



An Empirical Analysis of Digital Transformation on Enterprise Innovation in China Take Manufacturing as an Example

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Abstract. The improvement of innovation ability is the key for enterprises to win in the market competition. Digital transformation and upgrading is a channel for enterprises to enhance their innovation capabilities. This approach can generate value by generating digitized information and knowledge. Therefore, digitalization is an important part of the current economic development. As a new economic form, the digital economy takes digital technology as the core driving force and promotes the digital transformation of the global economy. China attaches great importance to the development of the digital economy. General Secretary Xi Jinping has repeatedly emphasized that the digital economy must become a new driving force for China's economic development. This article uses applied theory and empirical research methods and finds that digital transformation has a significant positive impact on corporate innovation, and can enhance the willingness and intensity of corporate innovation, especially in large enterprises or state-owned enterprises. Furthermore, this effect is generated through intermediaries related to R&D expenses. Therefore, more enterprise value can be created.

Keywords: Digital transformation · Transformation of firms · Innovation · Empirical analysis · Administration

1 Introduction

As a new economic form, the digital economy takes digital technology as the core driving force, and uses new technologies to form new industries, new industries to spawn new models, and new technologies to empower traditional industries. In this way, the digital transformation and high-quality development of the global economy can be promoted. How to efficiently use information technology and allocate resources to realize the transformation and upgrading of the digital economy has become a major issue in current economic development.

Manufacturing has always been the top priority of the economic development of various countries, and China is no exception. China's development of manufacturing is even more advanced. In recent years, many policies have been introduced to support the development of China's manufacturing industry. In the development, the transformation

from traditional manufacturing to intelligent manufacturing has become a way out for China's manufacturing industry. Digital transformation has also been put on the agenda. Xu [1] believes that digital transformation, which occurs between enterprise development and technological innovation, is an important force driving innovation in manufacturing enterprises.

This paper aims at discovering whether digital transformation has a positive role in promoting enterprise innovation, and it can be achieved through the intermediary of R&D expenses. This conjecture was then analyzed empirically. There will be empirical research designed with two hypotheses accompanied by a few variables. Data collected from the CSMAR database will be analyzed in the following research and will be discussed at last. This research complements the mechanism of the digital transformation of enterprises on enterprise innovation, and further enriches the related research on the economic consequences of digital transformation.

2 Empirical Design of Digital Transformation and Innovation

2.1 Hypothesis

Ferreira [2] indicated that digital transformation can help enterprises achieve efficient and accurate intelligent use of massive data sets in the complex production, operation, and management process after being investigated in middle and small-sized enterprises. Wang, Xia, Ma, and Lin [3] argued that the digital transformation of small and medium-sized enterprises can significantly strengthen organizational resilience and further improve innovation efficiency. The digital economy takes digital technology as the core, uses new technologies to generate new industries, then uses new industries to generate new models, and finally empowers traditional industries. In the process of digital transformation, data is transformed into digital knowledge and information, and value is generated from it. In this process, digitalization has become a channel for enterprises to improve their innovation capabilities. According to the statements above, this research argues that digital transformation has a positive effect on the innovation of enterprises. And this research put forward the hypothesis below:

H1: Digital transformation has a positive effect on the innovation of enterprises in the manufacturing industry.

Mediating effects are likely to arise between digital transformation and enterprise innovation. Wang, Xia, Ma, and Lin [3] mentioned the mediating effect of organizational resilience as well as the research they proposed to prove the positive effect of digital transformation on innovation. Xu [4] regarded enterprise dynamic capability as a mediating variable that the improvement of dynamic capabilities enhances technological innovation capabilities. However, in 2022, the Chinese government has adjusted its policy on R&D expenses of enterprises, namely the 'R&D Expenses Deduction Policy'. Jin, Ren, and He [5] studied the 'R&D Expenses Deduction Policy' in 2015, and found out that this kind of policy can promote the innovation of preferential enterprises, reduce the cost of innovation and the risk of financing, and is an important measure to encourage enterprises to carry out innovation activities. Therefore, this paper argues that R&D

expenses are also a mediating variable between digital transformation and innovation. This makes the following hypothesis:

H2: In the positive effect between digital transformation and innovation, R&D expenses will play an intermediary role.

2.2 Statistics, Variables and Model

This paper takes Chinese listed companies as the research object, and selects data from the past 15 years for research, from 2007 to 2021. All the statistics are found in the CSMAR database and exclude samples of non-ST firms in manufacturing. Variable settings and model settings are learned from Yang, Chen, Li [6] and Xu [1]. There are some adjustments in them.

