Study on the Impact of Digital Economy on Innovation of Pharmaceutical Companies

Li Jingran[1], Zhang Dawei[1], Jia Zheng[2], Xing Hua[1*]

(1. School of Business Administration, Shenyang Pharmaceutical University, Shenyang 110016, China;
2. Tangshan Vocational and Technical College, Tangshan 063000, China)

Abstract

Objective To study the importance of digital economy to promote the innovation development of enterprises under the background of the era of information technology reform. **Methods** The maximum entropy method was used to measure the comprehensive level of digital economy development at provincial level. Besides, the impact of digital economy on the innovation performance of pharmaceutical industry was investigated empirically by using A-share pharmaceutical companies listed in China from 2013 to 2020 as a research sample, and the mediating mechanism of R&D investment and financing constraints on the impact was examined. **Results and Conclusion** It is found that digital economy is significantly and positively related to the innovation performance of enterprises. The mechanism test shows that digital economy improves innovation performance through the expansion effect of R&D investment and alleviating financing constraints. In the context that digital economy has become a new driving force for enterprise innovation, the combination of digital economy and real economy should be actively promoted, R&D investment in pharmaceutical enterprises should be increased, and financing channels should be broadened.

Keywords: enterprise innovation performance; digital economy; mediating effect analysis

1 Introduction

Digital economy is a new economic form that integrates digital technology and the real economy and optimizes the economic structure with modern information network as a medium. In 2020, the added value of China's digital economy reached 39.2 trillion yuan, with a growth rate of 9.7% [1]. As a innovation-driven force, digital economy is of great strategic significance to promote the development of new technological innovation in various fields and optimize the regional technological innovation pattern. The wide application of digital information technology has fundamentally improved the ecological market environment for enterprise innovation, optimized the organization and management of innovation activities, and also facilitated the development of a "cross-border integration" model of enterprise technological innovation.

Therefore, the relationship between digital economy and enterprises' innovation performance in the same framework is suggested, which can deeply investigates the mechanism of the impact of digital economy on the innovation performance of Chinese

* Corresponding author: Xing Hua, associate professor. Major research area: Pharmaceutical policy and management, drug development project management, financial management. Tel: 13504908295, E-mail: gsglxyxh@126.com.

pharmaceutical enterprises. In addition, it can provide some suggestions for the government to seize the opportunity to release the growth dividend of digital economy and accelerate innovation.

2 Theoretical analysis and research hypothesis

2.1 Studies and hypotheses related to the positive correlation between digital economy and enterprise innovation performance

Min, et al. [2] argued that the digitization of industries drove the integration and linkages between traditional industries and the digital and real economies, thus enhancing innovation performance. Akcigit, et al. [3] believed that digital technology had greatly reduced the cost of information circulation and replication, improving the ability of knowledge transfer, the spillover performance of knowledge, and the power of mastering external knowledge and experience was an important way for science and technology subjects to enhance their creative effectiveness. Xiong and Cai [4] made an empirical analysis of the impact of digital economy-driven technological innovation in the Yangtze River Delta city cluster, and the findings showed that technology of digital economy could actively promote the upgrading of social and industrial innovation. Shen, et al. [5] pointed out that the development of digital economy could alleviate the dilemma of the lack of human resources for enterprise innovation through two channels in an empirical study: the aggregation effect of high-end human resources and the reduction of market environment uncertainty, thus improving the innovation performance of enterprises.

Digital economy has enabled great innovation collaboration among enterprises, enhancing their innovation performance [6]. In digital economy, the Internet mindset requires companies not to stick to internal technological innovation, but to use internal and external technologies with new ideas to maximize benefits. Digital economy can effectively remove the geographical obstacles to the free flow of traditional technological innovation elements, which will promote the interaction, collision and synergy between various nodes and technological innovation subjects, thus fully releasing the potential of cooperative innovation. The continuous improvement of digital management is an important feature of the company's development in recent years driven by new information technologies such as big data and cloud computing, which has formed a profound impact on the enterprise organization model, the efficiency of information system utilization, and the level of information decision management, thus improving the company's innovation performance to a certain extent. Therefore, the research hypothesis 1 is proposed.

H1: The level of digital economy development and enterprise innovation performance are positively correlated, and the higher the level of digital economy, the more it can lead to the improvement of enterprise innovation performance.

