Research on the Impact of Digital Transformation on Innovation Efficiency of Manufacturing Enterprises

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Abstract: With the development of the digital economy, digitalization has become an important driving force for enterprise innovation. So, to what extent will the innovation efficiency of manufacturing enterprises be affected, and what specific mechanisms will be affected? To investigate these issues, this article empirically tests the degree and mechanism of the impact of digital transformation on the innovation efficiency of manufacturing enterprises. Research has found that digital transformation has a promoting effect on the innovation efficiency of manufacturing enterprises, and can improve the level of innovation efficiency by alleviating financing constraints. Provide a basis for promoting the high-quality development of manufacturing enterprises.

Keywords: Digital Transformation; Innovation Efficiency; Manufacturing Enterprises

1 Introduction

Nowadays, China's digital economy has entered a period of coordinated development of the "four modernizations", in which digital industrialization and industrial digitization are experiencing a new stage of integration with the real economy, constantly producing new technologies. With the widespread application of the new generation of information technology, the digital economy is sweeping across the world, and China's achievements in the Internet field demonstrate the potential of digital technology. In the digital age, technologies such as big data and artificial intelligence have gradually penetrated into all aspects of economic and social life, and their impact on technological innovation in the manufacturing industry is an important aspect worth paying attention to. The manufacturing industry is the core part of the real economy, and the innovation efficiency of the manufacturing industry is a fundamental factor that affects the competitiveness of the manufacturing industry and even the quality of the overall development of the real economy. This article first analyzes and verifies the role of digital transformation in promoting innovation efficiency in manufacturing enterprises, and then empirically analyzes the mechanism by which digital transformation promotes innovation efficiency in manufacturing. Finally, it proposes countermeasures and suggestions on how to further deepen the application of digital technology in manufacturing enterprises and promote digital transformation in manufacturing.

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2 Theoretical mechanism

2.1 Digital transformation and enterprise innovation

Digital transformation not only drives global economic growth, but also continuously drives the cultivation and development of new driving forces for manufacturing enterprises. The innovation activities of enterprises have the chara cteristics of high uncertainty, high failure rate, long cycle, but large potential future benefits. Improving innovation efficiency is an important way for manufacturing enterprises to maintain their core competitiveness. Empowering enterprises to optimize resource allocation through digital technology can affect innovation efficiency[1].

Firstly, the digital transformation of manufacturing enterprises can provide greater tool support for enterprise aggregation and allocation of innovative resources[2-3]. Secondly, in the decision-making stage of determining innovation direction, digital transformation of manufacturing enterprises can empower decision-making. Finally, effective operation and maintenance of knowledge resources are crucial in the execution of innovative projects[4]. By utilizing digital technology, we can better grasp and analyze information, effectively collaborate with each other, help companies complete tasks faster, and promote their development more effectively, thereby improving the success rate of innovation activities in manufacturing enterprises.Therefore, hypothesis 1 is proposed

H1: The digital transformation of manufacturing enterprises has an improving effect on innovation efficiency

2.2 Digital transformation, financing constraints, and enterprise innovation

Enterprises need to systematically evaluate the input costs and investment returns included in their business activities, because only when the investment returns exceed the input costs can investment activity returns be achieved[5-6]. The fundraising also has a significant impact on research and innovation activities. However, due to information asymmetry, the relationship between investors and innovative entities has been affected, In the context of the digital economy, the widespread use of digital information technologies such as big data, mobile internet, and cloud computing can effectively reduce information asymmetry among various business entities.With the continuous enhancement of information transparency, enterprises not only benefit from good external supervision, but also from market recognition. In this way, they can ensure reasonable decisions between supply and demand sides, achieve capital flow, and attract high-quality external resource investment while improving the efficiency and inclusiveness of financial services; In addition, digital transformation has also promoted the improvement of credit systems to alleviate the common credit difficulties faced by banks due to adverse selection and moral hazard, making banks more willing to lend to enterprises[7].

Therefore, by implementing digital transformation, manufacturing enterprises can effectively meet the development needs of today's era and gain the attention and recognition of external investors, thereby attracting and gathering various innovative resources to support technological innovation activities. At the same time, it can also effectively eliminate information asymmetry, alleviate financing constraints faced by innovative projects, and improve innovation levels.Therefore, Hypothesis 2 is proposed.

H2: Digital transformation of manufacturing firms enhances innovation efficiency by alleviating financing constraints, i.e. financing constraints play a mediating effect in digital transformation and innovation efficiency of manufacturing firms.

