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The Impact of Digital Transformation on Manufacturing Enterprises Innovation

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Abstract: With the rapid development of big data, artificial intelligence and other information technologies, the world economy is entering a new economic era driven by digital technology. Under the background of China Manufacturing 2025, the new generation of digital technology has had a fundamental impact on the reform of China's manufacturing productivity. It also provides a strong driving force for China's manufacturing industry to achieve high-quality development. At present, how to give full play to the driving role of digital innovation elements and achieve performance improvement has become a key concern of the country and enterprises. Based on the data of A-share listed manufacturing enterprises from 2007 to 2021, this paper uses multiple perspectives to measure the digital transformation of enterprises, uses the fixed effect model to verify the promotion effect of digital transformation on innovation, and further uses the multi-period DID model to verify the impact of digital transformation on the innovation performance of manufacturing enterprises through the parallel trend test. Through the empirical test, it is found that digital transformation can significantly promote the improvement of enterprise innovation performance. The research conclusions not only further enrich the relevant research on enterprise innovation under the background of digital transformation, but also provide a theoretical basis for the formulation and implementation of enterprise digital transformation strategy, have certain policy implications, and have certain reference value for manufacturing enterprises to better carry out digital transformation practice.

Keywords: Digital transformation, Innovation performance, Manufacturing, Difference-in-difference model

Introduction

Digital economy is not only the main engine steady economic growth, is also important to promote the development of social economy high quality engine. China's manufacturing output in 2022 broke through the 40 trillion, accounted for 33.2% of GDP in that year reached the manufacturing scale has 13 consecutive years the highest in the world. As a new generation of the rapid development of science and technology, and industry evolve, the world economic landscape has evolved from the traditional pattern of power to the power mode. "China Manufacturing 2025", marking that China has embarked on a new journey from a traditional manufacturing power to a modern power, which is also part of China's dream of a modern socialist power. However, the development of China's manufacturing industry in key technology, technology accumulation has deficiencies, lack of talent and investment conditions, many industries because of without import and lost its own core competitiveness. In the 14th Five-Year Plan, China clearly pointed out that it is necessary to accelerate the construction of digital economy, digital society and digital government, and drive the overall transformation of production mode, life mode and governance mode through digital transformation. Digital technology and the traditional manufacturing depth fusion, continue to implement the innovation growth at the same time, also present a strong trend of the digital transformation of innovation. Digital innovation to promote the organization form of manufacturing, manufacturing mode change constantly, reflects the strong growth potential and creativity, make it become a new engine to promote the development of economy, high quality. Digital transformation whether did raise the enterprise innovation performance, there is no consensus. Some scholars believe that digital technology itself enables innovation, and can create new value models by reconstructing business models and corporate strategies, thus improving the innovation efficiency of enterprises. Some people also believe that digitalization is highly likely to have a negative impact on the innovation performance of enterprises. To this end, this paper will carry out empirical research on the manufacturing enterprises in A-share stock markets in Shanghai and Shenzhen to verify the impact of digital transformation on the innovation performance of manufacturing enterprises.

Literature Review

The study on the impact of enterprise digital transformation on innovation has only attracted the attention of research scholars in recent years, so there are not many relevant references. Golzerp (2017) [1] and Loebbeckec and Picot (2015) [2] pointed out that the essence of enterprise digital transformation is the innovation of enterprise operation mode, which will certainly have some impact on innovation performance in its own operation process. Enterprises that have integrated digital technology into their operations may have two positive impacts on promoting technological innovation. This is also confirmed by the relevant research conclusions of He (2019), [3] which confirmed that the related capabilities of digital technology significantly promoted the improvement of enterprise innovation performance. Li (2017) [4] further put

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forward that digital technology itself has a strong ability of data collection, also can help companies achieve business model innovation. Yang et al. (2020) [5] found that the digital transformation of enterprises mainly stimulates enterprise innovation through dynamic data application, data information sharing and the construction of digital platforms. Yang (2021) [6] studied that the digital transformation of manufacturing enterprises has an impact on their own innovation activities mainly through product innovation, organizational innovation, business model and process innovation driven by digitalization. Comparatively (2021) [7] in 173 manufacturing enterprises data analysis, empirically the digital transformation of the enterprise innovation performance of the pearl river delta Yangtze river delta, the study found that digital transformation has a positive influence on enterprise innovation performance. Wang hui (2021) [8], such as data from 261 traditional industries and small sample, studies have shown that small and medium-sized enterprise digital transition significantly improve the efficiency of innovation.