2.2.1 Explained Variables

This paper use patents (PT) and inventions (INV) as explained variables, which represent the innovation capabilities of enterprises. Among them, INV is used for the robustness test.

2.2.2 Explanatory Variables

By learning from relevant policy documents and the processing ideas of Zhao et al., specific key words representing the digital transformation of enterprises are selected from practical applications such as artificial intelligence, the Internet, big data, blockchain, cloud computing, e-commerce, and intelligent manufacturing. And use the total word frequency (DT) to represent the degree of digitization.

2.2.3 Mediation Variables

As mentioned in the second hypothesis, this paper chooses the logarithm of R&D (RD) as mediation variables.

2.2.4 Control Variables

This paper choose size of the enterprises (SIZE), return on assets (ROA), leverage (LEV), Enterprise nature (SOE), and two virtual variable of year and industry as control variables (Table 1).

For the two assumptions, the following models are established:

$$PT_{i,t} = \alpha_0 + \alpha_1 DT_{i,t} + \alpha_2 Controls_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$MED_{i,t} = \alpha_0 + \alpha_1 DT_{i,t} + \alpha_i Controls_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$PT_{i,t} = \alpha_0 + \alpha_1 DT_{i,t} + \alpha_2 MED_{i,t} + \alpha_i Controls_{i,t} + \varepsilon_{i,t} \quad (3)$$

Among two models, MED is the mediation variable.

Table 1. Variable settings

Category	Name(code)	Measurement
Explained variables	Innovation capability (PT)	Amount of patent in certain year
Explanatory variables	Digital transformation (DT)	Frequency of certain words
Mediation variables	R&D expense (RD)	Logarithm of R&D
Control variables	Size of a company (SIZE)	Logarithm of total asset in certain year
	Return on asset (ROA)	Net profit/Total asset
	Leverage (LEV)	Total leverage/Total asset
	Equity nature (SOE)	Stateowned is 1, others 0
	i.year	
	i.industry	

3 Results and Analysis

3.1 Descriptive and Correlation Statistics

In descriptive statistics, it can be observed that the mean value of PT, that is, the innovation ability of enterprises, is relatively low and the variance is relatively large. It shows that there are great differences in the innovation ability of different enterprises. In addition, the level of digital transformation (DT) is generally low, because its mean value and variance are both at a low level. R&D expenses show the opposite trend to the first two indicators, with a higher mean and a smaller standard deviation, which means that each company has a high degree of R&D investment.

In the correlation analysis, except for corporate leverage, all other indicators are positively correlated with corporate innovation capability (Tables 2, 3, 4, 5, and 6).

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
PT	8936	120.397	530.988	1	20107
DT	8936	7.067	18.548	0	281
SIZE	8936	22.111	1.171	19.288	27.307
ROA w	8936	.047	.052	-.151	.197
LEV w	8936	3.64	3.012	1.126	18.75
SOE	8936	.325	.468	0	1
RD	8936	18.108	1.349	7.17	25.025

Table 3. Matrix of correlations

Variables	PT	DT	SIZE	ROA_w	LEV_w	SOE	RD
PT	1.000						
DT	0.099	1.000					
SIZE	0.320	0.009	1.000				
ROA_w	0.016	0.000	-0.078	1.000			
LEV_w	-0.093	0.016	-0.383	0.283	1.000		
SOE	0.053	-0.071	0.342	-0.169	-0.237	1.000	
RD	0.314	0.126	0.700	0.069	-0.227	0.171	1.000

Table 4. Regression model

	Model (1)	Model (2)	Model (3)
	PT	PT	PT
DT	2.843 ^{***} (0.301)	2.650 ^{***} (0.286)	1.259 [*] (0.691)
SIZE		156.4 ^{***} (5.102)	92.13 ^{***} (16.88)
SOE		-55.65 ^{***} (12.22)	-21.09 (17.26)
ROA_w		301.6 ^{***} (106.2)	45.31 (51.35)
LEV_w		3.154 (1.982)	5.705 ^{***} (1.639)
_cons	100.3 ^{***} (5.982)	-3363.3 ^{***} (114.2)	-1954.6 ^{***} (362.3)
year	N	N	Y
industry	N	N	Y
N	8936	8936	8936
R ²	0.010	0.116	0.057
adj. R ²	0.010	0.115	0.050

Standard errors in parentheses

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

Table 5. Mediation test

Sobel test	Mediation variable: R&D expense (RD)
	Z statistic: 4.653***
	Effective mechanism - forward conduction
Proportion of total effect that is mediated: 8.2%	
Co-efficient of effect	Indirect effect = .14351 .030842 4.65312 3.3e-06
	Direct effect = 1.60543 .306049 5.24567 1.6e-07
	Total effect = 1.74894 .30635 5.70897 1.1e-08

