

# The Impact of Digital Transformation on the High-quality Development of the Manufacturing Industry

## -- An Empirical Study based on Systematic GMM and Threshold Modeling

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### Abstract

The digital transformation of manufacturing industry facilitates enterprises to access and utilize data information to improve the efficiency of resource allocation, expand product and service business models, and accumulate human capital stock to empower the high-quality development of manufacturing industry by creating a large number of databases. This paper adopts panel data of 30 provinces and cities in China from 2011-2020, and uses system GMM to verify the correlation between two variables. It also introduces environmental regulation as a threshold variable to analyze the threshold effect. The results of the study indicated that: firstly, the association between digital transformation of manufacturing industry and high-quality development of manufacturing industry shows a U-shaped relationship, secondly, the digitalization of manufacturing industry exhibits different impact effects on the four dimensions of high-quality development of manufacturing industry, and lastly, only when the environmental regulation is within a certain level, it can have a driving effect on high-quality development of manufacturing industry. Therefore, it is important to grasp the strategic opportunities of digital economy, strengthen the integration of digital economy and traditional industries, accelerate the digital transformation of manufacturing enterprises, and improve the high-quality development of China's manufacturing industry.

### Keywords

Digital Transformation; High-quality Development of Manufacturing; Environmental Regulation; GMM Models.

### 1. Introduction

High-quality development of the manufacturing industry is under the guidance of the new development concept, the whole process of production, manufacturing and sales of the manufacturing industry to realize high-level sustainable development with low input of production factors, high efficiency of resource allocation, strong strength of quality enhancement, excellent quality of the ecological environment and good economic and social benefits. China has entered a new stage of high-quality development, and the digital economy based on a new generation of information technology is reshaping the economic structure with unprecedented development speed, development scale and radiation scope, becoming one of the core growth poles of the national economy. The rapid development of the digital economy leads to technological leaps that can empower traditional elements and industries, realizing the great development of "Internet+", which will surely have an important impact on the way of urban economic development, enterprise technological innovation, and ecological environment

governance. 2022 China Enterprise Digital Transformation Index report points out that Chinese enterprises are more pragmatic in their digital investment and transformation strategies, with nearly 60% of the surveyed executives indicating that they will increase their digital investment in the next one to two years, and that digital transformation has become a "must-have" option for more and more Chinese enterprises.

However, domestic research on the digital transformation of the manufacturing industry is still at an early stage, and a systematic study on how digital transformation can promote the high-quality development of the manufacturing industry has yet to be formed. At present, what is the level of digitalization and high-quality development of manufacturing industry in various regions of China? Can digital transformation effectively promote the high-quality development of China's manufacturing industry? Further, what is the impact of digital transformation on various aspects of high-quality development of the manufacturing industry? If environmental regulation is introduced as a threshold variable, will it have a threshold effect on the relationship between the impact of high-quality development of the manufacturing industry?

## 2. Literature Review

The section headings are in boldface capital and lowercase letters. Second level headings are Scholars basically study the development of transformation and upgrading of the manufacturing industry from the perspectives of the green[1] innovation[2] competitiveness[3][4] and sustainable[5]. At present, only a few scholars have quantitatively analyzed the level of high-quality development of the manufacturing industry. Li Lianshui[6] comprehensively evaluated the level of high-quality development of manufacturing industry from five aspects: economy, science and technology, energy, environment and social services. Wei Houkai[7] studied the quality of industrial growth in terms of industrial processing level, value-added degree, input-output efficiency and product quality. Peng Shutao and Li Pengfei[8] believe that the value-add rate, unit value added consumption and pollutant emissions are representative indicators that react to the quality of manufacturing development from both positive and negative aspects.

Regarding the studies related to the evaluation of digital transformation in manufacturing industry, few scholars have studied its evaluation index system, and have only launched measurement studies from the aspects of architectural concepts and maturity models. Chi Maomao[9] and Chen Yihua[10] use the relevant question items of the impact of digital technology on the internal transformation of enterprises to measure the degree of digital transformation. Chen Tang[11] constructs a regional digital transformation evaluation index system from the driving factors affecting digital transformation, i.e., the dimensions of labor force, capital investment, human capital, technological innovation and innovation environment. Zhou Huihui[12] conducted an empirical study using panel data of 28 industries in China's manufacturing industry from 2013 to 2018, and the results showed that both digital technology transformation and digital innovation capability transformation have a significant impact on green R&D performance, green manufacturing performance and green service performance. Lou Runping[13] concluded that the total enterprise digital investment and digital software investment have a significant positive contribution to enterprise innovation performance. Qi Yudong[14], Wu Fei[15] and Zhao Chenyu[16], all of which took listed companies as sample enterprises, analyzed that digitalization reduces the level of information symmetry and reduces the management cost as the path of performance enhancement, while digitalization optimizes the human capital and promotes the integration of manufacturing industry and modern service industry as the main mechanism of innovation empowerment.

