J. Asia soc.sci. pract. (2025), vol(2): 61-87 eISSN: 3079-7659

JORNAL OF ASIA SOCIAL SCIENCE PRACTICE
www.shiharr.com

RESEARCH ARTICLE

THE IMPACT OF DIGITAL ECONOMY DEVELOPMENT ON THE UPGRADING OF INDUSTRIAL STRUCTURE ——TAKING THE METROPOLITAN CIRCLE AROUND THE "JI" SHAPE BEND OF THE YELLOW RIVER AS AN EXAMPLE

Yan Haohao [1*]

[1]School of Economics and Management, Inner Mongolia University of Technology, Hohhot 010051, Inner Mongolia, China

ARTICLE INFO

Submission 29 Mar., 2025
Acceptance 07 Apr., 2025

Keywords
Digital Economy;
Upgrading of Industrial Structure;
Urbanization;
Threshold Effect

Corresponding Author
wzyi980@163.com

ABSTRACT

Based on the panel data of 19 prefecture-level cities in the Metropolitan Circle around the "ji" Shape Bend of the Yellow River from 2011 to 2022, the entropy method, CRITIC method and mean variance method are combined to measure the digital economy development level of each city in the metropolitan circle. The double fixed effect model is selected to explore the impact of the digital economy on the upgrading of the industrial structure in the Metropolitan Circle around the "ji" Shape Bend of the Yellow River, and the panel threshold model is established to analyze the nonlinear relationship between the development of the digital economy and the upgrading of the industrial structure. The results show that the digital economy has a significant positive impact on the upgrading of the industrial structure in the Metropolitan Circle around the "ji" Shape Bend of the Yellow River. From 2011 to 2016, the impact of the digital economy on the upgrading of the industrial structure is negative, while from 2017 to 2022, it is positive. Per capita GDP and urbanization play a completely mediating role in the impact of the digital economy on the upgrading of the industrial structure. There are significant nonlinear characteristics in the impact of the digital economy on the upgrading of the industrial structure, showing a trend of increasing marginal effect.

1. Introduction

The "14th Five-Year Plan" for the Development of Digital Economy proposes that the digital economy is the main economic form following agricultural and industrial economies. It is characterized by data resources as key elements, modern information networks as the primary carrier, and the integrated application of information and communication technologies and the digital transformation of all factors as important drivers, promoting a new economic form that unifies fairness and efficiency. Zhang (2016) believes that technologies such as computers and network communications have given rise to the digital economy. As a new type of economic form, the digital economy has characteristics such as external economies and sustainability, and can provide new impetus for the upgrading of industrial structures. The level of industrial structure can reflect the level of regional economic development to some extent and is an indispensable driving force for regional economic development. Regions with developed economies have generally formed advanced levels of industrial structure and comprehensive industrial systems. Therefore, to achieve sustained regional economic development, it is necessary to promote the upgrading of industrial structures within the region. The "ji" shape bend of the Yellow River refers to the "ji" shaped bend formed by the upper and middle reaches of the Yellow River, which embraces a region. It is a bridgehead for economic exchanges and cooperation between China, Mongolia, and Russia, and is also an important node on the Silk Road Economic Belt. Promoting the construction of the Yellow River "ji" shape bend economic zone has significant strategic importance for promoting China's economic growth and ensuring energy security.

The impact of the digital economy on the upgrading of industrial structure can be divided into two aspects: industrial digitization and digital industrialization. In terms of industrial digitization, the digital economy integrates with traditional industries through data resources, cloud computing, and other technologies, enhancing the technological and digital levels of traditional industries, and promoting the upgrading of traditional industries. In terms of digital industrialization, the development of the digital economy can foster new economic forms, providing important technological support for industries such as telecommunications, software, and information services. From a single perspective of impact, Zang (2019) proposed that the digital economy has a higher degree of integration with the tertiary industry compared to the primary and secondary industries, and the prosperity of the digital economy industry has a positive impact on the optimization and upgrading of the industrial structure. Chen and Pei (2021) established an interaction effect model to test the mechanism of the digital economy on the upgrading of the industrial structure, concluding that the digital economy is conducive to the optimization and upgrading of the industrial structure. Chen (2018) the integration of the tertiary industry with intelligence, which helps to drive changes in the industrial structure. From a comprehensive perspective of impact, Xu and Lin (2023) explored the impact mechanism of the digital economy on the upgrading of the industrial structure from the perspective of technological innovation, and the results showed that different types of technological innovations play different intermediary roles, with breakthrough technological innovations having a significant intermediary effect. Lyu (2023) analyzed the impact of the digital economy on the industrial structure from the perspective of carbon emissions, and the results indicated that the digital economy achieves carbon reduction through digital technology and exerts a "forcing effect" on the industrial structure, promoting the upgrading of the regional industrial structure. From the perspective of nonlinear impact, Liu and Chen (2021) established a panel threshold model to analyze the nonlinear impact of the digital economy on the upgrading of the industrial structure, and the results showed that there is a trend of diminishing marginal effects of the digital economy on the advanced industrial structure.

