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DIGITAL ECONOMY EMPOWERING THE DEVELOPMENT LEVEL OF CHINESE MANUFACTURING INDUSTRY

Abstract. *With the transition and upgrading of China's industrial economy, the digital economy has gradually become a pivotal engine enabling the development of manufacturing. According to panel data from China's 30 provinces excluding Tibet from 2011 to 2019, this study analyses the path of the digital economy empowering the manufacturing development level using the moderated mediating effect model. The empirical results show that: Overall, the digital economy can break the time-space constraints of traditional information transmission and positively promote the development of manufacturing; In the viewpoint of the mechanism of action, there are two realisation paths: "the digital economy→alleviating the misallocation of talents→manufacturing development level" and "the digital economy→science and technology driven→ manufacturing development level", and the second path is positively regulated by the industrial integration degree.*

Keywords*: digital economy; manufacturing development level; mediating effect; moderating effect*

JEL Classification: J31, J24, L26

1. Introduction

China is gradually entering the stage of high-quality development, technology and digitalisation-based industries are expected to become new entries engines of growth. The digital economy has broken the time and space constraints, resulting in a large number of new business forms, new technologies, and new models, and improved the allocation efficiency of capital, technology, talent, and other elements. Therefore, in the context of China's vigorous promotion of digital economy development, effective integration of the digital economy and

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manufacturing transformation development is an important way to improve the development level of China's manufacturing industry.

The report of the 19th National Congress of the Communist Party of China pointed out that in order to take the lead in building a manufacturing power and realise advanced intelligence in manufacturing, China must vigorously promote the integration process of AI, big data, the Internet, and other emerging technologies with the real economy. How to effectively release the power of the digital economy to the development level of the manufacturing industry? Discussing and answering this question can provide theoretical support for evaluating the enabling and promoting role of the digital economy in the development of the manufacturing industry.

2. Literature Review

Academics have defined the digital economy from various perspectives. For example, Moulton (2000) and Kling (1999) agreed that the basis of the development of the digital economy is information technology. Weng and Mi (2006) defined the digital economy as the use of digital technology to assist enterprise operations. Hojeghan et al. (2011) pointed out that the digital economy is based on electronic goods and services produced by electronic enterprises and traded through electronic commerce. The digital economy is the integration of various general initiatives, broad social and economic actions, and related initiatives. He (2021) believes that the digital economy is the result of the integration of big data, the Internet, and artificial intelligence technology.

The emergence of various digital technologies brings possibilities to initiate the digital transformation journey. Digital Transformation (DT) is one of the significant challenges for traditional businesses, affecting all corporate functions, procedures, processes, operations, services, and products (Bouncken et al., 2021; Dehnert, 2020). A cutting-edge and emerging technology that possibly can be utilised to process the DT is Robotic Process Automation (RPA) (Sobczak, 2021). Afriliana & Ramadhan (2022) analysed RPA technology's trends, roles, best practices, and extent in a DT initiative, to improve process performance, profitability, adaptability, safety, and conformity.

The relationship between the digital economy and the development of the manufacturing industry. Suuronen et al. (2022) point out that digitalisation disrupts the way organisations cooperate and compete, and upends the world manufacturing industry; the digital transformation of manufacturing industry is urgent and necessary. Kim (2019) argues that the digital economy has brought about dynamic changes in manufacturing through ICT infrastructure, smart factories, digitally controlled logistics, and skilled ICT personnel. Ghobakhloo (2022) believes that the biggest problem facing the current manufacturing industry is how manufacturers can achieve the transition from the current stage to Industry 4.0 through a digital process. When it comes to Industry 4.0, widespread advance technology adoption is expected to accelerate the development of new knowledge within the workforce, as well as stimulate digital innovation (Ehrehail et al., 2018). As for “Smart Factory”, referring to a new industrial age, to achieve greater industrial performance by integrating cutting-edge developments in the digitalisation and automation of manufacturing processes (Dalenogare et al., 2018).

For the development path of digital economy enabling manufacturing industry, the existing research focuses on the allocation effect, technological innovation effect, structural effect, and the financial effect. For example, Yu et al. (2022) investigated the impact mechanism of the digital economy level on the resource allocation efficiency of China's manufacturing industry. Li and Han (2021) believe that the digital economy has promoted a deep integration of the service industry and manufacturing industry. Liao and Yang (2021) show that the digital economy promotes the transformation and upgrading of the manufacturing industry through three paths: the optimisation effect of resource allocation, the reduction effect of production costs, and the driving effect of innovation and development. It was found that the provision of infrastructure to support digital business has an impact on the decision making of opportunity-motivation technopreneurs and necessity- motivation technopreneurs (Wibowo, Sulartopo, Koerniawan, 2022).

