Evaluation Research on Digital Economy Development and Industrial Structure Upgrading
Taking Five Northwest Provinces of China as Examples

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Abstract
Studying the impact of digital economy on industrial structure upgrading is of great significance to industrial transformation and upgrading. This paper constructs an econometric model of digital economy development level and industrial structure upgrading, and makes an empirical analysis of the relationship between them based on the panel data of five provinces in Northwest China from 2013 to 2020. The results show that the development level of digital economy has a positive impact on the upgrading of China's industrial structure, and the degree of impact is affected by other factors such as the level of scientific research investment and financial development.

Keywords- *digital economy; industristructure; comprehensive evaluation*

1. INTRODUCTION

In the fight against the new crown pneumonia epidemic, the digital economy has played an irreplaceable role and has become a new engine for China's economic and social development. The digital economy is becoming a key force driving a new round of industrial transformation and is highly valued by the government. Digital China has become China's national strategy. According to the "White Paper on the Development of China's Digital Economy" released by the China Academy of Information and Communications Technology, the scale of China's digital economy will reach 39.2 trillion yuan in 2020, an increase of 3.3 trillion yuan over last year, accounting for 38.6% of GDP. At present, China is in a critical period of transformation and upgrading of its economic structure, especially the underdeveloped economy in Northwest China. Studying the impact of the digital economy on the upgrading of the industrial structure is of great significance for seizing the development opportunities of the digital economy and realizing industrial transformation and upgrading.

At present, scholars have less research on the relationship between digital economy industry development and industrial structure upgrading, and more focus on the impact of information technology on industrial structure. H. Jaakkola (1991) believed that information technology is the key technology to change the industrial structure, and described the process of information technology diffusion through the S-shaped curve [1]; O'Mahony and Vecchi (2005) used the dynamic panel data analysis of the United States and the United Kingdom to find information Communication technology has a significant positive impact on industry output growth [2]; Sungioo Lee et al. (2009) believe that informatization is a catalyst for softening and upgrading industrial structure [3]; Georgvon Krogh (2012) believes that the use of information technology can share knowledge (2016) believe that the introduction, absorption, integration and diffusion of information technology can promote the transformation and upgrading of industrial structure [4]; Bukht et al. (2018) Based on the existing definition of the digital economy, three related scopes of the digital economy are proposed and their scales are estimated [5]; Jinfang Tian and Yiran Liu (2021) measured the total factor productivity of China's digital economy listed companies from 2013 to 2018. The influencing factors of total factor productivity are discussed [6]; Wei Zhang et al. (2021) current dynamic trend of China's digital economy development and the impact of digital economy on high-quality economic development, verifying that technological progress is between digital economy and high-quality economic development mediating effect [7].

From the review of relevant literature, it can be seen that scholars mostly study the scope and measurement of

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the digital economy industry at the theoretical level, with more qualitative analysis based on theory and policy level, and less empirical analysis. The research on digital economy and industrial structure optimization is more about the impact on industrial structure optimization from the perspective of technological change and technological innovation. On the basis of summarizing the previous research results, this paper constructs a comprehensive index system of digital economy development to measure the development level of digital economy, empirically analyzes the impact of digital economy on industrial structure upgrading, and explores the path of digital economic development and industrial structure upgrading. Formulate industrial restructuring policies and provide policy recommendations.

2. THE IMPACT MECHANISM OF THE DIGITAL ECONOMY ON THE INDUSTRIAL STRUCTURE

The internal logic of world industrial structure upgrading shows that technological progress is the internal driving force of industrial structure upgrading. Every technological advance brings about a paradigm shift in the economy. Under the new economic paradigm, emerging technology industries often surpass traditional industries and gradually become the leading industries in the industrial system, and drive the transformation and upgrading of traditional industries through the effects of industrial association and technology diffusion, so as to upgrade the industrial structure to a higher level. The digital economy stimulates the development of emerging industries, transforms traditional industries, and constantly reshapes the basic form of the industrial structure through digital industrialization and industrial digitization, thereby promoting the upgrading of the industrial structure.

