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Does Digital Transformation Affect Enterprise Innovation?: Evidence from Chinese Listed Companies

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Abstract. Up against mass entrepreneurship and innovation in recent years, China has vigorously promoted enterprise digital transformation. Taking Shanghai and Shenzhen A-share listed companies from 2012 to 2022 as samples, this paper empirically tests the relationship between enterprise digital transformation and enterprise innovation. The research results show that enterprise digital transformation can significantly promote enterprise innovation. Meanwhile, internal control and financing constraints of enterprises play a moderating role between digital transformation and enterprise innovation. In the samples with different property rights and whether they are high-tech enterprises, the effect of enterprise digital transformation on enterprise innovation varies. Incorporating digital transformation and enterprise innovation into the same analysis framework, this paper expands existing research and puts forward corresponding suggestions and prospects.

Keywords: Digital Transformation; Enterprise Innovation; Internal Control; Financing Constraints; Nature of Property Rights.

1. Introduction

Enterprises are the subjects of innovation and the main force to promote innovation and creation. Strengthening the dominance of enterprises in innovation and promoting the gathering of various innovative elements to enterprises are key to achieving high-quality economic development in China. However, the large demand for project funds with high uncertainty of enterprise innovation and the inherent information asymmetry will induce problems such as adverse selection and moral hazard, which trigger serious external financing problems for enterprise innovation activities, greatly limiting enterprise innovation capabilities. Hence, how to innovate financial service tools and further improve the scale and efficiency of financial support for enterprise innovation funds have attracted the government and academia.

Digital transformation can greatly improve the efficiency of information processing and screening. It is of great theoretical and practical significance to study the relationship between digital transformation and enterprise innovation.

Selecting Shanghai and Shenzhen A-share listed companies from 2012 to 2022 as samples, this paper aims to verify the impact of digital transformation on enterprise innovation and conduct heterogeneous analysis from the perspectives of property rights and regional differences, so as to explore the various impacts of digital transformation on enterprise innovation in different samples. It enriches the existing research content and proposes constructive suggestions and reflections. The possible marginal contribution is mainly as follows: Given that the existing literature rarely studies the relationship between digital transformation and enterprise innovation, this paper probes into the role of digital transformation in promoting enterprise innovation, which broadens the research boundary and enriches the relevant impact paths.

2. Literature Review and Hypotheses

2.1. Literature Review

1. Research on the Economic Consequences of Digital Transformation

As a vital trend of current economic development, digital transformation has a far-reaching impact that cannot be ignored with extensive and far-reaching economic consequences. It reshapes business models, promotes economic and innovation performance, and even affects the comparability of accounting information and the enterprise environmental performance. First of all, as to business models, digital transformation has led the automotive industry to realize the transition from traditional sales to a new sales model combining online and offline channels. Secondly, studies have shown that digital transformation can effectively drive performance growth thanks to the improvement of operational efficiency and customer satisfaction (Yi et al., 2021). Furthermore, digital transformation uses big data analysis and data platforms to enable enterprises to gain more accurate insight into market demand, so as to develop new products or services that better meet consumer expectations, thereby improving innovation performance. In addition, scholars have found that digital transformation can enhance the transparency of accounting information and make accounting information more comparable between different companies (Nie et al., 2022). At the same time, through digital transformation, enterprises can more effectively monitor and manage their environmental performance and achieve sustainable development (Li, 2022), which undoubtedly injects new vitality into long-term enterprise development.

