

Can Digital Transformation Foster Business Innovation: Moderating Effect based on Internationalization Openness

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Abstract. Under the background of double innovation, China has vigorously promoted enterprise digital transformation. This paper takes A-share listed companies from 2012 to 2022 as a sample to empirically examine the relationship between enterprise digital transformation and enterprise innovation, and the research results show that: enterprise digital transformation can significantly and positively affect enterprise innovation; at the same time, the degree of enterprise internationalization and openness plays a positive moderating role between digital transformation and enterprise innovation; Compared with state-owned enterprises and enterprises whose executives have no overseas background, the digital transformation of non-state-owned enterprises and enterprises whose executives have overseas background has a more significant effect on enterprise innovation; this paper extends the existing research by including digital transformation and enterprise innovation in the same analytical framework, and puts forward corresponding suggestions.

Keywords: Digital Transformation; Corporate Innovation; Openness to Internationalization; Executive Backgrounds.

1. Introduction

The development of advanced productive forces contributes to the high-quality development of the national economy, and the Second Session of the 14th National People's Congress in 2024 mentioned the need to "vigorously promote the construction of a modernized industrial system, and accelerate the development of new quality productive forces". In recent years, the state has launched policies to support the digital transformation of enterprises, and with the development of the market economy, the rapid development of the industry and consumer demand is also constantly pushing many enterprises to carry out digital transformation. Digital transformation helps enterprises improve production efficiency, reduce production costs, improve the efficiency of personnel management, operational efficiency, and promote enterprise innovation and flexibility. Promote enterprise sustainability and long-term development.

This paper selects A-share listed companies from 2012 to 2022 as samples, establishes time and individual two-way fixed-effects models to test the relationship between digital transformation of enterprises and enterprise innovation, and at the same time introduces the internationalization openness level of enterprises as a moderating variable. The marginal contributions are: first, it introduces for the first time the firm's internationalization openness level as a moderating variable between digital transformation and firm innovation, which explains the significance of firms' going overseas for firm innovation from another perspective; second, this paper combines firm innovation with talent resource factors by combining the heterogeneity test with whether executives have overseas backgrounds or not.

2. Literature Review and Synthesis

2.1. Study on the Economic Consequences of the Digital Transformation of Enterprises

The digital transformation of enterprises can increase the transparency and sharing of enterprise information by optimizing the production process and making enterprise data transparent, thus



enhancing the productivity of enterprises and reducing production costs. Li Qi (2021) et al. suggested that digital transformation can significantly improve enterprise performance, in which supply chain integration and entrepreneurship act as mediating and moderating variables, respectively [1]. In addition, Fang Mingyue (2022) et al. concluded that the digital transformation of enterprises can enhance employment, labor share, and at the same time reduce the income gap, thus contributing to the country's beautiful vision of common prosperity [2].

2.2. Research on Factors Influencing Firms' Innovation

Corporate innovation is influenced by numerous factors, which most scholars categorize as internal and external, for example, Birkinshaw summarizes the process by which managerial innovation arises by mentioning that both internal organizational contexts and external environmental changes can have an impact on managerial innovation [3]. Internal factors affecting firm innovation include entrepreneurship, entrepreneurial personality traits, entrepreneurial leadership style, board characteristics, and equity structure, etc.[1], while external factors include financing, market structure, etc. [4], external factors include financing, market structure, relationship with the government, and business environment. Meanwhile, in recent years, with the development of digital economy, many scholars have suggested that the digital economy has the advantages of saving operating costs and reducing financing constraints, and thus the development of digital economy can promote enterprise innovation.

2.3. Research on the Impact of Digital Transformation on Business Innovation

In recent years, many scholars have paid attention to the impact of digital transformation on enterprises' green technological innovation. Many scholars have paid attention to the role of digital transformation on enterprise innovation. Liu Chang et al. (2023) focus on the green innovation of manufacturing enterprises and study the internal mechanism of digital transformation to improve the efficiency of enterprise green innovation [5]. Duan Youhua (2023) and others focus on the level of technological innovation in enterprises, and propose that digital transformation can alleviate the financing constraints, thereby increasing the degree of enterprise investment in technological innovation, and thus enhancing the level of enterprise innovation [6].

