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Research on the Influence of Enterprise Digitalization on R&D Innovation

-- Based on the Stock Market Data of Listed Companies in China

Junjie Chen

Jiangxi University of Finance and Economics, Nanchang, Jiangxi Province, 330006, China

Abstract: With the development of scientific and technological innovation and digital economy, more and more enterprises choose to implement digital transformation to enhance their influence. This paper takes China Shanghai and Shenzhen A-share listed companies from 2010 to 2020 as samples, obtains the keywords related to "digital transformation" in the annual report of enterprises with the help of crawler technology, and empirically tests the influence of digitalization of listed companies on enterprise R&D innovation under the background of social digital reform and innovation. The results show that the digital transformation of enterprises can significantly improve the R&D innovation of enterprises, that is, the higher the degree of digital transformation of enterprises, the more R&D innovation of enterprises. The above conclusions are still valid after endogenous test and robustness test. This study enriches the relevant literature on promoting R&D innovation in enterprises, and provides empirical evidence for the management of enterprises to carry out high-quality R&D innovation.

Keywords: Enterprise digitalization, R&D innovation, Fixed effect model, Patent.

1. Introduction

1.1. Background of topic selection and research contents

1.1.1. Background of the selected topic

With the continuous emergence of "ABCD" technologies (artificial intelligence, blockchain, cloud computing, big data), digitalization has become an important breakthrough point for innovation and change of global enterprises. At present, great changes have taken place in the development environment of enterprises, and the data processing capacity has leapt from KB level to PB level. In the 14th Five-Year Plan for People's Republic of China (PRC)'s National Economic and Social Development and the Outline of Long-term Goals in 2035 (hereinafter referred to as the 14th Five-Year Plan), digitalization has become a development goal that is described in a centralized way. Digital transformation has an important impact on the implementation of national digital strategy, especially after the COVID-19 epidemic in 2020 caused a major impact on China and even the global economy and society, the process of social digital transformation and innovation is even more urgent.

In addition, in the Tenth Five-Year Plan, "digitalization" was given 25 expressions. Especially in the fifth chapter, the development goal of digitalization has been described centrally, and its development has been made important arrangements. This shows that digitalization has become an important and basic part of national construction. At the same time, after the COVID-19 epidemic in 2020 has caused a great impact on China and even the global economy and society, the process of social digital transformation and innovation is even more urgent. As a micro-organization of social economy, the digital transformation of enterprises has a decisive impact on the implementation of national digital strategy. Therefore, it is of great significance to explore the influence of enterprise digital transformation on enterprise R&D innovation and promote the practice of digital transformation of listed enterprises in China.

However, at present, there are few documents that can accurately link "enterprise digitalization-enterprise R&D innovation" and reveal the influence relationship between them. In view of this, this paper intends to identify and test the influence relationship of "enterprise digitalization-enterprise R&D innovation", and provide new evidence for understanding the digital transformation performance and innovation development of listed enterprises in China.

1.1.2. Research significance

The possible marginal contribution of this paper lies in that, in the research conception, the enterprise digitalization in China in the new era is linked with enterprise R&D innovation, and the relationship between them is deeply analyzed, so as to enrich the understanding of the interactive mode between enterprise innovation development and enterprise digital transformation; On the research data, based on the text recognition function of Python crawler and the annual reports of A-share listed companies in Shanghai and Shenzhen stock markets, this paper uses the method of keyword frequency statistics to describe the digital transformation level of enterprises, which provides useful reference for evaluating the digital transformation of enterprises and its economic effects. In the research paradigm, it provides a research framework of "theoretical research-benchmark analysis-multiple tests-research result analysis" to discuss the influence of enterprise digitalization on enterprise R&D innovation.