In summary, there are diverse perspectives on the impact mechanism of the digital economy on the upgrading of industrial structure. Existing literature mainly studies the relationship between the digital economy and industrial structure upgrading from intermediary variables such as technological innovation, carbon emissions, circulation effects, and environmental regulations, with fewer explorations from the perspective of urbanization. Drawing on relevant research and using Stata17.0 software, this study selects panel data from the 2011-2022 Yellow River "Ji" character bend metropolitan area to test the impact of the digital economy on industrial structure upgrading and analyzes the role of per capita GDP and urbanization level in the relationship between the two. This enriches the research on the impact mechanism of the digital economy on industrial structure upgrading and provides a reference for the upgrading of industrial structure in the Yellow River "Ji" character bend metropolitan area.

2. Research Design

2.1. Data Source

This paper selects panel data from 19 prefecture-level cities in the "Ji" shape bend of the Yellow River from 2011 to 2022 for study. For the missing values, the linear interpolation method is used to fill in the years for individual prefecture-level cities. The data sources include the "China City Statistical Yearbook," the statistical yearbooks of various prefecture-level cities, and the EPS database.

2.2. Research Method

This paper investigates the impact of the digital economy on the upgrading of industrial structure and analyzes whether there is an intermediary effect of per capita GDP and urbanization. The causal stepwise regression method proposed by Wen and Ye (2014) is used for the mediation effect test. The mediation effect test equation is as follows:

$$Y = cX + e \tag{1}$$

$$M = aX + e \tag{2}$$

$$Y = c'X + bM + e \tag{3}$$

First, regress equation 1 to test whether the regression coefficient c of the independent variable on the dependent variable is significant. If it passes the significance level test, proceed to the second step; if it does not pass the significance level test, stop the mediation effect test. In the second step, regress the mediating variable M on the independent variable X to obtain the regression coefficient a. After adding the mediating variable M to equation 1, regress to obtain the regression coefficient b of M on Y. Test the significance of coefficients a and b. If both coefficients a and b are significant, proceed to the third step; if at least one of coefficients a and b is not significant, use the Bootstrap method for further testing to determine whether the mediating variable M has a mediation effect between the independent variable X and the dependent variable Y. If both coefficients a and b are significant, there is a significant indirect effect; if neither coefficient a nor b is significant, the indirect effect is not significant.

Step 3 involves adding the control variable M to equation 1, constructing a new regression equation 3, and regressing the dependent variable Y on the independent variable X and the mediating variable M. This yields the regression coefficient c′ of the independent variable X on the dependent variable Y. If coefficient c′ is not significant, it indicates that the direct effect of the independent variable X on the dependent variable Y is not significant, and there is a significant full mediating effect. If c′ is significant, it suggests that the direct effect of the independent variable X on the dependent variable Y is significant, and there is a significant partial mediating effect. Then proceed to step 4.

Step 4: If the sign of ab is the same as the sign of coefficient c, it indicates that the total effect of the independent variable X on the dependent variable Y and the mediating effect are in the same direction, with a partial mediating effect present, and the proportion is c/ab. If the sign of ab is different from the sign of coefficient c, it indicates the presence of a suppression effect, and analysis should be conducted according to the suppression effect.

2.3. Variable Selection

Dependent variable: Industrial advancement value W. The reference for industrial structure advancement is Fu (2010), who used the spatial vector angle method for calculation. According to the classification of the three industries, GDP is divided into three parts, with the added value of each part accounting for the proportion of GDP as a component in the spatial vector, thus forming a set of 3-dimensional vectors $X_0= (x_{1,0},x_{2,0},x_{3,0})$. Then, the angles θ_1,θ_2 and $\theta 3$ between X_0 and the vectors arranged from lower to higher levels of industry, $X_1= (1,0,0)$, $X_2= (0,1,0)$ and $X_2= (0,0,1)$, are calculated respectively.

$$\theta j = \arccos\left[\frac{\sum_{i=1}^{3}(xi,j \bullet xi,0)}{(\sum_{i=1}^{3}(x^2i,j)^{1/2} \bullet \sum_{i=1}^{3}(x^2i,0)^{1/2})}\right],\ \ j = 1,2,3 \quad (4)$$

The formula for calculating the value of industrial advancement W is defined as:

$$W = \sum_{k=1}^{3}\sum_{j=1}^{k}\theta j \quad (5)$$

The larger the W, the higher the degree of industrial sophistication.

