The impact of digital economy on digital and intelligent transformation of manufacturing industry

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Abstract. Promoting the digital and intelligent transformation of manufacturing industry with digital economy is the necessary way to improve the competitiveness of manufacturing industry in the information era. The article aims to study the degree of influence, mechanism of action and path of influence of digital economy on the digital and intelligent transformation of manufacturing industry, based on the panel data of 30 provinces (cities) in China from 2011 to 2020 , and conducts empirical tests using two-way fixed-effect model and mediated-effect model. It is found that: the digital economy has a significant role in promoting the digital and intelligent transformation of the manufacturing industry; the digital economy has a greater role in improving the level of digital and intelligent transformation of the manufacturing industry in the central and eastern regions compared with the western regions; the digital economy promotes the digital and intelligent transformation of the manufacturing industry by improving the regional innovation capacity and human capital level.

Keywords: digital economy; digital and intelligent transformation of manufacturing; regional innovation; human capital

1 Introduction

"Big but not strong" has always been a problem that needs to be solved in China's manufacturing industry. In the era of digital economy, digital and intelligent transformation is an important opportunity for China's manufacturing industry to break the lock at the low end of the value chain. The concept of digital economy was first introduced by Don Tapscott in 1996 in his book " The digital economy：the Hopes and danger of an Age of Networked intelligence ". Due to the dynamic development characteristics of the digital economy, different scholars have defined the digital economy with differentiated perspectives, and this paper summarizes its main connotations into the following three aspects: (1) The connotation of the digital economy lies in its technological attributes[1]. (2) The digital economy is the integration of technology innovation and industrial application[2]. (3) The digital economy is the transformation of the overall economy and society by digital technology at the level of production relations[3]. In the era of digital economy, with the progress of intelligent sensing and artificial intelligence technology, the digital and intelligent transformation of manufacturing industry is a more advanced

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stage. Regarding its specific dimensions, Yu Donghua and Zhang Hengyu (2022) [4] proposed that the digital and intelligent transformation of the manufacturing industry includes multiple links and dimensions such as research and development design, manufacturing, development models, business ecology and branding, marketing, and logistics.

Through the combing of existing research literature, it can be found that: there is a lack of empirical analysis on the impact of digital economy on the digital and intelligent transformation of manufacturing industry. The possible marginal contributions of this paper may be: in terms of research perspective, it enriches the empirical research on the degree of influence, mechanism of action and path of influence of digital economy contributing to the digital and intelligent transformation of manufacturing industry. In terms of research indicators, a new evaluation index system for the digital and intelligent development level of China's provincial-level manufacturing industry has been constructed. In terms of research recommendations, this article proposes regional heterogeneity suggestions on how to fully leverage the positive effects of digital economy driving the digital and intelligent development of manufacturing industry. At the same time, specific measures and suggestions are provided to activate new drivers of regional innovation and improve the soft power of human capital.

2 Theoretical analysis and research hypothesis

2.1 Direct effect of digital economy on digital and intelligent transformation of manufacturing industry and research hypothesis

The digital economy can empower the transformation and upgrading of the manufacturing industry in the following three aspects: First, the data elements enhance the competitive advantage of the manufacturing industry. Manufacturing enterprises can use data elements with high mobility to meet consumers' personalized needs, and effectively improve the added value of products. Second, digital technology improves manufacturing production methods. New digital technology will use big data, cloud computing, virtual simulation, Internet of Things, artificial intelligence and other technologies to break the traditional production model. Third, the digital economy optimizes the management mode of manufacturing industry. The various systems, platforms and applications derived from the digital economy have greatly improved the management efficiency of enterprises. Based on the above logical analysis, this paper proposes research hypothesis 1.

H1: The digital economy has a direct promotional effect on the digital and intelligent transformation of the manufacturing industry.

The spatial characteristics of the development level of China's digital economy are obvious, and there are serious fault lines in digital infrastructure, factor endowment and industrial development in different regions, which inevitably lead to different degrees of impact of the digital economy on the digital and intelligent transformation of the manufacturing industry. Based on the above logical analysis, research hypothesis 2 is proposed in this paper.