3 Research design

3.1 Sample selection and variable setting

This paper takes the listed manufacturing companies in Shanghai and Shenzhen A-shares from 2014 to 2022 as the research sample, and the following treatments are carried out: (1) eliminating companies with more missing values; (2) eliminating ST and PT companies. After the above screening, 19,762 samples are finally obtained. The financial data of this paper is from CSMAR database, and the annual reports of listed companies are sourced from Juchao Information Network. In order to exclude the possible influence of outliers, all continuous variables are subject to shrinking treatment. After the above processing, stata.17 was applied to analyse the data. Table 1 below is an explanation of the variables.And regarding the explanatory variables: Digital Transformation (DCG). This article uses Python, drawing on the measurement method of Wu Fei[8], and uses Python text analysis to explore the keyword frequency of digital transformation, constructing a measurement index for the level of digital transformation of manufacturing enterprises.In order to control the influence of other factors, this paper selects gearing ratio, firm size, return on total assets, percentage of independent directors, board size, firm age, Tobin's Q, and cash holdings as control variables.

Table 1. Variable.

Variable category	Variable code	Variable Declaration
Explained Variable	EFFI	Ln(patent applications+1)/Ln(R&D expenditure+1)
Explanatory variable	DCG	Ln (key word frequency for 1+digital transformation lexicon)
Mediating variable	FC	SA index
Control variable	LEV	Total liabilities/total assets
	Size	Ln(total assets of the company)
	ROA	Net profit/total assets
	Ind	Number of independent directors/total number of board members
	Board	Ln(total number of directors)
	Age	Ln (fiscal year - year of establishment of the enterprise + 1)
	Tobinq	Enterprise Market Value/Enterprise Assets
	Cash	Ln (cash held by enterprises)

	Year	Annual dummy variable
	Ind	Industry dummy variables

$$EFFI_{i,t} = \alpha_0 + \alpha_1 DCG_{i,t} + \alpha_i Controls + \sum Ind + \sum Year + \varepsilon_{i,t} \quad (1)$$

$$FC_{i,t} = \beta_0 + \beta_1 DCG_{i,t} + \beta_i Controls + \sum Ind + \sum Year + \varepsilon_{i,t} \quad (2)$$

$$EFFI_{i,t} = \gamma_1 + \gamma_2 DCG_{i,t} + \gamma_3 FC_{i,t} + \gamma_i Controls + \sum Ind + \sum Year + \varepsilon_{i,t} \quad (3)$$

Models (1), (2), and (3) respectively test H1 and H2

3.2 Empirical results and explanations

The descriptive statistics of the main variables in this paper are shown in Table 2. From the viewpoint of digital transformation of manufacturing enterprises, the mean value is 1.399, the median is 1.099, reflecting that the degree of digital transformation of China's manufacturing enterprises is not high and there is a large discrepancy between the enterprises, and from the viewpoint of innovation efficiency, the mean value is 0.170, the standard deviation is 0.0803, reflecting the overall level of innovation efficiency of manufacturing enterprises is not high. The mean value is 0.170 and the standard deviation is 0.0803, reflecting the overall level of innovation efficiency of manufacturing enterprises is not high.In addition to this, the maximum value of financing constraint (FC) is -3.315 and the minimum value is -4.454, which shows that there is more or less a certain degree of financing constraint in the sample firms. There are also the rest of the control variables which all indicate a representative selection of sample firms.

Table 2. Decriptive statistics.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
DCG	19,762	1.399	1.267	0	4.710
EFFI	19,762	0.170	0.0803	0	0.334
FC	19,762	-3.850	0.231	-4.454	-3.315
LEV	19,762	0.387	0.194	0.0551	0.916
ROA	19,762	0.0400	0.0695	-0.286	0.210
Tobinq	19,762	2.172	1.382	0.874	8.909
Board	19,762	2.096	0.188	1.609	2.565
Ind	19,762	37.81	5.381	33.33	57.14
Age	19,762	2.952	0.296	2.079	3.555
Size	19,762	22.07	1.159	19.98	25.67
Cash	19,762	19.92	1.324	16.64	23.61

The matrix of correlation coefficients is presented in Table 2, which reports the Pearson correlation coefficients between the variables involved in this study, demonstrating the correlation analysis of the variables in this paper. From the result values: firstly, the absolute values of the correlation coefficients are all small, which basically ensures that there is no multicollinearity in the model variables, and secondly, the correlations between the other control variables selected in the model of this paper and the innovation efficiency are all significant to a certain extent, which indicates that all these control variables have a certain impact on the innovation efficiency of the enterprises, which further indicates that the variable settings of this paper are scientific and reasonable, and that the variables of the study are of significance of regression analysis, which can be carried out later. Thirdly, it can be seen in the table that digital transformation (DCG) and innovation efficiency (EFFI) are significantly positively correlated, and innovation efficiency will increase with the digital transformation of manufacturing enterprises, and the two are moving in the same direction, which preliminarily verifies the correctness of the H1 hypothesis.This shows that the importance of digital transformation cannot be ignored.