3. Theoretical Analysis and Research Hypothesis

3.1. Digital Transformation and Enterprise Innovation

According to the principal-agent theory, in order to obtain good development, it is necessary to seek a good cooperation mode between the management and employees of the enterprise, and digital transformation can promote the transparency of production information, information symmetry and even ensure fairness, provide efficient management tools for the enterprise, and thus help the managers to find the optimal way to solve the agency problem. According to the theory of information asymmetry, digital transformation can help enterprises disclose information efficiently, which helps internal and external stakeholders to obtain information, enhances the transparency of information within the enterprise, and strengthens the transparency and efficiency of the enterprise in terms of governance.

Digital transformation can improve the economic efficiency of enterprises, so that enterprises have more strength and resources to think and invest in enterprise innovation, efficient operation of the enterprise can help enterprises spend less cost, less process to enterprise innovation. Enterprises can improve customer satisfaction and loyalty to build a good reputation and better adapt to the market environment, which can better promote enterprise innovation.

Based on the above, this paper proposes Hypothesis 1:

H1: Enterprise digital transformation positively affects business innovation.

3.2. Digital Transformation, Openness to Internationalization and Firm Innovation

The degree of internationalization and openness of an enterprise reflects the comprehensive strength of the enterprise as well as the level of external communication. It has been demonstrated that the overseas background of corporate executives and the degree of internationalization of the enterprise have a certain contribution to the digital transformation of the enterprise [7]. Some scholars have pointed out that the digital transformation of enterprises can promote the internationalization of R&D and thus the innovation performance of enterprises [8]. Enhancing the internationalized business environment can promote technological innovation, especially the quality of innovation, through the cost effect, export effect, and competition effect [9]. The internationalized business environment can promote technological innovation, especially innovation quality, through cost effect, export effect and competition effect. Some scholars also suggest that overseas executives can promote digital transformation by enhancing risk-taking, alleviating information asymmetry, and strengthening innovation capabilities [10].

Based on the above, this paper proposes hypothesis 2:

H2: Other things being equal, the higher the firm's openness to internationalization, the more significant the positive impact of digital transformation on firm innovation.

4. Research Design

4.1. Sample Selection and Data Sources

In this paper, China's Shanghai and Shenzhen A-share listed companies are selected as samples from 2012 to 2022, referring to the methodology of Wu Fei et al. (2021), the number of word frequencies of five dimensions such as AI technology, blockchain technology, cloud computing technology, big data technology, and digital technology application are counted to serve as a measure of the level of digital transformation of the enterprises, financial industry, ST, PT, and samples with missing data are excluded, and the enterprise characteristic data, financial data, number of patent applications and other related data are from CSMAR database. Meanwhile, in order to mitigate the influence of extreme values, the variables were subjected to 1%-99% quantile shrinkage, and finally 15,163 data were obtained.

4.2. Definition of Variables

4.2.1. Explained Variable: Innovation in the Firm (INP)

The methodology referenced in this paper measures firm innovation in terms of the number of patents obtained by the firm in the year. In the robustness test, the enterprise innovation is measured by the invention patents obtained by the enterprise in that year. Meanwhile, due to the right skewed characteristics of patent data, the measure of enterprise innovation in this paper is the total number of patents plus 1 and then take the logarithm. There is a lag in the occurrence of innovation, and in order to mitigate the impact of endogeneity, this paper adopts the patent data of the future period to measure the value of enterprise innovation.