H2: There are geographical differences in the direct promotion effect of digital economy on the digital and intelligent transformation of manufacturing industry.

2.2 Indirect effects of the digital economy on the digital and intelligent transformation of manufacturing industry and research hypothesis

(1) Mediating effect of regional innovation.

The digital economy is based on a powerful modern information network, which increases the breadth and depth of spatial association of resources and factors[5]. And innovation resources are allocated in the form of data transmission unique to the digital economy, which enables them to be docked more efficiently between different regions and different subjects, thus promoting the technological upgrade of manufacturing digitization and intelligence. Based on the above logical analysis, this paper puts forward research hypothesis 3.

H3: Digital economy promotes the digital and intelligent transformation of the manufacturing industry by improving the level of regional innovation.

(2) Mediation effect of human capital.

The development of digital economy can promote the improvement of human capital level. On the one hand, the rich educational resources and efficient learning methods brought by digital technology platforms and digital technology training can improve the comprehensive quality of manufacturing labor force. On the other hand, the development of digital economy makes the professional skill level of laborers improve, and the high quality laborers will pursue more high-quality and personalized products, thus can promote the digital and intelligent transformation and upgrading of manufacturing enterprises from the demand side[6]. Based on the above logical analysis, research hypothesis 4 is proposed in this paper.

H4: The digital economy promotes the digital and intelligent transformation of manufacturing by improving the level of human capital.

3 Study design

3.1 Model construction

The benchmark model of the level of digital economy development affecting the level of digital and intelligent of manufacturing industry in each province is as follows.

$$Mdi_{it} = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 \text{Control} + u_i + u_t + \varepsilon_{it} \quad (1)$$

where Mdi_{it} represents the level of digital and intelligent of manufacturing industry in province i in year t. Dig_{it} represents the level of digital economy development in province i in year t, and Control represents the set of control variables. u_i represents individual fixed effects, u_t represents the time fixed effect, and ε_{it} represents the random disturbance term.

In addition, this paper conducts a mediating effect test on regional innovation and human capital, and the mediating effect test econometric model is as follows:

$$Med_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 \text{Control} + u_i + u_t + \varepsilon_{it} \quad (2)$$

$$Mdi_{it} = \gamma_0 + \gamma_1 Dig_{it} + \theta Med_{it} + \gamma_2 \text{Control} + u_i + u_t + \varepsilon_{it} \quad (3)$$

where Med denotes the two mediating variables that contain regional innovation and human capital.

3.2 Variable descriptions and measures

(1) Explanatory variable: level of digital and intelligent development in manufacturing (Mdi).

Summarizing Chen (2018)[7] 's study and drawing on Tian, Gang-Yuan et al. (2022)[8] 's indicator selection, this paper measures the level of digitization and intelligence in manufacturing industry in seven secondary indicators using the entropy method. The indicator system is shown in Table 1.

Table 1. Index system of digitization and intelligence in manufacturing industry

Tier 1 Indicators	Secondary indicators	Properties
R&D Design	Y1: the number of industrial enterprises above the scale of R&D projects	Positive
	Y2: Full-time equivalent of R&D personnel in industrial enterprises above the scale	Positive
	Y3: R&D expenditure of industrial enterprises above the scale	Positive
Manufacturing	Y4: General industrial fixed waste comprehensive utilization volume	Positive
	Y5: Energy consumption of 10,000 yuan of industrial added value	Negative
Business Optimization	Y6: Total profit of industrial enterprises above the scale / main business income of industrial enterprises above the scale	Positive
	Y7: Industrial enterprises above the scale of management costs	Negative

(2) Core explanatory variables: level of digital economy development (Dig).

This article draws on the research results of Wang Jun et al. (2021)[9] and Yang Huimei and Jiang Lu (2021)[10] to construct an evaluation index system for the level of digital economy using the entropy method. The indicator system is shown in Table 2.