Through combing the existing literature, it is found that most scholars analyse the promotion of digital economy on the development of manufacturing industry from the connotation and characteristics of digital economy, digital upgrading and transformation of manufacturing industry, and other aspects. However, due to the varying understanding of the connotation of digital economy by different scholars, there is no final conclusion on the measurement method of digital scale. Most of the existing studies remain at the theoretical interpretation level of the point of view, lacking empirical research and analysing the role path of the digital economy to enable the development of the manufacturing industry. Therefore, the marginal contribution of this paper is reflected in: (1) Build the manufacturing industry development level indicator system from four dimensions of technological innovation, structural optimisation, economic efficiency, and environmental friendliness, and comprehensively evaluate the potential and influence of the manufacturing industry. (2) Selects science and technology driven and talent resource misallocation as intermediary variables to analyse the mechanism and realisation path to enable the development level of manufacturing industry in the digital economy.

3. Theoretical Basis and Research Hypothesis

The digital economy does not only directly promote the manufacturing development level; this study analyses the indirect effects of the digital economy empowering the manufacturing development level from three aspects: allocation effect, technology effect, and structural effect, and build a mediating effect model with moderating effect to identify the action path.

(1) Allocation effect: mediating role of misallocation of talents

This study selects human resources, one of the important innovation factors, as the research object to study. On the one hand, the manufacturing development level is inseparable from the support of the high-tech talent. The batch of compound scientific and technological talents fills the gap of mid-to-high-end skilled talents in the manufacturing, and continuously provides talent support for the breakthrough of core technology and the implementation of advanced manufacturing models. On the other hand, the digital economy can effectively improve the distortion of labour factor allocation in China. Therefore, this study proposes Hypothesis 1: the digital economy can empower the manufacturing development level by alleviating the misallocation of talents.

(2) Technology effect:mediating role of science and technology driven

First, the penetration of high-tech digital technologies such as cloud computing and AI can make manufacturing enterprises more efficiently use of existing human resources to carry out scientific research, and realise the innovation and refinement of cutting-edge disruptive technologies. Second, ICT construction such as information and communication networks will not only directly promote the upgrading of production processes, but also promote the transmission efficiency of innovative technology among manufacturing enterprises, forming a good situation of "competition + sharing", thereby accelerating the self-renewal and innovation upgrading of manufacturing. Therefore, this study proposes Hypothesis 2: the digital economy can empower the manufacturing development level by enhancing the force of the science and technology driven.

(3) Structural effect: moderating role of the industrial integration

On the one hand, industrial integration blurs the boundaries of industries, and the corresponding multi-field integration technologies and new customer demands pose challenges for manufacturing enterprises, forcing them to continue to innovate, accelerate the process of a new round of technological revolution, and turn challenges into opportunities for transformation. On the other hand, the synergistic relationship between scientific and technological innovation and the industrial integration has become increasingly prominent, which help transform the scientific and technological innovation into the driving force of manufacturing development. Based on this, this study proposes Hypothesis 3: the industrial integration between the manufacturing and the information industry can positively moderate the mediating role of the science and technology driven in the process of the digital economy empowering the manufacturing development level.

(4) The relationship between the pathways

On the basis of Hypotheses 1, 2 and 3, to study the relationship between the two action paths "the digital economy → alleviating the misallocation of talents→manufacturing development level", "the digital economy→science and technology driven→manufacturing development level (assuming "digital economy→science and technology driven" is moderated by the industrial integration degree), and obtain the value of the mediating effect, the total mediating effect and the difference between the two effects, this study will establish a multiple mediating model, which is further divided into parallel mediating effect and chain mediating effect. This study argues that human resources allocation and technology drive each exert their mediating effect without affecting each other, so this study proposes Hypothesis 4: The empowering path of the digital economy to the manufacturing development level is a parallel mediating effect rather than a chain mediating effect.

