A Study on the Impact of Digital Transformation on Corporate Technology Innovation

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ABSTRACT

With the emergence of the Internet and the rapid development of information technologies such as big data and artificial intelligence, the world is undergoing an unprecedented technological change. The emergence of the digital economy has injected new impetus into economic development, and digital transformation has become the main theme of industrial transformation. This paper uses the recently released World Bank survey data on Chinese enterprises and uses the multi-grid principal component analysis method to construct a digitalization index at the enterprise level. relationship with technological innovation. The research in this paper helps to better understand the differences in the impact of digitalization on different types of enterprises, so as to facilitate more targeted policy recommendations.

Keywords*: Digital transformation, Technology innovation, Industry competition, Institutional environment*

1. INTRODUCTION

In the era of digital economy, digital technologies centred on next-generation information technology are developing rapidly. The research results of the "White Paper on China's Digital Economy Development and Employment (2019)" show that in 2018, "the scale of my country's digital economy reached 31.3 trillion yuan, an increase of 20.9%, accounting for 34.8% of GDP", and economic development has increasingly shown "Digital Features". Under the wave of the digital economy, in order to better survive and develop, enterprises must carry out digital transformation in the process of production and business activities, and speed up the pace of enterprise transformation and upgrading has become an inevitable choice [5]. Using digital technology to drive industrial digital transformation and industrial organization innovation, and to create and optimize an industrial ecosystem that is compatible with the digital economy era is an urgent requirement to promote industrial transformation and upgrading and achieve high-quality development. Therefore, it is of great practical significance to study the impact of digitalization on enterprise transformation and upgrading. However, there is currently a lack of research on this issue.

2. THEORETICAL BASIS AND RESEARCH HYPOTHESIS

2.1 Theoretical basis of digital technology and digital transformation

Industrial digitalization is the application of new generation digital technologies represented by big data, cloud computing and artificial intelligence in multiple aspects such as production, operation, sales and management to realize the digital transformation of enterprises and the digital transformation of the whole chain industry [4]. Therefore, the impact of industrial digitalization on technological innovation includes direct impact at enterprise level and indirect impact at industry level.

At the enterprise level, digital technologies stimulate the innovation potential of enterprises by optimizing the combination of innovation factors, improving the innovation process, and shortening the innovation cycle, among other paths of action. In terms of optimizing the combination of factors, general-purpose technologies such as industrial robots and intelligent algorithms provide feasible solutions for enterprises to reduce R&D personnel investment, lower R&D costs and optimize the combination of R&D resources. Even in the highly knowledge-intensive pharmaceutical R&D industry, the

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application of AI technologies can reduce the marginal search cost of knowledge in the R&D process and replace the personnel input in innovation activities.

At the industrial level, With the construction of digital infrastructure and the development of digital platforms and ecosystems, the focus of technological innovation is gradually shifting from inside to outside the enterprise [3]. More enterprises have standardized digital infrastructure to provide the basis for ubiquitous connection of various innovation elements such as equipment, software and personnel, and digital platforms and ecosystems are thus equipped with comprehensive data collection capabilities, while the massive multi-dimensional high-frequency data create conditions for subsequent correlation analysis and deep mining, thus forming innovation models in the organization of industrial resources, knowledge transmission and diffusion.

2.2 Research hypothesis of digital transformation and technological innovation

Digital transformation of industry driven by digital technologies such as big data, cloud computing, artificial intelligence, blockchain, etc. to promote the combination of digital technology and economic activities to achieve data collection, transmission, storage, processing and feedback. A variety of new industries, new models, new dynamics, improve the efficiency of the whole industry operation, and build a new system of digital economy. Based on the above views, this paper proposes:

Hypothesis 1: Digital transformation can promote technological innovation of enterprises.

Companies with strong innovation capabilities are more likely to come up with new ideas and directions, combining ICT with more nodes in production, logistics and sales, helping companies to expand digital application scenarios, linking various "silos" in operations and improving management efficiency. Information technology is in the stage of rapid development, innovative enterprises can improve the intelligence level of production and operation through the application of new technologies, improve the efficiency of transformation from data to information, further improve management efficiency and reduce production costs, and improve the competitiveness of enterprises through technological advantages. [2]. Based on the above views, this paper proposes:

Hypothesis 2: The stronger the innovation ability of enterprises, the stronger the digital transformation promotes technological innovation.