1.2. Research contents

The purpose of this paper is to study the influence of enterprise digitalization on enterprise R&D innovation under the background of digital economy development by empirical method. Therefore, we have processed the financial and annual report data of listed companies in Shanghai and Shenzhen A-shares from 2010 to 2020, and constructed a complete variable structure. On this basis, grasp the relationship between variables, establish an effective fixed

effect model, and conduct multiple collinearity, robustness and endogenous tests to solve possible problems. Finally, this paper summarizes the empirical analysis results and puts forward corresponding conclusions and policy suggestions.

1.3. Research methods

This study uses the fixed effect model to explore the relationship between enterprise digitalization and enterprise R&D innovation. At the same time, multiple collinearity test, robustness test and endogenous test are carried out to ensure the reliability and effectiveness of the results.

1.4. Innovation

First, building a digital China is an important engine to promote Chinese modernization in the digital age and a powerful support to build a new competitive advantage for the country. In this context, it is of practical significance to study the influence of enterprise digitalization on enterprise R&D innovation, which can provide effective reference for the sustainable development of enterprise innovation.

Secondly, when measuring the R&D innovation of enterprises, this paper adopts the method of analyzing the total number of enterprise patent applications, and further proves it by analyzing the total number of invention patents and the total number of utility model patents, which improves the credibility of the research conclusions.

2. Literature Review

2.1. Research on Enterprise Digitalization

Digitalization of enterprises means that enterprises make comprehensive use of digital technology to continuously adjust the structure and operation of organizations in terms of value chain, business process and product and service innovation, so as to encourage enterprises to increase income, improve business, replace or convert business processes, and create a digital business environment with digital information as the core [1].

Academic views generally believe that digitalization brings new business opportunities, promotes technological innovation and operational efficiency of enterprises [2], and fundamentally changes the product creation process, service reengineering process and operational environment level of enterprises [3]. Digitalization has a far-reaching impact on the development of enterprises [4], which can help enterprises acquire knowledge and resources and reconstruct their business logic.

The wide application of enterprise digitalization has promoted the significant improvement of production technology level, thus bringing obvious advantages in profit acquisition and performance improvement [5]. However, with the increasing variety of digital technologies, the investment of researchers and R&D funds will also increase accordingly. In the absence of sufficient human resources and R&D funds, it may be unfavorable for enterprise innovation to conduct multiple technological researches at the same time. In addition, there is a huge gap between the requirements of resources and capabilities for developing a number of digital technologies at the same time and the existing resources and capabilities of enterprises, which makes it difficult for enterprises to effectively use a variety of technologies [6], which not only can not better promote enterprise innovation, but may inhibit enterprise innovation.

2.2. Research on R&D Innovation of Enterprises

The connotation of R&D innovation was intuitively defined as a brand-new product invention or greatly improved product accepted by the market and consumers in the early stage [7], and then the focus was gradually placed on the innovation of enterprise soft power, mainly in the aspect of strategic management ability, including enterprise organizational management structure, enterprise culture and resource integration ability [8]. Technological innovation is enterprise innovation in a narrow sense, while innovation in management, organization, technology and system belongs to enterprise innovation in a broad sense[9]. In view of the literature on the connotation and composition of enterprise innovation retrieved by SSCI in recent 30 years, the connotation, composition and evolution of enterprise innovation ability have finally been clarified by contacting various viewpoints [10].

From the enterprise level, this paper discusses the influencing factors of R&D innovation. Earlier studies concluded that R&D investment is directly proportional to the enterprise scale by analyzing the R&D expenditure of the top 500 enterprises [11]. The empirical analysis of the company's ownership structure as an influencing factor of enterprise innovation shows that both shareholder supervision and equity concentration can alleviate the agency problem of enterprises, thus increasing innovation investment [12]. Under the current enterprise system, most enterprise clients will show short-sighted behavior, aiming at pursuing short-term interests. Because R&D innovation is a long-term investment with risks, it will directly lead enterprises to reduce R&D investment [13]. The R&D investment of high-tech enterprises mainly depends on internal financing and stock financing [14].