Although enterprise digital transformation function to the promotion of innovation performance is supported by many scholars, but there have also been Tan Yunqing etc. (2013) put forward [9], even if the enterprise with the same digital capacity or in the same digital environment, enterprise innovation performance ascension effect may also have a lot of heterogeneity. Kohlirand Melville (2019) [10] found that the root of heterogeneity lies in enterprises' understanding and learning ability of digital technology. Chen Chunhua (2019) [11] also pointed out that digital transformation is not only an opportunity for enterprises, but also faces risks. Wang (2021) [12] also proposed that the original knowledge accumulation, innovation path and related equipment investment of enterprises may be incompatible with the digital situation, so that digital transformation may hinder enterprise innovation and ultimately affect the improvement of enterprise innovation performance.

Research Hypothesis

Digital transformation will increase the technological innovation of manufacturing enterprises. On the one hand, digital transformation will promote cross-border operation of enterprises to achieve cross-border integration, but on the other hand, it will further intensify the competition situation among enterprises. The enterprises will be starting from product design services, further from the aspects of equipment, process and supporting multiple increase investment in research and development, which provide the necessary infrastructure for the digital transition support and technical support, promote enterprise digital equipment integration ability, accelerate the enterprise transformation and promote innovation performance. The technological innovation output of enterprises will also be further improved due to the implementation of digital transformation. The reason is that, first of all, digital transformation updates the traditional technological innovation mode of enterprises, and the digital transformation of enterprises has advantages in communication and information, which further makes enterprises more closely connected with the industry, users and government departments. By coordinating and integrating innovation activities of partners, we can build an innovation ecosystem and enhance collaborative innovation capabilities to increase technological innovation output. Based on this, this paper puts forward the following hypothesis:

Hypothesis 1: The implementation of digital transformation has a significantly positive effect on enterprise innovation performance.

Sample selection and data sources

This paper takes the manufacturing listed companies in Shanghai and Shenzhen A-share markets from 2007 to 2021 as the research samples, and the data mainly come from CSMAR and Wind databases. The entry and exit of enterprises will have an impact on the innovation performance of enterprises, but the entry and exit of listed companies are generally not just the result of market competition. In order to accurately estimate the impact of digital transformation of manufacturing enterprises on the innovation performance, this research sample is processed as follows: Abnormal (1) the financial status of ST and * ST and PT companies, excluding north stock exchange listed company, the listed for less than one year or by a listed company delisting, suspension shall be removed; (2) Retain the sample data of the company for at least three consecutive years. (3) Considering that the supervision and financial indicators of the financial industry are inconsistent with those of other enterprises, we delete the financial industry and finally obtain 10,778 observation samples. To avoid the interference of outliers, in this paper, the manufacturing enterprise data by 1% and 99% of a shrinkage of the tail.

Variable Definitions and Descriptive Statistics

The explained variable. The innovation performance of manufacturing enterprises is the explained variable in this paper. The innovation performance of manufacturing enterprises can be measured from two dimensions: R&D investment and innovation output. samples that did not report R&D expenditure from 2007 to 2011 are regarded as missing values, while those that did not report R&D expenditure data after 2011 are assigned the value of 0. R&d expenditure is measured by enterprise R&D investment intensity (rdsale), which is calculated by the ratio of enterprise R&D investment to total operating revenue in the current year. Innovation output using the patent applications (patent) as a proxy variable.

Core explanatory variables. This study explained the core variable digital transition policy for the enterprise (x_it) and digital transformation (dig). If I has been implemented in enterprises in t digital transformation, t years and later x_it value is 1, otherwise 0. Reference Wu Fei (2021)[13], in its annual report of listed companies if the keywords, involving "corporate transformation" digital word frequency statistics to reflect the degree of its digital transformation, arranged

through Python crawler function that collects the Shanghai stock exchange, shenzhen stock exchange all manufacturing a-share listed company's annual report, and by extracting all text content, Further screening including vocabulary related to the underlying digital technology and digital technology application, corresponding keywords frequency statistics annual report, due to the index has the right, to the word frequency and the exponential as manufacturing enterprise digital transformation degree of proxy indicators.

