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Original Paper

The Impact of Digital Economy Development Industrial Structure Upgrading—An Empirical Analysis Based on Provincial Panel Data

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Abstract

On the basis of theoretical analysis, this paper measures the upgrading level of industrial structure from three dimensions: the speed of industrial transformation, the advanced level of industrial structure and the rationalization level of industrial structure, and uses the provincial panel data from 2011 to 2020 to explore the effect and mechanism of digital economy development on the upgrading of industrial structure. The results show that the development of digital economy can significantly promote the upgrading of the industrial structure, and this effect is the most significant in the central region; The level of regional innovation is an important transmission path of the development effect of digital economy.

Key words

digital economy, industrial structure, industrial structure upgrading, regional innovation, intermediary effect

1. Introduction

Digital economy refers to a series of economic activities with the use of digital knowledge and information as key production factors, modern information network as an important carrier, and the effective use of information and communication technology as an important driving force for efficiency improvement and economic structure optimization. In 2022, the scale of China's digital economy will reach 50.2 trillion yuan, of which the scale of digital industrialization and the scale of industrial digitalization will account for 18.3% and 81.7% of the digital economy, respectively, and the overall scale will rank second in the world for 11 consecutive years; The digital economy grew by 10.3% year-on-year in nominal terms, significantly higher than the nominal GDP growth rate in the same

period for 11 consecutive years. The 14th five-year plan will accelerate the development of digital economy and build a modern industrial system to a strategic height. The report of the 20th CPC National Congress also clearly pointed out that we should accelerate the development of the digital economy and promote the deep integration of the digital economy and the real economy. The development of digital economy has become an urgent task to transform the mode of economic development, improve the quality of economic development, and solve the problems of unbalanced and inadequate economic development. It is also a key force to comprehensively realize innovation driven development and accelerate the industry to move towards the middle and high end.

The upgrading of industrial structure refers to the process in which the proportion of high energy consumption, high pollution and low benefit industries in all industries decreases and the proportion of low energy consumption, low pollution and high benefit industries in all industries increases under the constraints of resources and environment, economic level, technical level and labor quality. Industrial structure upgrading includes two aspects: rationalization of industrial structure and upgrading of industrial structure. The rationalization of industrial structure refers to the degree of coordination and aggregation among industries, emphasizing the rational allocation of factor resources among various industrial sectors; The upgrading of industrial structure refers to the sequential evolution of industrial structure from labor-intensive to capital intensive to technology intensive and low added value to high added value. This change of industrial structure is consistent with the historical logic and general laws of Industrial Development.

Research on the impact of digital economy on the upgrading of industrial structure. Existing literature suggests that digital technologies such as big data, cloud computing and blockchain can not only improve the efficiency of traditional industries, but also trigger the interactive and integrated development of multiple industries and bring new industrial changes. In the process of digital economy development, both digital industrialization and industrial digitalization will accelerate the flow of all kinds of tangible and intangible production factors among industries and change their configuration status, which will have a far-reaching impact on the upgrading of industrial structure. Among them, industrial digitalization has increased the proportion of digital industry in the national economy, and the development of information and communication technology industry has promoted the upgrading of industrial structure. As far as the mechanism is concerned, digital economy can promote the process of factor marketization, influence the direction of capital investment, refine the division of labor among industries, optimize the allocation of resource factors, promote the increase of the proportion of the tertiary industry, optimize the employment structure, and cultivate new modes of business and other ways to promote the upgrading of industrial structure.

Boosting the upgrading of industrial structure with digital economy is an important measure to achieve high-quality economic development and enhance international competitiveness. Exploring the impact mechanism of the development of digital economy on the upgrading of China's industrial structure and exploring the countermeasures to promote the upgrading of industrial structure under the background

of digital economy is one of the research focuses in the field of economics. In this context, this paper uses the panel data of 31 provinces and autonomous regions (except Hong Kong, Macao and Taiwan) to study the impact of digital economy development on industrial structure upgrading. The first is to build indicators of the upgrading level of industrial structure from three dimensions: the speed of industrial transformation, the rationalization of industrial structure, and the upgrading of industrial structure, and to build indicators of the development level of digital economy from two levels: Internet development and digital Inclusive Finance, to empirically test the multi-dimensional impact of digital economy on industrial development; The second is to test the heterogeneous impact of digital economy on the upgrading of industrial structure from the regional position; The third is to introduce the level of regional innovation as an intermediary variable to analyze its conduction role in the impact of digital economy on industrial structure upgrading.