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

Table 6. Robustness test

	Model (3)	Model (4)
	PT	INV
DT	1.259*	1.170**
	(0.691)	(0.533)
SIZE	92.13***	51.27***
	(16.88)	(10.80)
SOE	-21.09	-6.691
	(17.26)	(9.298)
ROA_w	45.31	20.91
	(51.35)	(30.69)
LEV_w	5.705***	3.896***
	(1.639)	(1.085)
_cons	-1954.6***	-1080.9***
	(362.3)	(229.9)
<i>year</i>	Y	Y
<i>industry</i>	Y	Y
<i>N</i>	8936	8399
<i>R</i> ²	0.057	0.047
adj. <i>R</i> ²	0.050	0.040

3.2 Basic Regression and Two-Way Fixed Effects Model Regression

In the section of regression analysis, this paper conducts a three-part regression test. Where Model (1) is the basic regression analysis (OLS) on the explained variable (PT) and the explanatory variable (DT). Model (2) based on Model (1), control variables are

added for regression analysis, but fixed effects are not used. Model (3) is a regression analysis using a two-way fixed-effects model.

In the first two regression models, the results show that digital transformation (DT) has a significant promoting effect on enterprise innovation capability (PT), both of which pass the test at a significant level of 1%. In the two-way fixed effect model, due to the influence of SIZE and ROA and the control of dummy variables, the promotion effect of digital transformation (DT) on enterprise innovation capability (PT) only passed the test at the level of 10%, but still shows significance.

3.3 The Analysis Above Has Proved the First Hypothesis.3.3 Mediation Test

In this section, the Sobel test of the mediating effect was further carried out on the regression results, with research and development (RD) as the mediating variable. It can be concluded that the second hypothesis is true. The results showed that the mediating effect accounted for 8.2% of the total effect, and the test result passed the test at a significant level of 1%, indicating that the mediation effect was established. In addition, according to the calculation, the total promotion effect of digital transformation (DT) on enterprise innovation capability (PT) is the direct effect of 1.605 plus the indirect effect of 0.143. The total effect is 1.748. So the meditation, R&D expenses, do become a link when digital transformation has a positive effect on innovation.

3.4 Robustness Test

This section is the robustness test. In this paper, in the robustness test, the total number of patents (PT) is replaced by the number of invention patents (INV), and the regression analysis of the two-way fixed effect model is carried out. The results show that the positive promotion effect of digital transformation (DT) on the number of invention patents (INV) passes the test at the level of 5%. That is to say, the research and results of this paper are reliable.

4 Conclusion

The research in this paper shows that digitization is an important way for companies to improve their innovation capabilities. The innovation ability of an enterprise is the key to its ability to take the lead or even win in the market competition. Therefore, enterprises need to carry out digital transformation from the aspects of artificial intelligence technology, blockchain technology, cloud computing technology, big data technology and digital technology application, thereby enhancing the innovation ability of enterprises. To achieve the purpose of reducing costs, improving efficiency, and enhancing the competitiveness of enterprises. At the same time, this study also shows that enterprises can realize the driving effect of digitalization on enterprise innovation through R&D expenses, which refer to product design cost, material cost, manufacturing cost, testing cost. Normally, the more these kinds of cost have spent by an enterprise, the higher chance they will be succeed on their digitalization products of behaviors. And it

can increase R&D expenses, thereby increasing the proportion of R&D expenses in the total effect of digitalization on innovation.

However, increasing R&D expenses will inevitably lead to an increase in the innovation cost of enterprises, which will bring some troubles to enterprises. For example, it will cause the company's net profit to decline, or cause the company's liabilities to increase, so that the business risk becomes greater, and the company's financing will be more difficult. Without funds, it means that the enterprise will face a disadvantage in the market competition, and even problems such as the break of the capital chain will occur, which will make the enterprise go bankrupt. Therefore, the Chinese government needs to consider this aspect and introduce more incentives, preferential and subsidy policies, so that more enterprises can reduce the burden as much as possible in the process of digital transformation. Only in this way can the Chinese manufacturing industry achieve stable digital transformation and upgrading, enhance its international competitiveness, and then promote the development of the Chinese economy.

There are also some shortcomings in this study. The indicators of the level of corporate innovation and corporate R&D investment are relatively simple and may not be accurate enough. This may be the reason why the regression results are only significant at the 10% level in the regression analysis. In follow-up studies, the role of moderator variables can also be added. In addition to this, digitization-related research can be conducted on industries other than manufacturing.

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