2. Research on the Influencing Factors of Enterprise Innovation

From the macro perspective, many scholars have discussed the impact of enterprise innovation from the aspect of national fiscal policy, legal system, and economic policy uncertainty. Yuan Jianguo et al. (2016) found in early research that tax incentives have a significant positive impact on SMEs' innovation investment. According to Chen Jingwei and Jiang Nengpeng (2020), during the period of economic transformation, the imperfection of institutional factors leads to the unreasonable allocation of resources in the capital market, which not only hinders the release of enterprise innovation vitality and the improvement of efficiency, but also further limits the technological innovation capabilities of enterprises. In short, the institutional defects in economic transformation are becoming the bottleneck restricting enterprise innovation and technological progress. From a micro perspective, relevant research is about enterprise leverage, salary gap, and government-enterprise relationship. Jiang Tao and Guo Liangxi (2021) believed that the nature of enterprise ownership (state-owned or non-state-owned) has a vital impact on enterprise innovation performance. The internal control index of enterprises is intertwined with innovation investment. The more perfect the internal control system and the higher the execution quality, the higher the efficiency of innovation input and output. The above-mentioned phenomenon indicates that a sound internal control system is crucial to promoting enterprise innovation (Yang et al. 2019).

3. Research on Digital Transformation and Enterprise Innovation

In recent years, with the in-depth advancement of digital transformation, academic research on its impact has become increasingly active. The researchers not only explored the significant economic effects brought about by digital transformation, but also extensively studied its multi-dimensional impact on non-economic performance. The related research is becoming more abundant and comprehensive. The enterprise digital transformation is imperative to promote the green technology innovation of enterprises, with an even more significant role in boosting substantive green innovation. According to some scholars, digital innovation refers to the effective use of digital technology in the innovation process, such as big data analysis, cloud computing and other advanced tools, to realize the optimization and innovation of R&D, production and services. In addition, some scholars discussed the key role of artificial intelligence technology and product innovation in promoting digital innovation, revealing their far-reaching impact on innovation.

4. Overview of Current Research

Based on the existing literature, the research on enterprise innovation and digital transformation in academia is more abundant, but the relationship between digital transformation and enterprise innovation has not yet reached an agreement. Most studies use listed companies as samples for analysis, but few studies distinguish samples for discussion. On this basis, this paper takes listed

companies from 2012 to 2022 as research samples to explore the impact of digital transformation on enterprise innovation, as well as the mechanism of internal control and financing constraints on this process. Moreover, heterogeneous analysis of technological differences is conducted based on enterprises with various types of ownership.

2.2. Hypotheses

According to the principal-agent theory, the reason for enterprises to implement digital transformation is to find a good cooperation model between the management and employees of the enterprise. Based on the theory of information asymmetry, digital transformation can help enterprises disclose information efficiently, which helps internal and external stakeholders obtain information, enhances the transparency of enterprise internal information, and boosts the transparency and efficiency of enterprises in governance. Digital technology provides more efficient data collection, processing and analysis tools, enabling enterprises to achieve better decision-making and risk management. Through the digital platform, accurate and timely financial reports and non-financial information can be provided to enterprises, so as to enhance the trust and recognition of stakeholders in the enterprise. In addition, digital transformation can improve internal communication and enterprise collaboration, promote the optimization of organizational structure and processes, increase the efficiency and quality of enterprise operations, and drive innovation and development.

Digital transformation can improve the economic benefits of enterprises, endowing enterprises with more strength and resources to invest in enterprise innovation. Enterprises with efficient operation can spend lower costs and fewer processes to carry out enterprise innovation. Besides, enterprises can build a good reputation and better adapt to the market environment by improving customer satisfaction and loyalty, so as to better promote enterprise innovation. On this basis, this paper proposes Hypothesis 1:

H1: Enterprise digital transformation can positively affect enterprise innovation.

According to the theory of optimal resource allocation, efficient internal control is the key to successful digital transformation, which can ensure the rational allocation and effective use of enterprise resources. According to the signaling theory, high-scoring internal control sends a positive signal to the market, indicating that the enterprise has standardized management, high operating efficiency, and strong risk management capabilities. This signal enhances the reputation and market status of the enterprise, which in turn attracts more partners, investors and customers. Such desirable market feedback can further motivate enterprises to seek innovation through digital transformation in order to maintain and enhance their competitive advantages. On this basis, this paper proposes Hypothesis 2:

H2: Under the condition that other conditions remain unchanged, the higher the internal control score, the more significant the positive impact of digital transformation on enterprise innovation.