2. Mechanism Analysis and Research Hypothesis

Generally speaking, only when the digital economy promotes the upgrading and rationalization of industrial structure, it means that the digital economy has played a significant role in promoting the upgrading of industrial structure. The upgrading of industrial structure includes the increase of quantity and the improvement of quality. The former can be expressed by the industrial structure hierarchy coefficient that measures the speed of industrial transformation, and the latter can be measured by the weighted product of the proportional relationship between industries and the labor productivity of each industry. With the rapid development of digital economy, the speed of industrial transformation is also accelerating. On the one hand, the digital economy has promoted the digital transformation of traditional industries; On the other hand, the digital economy has promoted the formation and development of new industries. As a result, the proportion of industries with higher labor productivity has increased, and the level of industrial structure upgrading has increased.

At the same time, the development of digital economy can also improve the efficiency of resource allocation, which is conducive to the improvement of the level of rationalization of industrial structure. Since the G20 summit in Hangzhou in 2016, when the concept of "digital economy" first came into public view, China has issued a series of relevant industrial policies on digital economy, and put forward relatively clear industrial development goals and action guidelines, thus avoiding the resource mismatch caused by some blind investment to a certain extent. These policies help to make up for incomplete market information, improve resource utilization efficiency, strengthen the degree of correlation between industries, and then help to achieve coordinated development among industries. As a new driving force for economic development, the digital economy can also promote the transformation of industrial structure from labor-intensive and heavy industry to technology intensive and environment-friendly industrial structure, which is an important driving force for the upgrading of China's industrial structure. Therefore, this paper proposes that:

Hypothesis 1: digital economy can accelerate the speed of industrial transformation, improve the level

of upgrading and rationalization of industrial structure, and then realize the upgrading of industrial structure.

The impact of digital economy on the upgrading of industrial structure has regional heterogeneity, that is, different regions have different effects. Although there is controversy over whether this effect is more significant in the central and western regions or in the eastern regions, scholars generally agree that it has regional heterogeneity. Due to the unbalanced development among regions in China, the effects of digital economy industry development policies will naturally be different. Generally speaking, regions with higher development level of digital economy will have better technological foundation to promote the upgrading of industrial structure. Therefore, this paper proposes that:

Hypothesis 2: the impact of digital economy on industrial structure upgrading is heterogeneous due to different regions.

Digital economy can make full use of existing resources to empower traditional industries, create space for value-added and realize the transformation and upgrading of industrial structure through product innovation, business model innovation and other innovative forms. Innovation is an important path for the digital economy to promote the upgrading of industrial structure, which can be analyzed from three aspects: first, from the perspective of enterprises, innovation is often time-consuming, high sunk costs and high risks, but the digitization of production factors will help shorten the length of enterprise supply chain, improve the efficiency of supply chain, and then save costs and improve efficiency. That is, the digital economy provides enterprises with innovative resources and motivation. Second, from the perspective of consumers, the digital economy can solve the problem of information asymmetry between some developers and consumers through the Internet platform, stimulate the enthusiasm of consumers to participate in product research and development and "create" products, and promote the industrial development to be highly connected with consumers through innovation. The study found that B2C e-commerce platform can trigger consumers and manufacturers to jointly develop new products. Consumers can become an important participant in enterprise innovation by providing product needs and improvement suggestions to exchange and interact with R&D personnel, and ultimately help promote the upgrading of the whole industrial chain. Third, from the industrial level, big data, artificial intelligence, blockchain, Internet of things and other technologies help to promote the acquisition and sharing of R&D resources, promote the convergence of multiple innovation subjects to form innovation clusters, and improve the efficiency of industrial resource allocation. This diffusion effect of the digital economy should enable innovation to be realized at the industrial level. Therefore, this paper proposes that:

Hypothesis 3: digital economy can promote the upgrading of industrial structure by improving the level of regional innovation.