Digital industrialization breeds new industries, and the proportion of digital industries increases significantly. On the one hand, digital technology has developed into a new industry through industrialization. After nearly 30 years of development, the electronic information manufacturing industry, software industry, information service industry and other industries have become relatively mature. The Internet of Things industry, big data industry, cloud computing industry, and artificial intelligence industry are rising strongly and leading the development trend of the digital economy. On the other hand, digital technology gives birth to new business models, and new business models form new industries. Among them, e-commerce and sharing economy have become typical representatives of new business models.

The transformation of industrial digitalization has accelerated the digitalization level of traditional industries. The digital economy is highly permeable. Through the Internet, e-commerce, cloud computing and other means, digital technology, digital services, and digital information penetrate into all aspects of production, operation, and sales in traditional industries, improving industrial efficiency.

Improve the level of industrial digitalization, promote the transformation of traditional industries, and realize the upgrading of industrial structure. The promotion of the upgrading of the industrial structure by the digital economy through the transformation of traditional industries is mainly reflected in the following three aspects:

The development of the digital economy industry has changed the production methods of traditional industries and transformed traditional industries into intelligent and personalized transformation. Digital technology and intelligent equipment are widely used in production, which can improve the labor productivity and resource utilization of traditional industries, and realize the intelligent and digital development of traditional industries.

Digital technology promotes internal process reengineering of traditional industries and improves industrial efficiency. Under the e-commerce transaction mode, products can be delivered to users without time and location constraints, which expands the scope of transactions, reduces transaction costs, speeds up resource scheduling, triggers enterprise process reengineering, and promotes the development of traditional industries.

The digital economy changes the way of industrial organization and stimulates industrial innovation. With the continuous innovation and development of digital technology, the platform economy has developed rapidly, and the industrial organization mode has changed from a chain type to a network collaboration type, bringing more business opportunities to small and medium-sized enterprises.

3. MEASUREMENT OF THE EVALUATION INDEX SYSTEM FOR THR DEVELOPMENT LEVEL OF THE DIGITAL ECONOMY

3.1. Construction of the evaluation index system for the development level of the di gital economy

There are no official statistics on the development of the digital economy in the existing public information. In order to scientifically and reasonably measure the development level of the digital economy industry in the five northwest provinces of China, this paper adopts the comprehensive evaluation method to establish a comprehensive evaluation index system, and uses the principal component analysis method to calculate the digital economy development level of the five northwest provinces of China.

When determining the indicator evaluation system, in addition to referring to the measurement indicators of the development level at the industrial level, the characteristics of the digital economy industry are also considered. This paper establishes an index evaluation system for the development level of the digital economy based on the ideas of various scholars on the construction of evaluation indicators for the development level of the information technology industry. Taking the development level of the digital economy as the evaluation goal, from the three dimensions of digital infrastructure, digital industrialization and industrial digitization, combined with the comprehensiveness of index selection, data availability and other factors, the corresponding subdivision indicators are selected to build a digital economy. Development level index evaluation system. The details are shown in the table below.

TABLE 1. INDICATOR EVALUATION SYSTEM OF DIGITAL ECONOMY DEVELOPMENT LEVEL

Evaluation target	First-level indicator	Secondary indicators and units
Digital economy development level	digital infrastructure	Total telecom business
		Internet broadband access ports
		Optical cable line length
	digital industrialization	Number of enterprises in information transmission, software and information technology industries
		Information technology service income
		Number of employees in information transmission, software and information technology industries
	Industrial digitalization	Number of companies with e-commerce transactions
		E-commerce sales
		Number of computers used per 100 people
		The number of websites owned by the enterprise

3.2. Data sources and data processing

The data for the 10 indicators in this paper come from the National Bureau of Statistics of China. Taking into account the timing of China's relevant policies and the availability of relevant data, this paper evaluates the development level of the digital economy in the five northwestern provinces of China (Shaanxi, Ningxia, Gansu, Qinghai, and Xinjiang).

In order to eliminate the possible adverse effects caused by different dimensions of the indicator values, this paper standardizes the 10 indicators to increase the rationality of the evaluation of the development level of the digital economy industry. The normalization processing formula is as follows.

$$Z = \frac{X - \min(X)}{\max(X) - \min(X)} \tag{1}$$

Among them, X represents the original observation value of the indicator, and Z represents the standardized indicator value.

3.3. Evaluation of the development level of the digital economy

Using Eviews7.0 to conduct principal component analysis on the standardized data, the digital economy development level of the five northwestern provinces of China is obtained as shown in the following table.