4.2.2. Explanatory Variable: Digital Transformation of Enterprises (DIG)

This paper draws on Wu, Fei, et al. (2021) to construct enterprise digital transformation indicators by using statistics on the frequency of words about digital transformation appearing in annual reports, for example, by summing up the frequency of words such as "artificial intelligence technology", "big data technology", "blockchain technology", and "cloud computing technology" to construct enterprise digital transformation indicators. For example, the word frequency of "artificial intelligence technology", "big data technology", "blockchain technology" and "cloud computing technology" is summed up to construct enterprise digital transformation indicators. DIG1 is the sum of the word frequencies of the above dimensions obtained from the annual report, plus one, and then take the

natural logarithm, while DIG2 is the sum of the word frequencies of the above dimensions obtained from the management discussion, plus one, and also take the natural logarithm.

4.3. Modeling

In summary, this paper constructs the following multiple regression model to test the impact of digital transformation on corporate innovation.

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

where subscript *i* represents the firm and *t* represents the year; Controls represents all control variables; θ stands for the year's fixed effect and γ stands for the individual's fixed effect; ε stands for the residual term. Meanwhile, this paper lags the independent variables as well as the control variables by one period to eliminate possible reverse causation problems and to ensure the robustness of its results. If α_1 is positive, it means that hypothesis 1 of this paper is valid.

Table 1. Description of main variables

Variable category	variable name	Variable Meaning	calculation method
explanatory variable	INP	Enterprise Innovation Index	Number of corporate patent applications, in natural logarithms
explanatory variable	DIG1	Digital Transformation Index 1	Link to 4.2.2
	DIG2	Digital Transformation Index 2	Link to 4.2.2
moderator variable	Z	Degree of enterprise internationalization	
control variable	Size	Company size	Natural logarithm of total assets at year-end
	Lev	Asset-liability ratio	Total liabilities/total assets
	ROA	total asset-liability ratio	Net profit/average balance of total assets
	Cashflow	Cash flow ratio	Net cash flows from operating activities/total current liabilities Total current liabilities in denominator
	Growth	Revenue growth rate	(Amount of operating income for the current period of the year - Amount of operating income for the same period of the previous year) / (Amount of operating income for the same period of the previous year)
	Board	Board size	Board size
	Indep	Ratio of sole director	Ratio of the number of independent directors to the size of the board
	Top10	Shareholding ratio of top ten largest shareholders	Shareholding ratio of top ten largest shareholders
	InNstaff	Size of human resources	Natural logarithm of the number of full-time employees
	Top1	Shareholding ratio of the largest shareholder	Shareholding ratio of the largest shareholder (%)
	BM	Book-to-market ratio	Total assets/total market capitalization
	FA	Stylized assets	Total tangible assets/total assets
Age	Age of business	The current year minus the year the firm went public and add 1, then take the logarithm	

5. Empirical Results and Analysis

5.1. Descriptive Statistics

The descriptive statistics of the main variables involved in this paper are demonstrated in Table 2. The mean and standard deviation of digital transformation are 1.297 and 0.964, respectively, and 1.444 and 1.257, respectively, indicating that the level of digitization varies significantly among different firms. The mean and standard deviation of enterprise innovation are 2.750 and 2.045 respectively, indicating that the level of enterprise innovation also varies significantly among different enterprises. As for the descriptive statistics of the control variables, there is a high degree of consistency after comparing the existing relevant literature, and the ranges of values are all reasonable.