Core explanatory variable: Digital Economy Development (dig). In the current literature on the evaluation of the level of digital economy development, different scholars have varying evaluation indicators for the digital economy, but most studies are based on perspectives such as infrastructure, innovative development, technological development, and industrial development. This article draws on the digital economy indicator systems of Wang (2021), He (2021), and Ma (2022), and selects nine indicators based on data availability and accuracy to construct a digital economy development level evaluation indicator system to measure the level of digital economy development. These indicators include the number of internet users per 100 people, the proportion of employees in the computer services and software industry, the total volume of telecommunications per capita, the number of mobile phone users per 100 people, the level of expenditure on science and technology, the level of human capital, the depth of digital finance usage, the breadth of coverage, and the degree of digitization. Following the methodology of Zhang (2023), weights were calculated using the Entropy Method, CRITIC method, and Mean-Variance Method respectively. Final weights were then determined by taking the arithmetic mean of these values, and subsequently applied to compute the Digital Economy Development Index.

Table 2.1: Evaluation index system for the development level of the digital economy

Primary Indicator	Secondary indicators	Level 3 indicators	Unit
Level of Development of the Digital Economy	Digital Foundation	Number of internet users per 100 people	/
		Number of mobile phone users per 100 people	/
	Development of the digital industry	The proportion of employees in the computer services and software industry	%
		Per capita total telecommunications business volume	Ten thousand yuan
	Innovative Development	Level of expenditure on science and technology	%
		Human Capital Level	%
	Digital Finance	The depth of use of digital finance	/
		Digital Finance Coverage Breadth	/
		Digital Finance Digitalization Level	/

Mediating variable: Per capita GDP (lnrgdp). The ratio of regional gross domestic product to the year-end resident population, taken the natural logarithm. Urbanization (lncity). The level of urbanization is measured by the urbanization rate, and the natural logarithm is taken. Control variables: This paper selects government intervention (lngov), financial development level (lnfund), and human capital (lnlabor) for control. Government intervention:

the proportion of fiscal expenditure in regional gross domestic product. Financial development level: the proportion of the year-end loan balance of regional financial institutions in regional gross domestic product. Human capital: the proportion of the number of regular undergraduate and college students to the resident population. Then take the natural logarithm for measurement.

2.4. Model Construction

Based on the analysis above, Following the approaches of Cheng (2021) and Liu (2022), we control for variables including government intervention, financial development, and human capital, and selecting per capita GDP and urbanization as mediating variables, we test the impact mechanism of the digital economy on the advanced industrial structure of the "Ji" character-shaped urban agglomeration along the Yellow River. The constructed mediating effect model is as follows:

$$W_{\mathrm{it}} = \alpha_0 + \alpha_1 dig_{it} + \varepsilon_{it} \tag{6}$$

$$W_{\mathrm{it}} = \alpha_0 + \alpha_1 dig_{it} + \alpha_2 \sum x_{it} + \varepsilon_{it} \tag{7}$$

$$\ln rgdp_{it} = \beta_0 + \beta_1 dig_{it} + \beta_2 \sum x_0 + \varepsilon_{it} \tag{8}$$

$$W_{it} = \gamma_0 + \gamma_1 dig_{it} + \gamma_2 \ln rgdp_{it} + \gamma_3 \sum x_{it} + \varepsilon_{it} \tag{9}$$

$$\ln city_{it} = \delta_0 + \delta_1 dig_{it} + \delta_2 \sum x_0 + \varepsilon_{it} \tag{10}$$

$$W_{\mathrm{it}} = \eta_0 + \eta_1 dig_{it} + \eta_2 \ln city_{it} + \eta_3 \sum x_{it} + \varepsilon_{it} \tag{11}$$

The impact of the development of the digital economy on the upgrading of industrial structure may have a nonlinear relationship. We adopt a panel threshold model to test the nonlinear relationship between the two. Based on equation (5), we construct the following panel threshold model:

$$W_{it} = \alpha_0 + \alpha_1 digitI\left(c \le \delta_1\right) + \alpha_2 dig_{it} I\left(\delta_1 \smile c \le \delta_2\right) + \alpha_3 dig_{it} I\left(c \vee \delta_2\right) + \alpha_4 \sum x_{it} + \varepsilon_{it} \tag{12}$$

2.5. Descriptive statistics of variables

The descriptive statistics of the variables are shown in Table 2.1 From the mean perspective, the number of internet users per hundred people is the largest, while government intervention is the smallest. In terms of standard deviation, both the number of internet users per hundred people (internet) and the level of human capital (lnlabor) are greater than 1, indicating that the dispersion of these two indicators is significantly greater than that of other indicators, with greater differences between regions. The standard deviation of the social consumption level (c) indicator is smaller, indicating that the dispersion of the indicator data is smaller, with less regional differences.