To sum up, the connotation of high-quality development of manufacturing industry has stage limitations and does not reflect the characteristics of the transformation logic in the late stage

of industrialization. Nowadays, the logic of high-quality development of the manufacturing industry has shifted from focusing on the expansion of industrial volume to the improvement of product quality, and from imitation development to independent innovative development. Meanwhile, relevant empirical studies accurately assessing the impact of digital transformation on the high-quality development of the manufacturing industry are still lacking, and less literature has examined the impact of digital industrialization on the high-quality development of the manufacturing industry, as well as the role of digitalization of the manufacturing industry in influencing the high-quality development of the manufacturing industry. Therefore, this paper explores the impact of digital transformation on the level of manufacturing quality development, with a view to expanding relevant research for subsequent studies.

### **3. Theoretical Analysis and Research Hypotheses**

#### **3.1. Digitization of Manufacturing and High-quality Development of Manufacturing**

On the one hand, with the deep integration of the Internet, big data, artificial intelligence, cloud computing, blockchain and other digital technologies with the manufacturing industry, the asymmetry of internal and external information of manufacturing enterprises has been alleviated, and upstream and downstream industries and cross-field sectors have broken the "information island" to realize interconnectivity and integration and sharing. Manufacturing enterprises can more accurately and timely access to internal and external information to accurately implement market segmentation strategies, production planning arrangements, and improve the efficiency of resource allocation; on the other hand, the digital economy has changed the form and function of the traditional consumer goods, smart consumption and intelligent consumer products to bring consumers a high-quality, diversified content of the consumer experience to enhance the sense of satisfaction of the consumption of products, the development of digital science and technology to strengthen the data and information in the production chain and value chain, and to strengthen the data and information in the production chain and value chain. The development of digital technology has strengthened the flow and circulation of data in the production and value chains, further expanding the space and enriching the mode of service-oriented manufacturing, and this consumer-centered production mode is conducive to enterprises to better meet the market demand, and is also conducive to promoting the innovation and development of enterprises.

However, Han Xianfeng[17] finds that with the increase of "marginal effect", the spillover effect of network technology innovation is obviously nonlinear. In terms of digital transformation in the early stage of digital transformation due to the imperfect construction of information infrastructure, the utilization of digital technology is low, resulting in a low level of digital transformation of the manufacturing industry, the role of the manufacturing industry in promoting innovation performance is not high, and did not improve the level of high-quality development of the manufacturing industry, however, with the increasing improvement of the information infrastructure and the level of digital transformation, the manufacturing enterprise's, the marginal cost of acquiring, processing and analyzing information decreases, while the innovation performance obtained tends to increase at the margin, from And empowering the high quality development of the manufacturing industry.

This led to the research hypothesis:

H1: There is a non-linear effect of digital transformation on the level of high-quality development in manufacturing.

### 3.2. Threshold Role of Environmental Regulation

The core of transforming the mode of economic development lies in paying more attention to resource and environmental issues and promoting sustainable development. This is mainly reflected in two aspects: first, Porter's hypothesis that appropriate environmental regulation can stimulate technological innovation in enterprises, thereby enhancing their market competitiveness. The effect of "Porter's hypothesis" can force enterprises to actively develop high-tech, and the development of digital technology also helps to realize the re-innovation of the production process, thus reducing the excessive consumption of resources and promoting industrial transformation and upgrading. The development of digital technology helps enterprises to realize the re-innovation of production process, thus reducing the excessive consumption of resources and promoting industrial transformation and upgrading. Secondly, the inclusion of environmental performance in the assessment system of local authorities has led to changes in the budgetary behavior of local authorities, which in turn improves the efficiency of resource allocation. When the intensity of environmental regulation exceeds a reasonable range, in order to meet the demand for environmental governance, local governments will increase their investment in pollution management and environmental optimization, and put in a large amount of manpower and material resources to solve environmental problems.

This led to the research hypothesis:

H2: Environmental regulation has a threshold role in digital transformation affecting high quality development in manufacturing.