In any case, the progress of R&D and innovation has always been regarded as the engine of economic development. Enterprises that innovate constantly can usually develop continuously, while enterprises that ignore innovation may stagnate [15]. In a complete market economy, maintaining the leading position in R&D and innovation is very important and decisive for the performance of enterprises. The decision of enterprise management on R&D innovation will have an impact on the future growth, sustainability and reputation of the enterprise. R&D innovation is no longer regarded as a development or cost, but a potential wealth investment with value-added function [16].

2.3. Literature review

To sum up, in recent years, many scholars at home and abroad have carried out rich research on the relationship between enterprise digitalization and enterprise R&D innovation[17]. In the selection of indicators, scholars mainly collect data by designing the indicator system of the scale and issuing questionnaires, while there are relatively few literatures about using publicly available objective data to construct indicators for empirical research. Recent studies have gradually begun to pay attention to the innovation-driven effect of digitalization from the national, regional or enterprise level, but the discussion on the micro-mechanism is still not profound, and there are few literatures concerned about the nonlinear influence of enterprise digitalization on enterprise R&D and innovation.

In view of this, with the help of objective data, this paper

measures the degree of digitalization of enterprises by the frequency of digitalization-related words in enterprise annual reports. The method of measuring the R&D innovation degree of enterprises based on the objective data of enterprises is adopted. In terms of research methods, this paper analyzes the relationship between the two through quantitative methods, selects China's A-share listed companies as research samples, and establishes a fixed effect model to quantitatively analyze the impact of enterprise digitalization on enterprise R&D innovation. I hope to provide concrete and effective suggestions for enterprises to use digitalization to promote R&D innovation and improve their performance in the future through empirical methods.

3. Data Processing and Descriptive Statistics

3.1. Data Source and Processing

The data used in this article mainly comes from three parts: one is the China City Statistical Yearbook; The second is CNRDS database; The third is CSMAR database. Considering the availability of data comprehensively, in order to test the influence of enterprise digitalization on enterprise R&D innovation, this paper mainly selects the data of China's Shanghai and Shenzhen A-share listed companies as research samples, and the time span is 2010-2020. Among them, the number of enterprise patent applications comes from CNRDS database, the data of enterprise digital transformation degree, high-tech enterprise identification data and other financial variables all come from CSMAR database, and the rest indicators come from China City Statistical Yearbook.

In order to ensure the rationality and validity of the data, the obtained data are processed as follows: first, the samples withdrawn from the market during ST and period are excluded; Second, delete the part with missing data values; Thirdly, in order to reduce the influence of outliers, this paper truncates all micro-level continuous variables by 1% and 99%.

3.2. Selection and construction of main indicators

3.2.1. Interpreted variables

The explained variable in this paper is enterprise R&D innovation. In this paper, the R&D innovation of enterprises is measured according to the total number of patent applications (R&D). At the same time, in order to further deepen the research, this paper analyzes the total number of invention patents (R&D1) and the total number of utility model patents (R&D2). Patents are the result of innovation output of enterprises, and the demand for R&D investment of invention patents and utility model patents is higher than that of non-invention patents. Therefore, the total number of patent applications can better represent the innovation will of managers, which is consistent with the basic logic studied in this paper.

3.2.2. Explanatory variables

The explanatory variable in this paper is the degree of digital transformation (DCG). Digital transformation of enterprises is an important strategy for high-quality development of enterprises in the new era, and this kind of characteristic information is more easily reflected in the annual report of enterprises with summary and guidance. The vocabulary usage in the annual report can reflect the strategic characteristics and future prospects of enterprises, and to a great extent, reflect the business philosophy that enterprises admire and the development path under the guidance of this concept. Therefore, it is feasible and scientific to describe the degree of transformation from the perspective of word frequency statistics related to "digital transformation of enterprises" in the annual report of listed enterprises. Therefore, this paper measures the frequency of corresponding keywords in the annual report published by listed companies as the proxy index of the degree of digital transformation of enterprises. The specific steps are as follows: firstly, this paper uses Python to crawl the annual reports of listed companies and convert them into TXT format; Then, word segmentation is carried out. In this paper, "Jieba" Chinese word segmentation module is used to segment the studied text. Finally, using the word segmentation dictionary built by Zhao Chenyu (2021) for reference, including Internet mode, digital technology application, intelligent manufacturing and modern information system, Python is used to crawl the related words in the annual report and calculate the word frequency. Because of the right bias of the data, this paper adopts the value after taking the natural logarithm as the measurement index of the degree of digital transformation of enterprises.