3. Research Design

3.1 Model Setting

In order to verify the above three research hypotheses, the following basic models were constructed:

$$isu_{it} = \alpha_0 + \alpha_1 dge_{it} + \alpha_c X_{it} + \mu_i + \delta_t + \varepsilon_{it}\# \quad (1)\#$$

Among them, the explained variable represents the upgrading level of the industrial structure of region in the period, which is measured from three dimensions: the speed of industrial transformation isu_1, the advanced level of industrial structure isu_2, and the rationalization level of industrial structure isu_3; The explanatory variable represents the digital economy development level of region in period t, and represents a set of control variables, means constant term, α_1 is the estimated parameter of the explanatory variable, represents a set of estimated parameters corresponding to a set of control variables, refers to the individual fixed effect that does not change with time in region i, is the time fixed effect, stands for random disturbance term.

In order to test whether the regional innovation level plays an intermediary effect in the process of promoting industrial structure upgrading by digital economy, the following intermediary effect regression model is set by using the traditional stepwise regression method:

$$rii_{it} = \beta_0 + \beta_1 dge_{it} + \beta_c X_{it} + \mu_i + \delta_t + \varepsilon_{it}\#(2)$$

$$isu_{it} = \gamma_0 + \gamma_1 dge_{it} + \gamma_2 rii_{it} + \gamma_c X_{it} + \mu_i + \delta_t + \varepsilon_{it}\#(3)$$

Wherein, equation (2) is the linear regression model of explanatory variable (digital economy development level dge_{it}) to intermediate variable (regional innovation level rii_{it}), and equation (3) is the linear regression model of explanatory variable (digital economy development level dge_{it}) and intermediate variable (regional innovation level rii_{it}) to explained variable (industrial structure upgrading level isu_{it}); β_1, and is the estimated parameter, if both of them can pass the significance level test, we can judge that the level of regional innovation has played an intermediary role in the impact of digital economy on the upgrading of industrial structure.

3.2 Variable Definition

3.2.1 Explained Variable: Industrial Structure Upgrading Level (ISU)

This paper uses the industrial structure hierarchy coefficient (IAS) to represent the speed of industrial

transformation ius_1. The level coefficient of industrial structure is an index reflecting the change of industrial structure. It can describe the evolution process of the three industries through the relative change of share proportion, which can better represent the speed of industrial transformation. The calculation formula is as follows:

$$IAS = \sum_{i=1}^{3} \theta_i \cdot q_i = isu_1 \# \quad (4)$$

Of which, is the weight of the industry, and is the proportion of the added value of the I industry in GDP. According to the overall trend of the development of the three industries, that is, with the improvement of the economic level, the proportion of the primary industry gradually decreases, the proportion of the secondary industry first increases and then decreases, and the proportion of the tertiary industry continues to rise. The weights of the three industries 1, 2, and 3 are given in order to get the speed of industrial transformation of each region.

This paper constructs the advanced index of industrial structure (isu_2) and the rationalization index of industrial structure (isu_3). The advanced level of industrial structure is measured by the ratio of the added value of the tertiary industry to the added value of the secondary industry, namely:

$$isu_2 = \frac{Added\ value\ of\ tertiary\ industry}{added\ value\ of\ secondary\ industry} \# \quad (5)$$

The rationalization level of industrial structure is measured by Theil index (TL). The closer the index is to 0, the more reasonable the industrial structure is; Otherwise, it is more unreasonable. The calculation formula is as follows:

$$TL = \sum_{i=1}^{3} \frac{Y_i}{Y} \ln\left(\frac{\frac{Y_i}{L_i}}{\frac{Y}{L}}\right) = isu_3 \# \quad (6)$$

Where represents the output value of the industry, represents the number of employees in the industry, represents the output value of all industries, and represents the number of employees in all industries.