Table 2. Descriptive statistics results of the main variables

variant	sample size	average value	standard deviation	minimum value	upper quartile	maximum values
INP	15163	2.750	2.045	0.000	2.944	7.044
DIG1	15163	1.297	1.444	0.000	0.693	5.165
DIG2	15163	0.964	1.257	0.000	0.000	5.938
Size	15163	22.139	1.241	20.081	21.936	26.230
Lev	15163	0.379	0.190	0.050	0.369	0.831
ROA	15163	0.053	0.062	-0.191	0.050	0.234
Cashflow	15163	0.050	0.065	-0.130	0.049	0.237
Growth	15155	0.180	0.332	-0.439	0.127	1.826
Board	15160	2.108	0.189	1.609	2.197	2.639
Indep	15160	0.377	0.053	0.333	0.364	0.571
Top10	15163	0.600	0.145	0.259	0.610	0.907
InNstaff	15163	7.663	1.190	5.347	7.532	11.234
Top1	15163	33.334	14.269	8.430	31.310	72.290
BM	15163	0.819	0.856	0.086	0.548	5.223
FA	15163	0.928	0.081	0.572	0.955	0.999
Age	15163	1.770	0.920	0.000	1.792	3.296

5.2. Principal Regression Analysis

Table 3 demonstrates the regression results between digital transformation and firm innovation. The explanatory variables in columns (1) and (2) are DIG1, and those in columns (3) and (4) are DIG2. The regression results show that the regression coefficients of digital transformation are 0.061, 0.057, 0.066, and 0.062, which are positively significant at the 5% significance level, so that digital transformation promotes firms' innovations and enhances firms' patent output. Therefore, hypothesis 1 is verified.

Table 3. Main regression results

	(1)	(2)	(3)	(4)
	INP _{i,t}	INP _{i,t}	INP _{i,t}	INP _{i,t}
DIG1 _{i,t-1}	0.061**	0.057**		
	(2.37)	(2.17)		
DIG2 _{i,t-1}			0.066**	0.062**
			(2.53)	(2.35)
Size _{i,t-1}		0.019		0.024
		(0.23)		(0.30)
Lev _{i,t-1}		-0.487**		-0.489**
		(-2.06)		(-2.07)
ROA _{i,t-1}		0.321		0.318
		(0.68)		(0.67)
Cashflow _{i,t-1}		-0.542		-0.529
		(-1.48)		(-1.44)
Growth _{i,t-1}		0.104*		0.104*
		(1.71)		(1.72)
Board _{i,t-1}		-0.242		-0.234
		(-1.04)		(-1.00)
Indep _{i,t-1}		-1.160*		-1.161*
		(-1.72)		(-1.72)
Top10 _{i,t-1}		-0.379		-0.369
		(-1.10)		(-1.08)
lnNstaff _{i,t-1}		0.138*		0.136*
		(1.77)		(1.75)
Top1 _{i,t-1}		0.011***		0.011***
		(2.62)		(2.60)
BM _{i,t-1}		0.071		0.072
		(1.38)		(1.38)
FA _{i,t-1}		0.234		0.236
		(0.70)		(0.70)
Age _{i,t-1}		0.058		0.054
		(0.80)		(0.75)
_cons	2.169***	1.370	2.175***	1.252
	(33.94)	(0.85)	(34.44)	(0.77)
Year FE	Yes	Yes	Yes	Yes
Stkcd FE	Yes	Yes	Yes	Yes
N	10465	10458	10465	10458
R ²	0.034	0.037	0.034	0.038

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.3. Firm Digital Transformation, Openness to Internationalization and Firm Innovation

In order to test whether hypothesis 2 is valid, this paper makes a judgment on whether there is a moderating effect of the degree of firm internationalization. The results are shown in Table 4, which can be obtained from Column (1) and Column (2) that the interaction term of digital transformation and the degree of internationalization of the enterprise (DIG×Z) has a significantly positive effect on enterprise innovation at the 1% level. It can be seen that when the degree of internationalization of enterprises is higher, the promotion effect of digital transformation on enterprise innovation is more significant, i.e., Hypothesis 2 is verified.