## 4. Research Design

### 4.1. Research Model

#### 1) Dynamic panel model

Based on the above theoretical analysis, this paper establishes a dynamic panel benchmark regression model to empirically analyze the correlation between the digital transformation of the manufacturing industry and the level of high-quality development of the manufacturing industry, and the squared term (*SMIdig*) is added as an explanatory variable in the equation. The model is set as follows:

$$Hqdm_{it} = \beta_0 + \alpha Hqdm_{it-1} + \beta_1 Mdig_{it} + \beta_2 SMdig_{it} + \sum_{j=3}^6 \beta_j Controls_{it} + \mu_i + \theta_t + \varepsilon_{it} \quad (1)$$

*i* and *t* denote province and time respectively, *Hqdm<sub>it</sub>* denotes the level of high-quality development of manufacturing industry, *Hqdm<sub>it-1</sub>* denotes the level of high-quality development of manufacturing industry in the previous period, *Mdig<sub>it</sub>* denotes the level of digitalization of manufacturing industry, *Controls<sub>it</sub>* is the group of control variables,  $\mu_i$ ,  $\theta_t$ ,  $\varepsilon_{it}$  denote the province fixed effect, time fixed effect, and the random perturbation term, respectively, and  $\beta_1, \beta_2, \beta_j$  are regression coefficients for explanatory variables and control variables.

#### 2) Dynamic panel threshold model

In order to test whether the impact of environmental regulation on the high quality of the manufacturing industry is a threshold effect, the following dynamic panel threshold model was constructed using the total index of environmental regulation intensity (*lnREG*) as the threshold variable, based on the methodology adopted by Hansen et al:

$$Hqdm_{it} = \omega_0 + \alpha Hqdm_{it-1} + \omega_1 MIdig_{it} \cdot I(\ln REG \leq \gamma) + \omega_2 SMIdig_{it} \cdot I(\ln REG \leq \gamma) + \omega_3 MIdig_{it} \cdot I(\ln REG > \gamma) + \beta \omega_4 SMIdig_{it} \cdot I(\ln REG > \gamma) + \sum_{j=5}^8 \omega_j Controls_{it} + \varepsilon_{it} \tag{2}$$

I(.) is the indicator function, the value depends on the threshold variable (lnREG) and the threshold value (γ): when the expression in parentheses is established, I(.)=1, otherwise I(.)=0. By comparing the size of the environmental regulatory intensity index (lnREG) and the threshold value (γ), the sample provinces, autonomous regions, and municipalities can be categorized into high-environmental regulatory intensity regions and low-environmental regulatory intensity regions, and then respectively estimate the Impact coefficient.

### 4.2. Variable Selection

#### 1) Explanatory variable

The explanatory variable of this paper is the level of high-quality development of the manufacturing industry in each province. we constructed a high-quality development assessment system for the manufacturing industry from four dimensions, namely, with a total of nine indicators. Specific indicators are shown in below Table 1.

**Table 1.** Evaluation system for high-quality development of manufacturing industry

Index	Indicators	Secondary indicators	Unit	Attribute
High-quality Development Level of Manufacturing Industry (Hqdm)	Innovative development	Sales Revenue of New Products of Regulated Industries	ten thousand yuan	+
		Number of invention patents / number of R&D personnel	%	+
	Green Development	Solid Waste Production/Industrial Output Value	%	-
		Waste gas production/industrial output value	%	-
		Wastewater Production/Industrial Output Value	%	-
	Economic Benefits	Main business income of high-tech industry / Main business income of manufacturing industry	%	+
		Total output value of manufacturing industry / fixed asset investment	%	+
	Social Benefits	Number of employed persons in manufacturing industry	ten thousand people	+
		Total profit and tax of manufacturing enterprises	ten thousand yuan	+

#### 2) Core explanatory variables

The core explanatory variable of this paper is the development level of regional manufacturing digitalization. In terms of digital production, the improvement of production technology and production equipment reflects the development of the level of production digitization, and enterprises increase their R&D investment in digital technology and cutting-edge science and technology to seize more corporate resources and provide support for their innovative activities, the key to digital upgrading of the manufacturing industry is the improvement of the digital production capacity, which requires the updating and renovation of production equipment and tools, and investment in new types of equipment, with the CNC and automation

of the production process increases, some labor-intensive manufacturing industries may require fewer actual operators, see Table 2 for specific evaluation indicators.