4. Research Methodology

4.1. Variable selection

4.1.1. Explained variable

According to the principles of comprehensiveness, hierarchy, availability, and completeness of data, this study constructs the evaluation indicator system of the manufacturing development level (MDL) index from four aspects, such as technological innovation, structural optimisation, economic efficiency, and environmental friendliness (Table 1). This study uses the improved CRITIC-entropy weight method to weight each index. Assume that CRITIC weight method and entropy weight method have equal importance, that is, the improved CRITIC-entropy weight=0.5×(CRITIC weight+ entropy weight).

Table1. Evaluation indicator system of manufacturing development level (MDL)

Primary indicator	***Secondary indicator***	***Tertiary indicator***	***Calculation***
Technological innovation	Innovation inputs	R&D expenditure investment intensity of industrial enterprises(%)	R&D expenditure of industrial enterprises above designated size (ten thousand yuan)/ Revenue from principal business of industrial enterprises above designated size (billion yuan)
		R&D personnel investment intensity of industrial enterprises(%)	R&D Personnel full-time Equivalent (man-year)/ Number of employed persons in urban units of industry (ten thousand people)
	Innovation outputs	Number of invention patents per unit of R&D expenditure (pieces/ten thousand yuan)	Number of patent applications of industrial enterprises above designated size (piece)/ R&D expenditure of industrial enterprises above designated size (ten thousand yuan)
		Sales revenue of new products of industrial enterprises above designated size (ten thousand yuan)	Direct access
	Innovation Environment	Expenditure of science and technology (%)	Local fiscal expenditure on science and technology (billion yuan)/ General budget expenditure of local finance (billion yuan)

Primary indicator	***Secondary indicator***	***Tertiary indicator***	***Calculation***
Structural optimisation	Industry Structure	Income of main business of high-tech industry (%)	Revenue from principal business of high-tech industry (billion yuan)/ Revenue from principal business of industrial enterprises above designated size (billion yuan)
		Sales revenue of new products in high-tech industry (%)	Sales revenue from new products in high-tech industry (ten thousand yuan)/ Sales revenue from new products of industrial enterprises above designated size (ten thousand yuan)
	Employment Structure	Proportion of employed persons in urban units of manufacturing (%)	Number of manufacturing workers in urban units (ten thousand people)/ Number of industrial workers in urban units (ten thousand people)
Economic efficiency	Labour Efficiency	Labour productivity (billion yuan/ten thousand people)	Industrial added value (billion yuan)/ Number of industrial workers in urban units (ten thousand people)
	Production Cost	Cost of main business revenue (billion yuan)	Cost from principal business of industrial enterprises above designated size (billion yuan)/ Revenue from principal business of industrial enterprises above designated size (billion yuan)
	Profitability	Profit margin (%)	Profits of industrial enterprises above designated size (billion yuan)/ Revenue from principal business of industrial enterprises above designated size (billion yuan)
	Business Risk	Gearing ratio (%)	Liabilities of industrial enterprises above designated size (billion yuan)/ Property of industrial enterprises above designated size (billion yuan)
	Growth contribution	Economic growth contribution rate (%)	Industrial added value increment (billion yuan)/GDP increment (billion yuan)
Environmental friendliness	Solid Pollution	Utilisation rate of industrial solid waste (%)	Utilisation of industrial solid waste (ten thousand ton)/ production of industrial solid waste (ten thousand ton)
	Gas pollution	Industrial sulphur dioxide emissions (tons)	Direct access
		Industrial nitrogen oxide emissions (ton)	Direct access
		Cost of industrial waste gas treatment facilities (ten thousand yuan)	Direct access
		Capacity of industrial waste gas treatment facilities (standard) (10,000 cubic meters/hour)	Direct access

Primary indicator	***Secondary indicator***	***Tertiary indicator***	***Calculation***
	Water pollution	Capacity of industrial wastewater treatment facilities (ten thousand tons/day)	Direct access
		Annual fee of industrial wastewater treatment facilities (ten thousand yuan)	Direct access
	Electricity consumption	Energy consumption per unit of industrial value added (KWH/yuan)	Consumption of electricity (billion KWH)/ Industrial added value (billion yuan)

4.1.2. Core explanatory variable: the digital economy index

On the basis of the previous theoretical analysis, this study constructs evaluation indicator system of the digital economy index from 11 indicators under 3 dimensions (infrastructure construction, industrial development level, and inclusive development of digital finance), and the improved CRITIC-entropy weight method is used to weight each indicator (Table 2).