Table 1. Index System of Industrial Structure Upgrading Level

Primary index	Secondary index	Secondary index calculation
Upgrading level of industrial	Speed of industrial transformation (isu_1)	Hierarchy coefficient of industrial structure

structure(isu)	Advanced level of industrial structure (isu_2)	Added value of tertiary industry/Added value of secondary industry
	Rationalization level of industrial structure (isu_3)	Theil index

3.2.2 Explanatory Variable: Digital Economy Development Level (DGE)

This paper measures the development level of digital economy from two aspects: the development level of Internet and the development level of digital Inclusive Finance (Table 2). Among them, the measurement of Internet development level includes four sub indicators: first, Internet penetration, measured by the number of Internet broadband access ports per 100 people; The second is the Internet output, which is measured by the total telecom business per capita; Third, the penetration rate of mobile Internet, measured by the number of mobile phone users per 100 people; Fourth, the number of employees in Internet related industries is measured by the ratio of the number of employees in information transmission, computer services and software industries to the number of employees in urban units. The development level of digital Inclusive Finance is measured by the digital inclusive finance index, which is jointly prepared by the digital finance research center of Peking University and ant financial group. Based on the existing research, the entropy method is used to determine the weight of each index, and the digital economy development level index is obtained by weighted summation.

Table 2. Index System of Digital Economy Development Level

Primary indicators	Secondary indicators	Tertiary indicators	Calculation of tertiary indicators
Development level of digital economy(dge)	Internet development level	Internet penetration	Number of Internet broadband access ports per 100 people
		Internet output	Total telecom services per capita
		Mobile Internet penetration	Number of mobile phone users per 100 people
		Number of employees in Internet related industries	Ratio of the number of employees in information transmission, computer services and software industries to the number of employees in Urban Units

	Development level of digital Inclusive Finance	Development level of digital Inclusive Finance	Digital inclusive finance index

3.2.3 Intermediary Variable: Regional Innovation Index (RII)

In this paper, the regional innovation index jointly developed by the National Development Research Institute of Peking University and Longxin data research institute is used as the intermediary variable. The index uses five dimensions including the number of new enterprises, attracting foreign investment, attracting venture capital, the number of patent authorizations, and the number of trademark registrations, as well as seven basic indicators including the number of new enterprise registrations, the number of new foreign legal person investments, the number of new venture capital enterprises, the number of new patent authorizations, the number of new utility model patents, the number of new design patents, and the number of new trademark registrations to measure China's regional innovation and entrepreneurship performance.

3.2.4 Control Variables

Based on the existing research, seven control variables were selected. (a) Economic development level (^{pgdp}). Economic development is an important driving force for the upgrading of industrial structure, measured by per capita GDP. (b) Foreign direct investment (^{fdi}). Foreign direct investment may bring new technology and management experience, which is conducive to improving industrial production efficiency and promoting the upgrading of industrial structure. It is measured by the proportion of actually utilized foreign direct investment in GDP. (c) Labor force level (^{epu}). The level of labor force is an important factor affecting the transformation and upgrading of industrial structure, which is expressed by the number of employed persons in urban units at the end of the year. (d) Social consumption (^{soc}). The constant change of consumer demand and the diversification of consumption structure can promote the adjustment of industrial structure, which is expressed by the proportion of the total retail sales of social consumer goods in GDP. (e) Government intervention (^{gov}). As an important part of industrial policy, the degree of government intervention will affect the upgrading of industrial structure, which is measured by the proportion of general public budget expenditure in GDP. (f) Urban unemployment rate (^{uup}). The number of unemployed people in cities and towns will affect the adjustment of industrial structure, which is expressed by the registered unemployment rate in cities and towns. (g) Science and education support (^{tne}). The support of local governments for science

education can play a potential role in the upgrading of industrial structure, which is measured by the expenditure on education and science and technology in the general public budget.