TABLE 2. 2013-2020 DIGITAL ECONOMY DEVELOPMENT LEVEL OF FIVE NORTHWEST PROVINCES IN CHINA

Year	Shaanxi	Ningxia	Gansu	Qinghai	Xinjiang
2013	-4.2222	-3.3100	-3.7308	-3.9204	-3.5550
2014	-2.9028	-3.1182	-2.9996	-2.4682	-2.7826
2015	-2.1922	-2.1180	-1.8621	-0.8370	-1.5452
2016	-1.0381	-0.6009	-0.7439	-0.2955	-0.9755
2017	0.0947	0.3593	0.1818	0.3965	0.0026
2018	1.6930	2.0445	1.9173	0.7652	1.3381
2019	3.3269	2.7250	3.1310	2.2786	3.1129
2020	5.2408	4.0183	4.1062	4.0808	4.4048

On the whole, the development level of the digital economy in the five northwestern provinces of China has steadily improved, but the development of different regions is quite different, and the development level of the digital economy in Shaanxi is ahead of the other four provinces.

4. MEASUREMENT OF INDUSTRIAL STRUCTURE UPGRADING

Different scholars use different methods to measure the level of industrial structure upgrading. Some scholars use the advanced and rationalized industrial structure to measure the upgrading of industrial structure, and the specific calculation methods are different. Some scholars use the ratio of different industries to total industrial output value to represent the upgrading of industrial structure, while others use the ratio of service industry to GDP to measure the upgrading of industrial structure. Drawing on the measurement methods of most scholars, this paper adopts the advanced industrial structure and industrial structure rationalization to measure the level of industrial structure upgrading.

Advanced industrial structure refers to the transformation of industrial structure from a low-level form to a high-level one. The structural level coefficient

(TN) is used to measure the advanced degree of industrial structure, and the calculation formula is as follows.

$$TN = \sum_{i=1}^{n} \beta_i q(i) \tag{2}$$

Among them, β_i is the proportion of the ith industry, $q(i)$ is the proportion of the added value of the ith industry in GDP, and n is the number of industries. The larger the structure level coefficient (TN), the higher the level of industrial sophistication.

The rationalization of industrial structure refers to the rational use of resources under the existing resource conditions, the effective allocation of production factors, and the coordinated development of various industrial sectors. The Theil Index (TL) is used to measure the rationalization level of the industrial structure. The specific calculation companies are as follows:

$$TL = \sum_{i=1}^{n} \frac{Y_i}{Y} \ln\left(\frac{Y_i / L_i}{Y / L}\right) \tag{3}$$

Among them, Y_i , L_i represents the output value and employment of the i-th industry, respectively, n represents the number of industries, and Y / L represents the productivity. The more TL tends to 0, the more reasonable the industrial structure is.

Obtain the data related to the primary, secondary and tertiary industries, employment, and GDP of the five provinces in Northwest China (Shaanxi, Ningxia, Gansu, Qinghai, and Xinjiang) from the National Bureau of Statistics of China, and calculate the structural levels of the five provinces in Northwest China according to the above formula.

5. EMPIRICAL ANALYSIS OF THE IMPACT OF DIGITAL ECONOMY DEVELOPMENT ON INDUSTRIAL STRUCTURE UPGRADING

5.1. Overview of the panel data model

This paper analyzes the impact of digital economy development on the upgrading of industrial structure by building a panel data model. Panel data model can solve the problem of insufficient sample size, provide more information and less collinearity, which is beneficial to reflect the variability of economic structure and help to correctly analyze the relationship between variables. The basic form of the panel data model is:

$$Y_{it} = \alpha + \beta X_{it} + \mu_{it}$$

$$i = 1, 2, \ldots, N \; t = 1, 2, \ldots, T \tag{4}$$

Among them, i represents the individual, t represents the time, Y_{it} is the explained variable, X_{it} is the explanatory variable, α 、 β is the regression coefficient, N represents the number of individuals, T represents the length of time, and μ_{it} is the random disturbance term.