Table2. Evaluation indicator system of the digital economy index

Primary indicator	***Secondary indicator***
Infrastructure construction	Optical cable construction level (km/ km^2)
	Internet broadband port (10000)
	Internet broadband access users (million households)
	Mobile phone penetration rate (number of mobile phones per 100 people)
	Number of domain names (10000)
	Number of Web pages (10000)
	Internet penetration rate (%)
Industrial development level	Information transmission, software and information technology service workers in urban units (million people)/ workers in urban units (million people)
	Telecom business volume (billion yuan) / Resident population (million people)
	Revenue from principal business of electronic and communication equipment manufacturing (billion yuan)
Inclusive development of digital finance	The Peking University Digital Financial Inclusion Index of China(PKU-DFIIC)

4.1.3. Mediating Variable

(1)The science and technology driven index. This study measures the science and technology driven (SATD) index by using three indicators: the expenditure of developing new products, the number of new product projects, and the number of patent applications of industrial enterprises above designated size. The weight of each indicator is still calculated using the CRITIC-entropy weight method.

(2)The misallocation of talents index. This study uses the degree of the misallocation of talents to reflect the efficiency of resource allocation.

① Calculate the stock of innovation capital according to the formula

$$INNOK_{it} = \frac{INVEST_{it}}{PINDEX_{it}} + (1-\delta)INNOK_{i,t-1}$$

Where $INNOK_{it}$ 、 $INNOK_{i,t-1}$ represent the stock of innovation capital in the current period and the previous period respectively. The stock of innovation capital of the base period is denoted as $\frac{INVEST_{it}}{PINDEX_{it}}$. $INVEST_{it}$ represents the innovation capital investment of province i in year t , measured by the internal expenditure of R&D funds of industrial enterprises above designated size; $PINDEX_{it}$ is the price index of innovation capital investment of province i in year t , using a weighted values of the GDP deflator and the consumer price index(the weights are 0.55 and 0.45, respectively). δ is the depreciation rate, which is 9.6% widely used.

② Calculate the elasticity of talent output

The model of innovation factor input and output is constructed according to the C-D production function with constant returns to scale:

$$INNOY_{it} = A \cdot INNOK_{it}^{\beta_{k_i}} \cdot INNOL_{it}^{1-\beta_{k_i}}$$

Where $INNOY_{it}$ 、 $INNOK_{it}$ 、 $INNOL_{it}$ are respectively measured by the new product sales revenue of industrial enterprises above designated size, the stock of innovation capital calculated in step ①and the full-time equivalent of R&D personnel.

Taking the logarithms of both sides of this equation, we get:

$$\ln\left(\frac{INNOY_{it}}{INNOL_{it}}\right) = \ln A + \beta_{k_i} \ln\left(\frac{INNOK_{it}}{INNOL_{it}}\right) + \varepsilon_{it}$$

The talent-output elasticity is calculated by regressing the deformed equation. Considering the objective differences in talent-output elasticity between provinces and cities in China, the interaction term between the regional dummy variable and the independent variable is introduced for fitting to obtain the capital-output elasticity β_{k_i} of each province and city in China. Assuming constant return to scale, the talent-output elasticity is obtained by subtracting the capital-output elasticity from 1.

③ Calculate the absolute distortion coefficient

$$\hat{\gamma}_{L_{it}} = \left(\frac{INNOL_{it}}{SUMINNOL_t}\right) / \left(\frac{S_{it}(1-\beta_{k_i})}{SUM\beta_t}\right)$$

Where $SUMINNOL_t$ is the total innovation labor input in 30 provinces and cities in year t . S_{it} is the proportion of innovation output of province i in year t to the total innovation output of 30 provinces and cities in year t . $SUM\beta_t$ is the weighted talent-output elasticity in year t , and the formula is $\sum_{i}^{30} S_{it}(1-\beta_{k_i})$.

④ Calculate the misallocation of talents index $MOTA_{it} = \left|\frac{1}{\hat{\gamma}_{L_{it}}} - 1\right|$.

Considering that the difference between the inverse of the absolute distortion coefficient and 1 may be negative, the result after taking the absolute value of the difference is usually taken as the misallocation of talents index. The larger the absolute value, the higher the degree of misallocation.