2.2 Studies and hypotheses on improving enterprise innovation performance by increasing enterprise R&D investment in digital economy

Empirical studies made by Wen [7] showed that digital economy development had different effects on invention and design innovation. With the expansion of digital economy, companies facing the threat of information transparency and fierce competition must drive innovative product development through increased technological investment. At the same time, the connection between users and companies is reconstructed, and users are able to submit market demand data directly to companies, which reduces market operation risks, lowers overall production costs, and continuously expands profit margins. Ma, et al. [8] pointed out that technology innovation investment could not only increase the innovation output of companies, but also played a bridge role between venture capital and innovation development. Li, et al. [9] concluded that there was a non-linear association between innovation investment and enterprise performance creation in listed companies in China. To a large extent, digital economy also determines the impact of innovation investment on the innovation performance of companies. The performance of innovation investment depends to a large extent on the size of digital economy, which in turn enhances the ability to create more output [10]. The development of digital technology has improved the ability of enterprises to grasp demand-side information and the market consumption situation accurately, thus facilitating enterprises to actively adjust their technological innovation activities and reduce the risk of research investment and the threshold of technological innovation. In turn, it improves the management of technological innovation of enterprises. Therefore, the research hypothesis 2 is proposed.

H2: Digital economy promotes enterprises to invest more in R&D, which in turn improves their innovation performance.

2.3 Studies and hypotheses related to digital economy improving enterprise innovation performance by alleviating financing constraints

Insufficient R&D investment fund and financing constraints seriously hinder the development of enterprise R&D projects [11]. The high cycle, high risk and irreversible characteristics are essential for the enterprise's technology innovation activities, which makes enterprise vulnerable to great financial constraints when carrying out technological innovation [12]. If investors have a clear understanding of the company, they can promote a positive interaction between financing needs and investment needs. It means the flow of capital to high-quality companies can support them to receive reasonable investment for the development of new projects [13]. The empirical analysis made by Dong, et al. [14] showed that the financing constraint had a significant inhibitory effect on enterprises' innovation, while the negative impact of social investment on innovation performance varied from one level to another. The development of the digital economy helps to reduce the cost of external financing for companies, thus providing more financial support [15]. Li, et al. [16] argued that the application of big data, artificial intelligence and digital information technology could make the company's data transparent, thus alleviating the external financing constraint. A well-developed digital infrastructure and mature digital products can expand the communication channels with the outside world [17]. The data economy reduces financing constraints by getting rid of information asymmetries, which increases the speed and breadth of information transfer. The development of digital enterprises promotes data and resource sharing, facilitates the digital transformation of enterprise management and business. Besides, it also helps to enhance the IT environment and business atmosphere of enterprises, thus reducing financial constraints [18]. Hu, et al. [19] investigated the mechanism of the impact of digital economy on small and medium enterprises' breakthrough technological innovation based on the supply and demand of the market. Their study also found that the technological innovation-driving effect of digital economy could be achieved by promoting the collaborative development of industry-academia-research and increasing the patent revenue of enterprises. In summary, the research hypothesis 3 is proposed.

H3: Digital economy improves the innovation performance of enterprises by easing their financing constraints.

3 Study design

3.1 Data source and sample selection

In this paper, 137 listed companies of pharmaceutical industry in A-share from 2013 to 2020 were selected as the research sample. Among them, the data of the development level of digital economy were obtained from the National Bureau of Statistics, the basic information and financial data of listed companies were obtained from China Stock Market & Accounting Research (CSMAR) database, and the patent application data were obtained from Chinese Research Data Services (CNRDS). After collating all the continuous variables by tailoring, 1 095 sample data were initially obtained.