3.2.3. Control variables

In order to improve the research accuracy, a series of control variables are added in this paper. Including enterprise scale (Size), asset-liability ratio (Lev), total return on assets (Roa), ratio of Cash to total assets (cash), Board size (board), ratio of independent directors (Indep) and book-to-market ratio (BM). See Table 1 for detailed definitions of variables.

3.3. Descriptive statistic

Table 2 shows the descriptive statistical results of the main variables. After deleting the missing samples, the total number of samples is 26819. The average value of invention patent application and utility model patent application is 1.972732 and 2.053683, respectively, and the difference is small, but the average value of the total number of patent applications is 2.646852, and the standard deviation is 1.817558, indicating that the overall performance of listed companies in China is unstable. In the aspect of enterprise digitalization, the standard deviation of the degree of digital transformation is 1, the minimum value is -2.16744, and the maximum value is 3.29293, which shows that there are significant differences in digitalization among different listed companies. The standard deviation of the board size is large, which is 2.392885, but there is almost no difference in the proportion of independent directors, indicating that the board of directors of listed companies has basically achieved unity in form. Among other control variables, the standard deviation of enterprise scale is relatively small and the distribution is symmetrical. The average and standard deviation of asset-liability ratio, total return on assets, cash-to-total assets ratio and book-to-market ratio are quite the same, which shows that there is little difference in the performance of listed companies in these aspects.

Table 1. Definition of main variables

Variables type	Variables name	Symbol	Definition of variables
Explanatory variable	Degree of digital transformation	DCG	From internet mode, digital technology application, intelligent manufacturing, Modern information system and other four aspects, using word frequency statistics to log again
Explained variable Enterprise R&D innovation	Total number of patent applications	R&D	All are based on the number of patent applications of listed companies in the next issue. Add 1 and take the natural logarithm.
	Total application for invention patents	R&D1	
	Total number of applications for utility model patents	R&D2	
Control variable	Scale	Size	Operating income takes natural logarithm.
	Asset-liability ratio	Lev	Total liabilities/total assets
	rate of return on total assets	Roa	Net profit/total assets
	Ratio of cash to total assets	Cash	Net cash from operating activities/total assets
	Board size	Board	The number of directors shall be taken as natural logarithm.
	Proportion of independent directors	Indep	Proportion of independent directors
	Book to market ratio	BM	Total shareholders' equity/market value of the company

Table 2. Results of Descriptive statistic

VARIABLES	(1) Obs	(2) Mean	(3) Sd	(4) Min	(5) Max
Total number of patent applications	22,249	2.646852	1.817558	0	9.606967
Application for invention patent	22,249	1.972732	1.625897	0	9.074292
Application for patent for utility model	22,249	2.053683	1.715577	0	8.904766
Degree of digital transformation	26,819	1.33e-16	1	-2.16744	3.29293
Scale	26,818	21.48769	1.500092	13.53741	28.7183
Asset-liability ratio	26,819	0.4352195	0.213495	0.00708	4.025975
rate of return on total assets	26,819	0.0323848	0.0954706	-4.94645	0.7858651
Ratio of cash to total assets	26,818	0.1584301	0.1261997	-0.059826	0.972426
Board size	26,819	9.398635	2.392885	3	27
Proportion of independent directors	26,819	0.3781332	0.0654945	0.1666667	0.8
Book to market ratio	26,819	0.297686	0.1637285	-0.342593	2.292028