Control variables. In order to comprehensively and accurately analyze the impact of digital transformation on the innovation performance of manufacturing industry and mitigate the impact of omitted variables on the empirical results, this paper refers to relevant studies and controls variables such as enterprise size, enterprise age, growth opportunity, financial leverage ratio, cash flow status, job integration, shareholding ratio of the top ten shareholders, nature of equity and types of audit opinions. The definitions and descriptive statistics of the main variables are shown in Table 1.

Varibles	Name	Definiation	Mean	SD
Explained variable	rdsale	Ratio of R&D investment to total operating revenue	3.290	2.940
	Patent1	Ln(Patent1+1)	0.780	1.650
Explaining Variable	dig	Ln(Word frequency+1)	0.670	0.950
	xit	Implementation of digital transformation 1， otherwise 0	0.567	0. 495
Control variable	age	Observation year minus IPO year	12.710	6.040
	lna	ln(Total assets+1)	22.39	1.190
	tobinq	TobinQ=current market value/total assets	2.060	1.270
	lev	Total liabilities/total assets	0.450	0.190
	cf	Operationg net cash flow/beginning total assets	0.060	0.080
	dz	If the chairman and general manager is the same person	0.210	0.410
	Bs10	First big ten shareholder's stake	54.640	14.400
	gx	state-owned enterprise 1， otherwise 0	0.470	0.500
	audit	standard unqualified audit opinion 1， otherwise 0	0.980	0.150

Table 1:Variable definition and descriptive statistics

Model construction

Referring to previous studies, The digital transformation policy is regarded as a quasi-natural experiment, and DID is used to test the impact of the policy， this paper constructs the following model of the impact of digital transformation on the innovation performance of manufacturing enterprises under the empirical logic of DID method:

$$rdsale_{it} = \gamma_0 + \gamma_1 x_{it} + \gamma_2 controls_{it} + \theta_i + \eta_t + \varepsilon_{it} \quad (1)$$

$$patent_{it} = \gamma_0 + \gamma_1 x_{it} + \gamma_2 controls_{it} + \theta_i + \eta_t + \varepsilon_{it} \quad (2)$$

Where the subscripts i and t represent the enterprise and the year, rdsale and patent are the innovation performance of the enterprise, and xit represents whether the enterprise has carried out digital transformation. controls denotes a series of control variables. θ is the enterprise individual fixed effect, which is mainly used to control the impact of enterprise characteristic factors that do not change over time on innovation performance. η is the year fixed effect, thus controlling for the influence of unobservable factors that change over time on the results, and ε is the random error term. X coefficient of gamma as the focus, this paper reflects the digital transformation of manufacturing enterprise innovation performance. If gamma estimate is significant for the regular shows that implementation of the digital transformation of the rise of manufacturing enterprise of innovation performance was obviously higher than that without the implementation of digital transformation of enterprises, namely the digital transformation can significantly improve innovation performance. In order to further solve the heteroscedasticity problem that may exist in the research process, robust standard errors are used in the model regression.

Regression Results

The p-value of houseman test results is less than 0.01, which means that the original hypothesis is rejected, indicating that fixed effects should be used. Table 2 reports the digital transformation of policy implementation of manufacturing enterprise innovation performance benchmark return results. Columns (1) for the regression results without any control, column (2) to join a series of control variable and control time and bidirectional fixed effects regression results, column (3) replace be explained variable to control the regression results, column (4) for the control of enterprise and time bidirectional fixed effects regression model results. These results all show that the coefficient of the digital transformation policy variable is significantly positive at the level of 1%, which further verifies that the digital transformation policy can improve the innovation performance of manufacturing enterprises, thus verifying Hypothesis 1.

Variables	**(1)**	**(2)**	**(3)**	**(4)**
	rdsale	**rdsale**	**patent**	**patent**
xit	1.327***	1.303***	0.255***	0.101***
	(0.054)	(0.055)	(0.031)	(0.037)
Control variables	No	Yes	No	Yes
Year effect	No	Yes	No	Yes
Entity effect	No	Yes	No	Yes
Observations	10778	10778	10778	10778
adj. R^2	0.169	0.172	0.024	0.026

Table 2: regression results

Note: *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively. Robust standard errors are in parentheses.

