The Impact of Digital Economy on Industrial Structure Upgrading in Hubei Province

Shuying Huang*

School of Statistics and Mathematics, Zhongnan University of Economics and Law, Applied Statistics Major, Wuhan, China

*2641508477@qq.com

Abstract. As a core province in Central China and a key node of the Yangtze River Economic Belt, Hubei Province faces structural challenges such as lagging transformation of traditional industries and insufficient cultivation of emerging industries. The digital economy has become a core pillar for its industrial structure upgrading. Based on panel data of Hubei Province from 2011 to 2023, this study measures the level of digital economy using the entropy weight method, and explores the impact mechanism between digital economy and industrial structure upgrading through the two-way fixed effects model, multiple mediation effect model, and robustness tests. The results show that: Hubei's digital economy presents a trend of steady cultivation—accelerated leapfrog growth, while industrial structure upgrading shows characteristics of fluctuating adjustment—sustained rise, with a significant positive correlation between the two; mediation effect analysis indicates that the digital economy can indirectly promote industrial upgrading through three paths: market demand expansion, urbanization agglomeration, and technological innovation improvement; among control variables, government intervention, degree of opening-up, and high-end technical talents all have significant positive effects, while population density has no significant impact. This study clarifies the internal mechanism of the digital economy driving industrial structure upgrading in Hubei, providing a scientific basis for Hubei Province to formulate differentiated policies and strengthen its function as a regional strategic pivot.

Keywords: Hubei Province, digital economy, industrial structure upgrading, fixed effects model

1 Introduction

Since the reform and opening-up, China's economy has achieved leapfrog growth, with the industrial structure continuously optimized. As a new economic form, the digital economy has become an important engine for high-quality development. Digital technology, with data as the key factor, injects strong momentum into the overall transformation and upgrading of the industrial structure by spawning new models, new formats, and improving total factor productivity.

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Hubei Province, as a core province in Central China and a key node of the Yangtze River Economic Belt, connects the east and west, links the north and south. It is a national leading modern manufacturing base and a comprehensive transportation hub connecting the whole country. However, under the new normal of economic development, Hubei Province also faces industrial structural challenges: the modernization transformation of traditional agriculture in the Jianghan Plain is arduous, and traditional advantageous industrial fields such as automobiles and chemical industry are under pressure of capacity optimization and innovative upgrading. With its strong permeability and integration, the digital economy can provide key support for the digital transformation of traditional industries and the cultivation of emerging industrial clusters in Hubei Province, and is a strategic starting point to promote the province's industrial structure upgrading.

Therefore, in-depth research on the specific impact of the development of the digital economy on the transformation and upgrading of the industrial structure in Hubei Province not only helps to clarify its internal mechanism, but also helps Hubei Province seize the high ground of the digital economy in the new development pattern and strengthen the strategic pivot function of the Yangtze River Economic Belt and the rise of Central China.

2 Literature Review

This paper combs the literature from three aspects: digital economy, industrial structure upgrading, and the impact of digital economy on industrial structure upgrading.

2.1 Digital Economy-Related Research

At present, there are two main categories of digital economy measurement: constructing a measurement index system and constructing a digital economy value-added accounting system. Zhang Xueling et al. (2019) constructed a new comprehensive evaluation model, which objectively evaluates the development level of the digital economy in various provinces and regions in China based on three indicators: the completeness of digital infrastructure, the penetration degree of digital application, and the development degree of digital industrial upgrading[1]. Li Haiyang et al. (2025) will propose a more specific evaluation model in 2025, dividing the first-level indicators of digital economy evaluation into industrial innovation level, infrastructure level, and development environment quality[2]. From the perspective of added value, to objectively evaluate the comprehensive benefits and impacts of the digital economy on China's economic development, Huang He et al. (2024) compiled detailed input-output data of economic digital transformation for multiple economic regions including the whole country. By using macro data from the national input-output tables in 2018 and 2020, the scope and characteristics of the digital economy industry are defined, and an input-output model suitable for the segmentation of digital industries is constructed[3].

2.2 Industrial Structure Upgrading-Related Research

In terms of influencing factors, Alfaro (2010) believed that the financial market can realize the efficient allocation of resources, supply funds for the development of emerging industries, and thus promote the upgrading of the industrial structure[4]. Cai Haiya and Xu Yingzhi (2017) conducted a mediation effect test using inter-provincial panel data, and the results showed that trade opening can promote changes in internal industries of industry and service industry through increasing capital accumulation, stimulating consumer demand and other channels, thereby promoting industrial structure upgrading[5].