4.1.4. Moderating variable: industrial integration degree

Based on the previous theoretical foundation and research hypothesis, the industrial integration degree is selected as the moderating variable for the first half of the path of the mediating effect of the science and technology driven. For the convenience of calculation and with reference to relevant literature, the integration degree ITGD is given by

$$ITGD = \sqrt{\frac{MDL \times INF}{\left(\frac{MDL+INF}{2}\right)^2} \cdot \frac{MDL+INF}{2}}$$

Where MDL represents the manufacturing development level index; INF represents the information industry development level index calculated by the indicators from three aspects of Telecom, Software and Information Technology Services, and Internet (Table 3, the calculation method is also the CRITIC-entropy weight).

Table3. Evaluation indicator system of information industry development

Target layer	Rule layer	Indicator layer
INF	Telecom	Total telecom business (100 million yuan)
	Software and Information Technology Services	Software business income (10000 yuan)
		Software product income (10000 yuan)
		Embedded system software income (10000 yuan)
		Information technology service income (10000 yuan)
	Internet	Number of websites per 100 enterprises
		Internet broadband access ports (10000)

4.1.5. Control variables

In order to eliminate the estimation error caused by the omission of dependent variables, this study sets control variables from three dimensions: economic development ECOD which is measured by per capita GDP (yuan/person), government policy GOVP which is measured by proportion of local fiscal general budget revenue to the GDP (%), and industry scale INDS which is measured by proportion of industrial added value to the GDP (%).

4.2. Model Setting

Referring to other authoritative studies, the mediated effects model with moderation was constructed as a way to test the mediating effect of the mediating variables and the moderating effect of the moderating variables. The expression of the model is given by

$$Mediator_{i,t} = \beta_0 + \beta_1 DIG_{i,t} + \sum \beta_i CV_{i,t} + \delta_i + \eta_t + \xi_{i,t}$$

$$MDL_{i,t} = \gamma_0 + \gamma_1 DIG_{i,t} + \gamma_2 Mediator_{i,t} + \sum \gamma_i CV_{i,t} + \delta_i + \eta_t + \xi_{i,t}$$

$$SATD_{i,t} = \chi_0 + \chi_1 DIG_{i,t} + \chi_2 ITGD_{i,t} + \chi_3 DIG_{i,t} \times ITGD_{i,t} + \sum \gamma_i CV_{i,t} + \delta_i + \eta_t + \xi_{i,t}$$

Where $Mediator_{i,t}$ represent the mediating variables including the science and technology driven index (SATD) and the misallocation of talents index (MOTA), and the meanings of other variables are the same as above. $CV_{i,t}$ represent the control variables.

4.3 Data sources

The research area of this study is 30 provinces in China (Tibet was not included in this study because of the lack of many data) from 2011 to 2019, and the missing data are filled by means of linear interpolation or the ARIMA method. The data were retrieved from the China Statistical Yearbook, China Statistical Yearbook on Environment, China Industry Statistical Yearbook, China Statistical Yearbook on High Technology Industry, China Statistical Yearbook on Electronic Information Industry, China Stock Market & Accounting Research Database and Institute of Digital Finance, Peking University.

5. Analysis of Empirical Results

5.1. Mediating effect of the digital economy

5.1.1. Analysis of basic mediating effect model

As for the mediating effect test method, Fang et al. (2012) believed that the diagnosis method for distinguishing fully mediating from partially mediating based on the significance results of direct effects was too arbitrary and had relatively large limitations by comparing various testing methods. In summary, the improved Bias-corrected Bootstrap method (repeat sampling 5000 times) are used to test the mediating effect. Table 4 lists the detailed results. The direct effect and mediating effect of science and technology driven empowering the high-quality development of manufacturing industry are 56.13% and 43.87%, respectively. The direct effect and mediating effect of misallocation of talents empowering manufacturing industry are 96.3% and 3.7%, respectively. It can be seen from column (2) of Table 4 that the digital economy has a positive and significant impact on the science and technology driven, and the science and technology driven have a positive and significant effect on the manufacturing development level at 99% confidence level; Similarly, it can be seen from column (3) that the digital economy has a negative and significant effect on the misallocation of talents, and the misallocation of talents has a negative effect on the manufacturing development level, so the digital economy can promote the manufacturing development level by reducing the degree of misallocation of talents. In summary, there are two paths of action "digital economy→alleviating the misallocation of talents→manufacturing development level" and "digital economy→science and technology driven→manufacturing development level", which verifies H1 and H2.