4. Measurement Model and Estimation Method

4.1. Benchmark model and estimation method

In order to verify the influence of enterprise digitalization on its R&D innovation, this paper adopts the benchmark measurement model and the regression model is set as follows:

$$R\&D = \mu_t + v_i + \beta_1 DCG_{it} + \beta_2 Controls_{it} + \varepsilon_{it} \quad (1)$$

In model (1), the explanatory variable is the total number of patent applications (R&D), the explanatory variable is the degree of digital transformation (DCG), and the Controls are the control variables of this paper, including enterprise Size, asset-liability ratio (Lev), total return on assets (Roa), Cash to total assets (Cash), Board size and the proportion of independent directors. Considering that there are great individual differences in R&D innovation of different enterprises and the R&D changes with the time trend, this paper also controls the year fixed effect (μ_t) and the company-level individual fixed effect (v_i), and ε is a random disturbance term.

In order to further study the impact of R&D innovation of enterprises, this paper constructs model (2) and model (3) to test the impact of the degree of digital transformation of enterprises on the total number of invention patents (R&D1) and utility model patents (R&D2) respectively, which can also prove the results of model (1). The specific models are as follows:

$$R\&D1 = \mu_t + v_i + \beta_1 DCG_{it} + \beta_2 Controls_{it} + \varepsilon_{it} \quad (2)$$

$$R\&D2 = \mu_t + v_i + \beta_1 DCG_{it} + \beta_2 Controls_{it} + \varepsilon_{it} \quad (3)$$

4.2. Possible problems and solutions of the model

4.2.1. Multicollinearity

In this paper, VIF variance expansion factor is used to test multicollinearity. From the Mean VIF of 1.68 (close to 1), we can see that the multicollinearity in this paper is weak, and it passes the test.

Table 3. Test of multicollinearity

Variable	VIF	1/VIF
Degree of digital transformation	2.05	0.487058
Scale	2.15	0.465019
Asset-liability ratio	3.32	0.300873
rate of return on total assets	1.36	0.735190
Ratio of cash to total assets	1.47	0.680127
Board size	1.23	0.813336
Proportion of independent directors	1.14	0.875442
Book to market ratio	1.94	0.515585
Mean VIF	1.68	

4.2.2. Robustness test

4.2.2.1 The endogenous problem is a part of the robustness problem. For the endogenous problem of missing variables, this paper adopts the panel fixed effect model, which is an important way to solve the endogenous problem.

In this analysis, we add two control variables "fixed assets ratio" and "enterprise age", and the results are shown in Table 4. Items (1), (3) and (5) are listed as the results without adding control variables. The results show that there is a significant positive correlation between enterprise digitalization and enterprise R&D innovation at the level of 1%; Columns (2), (4) and (6) are the results of adding control variables, and the coefficient of DCG is significantly positive at 1% level. The results show that there is a significant positive correlation between enterprise digitalization and enterprise R&D innovation, that is, the higher the degree of enterprise digitalization transformation, the more enterprise R&D innovation, which is consistent with the results in Table 6.