The existence of financing constraints has increased the difficulty for enterprises to obtain external funds, which may trigger limited enterprise investment in digital transformation. The lack of funds not only hinders the ability of enterprises to adopt cutting-edge technologies, expand broader markets or develop innovative products, but also fundamentally restricts the positive role of digital transformation in promoting enterprise innovation and development. In summary, financing constraints have harmed the innovation vitality and market competitiveness of enterprises during the digital transformation by causing a shortage of funds. On this basis, this paper proposes Hypothesis 3:

H3: Under the condition that other conditions remain unchanged, financing constraints can weaken the positive impact of digital transformation on enterprise innovation.

3. Research Design

3.1. Sample Selection and Data Sources

Selecting China's Shanghai and Shenzhen A-share listed companies from 2012 to 2022 as samples, this paper refers to the method of Wu Fei et al. (2021) and counts the word frequencies of artificial intelligence technology, blockchain technology, cloud computing technology, big data technology and digital technology applications for measuring the enterprise digital transformation. Excluding the financial industry, ST, PT and missing sample data, relevant data such as enterprise characteristic data, financial data, and the number of patent applications are all from the CSMAR database. At the same time, in order to reduce the influence of extreme values, the variables are winsorized to 1%-99% quantile, which finally obtains 12,856 pieces of data.

3.2. Variable Definition

1. Explained Variable: Enterprise Innovation (INP)

This paper measures enterprise innovation by the number of patents obtained by the enterprise in the year. In the robustness test, the enterprise innovation is measured by the invention patents obtained by the enterprise in the year. Meanwhile, due to the right-skewed characteristics of patent data, the measurement value of enterprise innovation in this paper is the total number of patents plus 1 and then takes the logarithm .

2. Explanatory Variable: Enterprise Digital Transformation (DIG)

This paper refers to Wu Fei et al. (2021) who counted the word frequency of digital transformation in the Annual Report to build enterprise digital transformation indicators, such as summing the word frequencies of artificial intelligence technology, big data technology, blockchain technology and cloud computing technology. In addition, DIG1 is the sum of the word frequencies obtained in the above dimensions in the Annual Report plus 1, and then take the natural logarithm. DIG2 is the sum of the number of word frequencies obtained from managers for the above dimensions plus 1, also taking the natural logarithm.

3.3. Model Setting

To sum up, this paper constructs the following multiple regression model to test the impact of digital transformation on enterprise innovation.

$$INP_{i,t} = \alpha_0 + \alpha_1 DIG_{i,t-1} + \alpha_i Controls_{i,t-1} + \theta + \gamma + \varepsilon_{i,t} \quad (1)$$

The subscript i represents the enterprise, and t represents the year. Controls represent all control variables, including enterprise size (Size), asset-liability ratio (Lev), return on assets (ROA), the ratio of cash flow (Cashflow), the growth rate of operating income (Growth), board size (Board), the ratio of independent directors (Indep), the shareholding ratio of the top ten largest shareholders (Top 10). θ represents fixed effects for the year and γ represents fixed effects for the industry. ε represents the residual term. At the same time, this paper lags the independent variables and control variables by one period to eliminate possible reverse causality and ensure the robustness of the results. If α_1 is positive, H1 in this paper is tenable.

4. Empirical Analysis

4.1. Descriptive Statistics

According to Table 2 that shows the basic statistical characteristics of the main variables, the average digital transformation is 0.920, the standard deviation is 1.234, the minimum is 0, and the maximum is 5.938. There are certain differences in digital transformation among enterprises. The average enterprise innovation output is 227.2, the standard deviation is 1396, the minimum is 0, and the

maximum is 96626, which indicates that the enterprise innovation output is unevenly distributed. From the perspective of control variables, the minimum enterprise size (Size) is 18.43, and the maximum is 28.64. The minimum growth rate of operating income (Growth) is -0.913, and the maximum is 944.1. The distribution of other control variables is also more balanced. In general, the descriptive statistical results of the control variables involved in the model are generally consistent with existing studies, which are within a reasonable range.