When using panel data for analysis, the effect model needs to be determined. Panel effect models include mixed models, fixed-effects models, and random-effects models. Mixed models mean that all provinces can be represented by the same equation, with the same intercept and slope terms; fixed-effects and random-effects models assume that all provinces have the same slope but different intercepts. Corresponding tests are required to determine the model used for panel data. The F test can be used to determine whether to establish a mixed model or a fixed effect regression model. The formula for calculating the F value is as follows:

$$F = \frac{(SSE_r - SSE_u) / (N - 1)}{SSE_u / (NT - N - k)} \tag{5}$$

Among them, , SSE_r 、 SSE_u are the residual sum of squares of the mixed estimation model and NT is the fixed effect model, respectively, is the sample data size, N is the cross-sectional data size, and k is the number of explanatory variables.

The Hausman test can further determine whether to choose a fixed-effects model or a random-effects model.

5.2. Indicator selection and data description

This paper uses the above-mentioned industrial structure advanced (TN) and industrial structure rationalization (TL) as the explained variables, the digital economy development level (DE) is used as the explanatory variable, and the financialization level (FD) and the scientific research investment level (RD) are introduced as the explanatory variables. Control variables: The level of financialization is measured by the proportion of the added value of the financial industry in GDP, and the level of scientific research investment is measured by the proportion of the expenditures for new product development of industrial enterprises above designated size and the sales revenue of new products of industrial enterprises above designated size.

5.3. Panel Data Model Construction

In this paper, the structural level coefficient (TN) and Theil index (TL) are used as the explained variables, and

the digital economy development level (DE) is used as the explanatory variable to construct the following panel models:

$$TN_{it} = c + \beta_1 DE_{it} + \beta_2 FD_{it} + \beta_3 RD_{it} + \varepsilon_{it} \quad (6)$$

$$TL_{it} = c + \beta_1 DE_{it} + \beta_2 FD + \beta_3 RD + \varepsilon_{it} \quad (7)$$

Among them, TN_{it}、TL_{it} are the structural level coefficient and Theil index of the i-th province in year t, respectively, DE_{it}、FD_{it}、RD_{it} are the digital economy development level, financialization level, and scientific research investment level of the i-th province in year t, respectively, is constant terms, β_1、β_2、β_3 is the regression coefficient of each explanatory variable, and ε_{it} is the disturbance term.

5.4. Empirical analysis of the impact of digital economy development on the advanced industrial structure

5.4.1. Determine the model category

First, use Eviews7 as a mixed effect model to calculate $SSE_r = 0.0052$, and use Eviews7 as an individual fixed effect model to calculate $SSE_u = 0.0008$; second, calculate $F = \frac{(0.0052 - 0.0008)/(5-1)}{0.0008/(40-5-4)} = 42.625$, because the F value is greater than the critical value under 5% significance, the original hypothesis of the mixed regression model is rejected. Thirdly, use Eviews7 software to analyze the constructed random effect model and conduct Hausman test, and the results are as follows:

TABLE 3. HAUSMAN TEST RESULTS

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	0.000000	3	1.0000
Period random	0.000000	3	1.0000
Cross-section and period random	0.000000	3	1.0000

Finally, the results of the Hausman test show that the null hypothesis should be rejected, so it is more reasonable to establish a fixed effect model.

5.4.2. Model regression analysis

Use Eviews7 software to perform regression analysis on the constructed panel model (6), and the regression results are as follows:

TABLE 4. PANEL MODEL (6) TEST RESULTS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.412936	0.001184	348.7779	0.0000
DE?	0.003418	0.001719	1.988403	0.0388
FD?	0.020796	0.004619	4.502703	0.0002
RD?	-0.006429	0.004019	-1.599765	0.1233
R-squared	0.959230	Prob(F-statistic)		0.0000

It can be seen from the regression results that the model passes the significance test and the overall fit is good. Next, analyze the results of the model review:

a) Analysis of the impact of the digital economy industry on the advanced industrial structure

It can be seen from the above table that the digital economy development level, as the core explanatory variable, has a significant positive effect on the advanced industrial structure of the explained variable through the significance test. With the improvement of the development level of the digital economy, the advanced level of the industrial structure has been continuously improved. With other variables unchanged, the development level of the digital economy increases by 1 unit, and the structural level coefficient increases by 0.0034 units. Therefore, vigorously developing the digital economy industry will help optimize the industrial structure of the five northwestern provinces of China.

b) Analysis of the influence of control variables on the advanced industrial structure

The level of financial development passed the significance test, and the level of scientific research investment failed the significance test. The level of financial development increased by 1 unit, and the advanced industrial structure increased by 0.0208 unit. Optimizing the development of the financial industry has a significant positive impact on advancing the advanced industrial structure.