Table 4. Robustness test: add two control variables

	(1) Total number of patent applications	(2) Total number of patent applications	(3) Application for invention patent	(4) Application for invention patent	(5) Application for patent for utility model	(6) Application for patent for utility model
Degree of digital transformation	0.385***	0.198***	0.385***	0.213***	0.283***	0.124***
	(30.149)	(17.029)	(31.695)	(19.219)	(23.378)	(11.018)
Scale		0.544***		0.506***		0.472***
		(68.160)		(66.489)		(61.119)
Asset-liability ratio		-0.718***		-0.777***		-0.451***
		(-10.286)		(-11.668)		(-6.689)
Proportion of fixed assets		-0.029		-0.210***		0.234***
		(-0.417)		(-3.134)		(3.449)
rate of return on total assets		0.511***		0.421***		0.327**
		(3.706)		(3.203)		(2.453)
Ratio of cash to total assets		-0.254***		-0.117		-0.277***
		(-3.289)		(-1.586)		(-3.706)
Board size		0.019***		0.019***		0.012***
		(5.271)		(5.296)		(3.342)
Proportion of independent directors		0.005		-0.006		-0.029
		(0.040)		(-0.052)		(-0.231)
Book to market ratio		-0.528***		-0.680***		-0.339***
		(-7.727)		(-10.431)		(-5.128)
Enterprise age		-0.000		0.006***		-0.000
		(-0.031)		(4.200)		(-0.228)
_cons	1.638***	-9.984***	1.378***	-9.386***	0.758***	-9.382***
	(10.557)	(-46.463)	(9.343)	(-45.776)	(5.154)	(-45.159)
N	22249	22248	22249	22248	22249	22248

Note: * * *, * * and * indicate significant at the level of 1%, 5% and 10% respectively, and t value is in brackets. The following table is the same.

4.2.2.2 Robustness test examines the robustness of the explanatory power of evaluation methods and indicators, that is, whether evaluation methods and indicators still maintain a relatively consistent and stable explanation of evaluation results when some parameters are changed. In order to examine the robustness of the empirical results, we removed all the data in 2010 to verify whether the main conclusions are still valid, and the results are shown in Table 5. Whether control variables are added or not, the results show that there is a significant positive correlation between enterprise digitalization and enterprise R&D innovation at the level of 1%, that is, the higher the degree of enterprise digitalization transformation, the more enterprise R&D innovation, which is consistent with the results in Table 6.

Table 5. Robustness test: delete the 2010 sample

	(1) Total number of patent applications	(2) Total number of patent applications	(3) Application for invention patent	(4) Application for invention patent	(5) Application for patent for utility model	(6) Application for patent for utility model
Degree of digital transformation	0.390***	0.201***	0.389***	0.212***	0.289***	0.124***
	(29.506)	(17.077)	(30.940)	(18.857)	(23.080)	(10.891)
Scale		0.551***		0.521***		0.478***
		(68.197)		(67.561)		(61.097)
Asset-liability ratio		-0.705***		-0.762***		-0.436***
		(-9.803)		(-11.073)		(-6.246)
Proportion of fixed assets		0.513***		0.390***		0.308**
		(3.681)		(2.926)		(2.274)
rate of return on total assets		-0.256***		-0.075		-0.344***
		(-3.260)		(-1.001)		(-4.522)
Ratio of cash to total assets		0.020***		0.019***		0.013***
		(5.143)		(5.221)		(3.494)
Board size		-0.052		-0.087		-0.076
		(-0.393)		(-0.681)		(-0.590)
Proportion of independent directors		-0.507***		-0.685***		-0.318***
		(-7.262)		(-10.256)		(-4.693)
_cons	1.772***	-9.960***	1.470***	-9.564***	0.870***	-9.336***
	(10.931)	(-44.714)	(9.525)	(-44.928)	(5.652)	(-43.218)
N	20848	20847	20848	20847	20848	20847

5. Empirical Analysis Results

Table 6 shows the regression results of the influence of enterprise digitalization on enterprise R&D innovation. Items (1), (3) and (5) are listed as the results without control variables. The results show that there is a significant positive correlation between the digital transformation of enterprises and the R&D innovation of enterprises at the level of 1%, and the total number of patent applications of enterprises will increase by 0.385 units, the number of invention patents will increase by 0.385 units and the number of utility model patents will increase by 0.283 units for each unit of digital transformation. Items (2), (4) and (6) are the results of adding control variables. The coefficient of digital transformation degree of enterprises is significantly positive at the level of 1%, and under the control of other variables, the total number of patent applications of enterprises will increase by 0.198 units, the number of invention patents will increase by 0.211 units, and the number of utility model patents will increase by 0.120 units. The results show that there is a significant positive correlation between enterprise digitalization and enterprise R&D innovation, that is, the higher the degree of enterprise digitalization transformation, the more enterprise R&D innovation.