The technological innovation of enterprises is highly related to the characteristics of the industry they are in. The more competitive the industry is, the more enterprises tend to find new markets and profits through technological innovation [1]. With the continuous improvement of production technology and material level, consumers' demands tend to be more and more personalized. The low efficiency of product updating and iteration under the traditional production method makes it difficult to meet the diversified needs of users, thus creating problems such as fierce competition and overcapacity. Facing the huge cost, efficiency and competition pressure, digital transformation becomes an important way for enterprises to improve competitiveness and develop overseas markets. Based on the above views, this paper proposes:

Hypothesis 3: The more competitive the industry is, the stronger the promotion effect of digital transformation on technological innovation.

The institutional environment has an obvious role in guiding the digital transformation behaviour of enterprises. In the report of the 19th Party Congress, the concept of "Digital China" was formally proposed, which means making full use of the Internet, big data, artificial intelligence, and the deep integration of the real economy. At the G20 Hangzhou Summit, the "digital economy" was listed for the first time as an important issue in the G20 blueprint for innovation and growth. The digital economy is a new form of economic performance and an important driver of China's economic transformation. The Internet industry has ushered in the mobile era, and the establishment of mobile terminals based on information interaction has connected people's online and offline lives, with significant two-way effects. Based on the above views, this paper proposes:

Hypothesis 4: The better the institutional environment, the stronger the role of digital transformation in promoting technological innovation.

3. VARIABLE SETTINGS

3.1 Data description

As of the latest public data, the World Bank Enterprise Survey data involves 135,000 enterprises in 139 countries (regions), and Chinese enterprise data is used here. The data used in this section are consistent with the data sources used to measure the level of digitalization of enterprises, from the China part of the World Bank Enterprise Survey. There are 2,848 enterprises in the Chinese enterprise survey, including 2,700 non-state-owned enterprises and 148 state-owned enterprises. These companies are located in 25 cities in mainland China, covering not only the eastern region but also the central and western regions, and the sample mainly includes information on production and sales, factor inputs, finance, competition, law and business environment.

3.2 Theoretical basis of digital technology and digital transformation

3.2.1 Explained variables

Corporate technology innovation (rd): Referring to the studies on corporate innovation, we use corporate innovation output (whether to introduce new products) to measure the level of corporate R&D. Innovation output can more directly reflect the innovation efficiency of a company compared with innovation input, and is more relevant in the study of corporate export performance.

3.2.2 Explanatory variables

Digital index (digital): Enterprise survey data includes many dimensions of digital measurement such as mail correspondence, network construction, Internet application, etc. For such data, Using principal component analysis (PCA), we can measure the weights of each subdivision and obtain a comprehensive index of the variables of interest, thus achieving effective dimensionality reduction of complex evaluation indicators. However that PCA applied directly to the analysis of discrete variables can cause biased estimation results, so it can be corrected by using Polychromic PCA.

For individual digitized indicators, the decomposition of multiple principal components in their directions can be written as follows:

$$dig_{1j} = v_{11} \times A_{1j} + v_{12} \times A_{2j} + \cdots + v_{1N} + A_{5j} \quad (1)$$

…

$$dig_{Nj} = v_{N1} \times A_{1j} + v_{N2} \times A_{2j} + \cdots + v_{NN} + A_{Nj}$$

where A represents each principal component, J represents the number of enterprises, N represents the number of digitized indicators, and: represents the component of the principal component on each digitized component indicator. Transposing the coefficient matrix of equation (1) results in the expression of the weight of each digital component in the principal component.

$$A_{1j} = f_{11}(c_1|dig_{1j}) + f_{12}(c_2|dig_{2j}) + \cdots + f_{1N}(c_N|dig_{Nj}) \quad (2)$$

…

$$A_{Nj} = f_{N1}(c_1|dig_{Nj}) + f_{N2}(c_2|dig_{2j}) + \cdots + f_{NN}(c_N|dig_{Nj})$$

where is the weight coefficient of each digitalization component, and f is the mapping of each digitalization component taking values to the corresponding coefficients. Based on the above method, this paper selects indicators to measure the digitization of companies from various dimensions such as communication channels, data operation and innovation drive. Specifically, they include: whether to use email for business transactions (c22a), whether to build a company website (c22b), whether to use the Internet for purchasing (c24b), sales (c24f), and R&D (c24d).