Parallel trend test

By comparing and analyzing whether the change trend of the treatment group and the control group before the implementation of the digital transformation policy of manufacturing enterprises is consistent, this paper makes the hypothesis of parallel trend valid when the multi-time DID estimation is applied in the empirical research. Referring to the event study method proposed by Jacobson et al., the following model is set up:

$$rdsale_{it} = \gamma_0 + \sum_{j=-10}^{10} \gamma_i x_{it} + \gamma_2 controls_{it} + \theta_c + \eta_t + \varepsilon_{it} \quad (3)$$

Among them, the gamma _i representative estimates of the before and after the digital transition policy, policy current as the reference period, finish on both ends of the observed value, than the evaluated to test various manufacturing enterprise in the digital transformation of policy implementation in the first 10 years to 10 years after the implementation of the dynamic trend of changes.

The parallel trend test results are shown in the figure below. After the digital transformation of enterprises, γ is significantly positive in each period, which further indicates that the impact of digital transformation policy on the innovation intensity of manufacturing enterprises has a significant promoting effect.

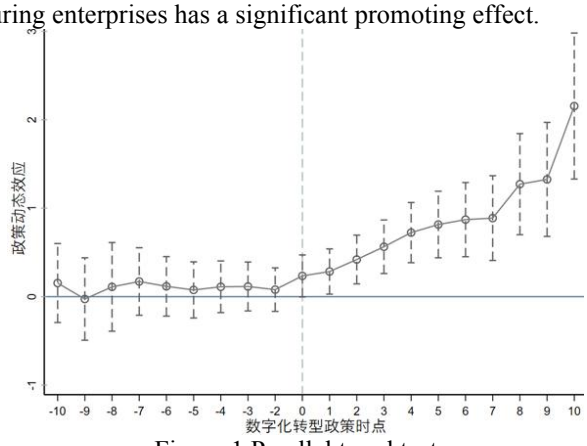

Figure 1 Parallel trend test

Robustness Test

Replace the explanatory variables. Referring to the practice of Zhang Yongshen et al. (2021)[14], the ratio of intangible assets related to digital transformation to the total intangible assets is used to measure the digitalization level of enterprises (dig_intan) as the proxy variable for the degree of digital transformation of manufacturing enterprises. If the

detailed items of intangible assets in the notes to the statement contain keywords of digital transformation technology such as "network", "management system", "software", "client" and "intelligent platform" or patents related to digital transformation, the detailed items will be identified as "digital intangible assets".

The following table reports the regression results of the proxy variable of digital transformation (dig_intan) on innovation performance. Column (3) shows the regression results of digital transformation on the total number of patent applications under the control of two-way fixed effects of time and province. Columns (1) (2) the results show that the digital transformation policy variable coefficient is significant at the 1% level is positive, column (3) the results show that significant at the 5% level, further verify the digital transformation can promote manufacturing enterprise innovation level, show the benchmark return results with robustness.

Variables	(1)	(2)	(3)
	rdsale	rdsale	patent
dig_intan	2.688***	2.464***	0.581**
	(4.01)	(3.81)	(2.12)
Control variable	No	Yes	Yes
Year effect	Yes	Yes	Yes
Province effect	Yes	Yes	Yes
Observations	10716	10716	10716
adj. R^2	0.149	0.219	0.040

Table 3: regression results

Note: *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.
Robust standard errors are in parentheses.

In order to further verify the impact of digital transformation (dig) on the technological innovation performance of manufacturing enterprises, this paper conducts time series analysis on the digital transformation variable (dig) with one lag, two lag and three lag periods. The results show that the digital transformation (dig) lag issue for manufacturing enterprises under the condition of the incentive effect of technology innovation has significant, but lag phase ii, phase iii results show that the time delay of digital transformation of manufacturing enterprise innovation turning effect weakened over time, the influence of again verify the robustness of the results of the benchmark return.