6. Conclusion and Policy Suggestions

6.1. Research conclusion

In the context of the rapid development of digital economy, it is of great practical significance to explore the impact of enterprise digitalization on R&D innovation, that is, it can not only verify the economic consequences of macroeconomic situation changes from the micro level, but also provide decision-making reference for enterprise transformation and upgrading. Therefore, this paper takes China's Shanghai and Shenzhen A-share listed companies from 2010 to 2020 as research samples, and empirically tests the impact of enterprise digitalization on enterprise R&D innovation. The results show that: (1) the degree of digital transformation of enterprises has significantly promoted the improvement of R&D innovation level, and the results are robust; (2) The test of R&D innovation output results shows that the digital transformation of enterprises has significantly promoted the increase of the number of invention patents. Comparatively speaking, it has little effect on promoting the increase of the number of enterprise utility model patents. This shows that the digital transformation of enterprises plays an important role in promoting high-quality innovation of enterprises.

Table 6. Enterprise Digitalization and Enterprise R&D Innovation

	(1) Total number of patent applications	(2) Total number of patent applications	(3) Application for invention patent	(4) Application for invention patent	(5) Application for patent for utility model	(6) Application for patent for utility model
Degree of digital transformation	0.385***	0.198***	0.385***	0.211***	0.283***	0.120***
	(30.149)	(17.364)	(31.695)	(19.317)	(23.378)	(10.823)
Scale		0.544***		0.512***		0.472***
		(69.643)		(68.627)		(62.575)
Asset-liability ratio		-0.718***		-0.757***		-0.456***
		(-10.302)		(-11.388)		(-6.762)
Proportion of fixed assets		0.514***		0.397***		0.308**
		(3.744)		(3.028)		(2.321)
rate of return on total assets		-0.247***		-0.070		-0.334***
		(-3.280)		(-0.968)		(-4.597)
Ratio of cash to total assets		0.019***		0.019***		0.012***
		(5.264)		(5.380)		(3.456)
Board size		0.005		-0.044		-0.023
		(0.038)		(-0.357)		(-0.181)
Proportion of independent directors		-0.529***		-0.703***		-0.333***
		(-7.753)		(-10.796)		(-5.055)
_cons	1.638***	-9.987***	1.378***	-9.500***	0.758***	-9.350***
	(10.557)	(-46.759)	(9.343)	(-46.584)	(5.154)	(-45.266)
N	22249	22248	22249	22248	22249	22248

6.2. Policy advice

First, the digital transformation of enterprises is of great significance for improving the level of R&D innovation of enterprises. In today's fierce market competition environment, enterprises should fully grasp the opportunity of digital transformation, attach importance to the transparency construction of information and operating environment, and effectively combine digital technology with enterprise production and operation based on sufficient internal and external information, so as to promote the improvement of production and operation efficiency and R&D innovation level and realize sustainable development.

Second, with the rapid development of digital economy, digital transformation has become an important market mechanism to promote high-quality innovation of enterprises. Although the government's industrial policy of encouraging innovation can play a certain role, it is easy to induce low-quality innovation and affect the competitive advantage and resource allocation of enterprises. Therefore, we should combine policy support, realize the two-pronged approach of innovation motivation and innovation ability incentive, and promote high-quality innovation of enterprises and high-quality economic development.

Third, in the process of digital transformation, the operational efficiency advantage formed by big data has become a new engine for performance improvement. Enterprises should continue to promote the market-oriented allocation of data elements, accelerate the reform of fiscal, taxation, finance and other systems, build a digital ecosystem that is conducive to improving the quality and efficiency of enterprises, and provide good conditions for the performance improvement of digital transformation enterprises. Entity enterprises should make full use of the opportunity of digital transformation, tap the value of big data, reconstruct internal business combination, collaborative mode and management level by integrating and sharing data information, realize professional and lightweight operation, strengthen supply quality and efficiency, and better promote performance growth.