**Table 2.** Evaluation index system for manufacturing digitization

Index	Indicators	Secondary indicators	Unit	Attribute
Level of digitization in manufacturing (MIdig)	Digital R&D inputs	Internal Expenditure on R&D of Regulated Industrial Enterprises	ten thousand yuan	+
	Digital process technology transformation investment	Expenditures on technological transformation of industrial enterprises	ten thousand yuan	+
	Percentage of investment in digital equipment and work tools	Investment in Fixed Assets, Equipment and Industrial Apparatus / Total Investment in Fixed Assets	%	+
	Average number of workers in labor-intensive manufacturing industry	Number of labor-intensive manufacturing industries/number of enterprises	%	-

3) Threshold variable

As the most extensive environmental regulation in China, environmental pollution control is realized through fixed capital investments, which are used to clean up industrial pollution sources and build urban environmental infrastructure. This year's environmental protection investment includes investment in industrial new and old pollution sources remediation projects, molding environmental protection acceptance projects, and urban environmental infrastructure construction from capital investment to enterprise investment control and additional public financial funds in the investment structure model. Based on the limitations of existing research and government statistics, this paper uses the logarithmic form of industrial pollution control investment in each province to measure environmental regulation (lnREG).

4) Control variables

Human capital (lnedu): chooses the average number of years of education to measure the output level of human capital. Economic development level (lngdp): it is expressed by the regional average gross domestic product (GDP) per person. Industrial structure (lnstru): calculated from the ratio of value added in the secondary industry to value added in the tertiary industry. Degree of government intervention (lngov): this indicator is measured by calculating the ratio of government public expenditure to GDP.

## 5. Empirical Investigation

### 5.1. Regression to Baseline

The regression results are shown in Table 3. The coefficient of column (1) Manufacturing Industry Digitization (MIdig) is -0.025, but it does not pass the significance test. Next, the secondary term of manufacturing digitization (SMIdig) is added to the model to examine whether manufacturing digitization affects the level of high-quality development of the manufacturing industry (Hqdm) in a nonlinear relationship, and the regression results are shown in Column (2), the coefficient of the primary term of manufacturing digitization is negative and the coefficient of the secondary term of manufacturing digitization is positive and passes the test of significance of 5%, with an inflection point [18] of 0.6723, indicating that

there is a significant U-shaped relationship between manufacturing digitization and the level of high-quality development of manufacturing.

**Table 3.** Benchmark regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Hqdm	Hqdm	Hqdmcx	Hqdmcx	Hqdmcls	Hqdmcls	Hqdmjj	Hqdmsh
L. Hqdm	1.046*** (0.057)	1.124*** (0.094)						
L. Hqdmcx			0.828*** (0.077)	0.811*** (0.088)				
L. Hqdmcls					1.258*** (0.029)	1.213*** (0.088)		
L. Hqdmjj							1.546*** (0.092)	
L. Hqdmsh								1.051*** (0.077)
MIdig	-0.025 (0.061)	-0.987** (0.404)	0.036 (0.030)	0.314*** (0.102)	-0.078*** (0.027)	-0.450** (0.217)	0.104* (0.054)	0.013 (0.021)
SMIdig		0.734** (0.316)		-0.224*** (0.077)		0.282* (0.163)		
lnedu	-0.012 (0.058)	0.106 (0.075)	0.017 (0.027)	0.002 (0.021)	-0.027 (0.035)	0.037 (0.032)	-0.031 (0.038)	-0.016 (0.012)
lngdp	-0.018 (0.021)	-0.047* (0.026)	-0.008 (0.006)	-0.005 (0.003)	-0.007*** (0.002)	-0.012 (0.008)	-0.002 (0.010)	-0.003 (0.004)
lnstru	0.063** (0.024)	-0.001 (0.014)	-0.000 (0.003)	-0.003 (0.004)	0.007 (0.007)	0.017* (0.010)	-0.008 (0.008)	-0.002 (0.007)
lngov	0.054** (0.022)	-0.061** (0.023)	0.007* (0.004)	0.008** (0.004)	-0.005* (0.003)	-0.004 (0.009)	0.017 (0.016)	0.006** (0.003)
Constant	-0.371** (0.179)	0.269 (0.159)	-0.051 (0.072)	-0.096 (0.072)	0.069 (0.092)	0.015 (0.102)	0.017 (0.101)	0.024 (0.056)
AR(1)-p	0.0183	0.00950	0.0100	0.0119	0.0923	0.0616	0.000496	0.00001
AR(2)-p	0.576	0.539	0.182	0.137	0.234	0.170	0.380	0.532
Hansen-p	0.471	0.888	0.783	0.933	0.961	0.948	0.542	0.967
N	270	270	270	270	270	270	270	270