Table 2.2: Descriptive statistics of variables

VarName	Obs	Mean	SD	Min	Max
W	228	6.653	0.311	6.082	7.276
dig	228	0.325	0.139	0.037	0.704
lnrgdp	228	1.838	0.592	0.589	3.246
lncity	228	-0.498	0.264	-1.142	-0.041
lngov	228	-1.524	0.449	-2.564	-0.269
lnlabor	228	0.164	1.081	-3.968	2.423
lnfund	228	0.014	0.553	-1.455	1.823
internet	228	14.610	7.847	5.427	38.647
c	228	0.295	0.124	0.050	0.594

3. Empirical Analysis

3.1. Benchmark Regression

The two-way fixed effects model effectively addresses omitted variable bias caused by time-invariant and individual-invariant characteristics by controlling for both individual and time fixed effects. Compared to one-way fixed effects or pooled models, it more thoroughly accounts for individual and temporal heterogeneities, reducing endogeneity biases. This approach is particularly suitable for panel data with significant heterogeneities in both individual and time dimensions. Given the study's long-time dimension, numerous city-level variables, and the presence of both time-invariant and city-specific heterogeneities—coupled with the results of the Hausman test—the two-way fixed effects model was selected. The regression results are shown in Table 3.1, which indicate that regardless of whether control variables are included, the estimated coefficients of the digital economy development on the advancement of industrial structure pass the 5% significance level test, showing a significant positive impact on the advancement of industrial structure. Before adding control variables, the regression coefficient of digital economy development is 0.304, meaning that an increase of one unit in the level of digital economy development leads to an average increase of 0.304 units in the level of industrial structure upgrading; after adding control variables, the regression coefficient of the digital economy is 0.286, indicating that for every one unit increase in the level of digital economy development, the level of industrial structure upgrading correspondingly increases by an average of 0.286 units.

Table 3.1: Benchmark regression

	(1)	(2)
	W	W
dig	0.304**	0.286**
	(0.137)	(0.138)
lngov		0.012
		(0.019)
lnlabor		0.002
		(0.012)
lnfund		0.028*
		(0.015)
_cons	6.483***	6.512***
	(0.026)	(0.041)
Individual/Time	yes/yes	yes/yes
N	228.000	228.000

r2	0.678	0.686

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, values in parentheses are standard errors (se).

3.2. Mechanism Analysis

This article employs stepwise regression to examine the mediating effects of per capita GDP and urbanization on the impact of digital economy development on industrial upgrading. The regression results for the mediating effect of per capita GDP are shown in Table 3.2, while the mediating effect of urbanization is presented in Table 3.3.

3.2.1. Economic Development Effect

Model (2) in Table 3.2 represents the direct impact of the digital economy on industrial structure upgrading, controlling for government intervention, financial development level, and human capital. Model (3) shows the direct impact of digital economy development on per capita GDP after adding control variables. Model (4) indicates the impact of digital economy development and per capita GDP on industrial structure upgrading after controlling for government intervention, financial development level, and human capital.

The regression results in Table 3.2 Model (3) show the direct impact of digital economy development on per capita GDP. According to the regression results, the impact coefficient of digital economy development on per capita GDP is 0.286, and the coefficient passes the significance test at the 5% level. Therefore, it can be concluded that digital economy development has a significant positive impact on per capita GDP. The construction of digital infrastructure and the application of digital technology are conducive to attracting investment, thereby promoting economic development. In summary, the second step of the mediating effect test is verified.

Based on the regression results in Table 3.2 Model (4) after adding the mediating variable per capita GDP, the impact of digital economy development on industrial structure upgrading is shown. According to the regression results, the impact coefficient of digital economy development on industrial structure upgrading is 0.216, which does not pass the significance test, while the impact coefficient of per capita GDP on industrial structure upgrading is 0.089, passing the significance test at the 1% level. At this point, per capita GDP has a significant positive impact on industrial structure upgrading, and therefore, per capita GDP plays a mediating role in the impact of digital economy development on industrial structure upgrading. Moreover, since the impact coefficient of digital economy development is not significant, per capita GDP plays a full mediating role at this time.