Fourth, innovation is the key driving force for digital transformation and the key step for entity enterprises to turn to high-quality development. We should speed up the establishment of an innovation system based on information technology, with entity enterprises as the main body and market orientation, promote the expansion and application of advanced digital technology, and realize the construction of "digital China" driven by China digital technology. Digital transformation enterprises should actively use digital technology and cross-border integration to cultivate new products, new formats and new kinetic energy, explore the transformation from factor-driven to innovation-driven, break the distorted barriers in the allocation of production factors, enhance the creation of data value, and walk at the forefront of high-quality development through reform and innovation.

References

[1] Yu Feifei, Cao Jiayu, Du Hongyan. Digitalization paradox: the double-edged sword effect of enterprise digitalization on innovation performance [J]. Research and Development Management, 2022,34(02):1-12.

[2] Marko Kohtamäki,Vinit Parida,Pankaj C. Patel, Heiko Gebauer. The relationship between digitalization and servitization: The role of servitization in capturing the financial

potential of digitalizat ion[J]. Technological Forecasting & Social Change,2020,151(C).

[3] Jian Chen, Huang Shuo, Liu Yunhui. From empowerment to empowerment-enterprise operation management in digital environment [J]. Management World, 2020,36(02):117-128+222.

[4] Li Min, Guo Qunqun, Lei Yusheng. Study on the spatial interaction effect between the agglomeration of scientific and technological talents and strategic emerging industries [J]. Scientific and technological progress and countermeasures, 2019,36(22):67-73.

[5] Yan Zichun, Xin Li, Wang Weinan. Research on Digital Transformation: Evolution and Future Outlook [J]. Scientific Research Management, 2021,42(04):21-34.

[6] Liu Yang, Dong Jiuyu, Wei Jiang. Digital innovation management: theoretical framework and future research [J]. Management World, 2020,36(07):198-217+219.

[7] W. Rupert Maclaurin. The Sequence from Invention to Innovation and its Relation to Economic Growth[J]. The Quarterly Journal of Economics,1953,67(1).

[8] Modesto A. Maidique. Entrepreneurs, Champions, and Technological Innovation[J]. IEEE Engineering Management Review,1984,12(1).

[9] Cai Dan. Research on the impact of technological innovation capability of SMEs on their innovation performance [D]. Sichuan University, 2006.

[10] Chen Litian, Zhao Xiaoqing, Wei Zhishan. The connotation and evolution of enterprise innovation capability: a systematic literature review [J]. Scientific and technological progress and countermeasures, 2012,29(14):154-160.

[11] Nicholas S. Vonortas. Research joint ventures in the US[J]. Research Policy,1997,26(4).

[12] Jennifer Francis,Abbie Smith. Agency costs and innovation some empirical evidence[J]. Journal of Accounting and Economics,1995,19(2).

[13] Li Ming. Analysis of institutional factors of low R&D investment in China enterprises [J]. Social Scientists, 2005,(04):76-77.

[14] Liu Zhen. R&D investment and scale investment [D]. Jinan University, 2009.

[15] Zaur Rzakhanov. Innovation, product development and market value: evidence from the biotechnology industryinnovation in biotechnology industry[J]. Economics of Innovation and New Technology,2004,13(8).

[16] Julio Pindado,Valdoceu de Queiroz,Chabela de la Torre. How Do Firm Characteristics Influence the Relationship between R&D and Firm Value? [J]. Financial Management,2010,39(2).

[17] Zhao Chenyu, Wang Wenchun, Li Xuesong. How does digital transformation affect the total factor productivity of enterprises [J]. Finance and Trade Economy, 2021,42(07):114-129.