In addition, from the four dimensions of manufacturing high-quality development to test, manufacturing digitalization on manufacturing innovative development (Hqdmcx) there is a significant inverted U-shaped relationship, with an inflection point of 0.7009, the reason may be that the digital transformation of manufacturing enterprises, although it can help to help enterprises optimize the production process, improve the efficiency and quality of production as well as to help enterprises better understand the market demand and consumer behavior, but the digital transformation of manufacturing enterprises can help enterprises optimize the production process, improve the efficiency and quality of production as well as to help enterprises better understand the market demand and consumer behavior. market demand and consumer behavior, but digital technology may lead to the disappearance of certain jobs and backwardness of skills, thus negatively affecting the innovation of enterprises, on the green development of the manufacturing industry (Hqdmcls) shows a significant U-shaped effect, with an inflection point of 0.7979, the reason for which may be that in the early stage of the digital transformation, the application of digital technology may lead to the problem of resource waste and environmental pollution, but with the depth of digital transformation, digital technology can help enterprises make their production processes more intelligent and automated, improve

production efficiency and product quality, and real-time monitoring and analysis of energy consumption in the production process, and timely detection and resolution of the problem of energy waste, the economic efficiency of the manufacturing industry has shown a significant role in promoting the economic benefits of the manufacturing industry, mainly by improving the manufacturing industry's The economic benefits of the manufacturing industry are significantly promoted, mainly through improving the efficiency of manufacturing industry production and the decision-making efficiency of obtaining and utilizing information data, the social benefits of the manufacturing industry are not significantly affected.

### 5.2. Regression Results and Analysis of Panel Threshold Models

The estimation results of the threshold model of the relationship between manufacturing digitization and manufacturing high-quality development with environmental regulation as the threshold variable can be seen in Table 4. When the intensity of environmental regulation is lower than or equal to the threshold value of 12.575, there is a significant U-shaped relationship between manufacturing digitization and high-quality development of the manufacturing industry, with an inflection point of 0.6244, which compares with the regression results in the previous section, and the turning point of the positive impact of environmental regulation on the high-quality development of the manufacturing industry is shifted to the left, when the intensity of environmental regulation is higher than or equal to the threshold value, there is a significant U-shaped relationship between manufacturing digitization and manufacturing high-quality development, with an inflection point of 0.6846, indicating that environmental regulation plays a positive and then negative role in the relationship between manufacturing digitization and manufacturing high-quality development, and as the level of environmental regulation becomes higher and higher, it may play an inhibitory role in the relationship between the two influences.

**Table 4.** Threshold regression results

	(1)		(2)
VARIABLES	Hqdm	VARIABLES	Hqdm
L.Hqdm(lnREG≤γ)	0.961***	L.Hqdm(lnREG>γ)	0.887
	(0.194)		(0.098)
MIdig(lnREG≤γ)	-2.269**	MIdig(lnREG>γ)	-7.302**
	(1.151)		(2.412)
SMI dig(lnREG≤γ)	1.817*	SMI dig(lnREG>γ)	5.333*
	(1.011)		(1.933)
Controls	Yes	Controls	Yes
cons	-1.854**	γ	12.575***
	(0.811)		(0.281)

The estimation results of the threshold model of the relationship between manufacturing digitization and manufacturing innovative development with environmental regulation as the threshold variable can be seen in Table 5. When the intensity of environmental regulation is lower than or equal to the threshold value of 12.459, there is no significant correlation between manufacturing digitization and manufacturing innovative development, when the intensity of environmental regulation is higher than or equal to the threshold value of 12.459, there is an inflection point of 0.6518, the inflection point is shifted leftward when compared to the baseline regression without the inclusion of the threshold variable, which indicates that environmental regulation plays a negative role in the relationship between manufacturing digitization and manufacturing high-quality development. The reason may be that the high intensity of environmental regulation will increase the cost of pollution control of enterprises, which will increase the cost of enterprises, and these additional costs will reduce the productivity and

profitability of enterprises, and may even lead to the reduction of enterprises' investment in factors of production and the reduction of the cost of technological innovation, which will have a negative effect on the innovative development of enterprises to a certain extent.