Table 4. Moderating effect of international openness

	(1)	(2)
	INP _{i,t}	INP _{i,t}
DIG1 _{i,t-1}	0.060***	
	(3.50)	
DIG1 _{i,t-1} × Z _{i,t-1}	0.145**	
	(2.32)	
DIG2 _{i,t-1}		0.046**
		(2.41)
DIG2 _{i,t-1} × Z _{i,t-1}		0.133*
		(1.87)
Level of internationalization (Z) _{i,t-1}	0.027	0.096
	(0.19)	(0.76)
Controls _{i,t-1}	Yes	Yes
Year FE	Yes	Yes
Stkcd FE	Yes	Yes
N	10458	10458
AR ²	0.043	0.041

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6. Heterogeneity Analysis

6.1. By Nature of Shareholding

Under the system of socialist market economy with Chinese characteristics, Chinese state-owned enterprises (SOEs) and non-state-owned enterprises (NSOEs) have similarities and differences in the degree and effect of digital transformation due to the differences in management systems and the degree of mastery of policy dividends. In this paper, listed companies are categorized into two groups, state-owned enterprises and non-state-owned enterprises, according to the nature of their equity. The regression results are shown in Table 5.

From the results in Table 5, we can learn that the regression coefficients of digitization type on enterprise innovation are 0.059 and 0.061 in the sample of non-state-owned enterprises, positively affecting enterprise innovation at 10% and 5% significance levels; in the sample of state-owned

enterprises, none of the effects of digitization type on enterprise innovation are significant. Therefore, the facilitating effect of digital transformation on corporate innovation is more pronounced in non-state-owned enterprises.

Table 5. Heterogeneity test results: nature of equity

	State-owned enterprises $INP_{i,t}$		Non-State Enterprise $INP_{i,t}$	
	(1)	(2)	(3)	(4)
	$DIG1_{i,t-1}$	$DIG2_{i,t-1}$	$DIG1_{i,t-1}$	$DIG2_{i,t-1}$
$DIG_{i,t-1}$	0.057	0.053	0.056*	0.061**
	(0.86)	(0.80)	(1.95)	(2.12)
Controls $_{i,t-1}$	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Stkcd FE	Yes	Yes	Yes	Yes
N	2386	2386	7966	7966
AR ²	0.044	0.044	0.038	0.038

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6.2. Executive Background

As the decision makers of the enterprise, executives with international vision and overseas experience can give a lot of help to the enterprise in making important decisions, formulating enterprise strategies, introducing resources, etc. This paper expects that compared with enterprises without overseas background executives, enterprises with overseas background executives will have a more significant effect of digital transformation on enterprise innovation, and the results are shown in Table 6.

Table 6. Heterogeneity test results: whether executives have an overseas background

	No background $INP_{i,t}$		Background $INP_{i,t}$	
	(1)	(2)	(3)	(4)
	$DIG1_{i,t-1}$	$DIG2_{i,t-1}$	$DIG1_{i,t-1}$	$DIG2_{i,t-1}$
$DIG_{i,t-1}$	0.020	-0.002	0.057	0.070*
	(0.43)	(-0.05)	(1.56)	(1.92)
Controls $_{i,t-1}$	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Stkcd FE	Yes	Yes	Yes	Yes
N	3775	3775	6267	6267
R ²	0.076	0.076	0.024	0.024

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

From the results in Column (1) and Column (2), we can learn that the regression coefficients of digital transformation on enterprise innovation are 0.057 and 0.070 respectively in the samples whose executives have overseas backgrounds, which positively affects enterprise innovation at the 10% significance level; and that the effect of digitization type on enterprise innovation is insignificant in the samples whose executives do not have overseas backgrounds. The above results indicate that the facilitating effect of digital transformation on corporate innovation is more pronounced in firms whose executives have overseas backgrounds.

6.3. Robustness Tests

6.3.1. Lagged Two-period Regression Test

There may be some lag in the time of innovation output, so this paper uses the number of patents obtained by listed companies in the next two periods as an explanatory variable to re-test, the results are shown in Table 7 below, DIG1 is positively significant at the 1% significance level, the DIG2 is positively significant at 5% level of significance. The results indicate that the higher the level of firm digitization, the higher the level of firm innovation in the next two periods, and the conclusions are robust.