3.2 Model design

In this paper, panel data are selected, and the results of *F*-test, Hausman test and joint significance test of time effects indicate that a two-way fixed effects model is more appropriate for regression analysis. Accordingly, the main regression model (1) is established.

$$Innov_{i,t}=a_0+a_1\ Index_{i,t}+a_2\ Control_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (1)$$

Where $Innov_{i,t}$ represents the explanatory variable enterprise innovation, and $Index_{i,t}$ is the level of the development of digital economy at the inter-provincial level, and $Cntrol_{i,t}$ is a series of control variables that may affect the level of enterprise innovation. In order to further analyze the internal mechanism of the digital economy affecting enterprise innovation, the mediating effect test of Wen, et al. [20] is introduced to examine the indirect effect of digital economy on enterprise innovation capability with R&D investment and financing constraints as mediator variables (mediator), respectively. The mechanism test models are (2), (3), and (4).

$$Rd_{i,t} = b_0 + b_1\ Index_{i,t} + b_2\ Control_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$

$$Sa_{i,t} = c_0 + c_1\ Index_{i,t} + c_2\ Control_{i,t} + \mu_i + \lambda t + \varepsilon_{i,t} \quad (3)$$

$$Innov_{i,t} = d_0 + d_1\ Index_{i,t} + d_2\ mediator_{i,t} + d_3\ Cntrol_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (4)$$

3.3 Variable selection

3.3.1 Explained variables: Enterprise innovation performance (Innov)

This paper focuses on innovation output and chooses the number of patent applications as a proxy variable for corporate innovation. It means the total number of inventions, utility model, and design patent applications are used to measure enterprises' innovation performance.

3.3.2 Explanatory variables: Development level of digital economy (Index)

Construction of digital economy development index system: Based on the connotation of digital economy, this paper selects 3 primary indicators of digital infrastructure, development level of digital industry and digital transaction development, and further refines them into 9 secondary indicators (Table 1) to measure the level of digital economy at provincial level.

Table 1 Evaluation indicator system of development level of digital economy

Primary indicator	Secondary indicator	Unit	Direction
Digital infrastructure	Long distance fiber optic cable line length	Kilometers	+
	Number of Internet broadband access subscribers	10 000 households	+
	Cell phone exchange capacity	10 000 households	+
Digital industry development level	Cell phone penetration rate	Department/100 people	+
	Total Telecommunications Business	Billion	+
	Software business revenue	Billion	+
	Cell phone year-end subscribers	10 000 households	+
Digital trading development	Number of websites per 100 companies	Individual	+
	The proportion of enterprises with e-commerce transaction activities	%	+
	E-commerce sales	Billion	+
	Number of computers per 100 people	Number	+

(1) The matrix $X = (xij)_{m\times n}$ is normalized and dimensionless according to the following model. Positive indicators:

$$T_{ij} = \frac{x_{ij} - min(x_{ij})}{max(x_{ij}) - min(x_{ij})} + 0.000\,01;$$

Negative indicators:

$$T_{ij} = \frac{max(x_{ij}) - x_{ij}}{max(x_{ij}) - min(x_{ij})} + 0.000\,01;$$

(2) Calculate the entropy value of the jth indicator:

$$h_j = -\frac{1}{\ln(n)}\sum_{i=1}^{n}\frac{T_{ij}}{\sum_{i=1}^{n} T_{ij}}\ln\frac{T_{ij}}{\sum_{i=1}^{n} T_{ij}};$$

(3) Measurement of the development level of digital economy:

$$U = \sum_{i=1}^{n}[1 - \frac{h_j}{\sum_{i=1}^{n}(1-h_j)}] * \frac{T_{ij}}{\sum_{i=1}^{n} T_{ij}}.$$

3.3.3 Mediating variables

To clarify the impact path of digital economy on enterprise innovation, R&D investment and SA indicator are selected as mediating variables.

In this paper, we use the amount of corporate R&D investment to measure corporate R&D investment (RD). In general, the more money spent on conducting research projects, the higher the likelihood of a enterprise's innovation output.

From the existing studies, the mature methods for quantitative measurement of financing constraints are the KZ indicator proposed by Lamont, et al. [21], the WW indicator proposed by Whited and Wu [22], and the SA indicator proposed by Hadlock and Pierce [23]. To avoid endogeneity, the absolute value of SA index is chosen as the financing constraint indicator in this paper.

3.3.4 Control variables

To control the effects of other variables on innovation performance, the following indicators are selected as control variables. These include net interest rate (*Roa*), enterprise size (*Size*), quick ratio (*Us*), asset-liability ratio (*Debt*), and ownership nature (*Cq*). The details of the definitions are shown in Table 2.