**Table 5.** Threshold regression results

	(1)		(2)
VARIABLES	Hqdmcx	VARIABLES	Hqdmcx
L.Hqdmcx(lnREG≤γ)	0.449***	L.Hqdmcx(lnREG>γ)	0.633
	(0.138)		(0.378)
MI dig(lnREG≤γ)	0.195	MI dig(lnREG>γ)	2.228**
	(0.188)		(0.968)
SMI dig(lnREG≤γ)	-0.131	SMI dig(lnREG>γ)	-1.709**
	(0.167)		(0.758)
Controls	Yes	Controls	Yes
cons	0.143	γ	12.459***
	(0.422)		(0.228)

The results of the threshold model estimation of the relationship between manufacturing digitization and manufacturing green development with environmental regulation as the threshold variable can be seen in Table 6. When the intensity of environmental regulation is lower than or equal to the threshold value of 11.240, there is a significant U-shaped correlation between manufacturing digitization and manufacturing green development, with an inflection point of 1.2454, when the intensity of environmental regulation is higher than or equal to the threshold value of 11.240, there is an inflection point of 0.5980, the inflection point is shifted to the left, which indicates that environmental regulation plays a positive role in the relationship between manufacturing digitization and manufacturing green development, and as the level of environmental regulation becomes higher and higher, it may play a facilitating role in the influential relationship between the two.

**Table 6.** Threshold regression results

	(1)		(2)
VARIABLES	Hqdmls	VARIABLES	Hqdmls
L.Hqdmls(lnREG≤γ)	0.850***	L.Hqdmls(lnREG>γ)	0.847
	(0.142)		(0.082)
MI dig(lnREG≤γ)	-0.514*	MI dig(lnREG>γ)	-0.781**
	(0.306)		(0.127)
SMI dig(lnREG≤γ)	0.433*	SMI dig(lnREG>γ)	0.653**
	(0.233)		(0.101)
Controls	Yes	Controls	Yes
cons	-0.031	γ	11.240***
	(0.115)		(0.788)

The results of the threshold model estimation of the relationship between manufacturing digitization and manufacturing economic efficiency with environmental regulation as the threshold variable can be seen in Table 7. When the intensity of environmental regulation is lower than or equal to the threshold value of 12.163, there is no significant correlation between the digitalization of manufacturing industry and the green development of manufacturing industry, when the intensity of environmental regulation is higher than or equal to the threshold value of 12.163, the digitalization of manufacturing industry has a more significant

negative correlation with manufacturing industry's economic efficiency. This indicates that the intensity of environmental regulation is to some extent not conducive to the enhancement of the economic efficiency of manufacturing enterprises, which may be due to the fact that the cost of pollution control brought about by environmental regulation cannot be offset by the profits or output of enterprises in the short term.

**Table 7.** Threshold regression results

	(1)		(2)
VARIABLES	Hqdmjj	VARIABLES	Hqdmjj
L.Hqdmjj(lnREG≤γ)	0.636*** (0.168)	L.Hqdmjj(lnREG>γ)	0.781 (0.115)
MIdig(lnREG≤γ)	0.033 (0.053)	MIdig(lnREG>γ)	-0.085* (0.071)
Controls	Yes	Controls	Yes
cons	0.029 (0.126)	γ	12.163*** (0.194)

The results of the threshold model estimation of the relationship between manufacturing digitization and manufacturing social benefits with environmental regulation as the threshold variable can be seen in Table 8. When the intensity of environmental regulation is lower than or equal to the threshold value of 12.410, there is a significant inverted U-shaped correlation between the digitalization of the manufacturing industry and the green development of the manufacturing industry, with an inflection point of 0.5769; when the intensity of environmental regulation is higher than or equal to the threshold value of 12.410, there is a significant inverted U-shaped correlation between the digitalization of the manufacturing industry and the social benefits of the manufacturing industry, with an inflection point of 0.6634. The reason may be that environmental regulation may cause enterprises to reduce investment and production scale and adopt more automated production methods, thus reducing the number of employees and total profits and taxes, and lowering the social benefits of manufacturing enterprises.

**Table 8.** Threshold regression results

	(1)		(2)
VARIABLES	Hqdmsh	VARIABLES	Hqdmsh
L.Hqdmsh(lnREG≤γ)	0.608*** (0.103)	L.Hqdmsh(lnREG>γ)	0.087** (0.248)
MIdig(lnREG≤γ)	0.240** (0.113)	MIdig(lnREG>γ)	2.436** (0.995)
SMIdig(lnREG≤γ)	-0.208** (0.095)	SMIdig(lnREG>γ)	-1.836** (0.710)
Controls	Yes	Controls	Yes
cons	0.351 (0.337)	γ	12.410*** (0.113)

### 5.3. Robustness test

The three provincial-level administrative regions of Beijing, Shanghai and Guangdong (hereinafter referred to as "Beijing, Shanghai and Guangdong") are at the forefront of China's pace of digitalization development due to their high economic level. In order to test the overall applicability of the role of manufacturing digitization in promoting the high-quality development of the manufacturing industry, in addition to the three provincial-level

administrative regions of Beijing, Shanghai and Guangdong, we also conducted regression analyses on the corresponding data of other provinces. The results are shown in Table 9: manufacturing digitization and manufacturing high-quality development exhibit an influential relationship with increasing marginal effects. In summary, the conclusions of this paper are robust.