Table 2. Index system of Digital economy development level

Tier 1 Indicators	Secondary indicators	Measurements	Properties
Digital Economy Development Carriers	Traditional Infrastructure	X1: Number of Internet broadband access ports	Positive
		X2: Number of Internet broadband access subscribers	Positive
		X3: Number of domains	Positive
		X4: Number of pages	Positive
	New Digital	X5: Number of cell phone base stations	Positive

	Infrastructure	X6: Number of IPV4 addresses	Positive
Digital Industrialization	Scale of electronic information manufacturing industry	X7: The main business income of electronic information manufacturing industry above the scale	Positive
		X8: Number of enterprises above the scale of electronic information manufacturing	Positive
	Telecommunications industry scale, communication capacity and service level	X9: Total telecom business	Positive
		X10: Mobile phone year-end subscribers	Positive
		X11: Mobile phone exchange capacity	Positive
		X12: Long distance fiber optic cable line length	Positive
	Software and Information Technology Services Scale	X13: Software business revenue	Positive
		X14: Information technology services revenue	Positive
		X15: Number of employees in information transmission, software and information technology services	Positive
Industry Digitization	Digitalization of Agriculture	X16: Value added of agriculture, forestry, animal husbandry and fishery	Positive
		X17: Rural broadband access ausers	Positive
	Industrial Digitalization	X18: Industrial value added	Positive
		X19: Number of computers per 100 people	Positive
	Digitalization of the tertiary sector	X20: Value added of tertiary industry	Positive
		X21: Number of enterprises with e-commerce transaction activities	Positive
		X22: E-commerce sales	Positive
		X23: Digital Inclusive Finance Index	Positive

(3) Mediating variables.

(i) regional innovation (Ric), measured using the logarithm of domestic invention patent applications granted; and (ii) human capital (Huca), measured using the share of education spending in regional GDP.

(4) Control variables.

(i) foreign trade dependence (Ftd), expressed by the proportion of the total import and export of each province to the regional GDP; (ii) financial development level (Fin), expressed by the proportion of the balance of loans in domestic and foreign currencies to the regional GDP at the end of the year; (iii) industrial structure level (Is), expressed by the proportion of the added value of the tertiary industry to the added value of the secondary industry.

3.3 Data sources

The sample of this paper is the panel data of 30 provinces (cities) except Tibet from 2011-2020. The sample data are obtained from the official website of the National Bureau of Statistics, the Bureau of Operation Monitoring and Coordination of the Ministry of Industry and Information Technology, Wind database, CSMAR database, China Internet Network Information Center, Digital Finance Research Center of Peking University, China Statistical Yearbook, China Electronic Information Industry Statistical

Yearbook, China Environmental Statistical Yearbook, and China Energy Statistical Yearbook.

4 Analysis of empirical results

4.1 Baseline regression results and analysis

In this paper, the hypothesis is tested by choosing a fixed-effects model based on the Hausman test results. Column (1) in Table 3 shows the regression results without the addition of control variables, and column (2) shows the regression results with the addition of control variables. From Table 3, it can be seen that the regression coefficient of digital economy is positive and significant, and hypothesis 1 of this paper is verified.

4.2 Heterogeneity results and analysis

In this paper, the sample of 30 provinces in the data is divided into eastern, central and western regions. The regression results for the eastern, central, and western regions are shown in columns (3) to (8) of Table 3, from left to right in each of the two columns in turn. The results show that the level of digital economy in all regions significantly improves the level of digitization and intelligence in manufacturing, but shows significant spatial heterogeneity; specifically, the estimated coefficient of the level of impact is the largest in the central region, followed by the eastern region, while the western region has a smaller value. In summary, hypothesis 2 of this paper was verified.