Table 1. Descriptive Statistics

Category	Name	Definition	Calculation Method
Explained Variable	INP	Enterprise Innovation	Number of enterprise patent applications and take the natural logarithm
			Number of enterprise invention patent Applications and take natural logarithm
Explanatory Variable	DIG1	Digital Transformation Index1	Summing word frequencies of artificial intelligence technology, blockchain technology, cloud computing technology, big data technology, and digital technology application and plus 1, then take the natural logarithm (Annual Report)
	DIG2	Digital Transformation Index2	Summing word frequencies of artificial intelligence technology, blockchain technology, cloud computing technology, big data technology, and digital technology application and plus 1 for natural logarithm (discussion of managers)
Moderating Variable	Incontrol	Internal Control Index	Internal control index of DIBO internal control quality database
	Constraints	Financing Constraints	SA Index
Control Variable	Leverage	Asset-Liability Ratio	Total Liabilities/Total Assets
	Size	Enterprise Size	Natural logarithm of total assets at the end of the year
	ROA	Return on Assets	Net Profit/Average Balance of Total Assets
	Growth	Growth Rate of Operating Income	Growth Rate of Operating Income
	Indep	Ratio of Independent Directors	Ratio of the number of independent directors to the size of directors
	Top1	Ownership Concentration	Shareholding ratio of the largest shareholder (%)
	CashFlow	Ratio of Cash Flow	Net cash flows from operating activities/ Total current liabilities
	Board	Board Size	Number of board directors
	Top 10	Ownership Concentration	Shareholding ratio of the top ten largest shareholders (%)

4.2. Benchmark Regression: Impact of Digital Transformation on Enterprise Innovation

According to Table 3 showing the benchmark regression of model (1), as for the digital transformation measured by the Annual Report and managers, they are both significant at a significance level of 1%. Based on the further analysis of columns (1) and (3) which are regression

results without control variables, the coefficients of digital transformation are 0.240 and 0.206 respectively, and the regression coefficients of digital transformation are significantly positive at 1%. It is concluded that digital transformation can positively promote enterprise innovation investment. After adding control variables, the regression coefficients between digital transformation and enterprise innovation are 0.142 and 0.120 respectively, which are still positive and significant at 1%, fully demonstrating that digital transformation can promote enterprise innovation.

Table 2. Descriptive Statistics

Variable	N	Mean	SD	p25	p50	p75	Min	Max
Digital1	12856	1.247	1.428	0	0.693	2.197	0	6.301
Digital2	12856	0.920	1.234	0	0	1.609	0	5.938
PatentsN	12856	227.2	1396	6	41	142	0	96626
InventionN	12856	53.26	484.3	0	7	28	0	49529
Size	12856	22.02	1.258	21.13	21.81	22.65	18.43	28.64
Lev	12856	0.375	0.192	0.218	0.361	0.514	0.008	0.994
ROA	12856	0.051	0.072	0.020	0.048	0.083	-0.710	0.969
Cashflow	12856	0.049	0.069	0.011	0.047	0.087	-0.662	0.726
Growth	12856	0.294	7.549	-0.010	0.118	0.275	-0.913	944.1
Board	12856	2.103	0.191	1.946	2.197	2.197	1.386	2.833
Indep	12856	0.377	0.056	0.333	0.364	0.429	0.167	0.800
Top 10	12856	0.598	0.148	0.494	0.611	0.714	0.036	1.012

4.3. Moderating Effect

1. Digital Transformation, Internal Control and Enterprise Innovation

To verify the moderating effect of internal control between digital transformation and enterprise innovation, this paper conducts a regression test on the transaction multipliers of digital transformation and internal control, with test results shown in Table 4. The coefficients of the cross-multiplication terms of digital transformation and internal control are both positive and significant at the significance levels of 5% and 1% respectively. Thus, when digital transformation improves the internal control of enterprises, the innovation efficiency and innovation effect can be boosted. Strengthening internal control helps enterprises better manage risks and ensure the rational allocation and effective use of resources, thus providing better support and guarantee for innovation activities. In other words, the more obvious the digital transformation conducted by enterprises to promote innovation, the more positive the regulatory role of the optimization of internal control, thus intensifying the role of digital transformation in promoting enterprise innovation. H2 has been verified.