3.3 Data Sources

Since the initial statistical year of the digital inclusive finance index is 2011, and the latest statistical year of the regional innovation index is 2020, this paper uses the statistical data of 31 provinces (cities, autonomous regions) from 2011 to 2020 for analysis. The relevant data are from the statistical yearbook of China and the statistical yearbook of various regions over the years. The control variables $pgdp$ (economic development level), (labor force level) and (Science and education support) with significant magnitude differences are normalized to improve the stability and interpretation of the model. According to the descriptive statistical results of relevant variables in Table 3, there is a significant gap in economic development between different regions.

Table 3. Descriptive Statistics of Relevant Variables

Variable type	Variable name	Variable symbol	Sample size	Mean	Standard deviation	Min	Max
Explained variable	Speed of industrial transformation	$isu1$	310	2.393	0.124	2.133	2.838
	Advanced level of industrial structure	$isu2$	310	1.335	0.720	0.527	5.244
	Rationalization level of industrial structure	$isu3$	310	0.091	0.040	0.018	0.202
Explanatory variable	Development level of digital economy	dge	310	0.301	0.208	0.046	1.000
Mediating variable	Regional innovation index	rii	310	79.215	16.036	21.956	100.000
Control variable	Economic development level	$pgdp$	310	0.251	0.181	0.000	1.000
	Foreign direct investment	fdi	310	0.020	0.018	0.0001	0.121
	Labor force level	epu	310	0.256	0.195	0.000	1.000

Social consumption	soc	310	0.394	0.054	0.222	0.500
Degree of government intervention	gov	310	0.297	0.210	0.120	1.354
Urban unemployment rate	uup	310	0.032	0.006	0.012	0.046
Science and education support	tne	310	0.198	0.152	0.000	1.000

4. Empirical Results and Discussion

4.1 The Development Effect of Digital Economy

Table 4 reports the linear regression results of digital economy development on industrial structure upgrading. Among them, model (1) - (3) is the estimation result of uncontrolled time effect and regional effect, and model (4) - (6) is the estimation result of controlling time effect and regional effect. It can be seen from R^2 that the latter has better goodness of fit.

Table 4 Effect of Digital Economy Development on Industrial Structure Upgrading

Variable	Uncontrolled time effect and regional effect			Control time effect and regional effect		
	(1)	(2)	(3)	(4)	(5)	(6)
	(isu_1)	(isu_2)	(isu_3)	(isu_1)	(isu_2)	(isu_3)
dge	0.157***	0.617***	-0.064***	0.133***	0.681***	-0.076***
	(0.034)	(0.185)	(0.010)	(0.040)	(0.188)	(0.012)
$pgdp$	0.336***	2.202***	-0.082***	0.302***	2.219***	-0.080***
	(0.029)	(0.148)	(0.009)	(0.030)	(0.141)	(0.009)
fdi	-0.797***	-3.055***	0.088*	-1.088***	-3.682***	0.144***
	(0.160)	(0.783)	(0.046)	(0.155)	(0.073)	(0.045)
epu	-0.073*	-0.261	0.012	-0.122***	-0.352*	0.010
	(0.039)	(0.208)	(0.012)	(0.043)	(0.203)	(0.012)
soc	0.343***	0.739***	-0.08***	0.327***	0.659**	-0.079***
	(0.056)	(0.276)	(0.016)	(0.054)	(0.257)	(0.016)
gov	0.256***	2.600***	0.028*	0.624***	4.090***	-0.013
	(0.042)	(0.276)	(0.014)	(0.072)	(0.340)	(0.021)

uup	-1.427**	1.702	0.293*	-1.556***	2.933	0.374**
	(0.557)	(2.719)	(0.159)	(0.533)	(2.516)	(0.155)
tne	0.100***	-0.220	-0.017	0.103***	-0.338*	-0.013
	(0.038)	(0.190)	(0.011)	(0.038)	(0.181)	(0.011)
Constant	2.112***	-0.348*	0.143***	2.046***	-0.763***	0.154***
	(0.038)	(0.205)	(0.011)	(0.039)	(0.186)	(0.011)
R^2	0.716	0.332	0.515	0.756	0.765	0.664
Sample size	310	310	310	310	310	310
The value of Wald chi square statistic (Prob>Chi2)	776.861 (0.000)	730.778 (0.000)	528.810 (0.000)			
The value of F-statistic (Prob>F)				105.226 (0.000)	110.570 (0.000)	66.879 (0.000)

Note. ***, **, * respectively indicate that the estimated parameters are significant at the significance level of 1%, 5% and 10%, and the standard error is in brackets. The same below.