Table 3. Baseline regression and heterogeneity test results

Explanatory variables	Baseline return		Regional Heterogeneity					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dig	0.941*** (13.210)	0.863*** (12.330)	1.385*** (9.660)	1.331*** (10.160)	1.379*** (12.030)	1.461*** (11.57)	0.128** (3.560)	0.080** (2.220)
Cons	-0.159*** (-7.840)	0.347*** (4.450)	-0.261*** (-7.500)	0.296* (1.74)	0.091*** (15.330)	0.085*** (2.700)	0.081*** (16.860)	0.069*** (4.050)
Individual/ Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	No	Yes	No	Yes	No	Yes	No	Yes
N	300	300	110	110	100	100	90	90
R^2	0.953	0.966	0.957	0.978	0.959	0.963	0.927	0.939

Note: t-values in parentheses, *, **, *** indicate significant at the 10%, 5%, 1% levels respectively, the same below

4.3 Regression results and analysis of intermediate effects

This paper uses two-way fixed effects for the mediating effects test, and the results are shown in Table 4. columns (1) and (3) in Table 4 show the regression results of the

digital economy on the two mediating variables of regional innovation and human capital respectively. Columns (2) and (4) show the regression results of mediating effects respectively. From Table 4, it can be seen that the digital economy can play a role in promoting the upgrading of digital and intelligent manufacturing by affecting the regional innovation capacity and human capital level, and both mediating variables show partial mediating effects. The mediating effect of regional innovation is 0.049 (1.007×0.049), which accounts for 5.68% of the total effect, and hypothesis 3 of this paper is verified. The mediating effect of human capital level is 0.035 (0.018 × 1.921), with a weight of 4.06% in the total effect, and hypothesis 4 is tested in this paper.

Table 4. Intermediate effect test results

Variables	Ric (1)	Mdi (2)	Huca (3)	Mdi (4)
Dig	1.007*** (2.650)	0.814*** (11.870)	0.018** (2.380)	0.828*** (11.950)
Ric		0.049*** (4.390)		
Huca				1.921** (3.480)
Cons	10.844*** (25.560)	-0.181*** (-1.280)	-0.019** (-2.210)	0.384*** (4.970)
Individuals/ Time Effect	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes
N	300	300	300	300
R^2	0.989	0.968	0.967	0.967

4.4 Endogeneity test

This paper, the lagged one-period values of digital economy indicators are used as instrumental variables in a two-stage least squares regression to alleviate the endogeneity problem, and the regression results are shown in Table 5.From the regression results, it can be seen that the effect of digital economy on the digital and intelligent transformation of manufacturing is consistent with the benchmark regression in Table 5 in terms of direction and significance, thus further confirming the positive effect of digital economy on the digital and intelligent transformation of manufacturing.

Table 5. Endogeneity test results

Variables	Phase I	Phase II
IV	1.033*** (29.510)	
Dig		1.417*** (10.500)
Individual/Time Effects	Yes	Yes
Control variables	Yes	Yes
N	300	300
R^2	0.970	0.960

LM statistic	45.951 [0.000]
Wald F statistic	282.926 [0.000]

4.5 Robustness tests

The results of the heterogeneity test by region above have proved the robustness of the basic conclusions of this paper. To further explore the reliability of the research conclusion, this article conducts tail reduction treatment at the 1% level and substitution of explanatory variables and dependent variables respectively. Columns (1), (2), and (3) represent the results of tail reduction explanatory variables, tail reduction dependent variables, simultaneous tail reduction explanatory variables and dependent variables, respectively. Columns (4), (5), and (6) are calculated using principal component analysis to replace explanatory variables, replace dependent variables, replace both the explanatory variable and the dependent variable simultaneously. Table 6 shows that the conclusion of this paper is that the digital economy has a positive role in promoting the digital and intelligent transformation of the manufacturing industry, which is robustness.