2. Financing Constraints

To verify the moderating effect of financing constraints on digital transformation and enterprise innovation, this paper conducts a regression test on the transaction multiplier of digital transformation and financing constraints, with test results shown in the table below. According to Table 5, the coefficients of the cross-multiplication terms of digital transformation and financing constraints are both negative, which indicates when enterprises face greater financing constraints, innovation benefits brought about by digital transformation may be weakened. Financing constraints can limit enterprise investment in digital transformation and innovation. With tight funds, enterprises may be

inclined to use limited resources to maintain daily operations, rather than investing in innovative projects with higher risks.

Table 3. Regression Results of Basic Regression

	(1)	(2)	(3)	(4)
	PatentsN	PatentsN	PatentsN	PatentsN
$Digital1_{t-1}$	0.240***	0.142***		
	(8.76)	(5.53)		
$Digital2_{t-1}$			0.206***	0.120***
			(6.96)	(4.35)
$Size_{t-1}$		0.620***		0.628***
		(17.25)		(17.48)
Lev_{t-1}		0.122		0.126
		(0.61)		(0.63)
ROA_{t-1}		-0.201		-0.207
		(-0.43)		(-0.44)
$Cashflow_{t-1}$		0.846**		0.829**
		(2.12)		(2.07)
$Growth_{t-1}$		0.086		0.093
		(1.44)		(1.55)
$Board_{t-1}$		0.181		0.190
		(0.85)		(0.90)
$Indep_{t-1}$		0.688		0.734
		(1.08)		(1.15)
$Top10_{t-1}$		0.373*		0.372*
		(1.70)		(1.69)
_cons	1.038**	-13.404***	1.098**	-13.580***
	(2.06)	(-13.87)	(2.19)	(-14.11)
Year·FE	Yes	Yes	Yes	Yes
Industry·FE	Yes	Yes	Yes	Yes
N	12856	12856	12856	12856
AR^2	0.164	0.258	0.158	0.256

4.4. Heterogeneity Analysis

1. Grouping by Equity Nature

Enterprises are grouped according to whether they are state-owned. As shown in Table 6, the study found that for the digital transformation measured by the Annual Report, the coefficients of the enterprise digital transformation are all positive and significant at the significance level of 1%. After passing the test of the group difference coefficients, the coefficient of state-owned enterprises is significantly greater than that of state-owned enterprises. For the digital transformation measured from the perspective of management, coefficients of enterprise digital transformation are also positive and significant at a significance level of 1%. After the test of the group difference coefficients, the

coefficients of state-owned enterprises are greater than those of non-state-owned enterprises. Hence, state-owned enterprises have more resources and policy support, and can use digital transformation more effectively to promote innovation, while non-state-owned enterprises may apply digital technology in a more flexible and innovative manner to find competitive advantages different from state-owned enterprises and innovation paths.

Table 4. Moderating Effect of Internal Control

	(1)	(2)
	PatentsN	PatentsN
$Digital1_{t-1}$	105.085*	
	(1.68)	
$Digital2_{t-1}$		8.874
		(0.84)
$Digital1 \times Incontrol_{t-1}$	0.212**	
	(2.08)	
$Digital2 \times Incontrol_{t-1}$		0.067***
		(2.77)
$Controls_{t-1}$	Yes	Yes
Year·FE	Yes	Yes
Industry·FE	Yes	Yes
N	12856	12856
AR^2	0.176	0.177

Table 5. Moderating Effects of Financing Constraints

	(1)	(2)
	PatentsN	PatentsN
$Digital1_{t-1}$	658.374*	
	(1.87)	
$Digital2_{t-1}$		215.201
		(0.64)
$Digital1 \times Constraint_{t-1}$	-165.304*	
	(-1.80)	
$Digital2 \times Constraint_{t-1}$		-47.791
		(-0.55)
$Controls_{t-1}$	Yes	Yes
Year·FE	Yes	Yes
Industry·FE	Yes	Yes
N	12856	12856
AR^2	0.213	0.211

