance [J]. Complex Systems and Complexity Science,2022,19(02):31-38.DOI:10. 13306/j.1672-3813.2022.02.004.

[9]   FANG V W, TIAN X, TICE S.Does stock liquidity enhance orimpede firm innovation? [J]. Journal of Finance, 2014,69(5):2085-2125.

[10]   ZAHEER A, BELL G G. Benefiting from network position: firm capabilities, structural holes, and performance [J]. Strategic Management Journal,2005,26(9):809-825.

[11]   Dan Liang, Yuhui Ge, Yueming chen. Prospect for a Study on the Application of the Hole Structural Theory to Social Capital of TMT [J]. East China Economic Management,2010, 24(4):97-99. DOI:10.3969/j.issn.1007-5097.2010.04.025.

[12]   Canyang Jin, AitingXu, Yuhan Zhu, Jinchang Li. Technology growth in the digital age: Evidence from China [J]. Technological Forecasting and Social Change, 2022, Vol 187, 122221

[13]   Shaker A. Zahra, Wan Liu, Steven Si. How digital technology promotes entrepreneurship in ecosystems [J]. Technovation, January 2023, Vol.119, 102457

[14]   Dan Zhang, Zuguang Hu. Impact of network structural holes on enterprise technological innovation activities [J]. Science Research Management, 2013(6):34-41.