In model (4), the influence coefficient of the development level of digital economy on the speed of industrial transformation is 0.133, which is significant at the significance level of 1%, indicating that the development of digital economy has accelerated the evolution of China's industrial structure from the dominant primary industry to the dominant secondary and tertiary industries. The possible reason is that the digital economy industry is mainly high-tech industry, and the development of digital economy will inevitably improve the speed of industrial transformation.

In model (5), the influence coefficient of the development level of digital economy on the upgrading level of industrial structure is 0.681, which is significant at the significance level of 1%, indicating that the development of digital economy promotes the upgrading level of industrial structure. The possible reason is that as the proportion of the tertiary industry with high labor productivity gradually rises, the technological innovation brought about by the development of the digital economy has produced a high conversion rate of innovation achievements, which has promoted the evolution of the industrial structure to an advanced level.

In model (6), the influence coefficient of the development level of digital economy on the rationalization level of industrial structure is -0.076, which is significant at the significance level of 1%, indicating that with the development of digital economy, the Theil index, which measures the rationalization level of industrial structure, shows a downward trend. The smaller the index, the more reasonable the industrial structure. Therefore, the development of digital economy is conducive to the rational adjustment of industrial structure. The possible reason is that in the early stage of the

development of the digital economy, the more clear industrial development goals and a good external market environment have improved the strength of enterprise cooperation, and thus increased the degree of correlation between industries, so that the employment structure and industrial structure tend to be rationalized. So far, hypothesis 1 has been proved.

According to the regression results of the control variables, the level of economic development, social consumption and government intervention can significantly improve the speed of industrial transformation and the level of upgrading of industrial structure, but the level of economic development and social consumption have a negative effect on the level of rationalization of industrial structure. The possible reason is that although the level of economic development and social consumption in less developed regions are constantly improving, their industrial structure is still dominated by traditional industries with low added value, and the level of rationalization is low, thus lowering the overall level of rationalization of industrial structure. Therefore, paying more attention to the quality of economic development and improving the innovation ability of the industrial chain should become an important task at the current stage. Foreign direct investment has a negative effect on the speed of industrial transformation and the upgrading level of industrial structure, which may be because foreign direct investment is often in low-end industries, leading to the concentration of resources in these industries, thus inhibiting the transformation and upgrading of industrial structure. The urban unemployment rate has slowed down the speed of industrial transformation and improved the level of rationalization of industrial structure. This may be because a considerable part of the registered unemployed in cities and towns belong to frictional unemployment rather than permanent unemployment. Therefore, this kind of unemployment is less harmful and may play a role in breaking the solidification of employment structure in the development of traditional industries. The increase of science and education support is conducive to the improvement of labor quality and scientific and technological level, promoting the development of technology intensive industries and accelerating the speed of industrial transformation.

4.2 Regional Heterogeneity Test

In order to test hypothesis 2, regression analysis was conducted on 10 provinces (cities) in Eastern China, 6 provinces in Central China, 12 provinces (cities, autonomous regions) in Western China and 3 provinces in Northeast China, and the interaction between regional dummy variables and explanatory variables was added to the benchmark regression model to obtain the following extended model:

$$isu_{it} = \alpha_0 + \alpha_1 dge_{it} + \alpha_2 dge_{it} \cdot area_i + \alpha_c X_{it} + \mu_i + \delta_t + \varepsilon_{it} \#(7)$$

Among them, represents the region (Eastern, Central, Western and Northeast), and the meaning of other symbols is the same as that of the benchmark regression model (1).