Table 4. Results of mediating effect test

	(1) Basic	(2) Mediating variable: *SATD*		(3) Mediating variable: *MOTA*	
DIG	0.3515***	1.7781***	0.1973***	-0.8257***	0.3385***
MOTA					-0.0157***
SATD			0.0867***		
ECOD	0.1906***	-0.0800	0.1976***	0.4091**	0.1971***
GOVP	-0.0463***	-0.0625	-0.0409***	0.0566	-0.0454***
INDS	0.1375***	0.2846***	0.1128***	-0.5230***	0.1293 ***

5.1.2. Mediating effect model with moderation

Under the condition of controlling ECOD, GOVP and INDS, this study added moderating variables to construct a moderated mediating effect model as a way to investigate whether there is a moderating mediating effect hypothesised above. The regression results of the moderated mediating effect “digital economy→science and technology driven” are shown in Table 5. The results show that after adding the industrial integration degree as a moderating variable in the mediating effects model, the interaction term between the digital economy and the industrial integration degree has a promoting effect on the science and technology driven, and this effect is significant at the 95% confidence level, which indicates that the industrial integration degree positively regulates the degree of facilitation of the science and technology driven by the digital economy.

In order to analyse the moderating effect under different levels of the industrial integration degree, this study further explores more intuitive effect changes by presenting simple slope.It can be seen that if the industrial integration degree is at a low level, the digital economy has a certain inhibitory effect on the science and technology driven; when the industrial integration degree is at a medium level, the digital economy has a small and insignificant promotion effect on the science and technology driven, and when the industrial integration degree is at a high level, the positive effect of the digital economy on the science and technology driven increases and very significant. Therefore, as the value of the industrial integration degree index and the simple slope increases, the positive effect of the digital economy on the science and technology driven gradually increases.

Table 5. The mediating effect test results with moderation

Explanatory variable	*Coeff*	*Se*	*P*	Lower confidence interval	Upper confidence interval
DIG	0.0718	0.1856	0.6993	-0.2938	0.4373
ITGD	0.2574	0.0862	0.0031***	0.0876	0.4273
DIG×ITGD	5.7046	0.4502	0.0000***	4.8176	6.5915
ECOD	-0.0862	0.0941	0.3609	-0.2716	0.0993
GOVP	-0.2166	0.0572	0.0002***	-0.3293	-0.1040
INDS	0.2034	0.0576	0.0005***	0.0898	0.3169

Finally, this study conducted a comparative analysis of the mediating effects at different industrial integration degree levels, and the results are shown in Table 6. The results show that the mediating effect values of the science and technology driven at the three industrial integration degree levels also shows an increasing trend, that is, as the industrial integration degree level increased, the empowerment mechanism of the digital economy on the manufacturing development level through the science and technology driven is more easily achieved (digital economy→science and technology driven→manufacturing development level), so H3 is verified.

Table 6. Mediating effect at three industrial integration degree levels

#	*ITGD* level	Mediating effect	Bootstrap Standard error	Lower confidence interval	Upper confidence interval
Moderated mediating effect	eff1(low level)	-0.0936	0.0320	-0.1664	-0.0407
	eff2(medium level)	0.0063	0.0178	-0.0307	0.0427
	eff3 (high level)	0.1063	0.0241	0.0673	0.1628

5.1.3 Multiple mediating effect model analysis

The multiple mediating effects can also be subdivided into parallel and chain mediating effects based on the existence of a relationship between different mediating variables. In this study, the key to determine whether it is a parallel mediating effect or a chain mediating effect is to determine whether the mediating effect of the "digital economy→alleviating the misallocation of talents→science and technology driven→manufacturing development level" is significantly present. This study tests the significance of the above path. The results from Table 7 are as follows: (1) bootstrap 95% confidence interval of path Ind3 ("digital economy→alleviating the misallocation of talents→science and technology drive→manufacturing development level") contains 0, which indicates that the mediating effect of this path is not significant, so H4 is confirmed; (2) the confidence intervals of Ind1-Ind2, Ind1-Ind3 and Ind2-Ind3 do not contain 0, which indicates that the differences between Ind3 and Ind1 ("digital economy→science and technology drive→manufacturing development level"), Ind2 ("digital economy→alleviating the misallocation of talents→manufacturing development level") are significant. The mediating effect values between Ind1 and Ind3, between Ind2 and Ind3 were 0.1547 and 0.0131, accounting for 92.18% and 7.82% of the total mediating effect, respectively.