**Table 9.** Threshold regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Hqdm	Hqdm	Hqdmcx	Hqdmcx	Hqdmsh	Hqdmsh	Hqdmsh	Hqdmsh
L.Hqdm	1.121***	1.104***						
	(0.130)	(0.049)						
LHqdmcx			0.788***	0.649***				
			(0.113)	(0.176)				
L.Hqdmsh					1.203***	1.123***		
					(0.068)	(0.053)		
L.Hqdmsh							1.453***	
							(0.129)	
L.Hqdmsh								1.027***
								(0.090)
MI dig	-0.080	-0.603**	0.029*	0.599**	-0.089*	-0.338*	0.118*	0.012
	(0.073)	(0.265)	(0.017)	(0.270)	(0.047)	(0.166)	(0.063)	(0.019)
SMI dig		0.438**		-0.469**		0.239*		
		(0.211)		(0.216)		(0.132)		
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.042	0.128	0.069	0.053	-0.166	0.069	0.032	0.019
	(0.244)	(0.162)	(0.112)	(0.117)	(0.246)	(0.111)	(0.114)	(0.050)
AR(1)-p	0.0362	0.0116	0.00935	0.0179	0.0840	0.0816	0.0191	0.000122
AR(2)p	0.619	0.772	0.229	0.182	0.663	0.108	0.409	0.539
Hansen-p	0.584	0.805	0.929	0.998	0.942	0.741	0.936	0.997
N	243	243	216	216	243	216	216	243

## 6. Conclusion and Policy Recommendations

First, there is a "U"-shaped relationship between manufacturing digitization and high-quality development of manufacturing industry. Second, manufacturing industry digitalization and manufacturing industry innovative development of inverted U-shaped relationship, and manufacturing industry green development of U-shaped relationship, significantly promote the development of manufacturing industry economic benefits, but the social benefits of the manufacturing industry does not have a significant impact. Third, there is a single threshold effect of manufacturing digitalization on the improvement of manufacturing high-quality development based on environmental regulation. When the regional environmental regulation is lower than the threshold, the inflection point of manufacturing digitization on the high-quality development of manufacturing industry is shifted from 0.6723 to 0.6244 on the left, when the regional environmental regulation is higher than the threshold, the inflection point of manufacturing digitization on the high-quality development of manufacturing industry is shifted from 0.6723 to 0.6846 on the right. Fourth, when the intensity of environmental regulation is lower than or equal to the threshold, there is no significant correlation between manufacturing digitization and manufacturing innovative development, when the intensity of environmental regulation is higher than or equal to the threshold, there is a significant inverted U-shaped relationship between manufacturing digitization and manufacturing innovative

development, with an inflection point of 0.6518, the inflection point shifts leftward compared to the baseline regression without the inclusion of the threshold variable. Fifth, when the intensity of environmental regulation is lower than or equal to the threshold, there is a significant U-shaped relationship between manufacturing digitization and the green development of the manufacturing industry, with an inflection point of 1.2454, when the intensity of environmental regulation is higher than or equal to the threshold, there is a significant U-shaped relationship between manufacturing digitization and the innovative development of the manufacturing industry, with an inflection point of 0.5980, the inflection point is shifted to the left. Sixth, when the intensity of environmental regulation is lower than or equal to the threshold value, there is no significant correlation between the digitalization of the manufacturing industry and the green development of the manufacturing industry, when the intensity of environmental regulation is higher than or equal to the threshold value, the digitalization of the manufacturing industry has a more significant negative correlation with the manufacturing industry's economic efficiency. Seventh, when the intensity of environmental regulation is lower than or equal to the threshold, the digitalization of the manufacturing industry on the green development of the manufacturing industry, there is a significant inverted U-shaped relationship, the inflection point of 0.5769, when the intensity of environmental regulation is higher than or equal to the threshold, the digitalization of the manufacturing industry on the manufacturing industry's social benefits there is also a significant inverted U-shape relationship, the inflection point of 0.6634.