Table 7. Robustness test results: lagged two-period regression test

	(1)	(2)	(3)	(4)
	INP _{i,t}	INP _{i,t}	INP _{i,t}	INP _{i,t}
DIG1 _{i,t-2}	0.095***	0.096***		
	(3.10)	(3.09)		
DIG2 _{i,t-2}			0.070**	0.071**
			(2.22)	(2.24)
Controls _{i,t-2}	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Stkcd FE	Yes	Yes	Yes	Yes
N	8076	8070	8076	8070
R ²	0.023	0.026	0.022	0.026

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6.3.2. Replacement of Explanatory Variables

The number of patents obtained by the company was used as a measure of corporate innovation above, and next, the number of invention patents obtained by the company in the current year (lnGrainv_1) is used as an explanatory variable in this paper. The results in Table 8 show that the regression coefficients of digital transformation are both positively significant at the 1% level and remain significant after adding the control variables, and digital transformation can positively promote technological innovation of enterprises, indicating that digital transformation still significantly affects enterprise innovation after replacing the explanatory variables.

6.4. Endogeneity test

6.4.1. Propensity Score Matching (PSM)

Whether an enterprise implements digital transformation is not random, but will be affected by the specific situation of the enterprise. This paper adopts the nearest-neighbor matching method of "one with two" and "no put-back" to match the experimental group with the final control group, and the regression results between digital transformation and enterprise innovation are shown in Table 9, significantly promote enterprise innovation, consistent with the original conclusion.

Table 8. Robustness test results: methods of replacing explanatory variables

	(1)	(2)	(3)	(4)
	lnGrainv_1 _{i,t}	lnGrainv_1 _{i,t}	lnGrainv_1 _{i,t}	lnGrainv_1 _{i,t}
DIG1 _{i,t-1}	0.019***	0.020***		
	(2.95)	(3.03)		
DIG2 _{i,t-1}			0.020***	0.022***
			(3.09)	(3.38)
Controls _{i,t-1}	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Stkcd FE	Yes	Yes	Yes	Yes
N	10101	10094	10101	10094
R ²	0.167	0.174	0.167	0.174

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9. Propensity Score Matching (PSM)

	(1)
	lnPatentsN
DT_dum	0.203***
	(2.82)
Controls	Yes
Year FE	Yes
Stkcd FE	Yes
N	5883
R ²	0.044

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

7. Conclusion and Discussion of the Study

7.1. Conclusion of the Study

Enterprise digital transformation, as an important part of corporate strategy, can help companies gain an advantage in the increasingly fierce competition. This paper takes Chinese A-share listed companies in Shanghai and Shenzhen from 2012 to 2022 as the research sample to explore the relationship between digital transformation and corporate innovation. It is found that digital transformation can significantly and positively affect corporate innovation; at the same time, the degree of internationalization of a company plays a positive moderating role in the promotion of corporate innovation by digital transformation; Finally, this paper further conducts heterogeneity analysis on enterprises, finding that the impact of digital transformation on enterprise innovation is more significant in non-state-owned enterprises than in state-owned enterprises; and in enterprises where top executives have overseas backgrounds, the impact of digital transformation on enterprise innovation is more significant than in enterprises where top executives have no overseas backgrounds.

7.2. Research Recommendations and Outlook

The findings of this paper help enterprises to further promote digital transformation and enterprise innovation. First, enterprises should actively promote digital transformation, make full use of the dividend period of digital transformation, improve the production and operation efficiency of enterprises, realize the efficiency and transparency of internal information exchange and communication, actively promote the internal innovation atmosphere of enterprises, and realize the high-quality development of enterprises as soon as possible. Secondly, enterprises should actively open up to the outside world, integrate into the world's innovation stream and international innovation sharing platform. Thirdly, enterprises should pay attention to internal flexibility, set up a reasonable organizational structure, give employees appropriate rights, and let employees participate in the process of enterprise innovation to help enterprises achieve their goals faster.

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