3.2.2. Urbanization Effect Analysis

Model (2) in Table 3.3 is the regression without the mediating variable, which has been analyzed above and will not be repeated. The regression results in Model (5) of Table 3.3 show the impact of digital economy development on urbanization. According to the regression results, the impact coefficient of digital economy development on urbanization is 0.381, passing the significance test at the 1% level, indicating that digital economy development has a significant promoting effect on urbanization. Digital economy development can lead to the upgrading and improvement of regional infrastructure, attract the concentration of production factors such as human resources and capital, and promote urbanization to a higher level.

The regression results in Model (6) of Table 3.3 after adding the mediating variable urbanization show the impact of digital economy development on industrial structure upgrading. According to the regression results in Table 3.3, the impact coefficient of digital economy development on industrial structure upgrading is 0.169, which does not pass the significance test, while the impact coefficient of urbanization on industrial structure upgrading is 0.307, passing the significance test at the 1% level. Urbanization has a significant promoting effect on industrial structure upgrading. The impact coefficient of the control variable, the level of social consumption, on industrial structure upgrading passes the significance test at the 1% level, and the change is small before and after adding the mediating variable. Social consumption can promote industrial structure upgrading through demand upgrading. Compared to when the mediating variable is not added, the impact coefficient of the digital economy has significantly decreased, and the significance has changed. Moreover, the impact coefficient of urbanization is significant, so the digital economy can indirectly affect industrial structure upgrading by influencing urbanization. In the process of digital economy development affecting industrial structure upgrading, urbanization plays a full mediating role.

Table 3.2: The mediating effect of per capita GDP

	(1)	(2)	(3)
	W	lnrgdp	W
dig	0.286**	0.783**	0.216
	(0.138)	(0.386)	(0.135)
lngov	0.012	-0.052	0.016
	(0.019)	(0.054)	(0.019)
lnlabor	0.002	-0.020	0.004
	(0.012)	(0.034)	(0.012)
lnfund	0.028*	-0.095**	0.036**
	(0.015)	(0.043)	(0.015)
lnrgdp			0.089***
			(0.025)
_cons	6.512***	1.331***	6.393***
	(0.041)	(0.116)	(0.052)
Individual/Time	yes/yes	yes/yes	yes/yes
N	228.000	228.000	228.000
r2	0.686	0.589	0.705

Note: * p < 0.1, ** p < 0.05, *** p < 0.01, values in parentheses are standard errors (se).

Table 3.3: Mediating effect of urbanization

	(1)	(2)	(3)
	W	lncity	W
dig	0.286**	0.381***	0.169
	(0.138)	(0.133)	(0.135)
lngov	0.012	0.005	0.010
	(0.019)	(0.019)	(0.018)
lnlabor	0.002	-0.012	0.006
	(0.012)	(0.012)	(0.012)
lnfund	0.028*	-0.002	0.028*
	(0.015)	(0.015)	(0.015)
lncity			0.307***
			(0.071)
_cons	6.512***	-0.673***	6.719***
	(0.041)	(0.040)	(0.062)
Individual/Time	yes/yes	yes/yes	yes/yes
N	228.000	228.000	228.000
r2	0.686	0.718	0.713

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, values in parentheses are standard errors (se).

3.3. Robustness Test

This article selects the following three methods for robustness tests: The first method draws on Liu and Chen (2021), replacing the explanatory variable, using the internet penetration rate to replace the development of the digital economy for regression, and the regression results are shown in Table 3.4 (1); The second method refers to Zhang (2019) , lagging the control variables by one period for the model to regress again, and the regression results are shown in Table 3.4 (2); The third method draws on Lü (2023) , after truncating the explained variable, industrial structure upgrading, by 2.5% at both ends, the model is regressed again, and the regression results are shown in Table 3.4 (3).

From Table 3.4 (1), it can be seen that after replacing the digital economy development with the internet penetration rate for regression, the influence coefficient has decreased but remains significant, having a significant impact on industrial structure upgrading; The regression results in Table 3.4 (2) show that after lagging the control variables and explanatory variables by one period for regression again, the digital economy development still has a significant positive impact on industrial structure upgrading; According to Table 3.4 (3), after truncation, the digital economy still has a significant positive impact on industrial structure upgrading, and the coefficients are similar to the benchmark regression results, with the same level of significance, indicating that the robustness test after truncation has passed. In summary, the robustness tests conducted using lagged variables, truncation, and replacement indicate that the aforementioned regression results are robust.

Table 3.4: Robustness test

	(1)	(2)	(3)
	W	W	W
internet	0.004*		
	(0.002)		
lngov	0.011		0.007
	(0.019)		(0.019)
lnlabor	0.004		0.004
	(0.012)		(0.012)
lnfund	0.029*		0.026*
	(0.015)		(0.016)
dig		0.381**	0.283**
		(0.151)	(0.139)
L.lngov		-0.008	
		(0.022)	

L.lnlabor		0.013	
		(0.013)	
L.lnfund		-0.000	
		(0.016)	
_cons	6.513***	6.466***	6.509***
	(0.044)	(0.046)	(0.042)
Individual/time	yes/yes	yes/yes	yes/yes
N	228.000	209.000	228.000
r2	0.684	0.645	0.666

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, values in parentheses are standard errors (se).