2.3 Industrial Structure Upgrading-Related Research

Scholars have studied the role of digital economy in promoting industrial structure upgrading from different perspectives and reached roughly the same conclusion: the development of digital economy is conducive to industrial structure upgrading. Shen Yunhong et al. (2020) used panel data of 11 prefecture-level cities in Zhejiang Province from 2008 to 2017, adopted the fixed effects model, and verified that the digital economy is conducive to the upgrading of China's manufacturing industrial structure from three aspects: digital infrastructure, digital industry, and digital technology innovation[6]. Peng Bingzhong and Yi Junyu (2021) believed that the direct drive of digital economy and the optimization of factor supply are conducive to industrial upgrading[7].

Li Xiaozhong and Wu Jiaxu (2020) proposed that the digital economy and its industrial sectors have a significant role in promoting the evolution and transformation of China's industrial structure, with regional heterogeneity[8]. The long-term two-way positive impact relationship between digital economy and industrial structure evolution varies in degree. From a macro perspective of spatial effects, Ma Xiaojun, Wu Jiaxu et al. (2022) established a spatial Durbin model through a weighted matrix of geographical and economic distances, and analyzed the impact of the development of the digital economy in 30 provinces in China on the transformation of China's industrial structure from 2011 to 2020. The research shows that the digital economy and industrial transformation and upgrading have a high spatial correlation, and show relatively fixed urban agglomeration in space[9].

This paper takes Hubei Province as the research object and uses the entropy weight method to measure the development level of the digital economy. Secondly, the panel model with two-way fixed effects is used to explore the path of the digital economy affecting industrial structure upgrading, and the mediation effect model is used to analyze the impact relationship between the two.

3 Methodology

3.1 Digital Economy Evaluation Index System

With reference to the research results of relevant scholars and combined with the connotation of the digital economy, this paper constructs a comprehensive evaluation index

system (as shown in Table 1) to measure the digital economy development index of Hubei Province from 2011 to 2023.

Table 1. Digital Economy Indicator System

First-level Indicators	Second-level Indicators	DefinitionUnit
Digital Infrastructure	Number of mobile phone users per 100 people	Person
	Internet broadband access ports	1,000 ports
Digital Industrialization	Number of Internet users per 100 people	Unit/100 people
	Proportion of employees in computer services and software	%
	Per capita telecommunications business volume	10,000 yuan/person
	Software industry revenue	10,000 yuan
	Number of patent authorizations in digital industry	Item
Industrial Digitalization	E-commerce transaction volume	number for the grant
	Digital inclusive finance index	heading for references

3.2 Evaluation Method

To objectively reflect the importance of each indicator in the system, the entropy weight method is adopted, which avoids the subjective factors of the subjective assignment method. The specific evaluation steps are as follows:

(1) Data Standardization

To unify the dimension differences of each indicator, the original data are first standardized.

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{1}$$

Where y_{ij} is the standardized value of the j-th evaluation indicator of the i-th evaluation object.

(2) Calculate the Weight of Each Indicator

$$p_{ij} = \frac{x_{ij}}{\sum x_{ij}} \tag{2}$$

(3) Calculate Information Entropy

The greater the difference in indicator data, the greater the entropy value, indicating that the indicator has higher information content. The formula for calculating information entropy is:

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{3}$$

(4) Calculate the Difference Coefficient of Each Indicator

$$G_j = 1 - E_j \tag{4}$$

(5) Calculate the Weight of Each Indicator

$$W_j = \frac{G_j}{\sum_{j=1}^{m} G_j} \tag{5}$$

This paper constructs a comprehensive evaluation index of the digital economy development level in Hubei Province through the comprehensive weighted calculation of the specific values and corresponding weights of each indicator in the above indicator system. The specific calculation formula is as follows:

$$Y_{ij} = y_{ij} * W_j \tag{6}$$

Where Y is the comprehensive index of digital economy development level, Wj is the weight value of each indicator processed by the entropy weight method, and yij is each indicator measuring the digital economy development level.