Table 2 Definition and description of control variables

Variable symbol	Variable name	Variable definition
Roa	Profitability	Net income / Total assets
Size	Enterprise size	Logarithmic value of total assets
Us	Quick ratio	Ratio of quick assets to current liabilities
Debt	Financial leverage	Ratio of total liabilities to total assets
Cq	Nature of ownership	State-owned enterprises take the value of 1, and non-state-owned enterprises take the value of 0

4 Empirical analysis

4.1 Descriptive statistics

This paper collected data from a sample of 137 pharmaceutical companies listed in the pharmaceutical industry for 8 years from 2013 to 2020, and finally obtained 1 095 annual company observations. Through the analysis of the descriptive statistics results of the main variables, it is found that the mean value of *Innov* of pharmaceutical companies' innovation performance is greater than the median, and the gap between the maximum value and the minimum value is larger, which indicates that some companies in the sample have more innovation output, which in turn improves the overall average level. Besides, there is a large gap between different companies' innovation performance. The mean value of *Innov* is 23.670, which means that the overall level of innovation of Chinese companies needs to be further improved. The degree of digital economization shows a small mean value, which indicates that the degree of digital economization of pharmaceutical enterprises in China is still in the initial stage, and other control variables also have certain degrees of differences. The results of the specific descriptive analysis were as shown in Table 3.

Table 3 Descriptive analysis

Variable	*N*	Mean	*P*50	SD	Min	Max
Innov	1 095	23.670	14.000	28.855	0.000	149.000
Index	1 095	0.006	0.005	0.005	0.001	0.024
Roa	1 095	0.075	0.062	0.058	0.002	0.285
Size	1 095	3.098	3.096	0.041	3.008	3.193
Us	1 095	2.523	1.644	2.660	0.300	16.536
Debt	1 095	−1.283	−1.180	0.633	−3.135	−0.158
Cq	1 095	0.291	0.000	0.455	0.000	1.000

4.2 Correlation analysis and multicollinearity test

As shown in Table 4, by comparing the correlation and significance levels between the data variables, it can be seen that the level of digital economy and the innovation performance of the enterprises are significantly positive at the 1%, thus initially verifying the accuracy of H1 hypothesis. Then, the mean squared inflation factor method was then used to diagnose all samples of enterprises on a common line (Table 5), and the conclusion showed that each VIF was below 10, allowing further regression analysis of the relationship between the variables.

Table 4 Correlation analysis

Variable	*Innov*	*Index*	*Roa*	*Size*	*Us*	*Debt*	*Cq*
Innov	1.000						
Index	0.152***	1.000					
Roa	0.085***	0.028	1.000				
Size	0.476***	0.205***	0.050*	1.000			
Us	−0.111***	−0.012	0.260***	−0.138***	1.000		
Debt	0.147***	0.001	−0.290***	0.193***	−0.786***	1.000	
Cq	0.060**	0.042	−0.059*	0.135***	−0.143***	0.176***	1.000

Note: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

Table 5 Multicollinearity test

Variable	*Index*	*Roa*	*Size*	*Us*	*Debt*	*Cq*
VIF	1.05	2.76	1.11	2.63	2.76	1.04
1/VIF	0.955 408	0.362 052	0.900 162	0.380 443	0.362 052	0.957 635

4.3 Main regression analysis

To verify the impact of digital economy on the innovation performance of pharmaceutical manufacturing enterprises, a two-way fixed-effects model was used to test the relationship based on the previous econometric model (1), and the results are shown in Table 6.

Table 6 Main regression test

Variable	(1) *Innov*	(2) *Innov*
Index	0.761 2**	0.914 6***
	(2.13)	(2.59)
Roa		0.029 3**
		(2.46)
Size		0.192 6***
		(4.78)
Us		0.000 8**
		(2.00)
Debt		0.003 6*
		(1.71)
Cq		−0.002 4
		(−0.64)
Constant	0.014 6***	−0.577 5***
	(7.69)	(−4.65)
Company FE	Yes	Yes
Year FE	Yes	Yes
Observations	1 095	1 095
R-squared	0.141	0.173

Note: *t*-statistics in parentheses; *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