3.4. Heterogeneity Test

3.4.1. Heterogeneity Test of Time

To explore the impact of time factors on the upgrading of industrial structure, the study period is divided into two time segments: 2011-2016 and 2017-2022. A heterogeneity test of time is then conducted, and the results are shown in Table 7. During 2011-2016, the development of the internet and digital technology was not yet mature, and the development of the digital economy was relatively low, which had a negative impact on the upgrading of industrial structure, with a lower level of significance; the impact coefficient of government intervention was 0.056, and it was significant at the 1% level. Government policies and financial support for industries help to introduce and accept the relocation of related industries, thereby promoting the upgrading of the local industrial structure. During 2017-2022, the impact coefficient of the digital economy was 0.386, and it was significant at the 10% level; during this period, digital technology, the internet, and information and communication technology all developed rapidly, and the level of the digital economy improved, thereby promoting the development of industrial digitization and digital industrialization, driving the upgrading of the regional industrial structure; the inertia of government policies towards high-energy-consuming industries has a certain negative impact on the upgrading of the regional industrial structure. Based on the above analysis, it can be concluded that the impact of the development of the digital economy on the upgrading of industrial structure varies greatly in different time periods.

3.4.2. Regional Heterogeneity Analysis

To explore the heterogeneous impact of different regions on the upgrading of industrial structure, the urban circle of the "几" character-shaped bend of the Yellow River is divided according to administrative divisions. Due to the fewer cities in Shaanxi and Ningxia, the cities of these two provinces are grouped together, and the cities of Inner Mongolia and Shanxi are each grouped separately, and regression analysis is conducted, with the results shown in Table 8.

Table 3.6 (1) shows the impact of the digital economy on the upgrading of industrial structure in Shaanxi and Ningxia cities. The impact coefficient is -0.184, but it did not pass the 10% significance level test. Table 3.6 (2) shows that the digital economy in some cities of Inner Mongolia has a positive impact on the industrial structure, with a lower level of significance, indicating that the development of the digital economy is good, but it has not had a significant impact on industries that contribute more to regional economic growth, and the digitization of industries needs to be further developed. Table 3.6 (3) shows that the impact coefficient of the digital economy on the upgrading of industrial structure in some cities of Shanxi Province is -0.288, and it passes the 10% significance level test. The digital economy has a significant negative impact on the upgrading of industrial structure. Due to insufficient conditions such as digital infrastructure and funds, the development of the digital economy will have a crowding-out effect on investment in other industries, and at the same time, the production costs will increase during the process of industrial digitization, which will have a negative impact on the upgrading of industrial structure.

Table 3.5: Time heterogeneity analysis

	(1)	(2)
	W	W
dig	-0.268*	0.386*
	(0.151)	(0.195)
lngov	0.056***	-0.030
	(0.020)	(0.031)
lnlabor	0.015	-0.017
	(0.010)	(0.028)
lnfund	0.012	0.100**
	(0.014)	(0.050)
_cons	6.678***	6.521***
	(0.043)	(0.093)
Individual/Time	yes/yes	yes/yes
N	114.000	114.000
r2	0.802	0.668

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, values in parentheses are standard errors (se) .

Table 3.6: Regional heterogeneity analysis

	(1)	(2)	(3)
	W	W	W
dig	-0.184	0.496*	-0.288*
	(0.194)	(0.261)	(0.159)
lngov	-0.009	0.026	0.127
	(0.021)	(0.045)	(0.080)
lnlabor	0.045*	-0.051*	0.015
	(0.024)	(0.027)	(0.010)
lnfund	0.057	0.127***	0.034***
	(0.037)	(0.045)	(0.012)
_cons	6.421***	6.609***	6.945***

	(0.049)	(0.081)	(0.147)
Individual/Time	yes/yes	yes/yes	yes/yes
N	72.000	84.000	72.000
r2	0.818	0.814	0.925

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, values in parentheses are standard errors (se).