Table 3. Correlation analysis.

	EFFI	DCG	LEV	Size	ROA	Ind	Board	Age	Tobinq	Cash	FC
EFFI	1										
DCG	0.257***	1									
LEV	0.194***	0.039***	1								
Size	0.386***	0.114***	0.453***	1							
ROA	0.049***	-0.026***	-0.410***	0.024***	1						
Ind	-0.012*	0.061***	-0.00100	-0.027***	-0.027***	1					
Board	0.089***	-0.054***	0.112***	0.241***	0.015**	-0.600***	1				
Age	-0.021***	-0.0110	0.140***	0.160***	-0.074***	-0.016**	0.082***	1			
Tobinq	-0.144***	-0.022***	-0.177***	-0.305***	0.135***	0.023***	-0.066***	-0.015**	1		
Cash	0.348***	0.163***	0.143***	0.786***	0.224***	-0.026***	0.203***	0.094***	-0.198***	1	
FC	0.029***	0.00300	-0.103***	-0.111***	0.056***	0.050***	-0.073***	-0.904***	0.078***	-0.053***	1

Bring models (1) (2) and (3) into Stata to obtain the following table,column (1) in the table 4 indicates a significant positive correlation between the degree of digital transformation and innovation efficiency at the 1% level, after controlling for other factors. This indicates that the higher the degree of digital transformation, the higher the innovation efficiency. The hypothesis H1 proposed in this article has been validated, with column (2) indicating a significant negative correlation between the degree of digital transformation and financing constraints at the 1% level, after controlling for other factors. This indicates that the higher the degree of digital transformation, the lower the financing constraints. Column (3) indicates that, after controlling for other factors, the improvement of digital transformation degree has an increased negative correlation coefficient with financing constraints and a positive correlation coefficient with innovation efficiency. Moreover, the innovation efficiency coefficient has increased significantly, and financing constraints play a mediating role between digital transformation and innovation efficiency in manufacturing enterprises. The hypothesis H3 proposed in this article has been validated.[9-10]

Table 4. Regression results.

	(1)	(2)	(3)
	EFFI	FC	EFFI
DCG	0.00155***	-0.00231***	0.00149***
	(0.000565)	(0.000573)	(0.000564)
LEV	-0.00630	-0.0388***	-0.00738
	(0.00475)	(0.00614)	(0.00477)
Size	0.0239***	-0.0150***	0.0235***
	(0.00153)	(0.00240)	(0.00154)
ROA	0.00191	-0.0498***	0.000514
	(0.00748)	(0.00898)	(0.00748)
Age	-0.0331***	-0.156***	-0.0374***
	(0.0107)	(0.0125)	(0.0108)
Ind	-0.000154	0.000202	-0.000148
	(0.000147)	(0.000145)	(0.000147)
Board	0.00107	0.00573	0.00123
	(0.00486)	(0.00489)	(0.00485)
Tobinq	0.000302	0.00730***	0.000507
	(0.000423)	(0.000600)	(0.000425)
Cash	0.00105	0.00429***	0.00117
	(0.000709)	(0.000627)	(0.000712)
FC			-0.0280**
			(0.0111)
IND	YES	YES	YES
YEAR	YES	YES	YES
Observations	19,506	19,506	19,506
R-squared	0.751	0.976	0.751

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

4 Conclusions

Against the backdrop of intensified global competition, China's digital development is still in its early stages. The government should accelerate the digital transformation of manufacturing enterprises, introduce clear policies to guide it, and increase macroeconomic regulation of the digital economy. It should establish and improve digital laws to promote stable market development, help enterprises clarify their development direction, and ensure that the digital transformation of manufacturing enterprises can be carried out in a healthy and orderly manner. At the same time, continuously increasing the level of digital investment will further unleash the dividends of the digital economy.

Manufacturing enterprises should recognize the importance of digital transformation in improving innovation efficiency. Therefore, they should accelerate the digitalization and intelligent construction of infrastructure to better support the cross regional flow of innovation elements. At the same time, enterprises should fully utilize the opportunities of digital transformation, integrate resources from all parties, continuously alleviate their own financing constraints, increase research and development investment, adhere to independent innovation, in order to continuously improve the innovation efficiency of enterprises.

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