Table 6. Heterogeneity of Equity Nature

	(1)	(2)	(3)	(4)
	PatentsN	PatentsN	PatentsN	PatentsN
$Digital1_{t-1}$	41.295***		19.023***	
	(3.03)		(3.13)	
$Digital2_{t-1}$		43.010***		14.664**
		(2.92)		(2.27)
$Controls_{t-1}$	Yes	Yes	Yes	Yes
P Value of Group Difference Test	0.150***		0.100**	
Year·FE	Yes	Yes	Yes	Yes
Industry·FE	Yes	Yes	Yes	Yes
N	3016	3016	9693	9693
AR^2	0.352	0.352	0.236	0.235

4.5. Robustness Test

There may be a certain lag in the time of innovation output, so this paper uses the number of patents from listed companies in the next two periods as the explained variable to re-test, with results shown in Table 7. The regression coefficients of digital transformation are 23.369 and 22.172 respectively, which are positively significant at the significance level of 10%. It indicates that the higher the enterprise digitalization, the higher the enterprise innovation in the next two periods. Besides, the results of this paper have not changed.

Table 7. Regression Results for the Next Two Periods

	(1)	(2)
	PatentsN	PatentsN
$Digital1_{t-2}$	23.369*	
	(1.89)	
$Digital2_{t-2}$		22.172
		(1.29)
$Controls_{t-2}$	Yes	Yes
Year·FE	Yes	Yes
Industry·FE	Yes	Yes
N	8968	8968
AR^2	0.182	0.182

5. Research Conclusion and Suggestions

5.1. Research Conclusion

As an integral part of enterprise strategy, enterprise digital transformation can help enterprises gain an advantage in the increasingly fierce competition and promote enterprise innovation for better development. Taking China's Shanghai and Shenzhen A-share listed companies from 2012 to 2022 as research samples, this paper explores the relationship between digital transformation and enterprise innovation based on theoretical perspectives such as principal-agent theory. It is found that the

enterprise digital transformation can significantly and positively affect enterprise innovation. At the same time, this paper introduces the internal control and financing constraints of enterprises. According to the results, if other conditions remain unchanged, the enterprise digital transformation can significantly and positively affect enterprise innovation. Meanwhile, the internal control and financing constraints of enterprises play a moderating role between digital transformation and enterprise innovation. In the sample of the nature of property rights and whether it is a high-tech enterprise, the effect of enterprise digital transformation on enterprise innovation is different. Incorporating digital transformation and enterprise innovation into the same analysis framework, this paper expands existing research and puts forward corresponding suggestions and prospects.

5.2. Research Suggestions and Prospects

The research conclusions of this paper will help enterprises further promote digital transformation and enterprise innovation. Firstly, enterprises should actively promote digital transformation, remove obstacles to digital transformation, and fully use the dividend period of digital transformation. In addition, they can improve the efficiency of production and operation, save the cost of production and operation, and realize the efficiency and transparency of information exchange and communication within enterprises, thus boosting the internal innovation atmosphere and realizing high-quality development. Secondly, enterprises should pay attention to internal flexibility, set up a reasonable organizational structure and give employees appropriate rights. Furthermore, they should allow employees to participate in enterprise innovation, which helps enterprises achieve their goals faster. Thirdly, enterprises should increase resource investment, reduce the lag effect, and promote the role of digital transformation in promoting enterprise innovation.

This paper probes into the relationship between digital transformation and enterprise innovation, with the main samples concentrated in listed companies. Given that the relationship between digital transformation and enterprise innovation as well as the mechanism between different industries varies, subsequent research can focus the survey sample on a certain industry or on small and medium-sized enterprises. At the same time, it can expand the sample period, and consider the lag of enterprise innovation and the different relationships that may occur at different stages.

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