3.5. Nonlinear Analysis

Table 3.7: Threshold quantity test

Dependent variable	Threshold variable	Threshold quantity	P Value	BS Number of times	Threshold value		
					1	2	3
W	c	Single threshold	0.003	300	0.2402		
		Dual thresholds	0.090	300	0.2402	0.3258	

Threshold regression models, compared to linear models, more accurately capture the nonlinear relationships between variables, such as scenarios where marginal effects vary with threshold variables. These models are particularly applicable to contexts involving regime switching or interval-specific effects. To explore the existence of the nonlinear impact of the development of the digital economy on the upgrading of industrial structure, the panel threshold model was adopted for testing, selecting the level of social consumption as the threshold variable. According to the model test, it is evident that the impact of the development of the digital economy on the upgrading of industrial structure has a double threshold effect, significant at the 10% level of significance; therefore, a double threshold model was set up for regression, and the regression results are shown in Table 3.8. The regression results indicate that there is a significant nonlinear relationship between the digital economy and the upgrading of industrial structure. Under the double threshold, the impact coefficients of the development of the digital economy on the upgrading of industrial structure before and after the threshold values are significant, but there is a clear difference in the level of significance. When the threshold variable c is less than 0.2402, the impact coefficient of the digital economy is 0.276, and it is significant at the 5% level of significance, indicating a more significant impact of the digital economy on the upgrading of industrial structure; when the threshold variable c is greater than or equal to 0.2402 and less than 0.3258, the impact coefficient of the digital economy rises to 0.577, and the significance level is improved, enhancing the positive impact on the upgrading of industrial structure; when the threshold variable c is greater than 0.3258, the impact coefficient of the development of the digital economy rises to 0.792, and it is significant at the 1% level of significance, indicating a more significant promotion of the upgrading of industrial structure. The reason why the impact of the digital economy on the industrial structure changes from weak to strong may lie in the fact that in the early stages of the development of the digital economy, digital infrastructure and digital application scenarios are not perfect, and the empowerment of industrial structure transformation by digital technology is relatively slow. With the improvement of consumption levels, new consumer demands lead to new product supply, and the development of digital technology also provides new scenarios for consumption, making consumption more convenient. The continuous development of digital industrialization and industrial digitization leads to an increasing trend of the impact of the digital economy on the upgrading of industrial structure.

Table 3.8: Regression results of threshold model

	(1)
	W
lngov	0.027
	(0.038)

lnlabor	-0.012
	(0.024)
lnfund	0.050
	(0.036)
dig（c<0.2402）	0.276**
	(0.104)
dig（0.2402<c≤0.3258）	0.577***
	(0.092)
dig（c>0.3258）	0.792***
	(0.080)
_cons	6.519***
	(0.069)
N	228.000
r2	0.505

Note: * p < 0.1, ** p < 0.05, *** p < 0.01, values in parentheses are standard errors (se).

4 . Conclusions and Recommendations

4.1. Conclusions

Based on the panel data of 19 prefecture-level cities in the Yellow River "Ji" bend metropolitan area from 2011 to 2022, this paper analyzes the impact mechanism of the development of the digital economy on the upgrading of industrial structure. The following conclusions are drawn:

(1) The development of the digital economy has a significant positive impact on the upgrading of the industrial structure in the Yellow River "Ji" bend metropolitan area, that is, the improvement of the level of digital

economy development can promote the upgrading of industrial structure.

(2) In exploring the mediating mechanism, both per capita GDP and urbanization play a complete mediating role in the impact of the development of the digital economy on the upgrading of industrial structure; the development of the digital economy can promote the upgrading of industrial structure by affecting per capita GDP and urbanization.

(3) In terms of the nonlinear relationship between the digital economy and the upgrading of industrial structure, the threshold variable social consumption level c has significant changes in the impact coefficient and significance of the digital economy before and after the threshold value, showing a trend of increasing marginal effect.

4.2. Recommendations

There are problems such as homogenization of industrial development, unreasonable structure, and low level of regional coordination in the Yellow River "Ji" bend industrial development. Based on the above conclusions, the following suggestions are proposed:

First, accelerate the construction of infrastructure to promote the digital industrialization. Under the background of the development of the digital economy, the existing infrastructure cannot meet the development requirements, and it is necessary to accelerate the construction of new infrastructure. The Yellow River "Ji" bend metropolitan area should first combine its own development status and future development, promote the construction of the Internet of Things, computing power infrastructure, and information and communication networks, provide good facilities for the development of the digital economy, enhance the level of industrialization of the digital economy, and promote the upgrading of the industrial structure of the metropolitan area.

Second, accelerate the integration of the real economy and the digital economy to promote industrial digitization. The digitization of agriculture, industry, and services can help promote the transformation and upgrading of the metropolitan area's industries, build a modern industrial system, and achieve high-quality regional economic development. In terms of agriculture, promote smart agriculture and livestock farming according to local conditions, install intelligent equipment, and achieve scientific production and intelligent feeding. In terms of industry, promote the integration of resource extraction industries and modern communication networks, improve the level of digitalization of extraction, and improve the efficiency and safety of extraction. In terms of services, rely on artificial intelligence, cloud computing, big data to enhance the ability to obtain and share information resources within the service industry, and enhance the level of modern service industries in the metropolitan area. The development of the digital economy can accelerate the flow of production factors, enhance the information acquisition ability of enterprises, promote the coordinated development of regional industries, and thus improve the rationalization level of industrial structure.