Table7. The test results of mediating effect

Path	Mediating effect	Bootstrap Standard error	Lower confidenc e interval	Upper confidenc e interval
Total mediating effects：Ind1+Ind2+Ind3	0.1675	0.0294	0.1137	0.2267
Ind1：*DIG→SATD→MDL*	0.1545	0.0277	0.1018	0.2105
Ind2：*DIG→MOTA→MDL*	0.0131	0.0064	0.0030	0.0277
Ind3：*DIG→MOTA→SATD→MDL*	-0.0002	0.0031	-0.0045	0.0086
Comparison：Ind1-Ind2	0.1414	0.0283	0.1984	0.0872
Comparison：Ind1-Ind3	0.1547	0.0291	0.0992	0.2130
Comparison：Ind2-Ind3	0.0133	0.0072	0.0012	0.0292

5.2. Heterogeneity test

In order to test the reliability of the above regression results, this study analysed the mediating effects by region, and the results are shown in Table 8. The results show are as follows: (1) from the results in the eastern region, it is able to achieve the empowerment mechanism of the digital economy on the manufacturing development level by alleviating the misallocation of talents and enhancing the science and technology driven at 95% confidence level, and their mediating effect values are 0.0261 and 0.1970 (The mediating effect of science and technology driven is stronger), respectively, which is consistent with the conclusion of the mediating effect test above and further indicates that the above results are robust; (2) from the results of the central and western regions, on the one hand, the mediating effect of the science and technology driven is significant, which verifies the robustness of the results, but the value of the science and technology driven effect in the central and western regions is largely lower than that in the eastern region; on the other hand, as shown in column (1) of Table 8, the digital economy in the central and western regions can significantly reduce the level of the misallocation of talents, but column (2) shows that the effect of talent allocation on manufacturing development level is not significant. The reason for the insignificant benefit of talent allocation in the central and western regions is that, compared with the provinces in the eastern region, the digital economy in the central and western regions is lower and the brain drain is more serious, so the inhibitory effect of the digital economy on the misallocation of talents is not enough to achieve the empowerment mechanism on the manufacturing development level.

Table 8. Heterogeneity Test of mediating effect (by region)

#	mediating variable	*MOTA*		*SATD*	
		(1)*MOTA*	(2)*MDL*	(3)*SATD*	(4)*MDL*
		Coeff	*Coeff*	*Coeff*	*Coeff*
Eastern region	*DIG*	-0.6055***	0.3249***	2.2007***	0.1540***
	MOTA		-0.0431***		
	SATD				0.0895***
	ECOD	0.3992***	0.1195***	-0.2802	0.1274***
	GOVP	0.6866***	0.0030	-0.1338	-0.0146
	INDS	0.1410	0.1487***	0.3160***	0.1144***
	Mediating effect	0.0261		0.1970	
	Confidence interval	[0.0046,0.0594]		[0.1295,0.2838]	
Central and Western regions	*DIG*	-2.0962***	0.3196***	0.0729***	0.2430***
	MOTA		-0.0065		
	SATD				1.2390***
	ECOD	0.4568	0.1933***	0.0175	0.1686***
	GOVP	-0.4160	-0.0729***	-0.0379***	-0.0233
	INDS	-0.9204***	0.1341***	0.0369***	0.0944***
	Mediating effect	0.0137		0.0903	
	Confidence interval	[-0.0230, 0.0422]		[0.0210,0.1908]	

6. Conclusions

Based on multiple perspectives, this study constructs a multi-level evaluation system, and analyses the empowerment mechanism of the digital economy on the manufacturing development level of China, from enhancing the force of the science and technology driven and weakening the degree of the misallocation of talents. The following conclusions can be drawn: (1) The empowering effect of the digital economy on the manufacturing development level is significant. The digital economy is a powerful driving force in promoting the optimal development of the manufacturing. (2) The digital economy empowers the manufacturing development level through the following two paths: "digital economy→alleviating the misallocation of talents→manufacturing development level" and "digital economy→science and technology driven→ manufacturing development level". (3) There is regional heterogeneity in the effect of the digital economy empowering the high-quality development of the manufacturing industry. The eastern region has more advantages than the central and western regions. (4) In the path of digital economy→science and technology driven→manufacturing development level, the industrial integration degree plays a positive moderating effect, and the higher the degree of the industrial integration, the more obvious the effect of the digital economy on empowering the manufacturing development level.

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