In column (1) of Table 6, there is a significant positive relationship between digital economy and enterprise innovation performance without any control variables. When control variables are added, the digital economy and enterprise innovation performance are significantly positive at the 1%, indicating that digital economy significantly contributes to the innovation performance of pharmaceutical enterprises. This verifies the previous research hypothesis 1. The coefficient of net interest rate (*Roa*) is positive because the increase in enterprise profitability motivates enterprises to have more capital for R&D and innovation activities. The coefficient of enterprise size (*Size*) is significantly positive, which indicates that with the increase of enterprise size, the company is able to use more human and material resources, and its risk resistance is also improved. Therefore, it can carry out high-risk and high-reward technological innovation activities. The coefficient of the quick ratio (*Us*), which is often used to measure unabsorbed redundancy, is significantly positive, indicating that as unabsorbed redundancy increases, managers are able to reduce unnecessary expenditures through intensive monitoring and to transform these funds to protect enterprises' R&D innovation. The asset-liability ratio (*Debt*) has an effect on the innovation performance of pharmaceutical industry, while ownership nature (*Cq*) has no significant effect.

4.4 Impact mechanism test

Based on the results of the above empirical analysis, it can be seen that the digital economy can significantly improve the innovation performance of pharmaceutical manufacturing industry. To verify the hypothesis that the digital economy affects the innovation of pharmaceutical manufacturing industry, that is, the digital economy affects the innovation of enterprises through R&D investment and financing constraints, the rationality and feasibility of the above mechanism will be discussed by using the intermediary effect model, as shown in Table 7.

Table 7 Intermediary role test

Variable	(1) *Innov*	(2) *Rd*	(3) *Innov*	(4) *Sa*	(5) *Innov*
Index	0.914 6***	0.136 4***	0.670 5*	−0.381 3***	0.753 2**
	(2.59)	(7.86)	(1.85)	(−6.00)	(2.10)
Rd			1.789 6***		
			(2.71)		
Sa					−0.423 2**
					(−2.35)
Roa	0.029 3**	0.000 7	0.028 1**	0.002 3	0.030 3**
	(2.46)	(1.16)	(2.37)	(1.07)	(2.55)
Size	0.192 6***	0.014 8***	0.166 2***	0.084 1***	0.228 2***
	(4.78)	(7.45)	(4.02)	(11.59)	(5.32)
Us	0.000 8**	0.000 0	0.000 8*	−0.000 2***	0.000 7*
	(2.00)	(1.01)	(1.92)	(−2.72)	(1.79)
Debt	0.003 6*	−0.000 0	0.003 6*	−0.000 6	0.003 3
	(1.71)	(−0.23)	(1.74)	(−1.53)	(1.59)
Cq	−0.002 4	0.000 0	−0.002 5	−0.001 3*	−0.003 0
	(−0.64)	(0.07)	(−0.65)	(−1.94)	(−0.79)
Constant	−0.577 5***	−0.045 3***	−0.496 5***	0.115 2***	−0.528 8***
	(−4.65)	(−7.42)	(−3.90)	(5.14)	(−4.21)
Company FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	1 095	1 095	1 095	1 095	1 095
R-squared	0.173	0.379	0.180	0.929	0.178

Columns (1) to (3) of Table 7 are used to verify the mediating role of R&D investment. According to the research method of Wen and Ye [20], firstly, the relationship between digital economy and enterprises' innovation capability is examined. The column of Table 7 (1) shows that the development of digital economy can significantly enhance the innovation capability of enterprises at 1%. Then, the regression of model (2) is conducted by adding the R&D investment variable. The results show that the estimated coefficients of the development of digital economization are positive at 1%, indicating that the development of digital economy will drive companies to expand the scale of R&D investment. Combining with column (3), we can find there is a partial mediating effect of R&D investment between digital economy and enterprises' innovation performance. The proportion of the mediating effect to the total effect is $b_1 \times d_2 / a_1 = 0.136\ 4 \times 1.789\ 6 / 0.914\ 6 = 0.\ 267$. Therefore, the proportion of the mediating effect to the total effect is 26.7%, thus verifying the research H2. It means digital economy promotes enterprises to increase their R&D investment, which in turn improves their innovation performance.