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
	rdsale	**rdsale**	**rdsale**	**rdsale**	**rdsale**
dig	0.122***	0.125***			
	(0.025)	(0.025)			
L.dig			0.123***		
			(0.027)		
L2.dig				0.087**	
				(0.030)	
L3.dig					0.075*
					(0.031)
Control variables	No	Yes	Yes	Yes	Yes
Entity effect	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes
Province effect	Yes	Yes	Yes	Yes	No
Observations	10778	10778	9092	7748	6658
adj. R^2	0.095	0.105	0.053	0.001	-0.044

Table 4: lag regression results

Conclusions and Implications

Under the background of the explosive growth of digital economy, the research on the innovation performance of enterprise digital transformation has attracted extensive attention. Using the data of China's listed manufacturing enterprises from 2007 to 2021, this paper identifies and tests the causal effect and influencing mechanism between digital transformation and enterprise innovation performance under the empirical framework of the difference-in-differences method, thus providing theoretical analysis and empirical evidence for the research of enterprise innovation performance in digital transformation. The research finds that, first of all, digital transformation can significantly promote the improvement of innovation performance of manufacturing enterprises, and this result is still valid after a series of robustness tests. Manufacturing enterprises should formulate a series of long-term development strategies for digital transformation and strengthen digital empowerment and innovation transformation. The government should also support and guide enterprises to implement digital transformation and development, so as to further improve the efficiency of resource allocation, enhance innovation vitality, and achieve high-quality economic development. It is necessary to enhance the integration between the real economy and digital technology, use technological innovation to drive industrial upgrading and development, and use digital economy as the medium to promote the development mode of green sharing economy. Secondly, manufacturing enterprises themselves should pay attention to the role of digital transformation in enterprise cooperative innovation and actively carry out digital transformation. Leverage your organization's resources to drive digital transformation. Manufacturing enterprises should follow the trend, respond to the relevant policies and calls of the state, learn relevant knowledge and successful experience of transformation with stronger initiative, formulate strong digital strategy, strengthen digital integration and digital technology investment, build digital control, and accelerate digital transformation. The next is to use digital technology to cultivate network interaction and knowledge retrieval skills to promote collaborative innovation performance improvement. On the one hand, the enterprise management should attach importance to information communication and interaction with the partners. Manufacturing enterprises need to pay more attention to the key role of digital technology in improving the efficiency of innovation, using the digital technology extends search depth of knowledge, on the other hand, the enterprise should be conducted on a regular basis to participate in joint innovation staff proper training, to improve the network can use the network interactive technology, using digital technology to increase interaction between companies and partners and knowledge search efficiency, Thus, the cooperation satisfaction and the stability of the relationship with the partners as well as the skill upgrading of technological innovation are improved.

According to market needs, manufacturing enterprises should quickly connect all kinds of social intellectual capital and innovation organizations. The integration of technology, ideas, patents and problem solutions can be realized through digital innovation platforms, and an innovation network can be formed through vertical and horizontal R&D cooperation, so as to transform the R&D mode from closed innovation to open innovation and from experiential innovation to data-driven innovation. First, support users to participate in innovation. Based on the digital platform, establish cooperation with a large number of users, analyze users' opinions, demands and ideas, and then clarify the direction of product and service improvement, so that product development and production from enterprise-led to enterprise-user cooperation. Second, strengthen technical cooperation with upstream and downstream enterprises of the industrial chain, and conduct joint research and development with supply chain enterprises on new parts technology and process required by new products to improve the matching degree of parts. Three is to strengthen and colleges and universities, research institutes and other collaborative innovation, strengthen cooperation with the depth of the source of innovation mechanism, around market demand joint research in cutting-edge technologies, faster to scientific knowledge, the effective transformation of technical achievements for the enterprise development technology, realize rapid adaptation of technology and market. Fourth, incubate and support diversified innovation and entrepreneurship teams, integrate online and offline resources, integrate scattered innovators into a unified platform, and participate in innovation and interaction through various forms, from small-scale offline cooperation to large-scale online cross-border interaction, so as to form an innovation and development model that is open, flexible and closer to users. Fifth, the exploration of innovation direction and the promotion of innovation process rely more on data flow, so as to change the traditional judgment based on experience, reduce innovation cost, improve innovation efficiency and improve technological innovation ability.

This paper uses the manufacturing industry data from 2007 to 2021 as the basis for research, but there are certain limitations, such as the inability to reveal the long-term dynamic relationship between variables, and the inaccurate measurement of innovation performance variables. Industry restrictions, the impact of digital transformation of manufacturing enterprises on innovation performance is the focus of this paper. However, the digital transformation of manufacturing enterprises does not only occur in the central and eastern regions, but also covers all regions of the manufacturing industry. Therefore, in the future, it is necessary to overcome the limitations of the industry and explore the mechanism through which the digital economy plays a role in collaborative innovation in other industries.

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