3.3 Model Construction

3.3.1 Benchmark Regression Model.

According to the previous analysis conclusions, the digital economy plays a core role in the process of industrial structure upgrading. Based on this, the following basic econometric model is constructed:

$$Optimization_{it} = \alpha_0 + \alpha_1 digi_{it} + \sum \lambda_i Control_{it} + \varepsilon_{it} \tag{7}$$

To enhance the robustness of the analysis results, this study implements a systematic model selection optimization process. In the evaluation process, the applicability of the pooled regression model, fixed effects model, and random effects model is focused on. The F-test is used for preliminary screening of the first two models. Based on the comprehensive judgment of the two statistical tests, the fixed effects model shows the optimal estimation performance in this study.

3.3.2 Mediation Effect Model.

This paper focuses on the total effect of the independent variable X on the dependent variable Y and the effect of the independent variable X on the mediation variable M. On the premise that the regression results are all significant, the Sobel test and Bootstrap test are performed respectively. If all test results are significant, it indicates that there is a mediation path of variable M in the impact of the independent variable X on the dependent variable Y. This paper constructs the following equations:

$$Y=\beta_0+\beta_1 X+\varepsilon_1 \tag{8}$$

$$M=\gamma_0+\gamma_1 X+\varepsilon_2 \tag{9}$$

Where X is the independent variable, Y is the dependent variable, and M is the mediation variable. Equation (3-8) indicates that X has a causal impact on Y, and the coefficient β is the total effect of the independent variable X on the dependent variable Y; Equation (9) indicates that X has a causal impact on M, and the coefficient γ is the effect of the independent variable X on the mediation variable M.

Therefore, this paper sets models (10) and (11) as recursive equations to test and identify the mediation effect of relevant variables and their occurrence mechanism.

$$Optimization_{it}=\beta_0+\beta_1 digi_{it}+\sum\lambda_i Control_{it}+\varepsilon_{it} \tag{10}$$

$$Mediator_{it}=\gamma_0+\gamma_1 digi_{it}+\sum\lambda_i Control_{it}+\nu_{it} \tag{11}$$

4 Variable Selection and Data Description

4.1 Variables Definition

Dependent Variable: The dependent variable of this paper is the industrial structure upgrading level.

Independent Variable: Digital economy development level.

Mediation Variables: On the demand side, the two mediation variables are market demand effect and urbanization effect. The market demand effect can be expressed as the total retail sales of social consumer goods / GDP. On the supply side, the technological innovation effect is one of the important intermediate variables, which can be measured by the logarithm of the number of patent applications authorized. The digital economy can provide data-driven and intelligent tools for enterprise technological R&D, such as real-time sharing and analyzing R&D data through the industrial Internet, and can also reduce the information search cost of innovation subjects and promote the collaborative innovation of industry, university, and research.

Control Variables: Government intervention degree: Expressed as the ratio of local general public budget revenue to regional GDP. Degree of opening-up: Expressed as the total import and export volume of the region where the business unit is located. High-end technical talent resources: Expressed as the full-time equivalent of R&D personnel in industrial enterprises above designated size. Population density: Expressed as the number of resident population at the end of the year divided by the administrative area.

4.2 Data Source

This paper selects the panel data of Hubei Province in China from 2011 to 2023 as the sample data, which are mainly derived from the original data of the Hubei Statistical Yearbook.

5 Empirical Results

5.1 Development Trend of Digital Economy in Hubei Province

Figure 1 shows the development trend of the digital economy in Hubei Province from 2011 to 2023: from 2011 to 2017, the index slowly increased from about 0.04 to 0.12, which was a stage of steady cultivation and development; the growth rhythm accelerated significantly after 2018, and the index climbed rapidly. Even if there was a slight decline in 2021, the overall upward trend was not reversed, and it had risen to more than 0.22 in 2023, which intuitively reflects that the development momentum of the digital economy in Hubei Province continued to strengthen in the later period.