Columns (1), (4), and (5) of Table 7 are used to verify the mediating role of financing constraints. The test results in column (4) of Table 7 show that the regression coefficient of the digital economy on the SA index is significantly negative at the 1%, indicating that the digital economy can significantly alleviate the financing constraints of enterprises. Therefore, the higher the level of development of the digital economy, the lower the degree of financing constraints suffered by enterprises. The regression results in column (5) show that the regression coefficient after controlling the SA index is significantly negative at the 5% and the coefficient of the impact of digital economy on enterprise innovation performance in equation (5) decreases compared with equation (1), indicating that the total effect of digital economy on enterprise innovation performance (coefficient of 0.914 6) is higher than the direct effect of its impact on enterprise innovation performance (coefficient of 0.753 2), there is a partial mediating effect of financing constraints between digital economy and enterprise innovation performance, and its mediating effect as a percentage of the total effect is $c_1 \times d_2 / a_1 = (-0.381\ 3) \times (-0.423\ 2) / 0.914\ 6 = 0.176$. So, the proportion of the mediating effect to the total effect is 17.6%. Thus, the research H3 is verified. Digital economy can improve the innovation performance of enterprises by alleviating their financing constraints.

4.5 Robustness test

4.5.1 Replacement of enterprise innovation measurement indicators

To ensure the robustness of the regression results, this paper seeks other alternative indicators to assess the innovation capability of enterprises. According to the innovation performance measure applied by Yu, et al. [24], the number of invention patent, utility model and product design applications of listed pharmaceutical companies are weighted by 0.5, 0.3 and 0.2, and they are used to measure the innovation performance of enterprises [25]. The total number of invention patents granted by listed companies is used to measure the innovation level of enterprises. The regression results after replacing the indexes are basically consistent with the baseline regression results.

4.5.2 Innovation performance lagging one stage

Given the lagging effect of digital economy on enterprise innovation performance, we adopt a robustness test on enterprise innovation performance data with a one-stage lag. The results show that the significance of the new indicators in capturing the enterprise innovation scenario for the variables is largely consistent with the regression findings above. The conclusions still support the original hypothesis that the findings are robust.

5 Key findings and related recommendations

5.1 Key findings

This paper empirically investigates the impact of the digital economy on the innovation performance of listed companies in pharmaceutical industry using a two-way fixed effects model, and analyzes its mechanism of action through a mechanism test to draw the following conclusions.

Firstly, in general, the impact of digitalization level on enterprises' innovation performance is positive. So, the increase of digitalization level will promote the improvement of enterprises' innovation performance.

Secondly, in terms of the impact mechanism, digital economy can play an internal and external synergistic enhancement effect on the innovation performance of enterprises by increasing their R&D investment and alleviating financing constraints.

5.2 Related recommendations

Firstly, we should actively explore more multi-dimensional ways to use digital economy to promote enterprise innovation, fully releasing the positive effects of the digital economy, actively promoting the combination of network, information, and the real economy. Then, we can further strengthen the investment in the network field to create a good digital operating environment.

Secondly, we should stimulate the innovation enthusiasm of pharmaceutical enterprises and promote the improvement of innovation performance. R&D investment is the inexhaustible motivation for pharmaceutical enterprises to maintain sustainable development. Increasing R&D investment in pharmaceutical enterprises can allow them to have more drug patents and improve their performance while enhancing their market competitiveness.

Thirdly, we should actively promote the market-oriented reform of financial services, continue to expand corporate financing channels, thus providing sufficient capital for high-quality innovation. At the same time, enterprises should find the focus and entry point when dealing with internal and external financing constraints, which will enhance the effectiveness of corporate innovation and corporate progress.

References

[1] China Academy of Information and Communications Technology. White Paper on China's Digital Economy Development (2021) [EB/OL]. (2021-04-23)[2022-04-15]. http: //www.Caict.ac.cn /kxyj /qwfb /bps/ 202104 / P020210424737615413306.pdf.

[2] Min Lulu, Xu Zhengzhong. Digital economy, innovation performance and high-quality economic development − empirical evidence from Chinese cities [J]. Statistics & Decision, 2022, 38 (3): 11-15.

[3] Akcigit U, Caicedo S, Miguelez E, et al. Dancing with the stars: Innovation through interactions [R]. CEPR Discussion Papers, 2018.

[4] Xiong Li, Cai Xuelian. The impact of digital economy on the improvement of regional innovation ability: Empirical research based on the panel data of Yangtze River delta [J]. East China Economic Management, 2020, 34 (12): 1-8.