The survey data selected in this paper are representative for the current characteristics of digital transformation in traditional industries and contain more diverse dimensions. Table 1 reports the results of the multi-grid principal component analysis using Stata 16. It can be seen that the characteristic roots of the first principal component are significantly higher than the other components, and the variance contribution rate reaches 47.49%, so the first principal component is adopted as the evaluation index of enterprise digitalization, which is defined as the enterprise digitalization index.

Table 1. Results of Principal Component Analysis of Digitalization Index

Component	Eigenvalue	Proportion	Cumulative
Comp1	2.37466	0.4749	0.4749
Comp2	1.33005	0.2660	0.7409
Comp3	0.708914	0.1418	0.8827
Comp4	0.434667	0.0869	0.9697
Comp5	0.151708	0.0303	1.0000

The descriptive statistics of the main variables of the sample are shown in Table 2.

Table 2. Variable Description Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
rd	148	1.533784	.9994253	-9	2
dig	148	1.168919	.3759526	1	2
Ina	148	69.7973	28.77143	-9	100
Ind	148	.4797297	.9509723	-7	3
Inst	148	.1418919	1.666028	-9	3
age	148	1883.601	454.2971	-9	2009
size	148	1244.486	6273.508	5	50000
tmexp	148	17.85811	9.941331	-9	40
private	148	21.22297	40.51553	-9	100
foreign	148	.4391892	4.946278	0	60
state	148	74.71622	43.35631	-9	100

4. EMPIRICAL ANALYSIS

4.1 Econometric model

The benchmark model will investigate the impact of digitization on firms' technological innovation and the moderating effects at the resource, industry, and institutional levels. To test the theoretical hypotheses, the following econometric equations are set in this paper:

$$rd_{ijc} = \beta_0 + \beta_1 digital_{ijc} + \beta_2 Ina + \beta_3 digital \times Ina + \beta_4 Ind + \beta_5 digital \times Ind + \beta_6 inst + \beta_7 digital \times inst + \alpha_x \Omega_{ijc} + \eta_j + \eta_c + \epsilon_{ijc} \quad (3)$$

4.2 Analysis of benchmark results

Table 3 reports the regression results for the benchmark model, where column 1 is the main effects model that includes only the digitization index, columns 2 through 4 include three moderating effects of innovation capability, industry competition and institutional quality, respectively, and column 5 is the overall model. The empirical results show that there is a significant positive relationship between firms' digitalization and exports in all regressions. Among them, the estimated results in the main effects model are significant at the 1% significance level, indicating that digital transformation can promote firms' exports, which supports the research hypothesis 1 of this paper.

Table 3. Baseline model regression results

	(1)	(2)	(3)	(4)	(5)
rd					
dig	0.157**	0.566*	0.276*	0.153***	0.725*
	(0.71)	(1.16)	(1.07)	(0.79)	(1.58)
ina		0.0107			0.0120
		(1.24)			(1.56)
dig_ina		-0.00595**			-0.00697
		(-0.91)			(-1.21)
ind			0.277		0.254
			(0.76)		(0.71)
dig_ind			-0.297*		-0.266
			(-0.90)		(-0.81)
inst				0.505**	0.567***
				(3.29)	(3.40)
dig_inst				0.203**	0.264***
				(-1.54)	(-1.80)
age	0.000448*	0.000468*	0.000440*	0.000339	0.000353
	(2.22)	(2.32)	(2.17)	(1.90)	(1.98)
size	0.0000178	0.0000194	0.0000181	0.0000107	0.0000124
	(1.27)	(1.38)	(1.29)	(0.87)	(1.00)
tmexp	0.00934	0.00741	0.0101	0.0139	0.0124
	(1.03)	(0.81)	(1.11)	(1.74)	(1.52)
private	-0.000282	0.000303	0.000599	-0.00117	-0.0000639
	(-0.06)	(0.06)	(0.12)	(-0.29)	(-0.01)
foreign	-0.0110	-0.0115	-0.0108	-0.0101	-0.0107
	(-0.65)	(-0.68)	(-0.64)	(-0.68)	(-0.71)
state	-0.000823	-0.000613	-0.000373	-0.000845	-0.000514
	(-0.19)	(-0.14)	(-0.08)	(-0.22)	(-0.12)
				(-1.54)	(-1.80)
_cons	0.390	-0.389	0.227	0.583	-0.386
	(0.62)	(-0.45)	(0.35)	(1.05)	(-0.49)
N	148	148	148	148	148

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001.