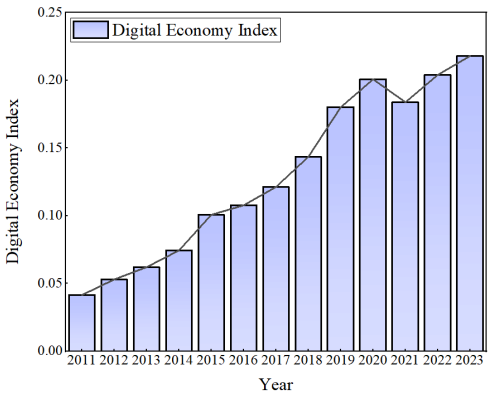

Fig. 1. Development Trend of Digital Economy in Hubei Province (2011-2023)

5.2 Development Trend of Industrial Structure Upgrading Level in Hubei Province

Figure 2 depicts Hubei Province's industrial structure upgrading level from 2011 to 2023: it stayed around 0.8 with slight fluctuations during 2011–2013 , then rose steadily from 2014 onward—growing rapidly after 2020 and peaking in 2021, driven by the integrated empowerment of the digital economy in traditional and emerging sectors—and finally saw a mild decline but remained at a high level in 2022–2023, a short-term adjustment in industrial transformation that did not reverse the overall upward trend.

5.3 Multicollinearity Test

To make the regression results more stable, the VIF multicollinearity test is performed on the involved variables. The results are shown in Table 2. It can be seen from Table 2 that the variance inflation factors of the core explanatory variable and all control variables are less than 10, indicating that there is no serious multicollinearity problem between variables.

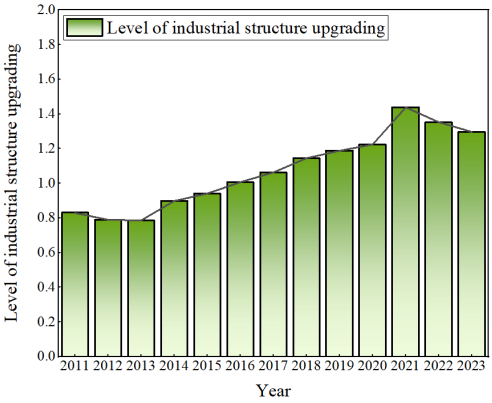

Fig. 2. Development Trend of industrial structure upgrading level in Hubei Province (2011-2023)

Table 2. VIF Test Results

Variable	VIF	1/VIF
lnT	3.54	0.282365
lnOpen	3.37	0.297050
P	3.05	0.328278
G	2.31	0.432084
digi	1.15	0.869360
Mean VIF	2.45	

5.4 Benchmark Regression

Table 3 presents the regression results of several models. When the dependent variable is industrial structure advancement, it can be found that regardless of the method used, the coefficient of the digital economy level is positive and statistically significant at the 1% level.

After adding the two-way fixed effects model, the digital economy (digi) has a significant positive impact on industrial structure upgrading at the 10% level. The improvement of the digital economy level positively promotes industrial structure upgrading. This is because the digital economy can break the information barriers between industries through digital technical means and promote the inter-industry transfer of production factors. The government intervention degree (G) has a significant positive impact on industrial structure upgrading at the 10% level. Because the government can formulate corresponding industrial policies, optimize factor allocation, and make up for the lack of market regulation. When the market's spontaneous regulation fails, the government can attract resources into key industries through financial subsidies, tax rebates and other ways to promote industrial structure upgrading. The degree of opening-up (lnOpen) has a positive impact on industrial structure upgrading at the 1% level. This

is because opening-up can bring advanced technology, management concepts and market concepts, and promote industrial structure upgrading. High-end technical talent resources (lnT) have a positive impact on industrial structure upgrading at the 1% significance level. High-end technical talents are the main force of industrial technological innovation and industrial upgrading. They provide technical innovation support for the industrial structure, can carry out technical transformation of traditional industries, and improve the level of productivity development. Population density (P) has no significant impact on industrial structure upgrading. The possible reason is that the adjustment of population density has not yet formed a certain scale effect or agglomeration effect to affect the industrial structure. Overall, in the two-way fixed effects model controlling for time effect and individual effect, the digital economy has a significant positive impact on the industrial structure at the 10% level, and some control variables also have a significant impact on the industrial structure under this model, which provides empirical support for understanding the relationship between the digital economy and the industrial structure.