Based on the above conclusions, the following policy recommendations are put forward: First, promote the benign development of the digital economy by promoting the sharing and common use of open data, establishing standards for the use of digital technology, and strengthening the strength of digital regulation, second, there is a need to improve the innovative capacity of the original digital technology, such as basic theories, core algorithms, and key equipment, which are the core areas of the cutting-edge and core technologies need to make further breakthroughs, and to promote the digital industrialization and development, third, improve the emerging digital infrastructure, which will help to improve the social benefits of the manufacturing industry. Development, third, improve the construction of emerging digital infrastructure, vigorously promote the development of cloud platforms such as the Internet, Internet of Things, big data, etc., based on the research and development and application of digital technologies such as artificial intelligence, blockchain, 5G, etc., to provide technological support and an important basis for the digital transformation of the manufacturing industry. Fourth, accelerating the construction of an integrated platform for the production, learning and research of the digital economy and improving the mechanism for the transformation of achievements.

## References

- [1] RehmanSU, KrausS, ShahSA, etal. Analyzing the relationship between green innovationan denvironmental performance in large manufacturing firms[J]. *Technological Forecasting and Social Change*,2021,163:120481.
- [2] KimMK, ParkJH, PaikJH. Factors in fluencing innovation capability of small and medium size denterprises in Korean manufacturing sector: Facilitators, barriers and moderators[J]. *International Journal of Technology Management*,2018,76(3-4):214-235.
- [3] GhalayiniAM, NobleJS, CroweTJ. Aninte grated dynamic performance measurement system for improving manufacturing competitiveness[J]. *International Journal of production economics*,1997, 48(3):207-225.
- [4] BlázquezL, Diaz-MoraC, González-DíazB.The role of services content for manufacturing competitiveness: A network analysis[J]. *Plosone*,2020,15(1):e0226411.

- [5] ShahzadM, QuY, JavedSA, etal. Relation of environment tsustainability to CSR and green innovation:A case of Pakistani manufacturing industry[J].Journal of Cleaner Production,2020, 253: 119938.
- [6] Li Lianshui, CHENG Zhonghua, LIU Jun. The “New Pattern“ of Chinese Manufacturing Industry and Its Evaluation Research[J]. China Industrial Economics,2015(02):63-75.
- [7] Wei Houkai. Evaluation of the quality of industrial growth in the regions of the country [J]. Economic Review Journal,1997(04):4-9+63.
- [8] Peng Shutao, Li Pengfei. Evaluation of Development Quality of China’s Manufacturing and Its Improvement Path[J]. Studies on Socialism with Chinese Characteristics,2018(05):34-40+54.
- [9] CHI Maomao, WANG Weijun, LU Xinyuan,Li Hao. Competing perspectives on the link between digital business strategy profiles and organizational restructuring capabilities [J]. Journal of Industrial Engineering and Engineering Management,2020,34(04):11-20.
- [10] CHEN Yihua, ZHANG Zhengang, HUANG Lu. Exploring the Mechanisms and Paths of Manufacturing Digital Enablement on Business Model Innovation [J]. Chinese Journal of Management,2021,18(05): 731-740.
- [11] Chen Tang, Chen Guang, Chen Pengyu. Digital Transformation in China: Development History, Operation Mechanism and Prospect [J]. Forum on Science and Technology in China,2022(01):139-149.
- [12]ZHOU Huihui, LI Haixia, ZHAO Linrui. Research on the impact of manufacturing digital transformation on green innovation performance: The moderating effects of digital level [J]. Science-Technology and Management,2021,23(01):33-43.
- [13]Lou Runping, Mai Shishi, Zhang Hao. Examining the Effect of Corporate Digital Investment on Corporate Value - Empirical Evidence Based on Listed Companies in the Manufacturing Industry [J]. Statistics & Decision,2023,39(01):177-182.
- [14]Qi Yudong, Xiao Xu. Transformation of Enterprise Management in the Era of Digital Economy [J]. Journal of Management World,2020,36(06):135-152+250.
- [15]Wu Fei, Hu Huizhi, Lin Huiyan, Ren Xiaoyi. Enterprise Digital Transformation and Capital Market Performance : Empirical Evidence from Stock Liquidity [J]. Journal of Management World,2021, 37(07):130-144+10.
- [16]ZHAO Chenyu, WANG Wenchun, LI Xuesong. How Does Digital Transformation Affect the Total Factor Productivity of Enterprises? [J]. Finance & Trade Economics,2021,42(07):114-129.
- [17]HAN Xianfeng, SONG Wenfei, LI Boxin. Can the Internet Become a New Momentum to improve the Efficiency of Regional Innovation in China [J]. China Industrial Economics,2019(07):119-136.
- [18]The inflection point is obtained by solving the nonlinear regression equation by taking a first-order partial derivative and then solving for zero.