4.3 Robustness tests

Digitization can break the limitation of distance and improve the efficiency of enterprise technology innovation. At the same time, the expansion of enterprise technology scale may also increase the demand for enterprise digital development and further improve enterprise digitalization, thus creating a reverse causal relationship and creating an endogenous problem. Since this paper uses cross-sectional data based on enterprise surveys, similar to similar studies, there is the problem of difficulty in finding appropriate instrumental variables through methods such as variable lags. In order to alleviate the problem of possible estimation bias caused by endogeneity as much as possible, this paper uses the mean value of enterprise digitization by industry-city dimension as the instrumental variable in order to alleviate the problem of possible bias caused by endogeneity, this paper uses the mean digitization level of enterprises by industry-city dimension as the instrumental variable for 2SLS estimation. The instrumental variables are chosen based on the fact that similar enterprises compete in a convergent nature, and the average digitization level of the same industry in the same city is representative of the digitization level of the enterprises in the group. Table 4 reports the regression results of the instrumental variable 2SLS test, and the main findings are consistent with the baseline regression results, demonstrating the robustness of the findings.

Table4. 2SLS instrumental variable regression

	(1)	(2)	(3)	(4)	(5)
rd					
dig	0.176***	0.0744**	0.190*	0.233***	0.100 *
	(1.31)	(0.56)	(1.51)	(1.36)	(0.67)
dig_ina		0.00167***			0.00213
		(0.74)			(0.91)
dig_ind			0.0451**		0.0145*
			(0.99)		(0.16)
dig_inst				0.211	0.214 **
				(1.40)	(1.39)
_cons	1.328***	1.312***	1.337***	1.299***	1.274***
	(6.20)	(5.66)	(6.14)	(5.74)	(4.98)
N	148	148	148	148	148

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001.

5. CONCLUSION AND INSIGHTS

Based on data from the World Bank's China Enterprise Survey, this paper constructs a digitalization index of Chinese enterprises using multinomial principal component analysis, examines the impact of digital transformation on technological innovation, and specifically examines the moderating effects of firm innovation, industry competition and institutional environment on the relationship between digitalization and technological innovation. The results show that digital transformation has a facilitating effect on enterprise exports; the intensity of enterprise innovation plays a positive moderating role on the relationship between digitalization and exports, and there is heterogeneity in the mechanism of action of different innovation dimensions: innovation capability can strengthen the facilitating effect of digitalization on export willingness by introducing new products and services, while innovation efficiency can strengthen the intensity of digitalization on exports by reducing costs and improving efficiency In industries with excessive competition, weak demand and overcapacity, digitalization can help enterprises achieve differentiation and promote exports more obviously; the quality of institutional environment plays a positive role in regulating the relationship between digitalization and technological innovation, and when the institutional environment is better, the promotion of digitalization on enterprises' technological innovation is more When the institutional environment is better, the promotion of digitalization on enterprise technology innovation is more obvious.

For enterprises, in the face of complex and changing technological innovation, they need to accelerate digital transformation and Increase the investment in R&D of cutting-edge digital technologies, improve the analysis and application capabilities of existing data, transform data into information through big data, artificial intelligence and other technologies, realize refined operations, and reverse-drive the digital transformation of the production side. For the government, first, it should promote the construction of new infrastructure represented by 5G, gradually reduce the imbalance in the development of digital technology facilities between regions, and continuously improve the level of China's

digital infrastructure. Second, we must comprehensively promote the development of the digital economy, build "digital China", encourage digital innovation in enterprises, and improve the mechanism for training professional talents. Third, to build a safe and orderly digital development environment, through the legal, regulatory, and technical aspects of the protection of network security of big data.

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