Third, promote digital governance. Give full play to the advantages of the digital economy in data processing and analysis, and promote the transformation of government management and service processes and concepts. Rely on digital technology to promote the construction of a digital government, accelerate the digitization of administrative approval, optimize the regional business environment, timely push relevant policies, enhance cross-city communication capabilities, and improve government governance levels and capabilities. The Yellow River "Ji" bend metropolitan area should implement digital governance strategies according to local conditions, promote the construction of a service-oriented government, build a digital government affairs system, provide policy support for the upgrading of the metropolitan area's industrial structure, and enhance the level of coordinated regional development.

Fourth, give full play to the role of urbanization in resource aggregation, promote the construction of new-type urbanization, and provide a resource base for industrial transfer and structural upgrading. The internal resource endowment differences within the Yellow River "Ji" bend metropolitan area are small, but there are significant differences in labor, technology, and capital factors. Each city can give full play to its comparative advantages, strengthen regional division of labor, develop characteristic and advantageous industries, integrate into the regional entire industrial chain, and avoid homogenized industrial development.

CONFLICT STATEMENT

The authors of the article "The Impact of Digital Economy Development on the Upgrading of Industrial Structure——Taking the Metropolitan Circle around the "JI" Shape Bend of the Yellow River as an Example", Yan Haohao, solemnly declare that throughout the entire process of creating this work and all subsequent activities related to it, including but not limited to collecting and analyzing research materials, forming opinions, writing, modifying, submitting, and publishing papers, I have no conflicts of interest that may interfere with the fairness, objectivity, and originality of the work.

COOPERATION STATEMENT

The first author (Yan Haohao) is responsible for writing the methodology, investigation, and initial draft.

References

Zhang, X. H. (2016). Digital economy and China's development. E-Government, (11), 2-11.

Zang, R. (2019). Research on the impact of the development of the digital economy industry on the optimization and upgrading of the industrial structure master's thesis, Beijing University of Posts and Telecommunications.

Chen, B., & Pei, X. (2021). Research on the mechanism of the impact of digital economy development on industrial structure upgrading—Based on the perspective of regional heterogeneity. Price: Theory & Practice, (04), 141-144.

Chen, Z. Y. (2018). Research on the digital economy and industrial structure changes. Inner Mongolia Education, (22), 46-47.

Xu, C., & Lin, M. T. (2023). Research on the impact of China's digital economy on industrial structure upgrading—Based on the mediation effect model of technological innovation. Henan Science, 41(4), 586-595.

Lyu, Z. Y. (2023). The impact of the digital economy on industrial structure upgrading—Taking carbon emissions as an intermediate variable. Journal of Commercial Economics, (14), 98-102.

Liu, Y., & Chen, X. D. (2021). The impact of China's digital economy development on industrial structure upgrading. Research on Economics and Management, 42(8), 15-29.

Wen, Z. L., & Ye, B. J. (2014). Analysis of mediation effects: Development of methods and models. Advances in Psychological Science, 22(5), 731-745.

Fu, L. H. (2010). An empirical study on the relationship between the upgrading of China's industrial structure and economic growth. Statistical Research, 27(8), 79-81.

Wang, Y., & Zhang, Z. B. (2021). Digital economy, factor allocation and the level of regional integration. Southeast Academic Research, (05), 129-138.

He, Y. Y. (2021). Research on the impact of China's digital economy on industrial structure upgrading master's thesis, Hebei University.

Ma, X. (2022). Research on the impact of digital economy development on the optimization and upgrading of Inner Mongolia's industrial structure master's thesis, Inner Mongolia University of Finance and Economics.

Zhang, W. (2023). The impact of digital economy on industrial structure upgrading in Henan Province Master's thesis, Henan University.

Cheng, H. F. (2021). Research on the spatial effect of China's fiscal expenditure on industrial structure upgrading master’s thesis, Xinjiang University of Finance and Economics.

Liu, Q. (2022). Analysis of the impact of the digital economy development in Hebei Province on industrial structure upgrading—Based on the mediation effect of scientific and technological innovation. Hebei Enterprises, (11), 59-61.

Zhang, W. (2019). Research on the impact of the conversion of cropland to forest on farmers' labor supply and income master’s thesis, Northwest A&F University.