Table 6. Robustness test results

Explanatory variables	shrinkage of the tail			Change of measurement method		
	(1)	(2)	(3)	(4)	(5)	(6)
Dig	0.766*** (9.250)	0.767*** (11.560)	0.758*** (10.260)	0.055*** (19.210)	6.627*** (12.070)	0.425*** (18.870)
Cons	0.431*** (5.100)	0.354*** (4.790)	0.390*** (5.110)	0.190*** (2.950)	4.522*** (7.390)	3.288*** (6.500)
Individual/Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
N	300	300	300	300	300	300
R^2	0.960	0.968	0.966	0.978	0.969	0.980

5 Conclusions and Recommendations

The following conclusions are drawn from this study: First, the improvement of the development of digital economy will have an obvious positive impact on the digital and intelligent transformation of manufacturing industry. Secondly, the positive effect of digital economy on the digital and intelligent development in manufacturing industry has obvious geographical differences, and the strength of the effect is from central region, eastern region, and western region in the order of large to small. Third, regional innovation and human capital play an important intermediary role in the process of digital economy promoting the digital and intelligent transformation of manufacturing industry.

Based on the above research findings, this paper puts forward the following suggestions: First, grasp the favorable opportunity of digital economy to empower the digital

and intelligent transformation of manufacturing industry. The government creates a favorable environment for the development of digital infrastructure, digital industrialization and industrial digitization through policy facilitation and tax preferences to lower the threshold of enterprise transformation. In response to the obvious geographical differences in China's digital economy affecting the digital and intelligent transformation of manufacturing industries, each region should develop policy measures that are appropriate to the development situation. It is suggested that in the eastern region, the construction of new generation digital infrastructure such as industrial Internet platform should be accelerated, and the transformation of high-end digital elements in the manufacturing industry should be accelerated. In the central region, explore the cross-regional cooperation development model of digital economy, while using the advantages of local resources to promote the cultivation of special digital industries. And in the western region, increase the investment in digital technology research and development. Second, activate the new dynamics of regional innovation. Local governments create a digital economy "government, industry, academia, research and use" all-round innovation alliance form, to stimulate the innovation enthusiasm of each subject within the manufacturing industry. Third, enhance the soft power of human capital. Encourage universities to actively carry out theoretical research and social practice on digital literacy education. At the same time, strengthen the training of digital skills for manufacturing workers, so as to cultivate composite talents who have both digital economy thinking and familiarity with the whole business process of manufacturing industry.

References

1. Pei, Chang-Hong, Ni, Jiang-Fei, Li, Yue. Analysis of the political economy of the digital economy[J]. Finance and Trade Economics,2018,39(09):5-22.
2. Xu Xianchun,Zhang Meihui. Research on the measurement of the size of China's digital economy--based on the perspective of international comparison[J]. China Industrial Economy,2020(05):23-41.
3. Ding Zhifan. Research on the mechanism of digital economy driving high-quality economic development:A theoretical analysis framework[J]. Modern Economic Inquiry,2020(01):85-92.
4. Yu Donghua, Zhang Hengyu. How can manufacturing enterprises break through the "service dilemma" through the transformation of digital intelligence? [J]. Gansu Social Science, 2022(06):203-217.
5. Jin Huan,Yu Lihong. Digital economy, urban innovation and regional convergence[J]. Southern Economy,2021(12):21-36.
6. Chen, Xiaofeng. The impact of digital economy development on China's manufacturing upgrading--an empirical examination based on inter-provincial panel data[J]. Journal of Nantong University (Social Science Edition),2022,38(03):128-140.
7. Chen Xiaohong. Analysis of technology integration and application innovation trends in the era of digital economy[J]. Journal of Central South University (Social Science Edition),2018,24(05):1-8.
8. Tian Gang-Yuan, Chen Fu-Liang. Digital economy, industrial agglomeration and high-quality development of manufacturing industry in the Yellow River Basin[J]. Statistics and Decision Making,2022,38(21):10-14.

9. Wang J, Zhu J, Luo X. Development level and evolution measurement of China's digital economy[J]. Research on Quantitative Economics and Technology Economy,2021,38(07):26-42.
10. Yang, Huimei, Jiang, Lu. Digital economy, spatial effects and total factor productivity[J]. Statistical Research,2021,38(04):3-15.