Table 3. Benchmark Regression Results of Industrial Structure Upgrading

Variable	(1) OLS	(2) RE	(3) RE	(4) FE	(5) FE
digi	0.0901***	0.193***	0.0957***	0.0385**	0.0494*
	(0.0301)	(0.0236)	(0.0316)	(0.0187)	(0.0271)
G	1.5277***		3.000*	9.264***	6.477*
	(0.7623)		(1.568)	(3.242)	(3.835)
lnOpen	-0.0434***		-0.0179	0.0243	0.0903***
	(0.0100)		(0.0203)	(0.0319)	(0.0330)
lnT	0.0684***		0.0259	-0.316**	0.3187***
	(0.0147)		(0.0315)	(0.129)	(0.103)
P	0.0133*		0.0197	-0.0176	-0.0152
	(0.0071)		(0.0142)	(0.0266)	(0.0271)
_cons	-0.2566***	0.0709***	-0.363**	0.892	-0.380***
	(0.0894)	(0.0239)	(0.177)	(0.544)	(0.210)
Time Effect	No	No	No	No	Yes
Individual Effect	No	No	No	No	Yes
Observations	169	169	4.71	0.99	2.70
R-squared	0.174			0.185	0.355

5.5 Robustness Analysis

To improve the credibility of the analysis conclusions and confirm that the benchmark regression results are not random, robustness tests need to be carried out. Common test methods include replacing the dependent variable, replacing the core explanatory variable, shortening or extending the time window, changing the sample size, etc. Since the measurement index and calculation method of industrial structure upgrading selected

in this paper are highly recognized in the academic circle, the dependent variable index is not replaced. This paper tests the regression results through the following two methods:

Shortening the time window: Among the originally selected data from 2011 to 2023, there are individual missing values in 2012 which are filled by interpolation. Therefore, the sample data of 2012 are excluded, and only the data from 2013 to 2023 are used for empirical analysis.

Winsorization: Perform (2.5, 97.5) winsorization on the data.

By comparing the regression results obtained by these two methods with the original regression results,As shown in Table 4, it can be found that the original regression results have high robustness.

Table 4. Robustness Test of Industrial Structure Upgrading

Variable	Original Regression	Shortened Time Window	Winsorization
digi	0.0494* (0.0271)	0.0568* (0.0312)	0.0512* (0.0295)
Control Variables	Yes	Yes	Yes
Time Effect	Yes	Yes	Yes
Individual Effect	Yes	Yes	Yes

5.6 Mediation Effect Test

Table 5 reports the regression results of the digital economy on the market demand effect and industrial structure upgrading. It can be seen that the impact of the digital economy on market demand is significant at the 10% significance level, the impact of the digital economy on industrial structure upgrading is significant at the 5% significance level, and the impact of the digital economy on industrial structure advancement is significant at the 10% significance level, that is, the regression results are all significant.

Table 5. Market Demand Mediation Effect Analysis

Variable	Market Demand Effect	Industrial Structure Upgrading
digi	0.107* (0.058)	0.049** (0.034)

Table 6 reports the regression results of the digital economy on urbanization and industrial structure upgrading. It can be seen from Table 6 that the impact of the digital economy on urbanization is significant at the 1% significance level, and the impact of the digital economy on industrial structure upgrading is significant at the 5% significance level, that is, the regression results are all significant.

Table 6. Urbanization Effect Analysis

Variable	Urbanization Effect	Industrial Structure Upgrading
digi	0.174***	0.150**
	(0.035)	(0.051)

6 Conclusions

First, the digital economy index of Hubei Province showed a trend of "steady growth followed by accelerated growth" from 2011 to 2023: it slowly increased from 0.04 to 0.12 from 2011 to 2017, which was a cultivation period for the initial layout of digital infrastructure; the growth rate accelerated after 2018, reaching more than 0.22 in 2023. This reflects that under the deepening of digital technology application and policy support in the later period, the digital economy has shifted to a growth stage of integrated empowerment. During the same period, the level of industrial structure upgrading fluctuated first and then climbed: it fluctuated around 0.8 from 2011 to 2013, which was an adjustment period dominated by traditional industries; it continued to rise to more than 1.4 in 2021 after 2014, which was in the same direction as the development of the digital economy, confirming the supporting role of the digital economy in industrial transformation. The later decline was a short-term adjustment in the transformation process.

Second, technological progress, human capital, and market demand play multiple mediation roles in the process of the digital economy affecting industrial structure upgrading. The mediation effect test shows that the digital economy can not only directly promote industrial structure upgrading, but also indirectly promote industrial upgrading through three paths: improving technological innovation level, accelerating urbanization agglomeration, and expanding market demand scale.

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