[5] Shen Minghao, Tan Weijie, Chen Zhaoying. The impact of digital economy development on corporate innovation − empirical evidence based on A-share listed companies [J]. South China Finance, 2022 (2): 30-44.

[6] Dang Lin, Li Xuesong, Shen Shuo. Digital economy, innovation milieu and cooperative innovation performance [J]. Journal of Shanxi University of Finance and Economics, 2021, 43 (11): 1-15.

[7] Wen Jun, Yan Zhijun, Cheng Yu. Digital economy and upgrading regional innovation capacity [J]. Inquiry into Economic Issues, 2019 (11): 112-124.

[8] Ma Yanran, Cai Jianfeng, Wang Miao. The impact of venture capital background, shareholding ratio on start-up innovation output [J]. Science & Technology Progress and Policy, 2018, 35 (15): 1-8.

[9] Li Xianjun, Wang Wei, Liu Wenchao. Research on the relationship among ownership attribution, innovation input and firm performance of listed auto companies in China [J]. Management Review, 2018, 30 (2): 71-82.

[10] Xia Jiechang, Yao Zhanqi, Xu Ziyan. A study on the impact of digital economy on regional innovation in China [J]. Social Science Front, 2021 (6): 67-78+281+282.

[11] Zhang Jie, Lu Zhe, Zheng Wenping, et al. Financing constraints, financing channels and corporate R&D investment [J]. The Journal of World Economy, 2012, 35 (10): 66-90.

[12] Tang Song, Wu Xuchuan, Zhu Jia. Digital finance and enterprise technology innovation: Structural feature, mechanism identification and effect difference under financial supervision [J]. Journal of Management World,

2020, 36 (5): 52-66+9.

[13] Wang Xingyu, Wan Yuanyuan. Investor perceptions, financing constraints and enterprise innovation [J]. Friends of Accounting, 2022 (4): 62-69.

[14] Dong Kunkun, Wang Qi. Social capital, financing constraints and innovation performance of artificial intelligence firms [J]. The Word of Survey and Research, 2021 (12): 43-50.

[15] Shen Hongbo, Kou Hong, Zhang Chuan. An empirical study of financial development, financing constraints and corporate investment [J]. China Industrial Economics, 2010 (6): 55-64.

[16] Li Yanlong, Peng Jin, Luo Tianzheng. Digitalization, spillover effect and enterprise performance [J]. Journal of Industrial Technological Economics, 2022, 41 (3): 25-33.

[17] Huang Hongbin, Zhai Shuping, Sun Xuejiao. Information disclosure of we-media and financing constraints [J]. Contemporary Finance & Economics, 2020 (7): 87-99.

[18] Sheng Sisi, Xu Zhan. The influence of regional digital economy development on enterprises financing constraints [J]. Journal of Industrial Technological Economics, 2022, 41 (1): 21-28.

[19] Hu Shan, Yu Yongze. Digital economy and corporate innovation: Breakthrough or incremental innovation? [J]. Research on Finance and Economics Issues, 2022 (1): 42-51.

[20] Wen Zhonglin, Ye Baojuan. Analyses of mediating effects: The development of methods and models [J]. Advances in Psychological Science, 2014, 22 (5): 731-745.

[21] Lamont O, Polk C, Saá-Requejo J. Financial constraints and stock returns [J]. Review of Financial Studies, 1997, 14 (2): 529-554.

[22] Whited TM, Wu GJ. Financial constraints risk [J]. Review of Financial Studies, 2006, 19 (2): 531-559.

[23] Hadlock CJ, Pierce JR. New evidence on measuring financial constraints: Moving beyond the KZ index [J]. Review of Financial Studies, 2010, 23 (5): 1909-1940.

[24] Yu Yongze, Liu Dayong. The effect of the space outflow of China's regional innovation and the effect of the outflow of value chains: A study, from the perspective of the innovative value chain, on the model of the panel of multidimensional space [J]. Journal of Management World, 2013 (7): 6-20+70+187.

[25] Jiang Dianchun, Pan Xiaowang. The effect of digital economic development on the enterprise innovative performance: Based on the empirical evidence of listed companies in China [J]. Journal of Shanxi University (Philosophy and Social Science Edition), 2022, 45 (1): 149-160.