5.5. Empirical analysis of the impact of digital economy development on the rationalization of industrial structure

5.5.1. Determine the model category

First, use Eviews7 as a mixed effect model to calculate $SSE_r = 0.6803$, and use Eviews7 as an individual fixed effect model to calculate $SSE_u = 0.0047$; second, calculate $F = \frac{(0.6803 - 0.0047)/(5-1)}{0.0047/(40-5-4)} = 1115.183$, because the F value is greater than the critical value under 5% significance, the original hypothesis of the

mixed regression model is rejected. Thirdly, use Eviews7 software to analyze the constructed random effect model and conduct Hausman test, and the results are as follows:

TABLE 5. HAUSMAN TEST RESULTS

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	0.001602	3	1.0000
Period random	0.850363	3	0.8374
Cross-section and period random	0.874318	3	0.8316

Finally, the results of the Hausman test show that the null hypothesis should be rejected, so it is more reasonable to establish a fixed effect model.

5.5.2. Model regression analysis

Use Eviews7 software to perform regression analysis on the constructed panel model (7), and the regression results are as follows:

TABLE 6. PANEL MODEL (7) TEST RESULTS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.161068	0.003784	42.56068	0.0000
DE?	-0.004375	0.000875	-4.999995	0.0000
FD?	0.010590	0.014813	0.714946	0.4798
RD?	-0.004687	0.012030	-0.389643	0.6994
R-squared	0.993286	Prob(F-statistic)	0.000000	

It can be seen from the regression results that the model passes the significance test and the overall fit is good. Next, analyze the results of the model review:

a) Analysis of the impact of the digital economy industry on the rationalization of the industrial structure

It can be seen from the above table that the development level of the digital economy is the core explanatory variable. Through the significance test, the elasticity coefficient is -0.0044. Although the elasticity coefficient is negative, because the rationalization of industrial structure is a reverse indicator, the larger the value, the less likely the industrial structure will be. Reasonable, the more it tends to 0, the more reasonable the industrial structure, and the development level of the digital economy has a significant positive effect on the industrial structure. Therefore, it is necessary to seize the opportunity of the development of the digital economy industry, improve the efficiency of industrial development and resource allocation, and realize the rational development of the industrial structure.

b) Analysis of the influence of control variables on the rationalization of industrial structure

The level of financial development passed the significance test, and the level of scientific research investment failed the significance test. The level of financial development increased by 1 unit, and the rationalization of the industrial structure decreased by 0.0106 unit. The level of financial development has a negative impact on the rationalization of the industrial structure. The reason for this is that the industrial inclination of capital is not conducive to the rational allocation of resources in my country's three domestic industries.

6. CONCLUSIONS AND RECOMMENDATIONS

According to the empirical relationship between the development level of the digital economy and the upgrading of the industrial structure, combined with the current situation of China's digital economy development and industrial structure upgrading, the following conclusions and suggestions are put forward.

First, vigorously develop the digital economy industry. According to the empirical analysis results, the development of the digital economy industry can significantly promote the optimization and upgrading of the industrial structure. At present, China is at a critical stage of industrial restructuring. As a high-tech industry, the digital economy industry plays an important role in the improvement of industrial efficiency and the expansion of new industries, and has become a new driving force for industrial structure upgrading. Therefore, vigorously developing the digital economy industry is an inevitable choice for my country's economic transformation and upgrading.

Second, improve the digital technology innovation system. Digital technology is the foundation for the development of the digital economy industry. At present, China's low technological innovation capability and lack of key core technologies make China's industrial development at a disadvantage. Improve core technological innovation capabilities, grasp the development opportunities of the digital economy industry, and promote the continuous optimization and upgrading of China's industrial structure driven by digital technology.

Third, accelerate the integration of digital economy industries and traditional industries. Accelerating the transformation of traditional industries and realizing industrial upgrading is an important link in the adjustment of China's industrial structure. The digital economy industry is innovative, permeable and driving. Accelerating the penetration and integration of digital economy industries and traditional industries will help the transformation and upgrading of traditional industries, give birth to new business forms and new models, and play an important role in the optimization and upgrading of the industrial structure.

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