According to the regional heterogeneity test results in Table 5 and Table 6, the development level of digital economy in all regions will promote the upgrading of industrial structure through three dimensions, but the economic effects are significantly different. Specifically, the impact of digital economy on the speed of industrial transformation and the level of rationalization of industrial structure

shows a trend of Central>Western>Northeast>Eastern. This may be because with the sustainable development of the economy, the industrial structure in Eastern is more reasonable than that in other regions, which is dominated by the primary and secondary industries. Therefore, the positive impact of the development level of the digital economy on the upgrading of the industrial structure is more obvious in the less developed and more developed regions. The better industrial development foundation in Central may be one of the reasons for the faster upgrading of its industrial structure. In terms of upgrading the industrial structure, the development of digital economy has a significant role in upgrading the industrial structure of the four regions. So far, hypothesis 2 has been proved.

Table 5. Regional Heterogeneity Test Results

Variable	isu_1				isu_2			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Eastern	Central	Western	Northeast	Eastern	Central	Western	Northeast
dge	0.126***	0.214***	0.187***	0.152***	1.381***	0.324***	0.365***	0.272***
	(0.067)	(0.100)	(0.058)	(0.280)	(0.379)	(0.383)	(0.260)	(0.817)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
time effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regional effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.050***	1.750***	2.161***	1.774***	-1.411***	-0.875***	0.089***	-0.181
R^2	0.835	0.953	0.744	0.858	0.876	0.934	0.720	0.949
Sample size	100	60	120	30	100	60	120	30
The value of F-statistic (Prob>F)	51.878 (0.000)	117.251 (0.000)	36.373 (0.000)	14.302 (0.000)	72.594 (0.000)	80.865 (0.000)	32.084(0.000)	44.070 (0.000)

Table 6. Regional Heterogeneity Test Results

Variable	isu_3			
	(1)	(2)	(3)	(4)
	Eastern	Central	Western	Northeast
dge	-0.013***	-0.069***	-0.052***	-0.048***
	(0.017)	(0.026)	(0.014)	(0.025)
Control variable	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
Regional effects	Yes	Yes	Yes	Yes

Constant	0.135***	0.180***	0.204***	0.089***
R^2	0.660	0.897	0.897	0.925
Sample size	100	60	120	30
The value of F-statistic	19.925	50.245	109.024	29.134
(Prob>F)	(0.000)	(0.000)	(0.000)	(0.000)

4.3 Mediating Effect Test of Regional Innovation Index

To test hypothesis 3, the mediating effect of the regional innovation index is tested. The regression results are shown in Table 7 and Table 8. Among them, model (1) (4) (7) is obtained from regression equation (1), which reports the impact of digital economy development level (dge) on the speed of industrial transformation, the level of upgrading of industrial structure and the level of rationalization of industrial structure. As the first step of the mediation effect test, the three pass the significance level test of 1%. Model (2) (5) (8) is obtained from regression equation (2), which tests whether digital economy promotes the improvement of regional innovation index. The results show that the estimated parameters are positive and significant at the significance level of 1%. Model (3) (6) (9) is obtained from regression equation (3). It can be seen that after adding the regional innovation index (RII) to the regression equation of the impact of digital economy development level on industrial structure upgrading, the impact of digital economy development level on industrial structure upgrading is lower than that of model (1) (4) (7), indicating that the regional innovation index plays an intermediary role in the process of the impact of digital economy development level on industrial structure upgrading, and the improvement of regional innovation level is an important path for digital economy to promote industrial structure upgrading. The indicators of the three dimensions of the speed of industrial transformation, the advanced level of industrial structure and the rationalization level of industrial structure support each other in this process, which proves that the research conclusion has good robustness. So far, hypothesis 3 has been proved.

The possible reasons why the digital economy can promote the upgrading of industrial structure by improving the level of regional innovation are as follows: first, the Internet platform provides rich data resources and saves the search cost and time cost, which provides people with innovation power. Secondly, in the era of big data, innovation does not need to invest a lot of physical equipment and fixed assets, which improves the convenience of scientific and technological innovation and the development of new formats. The improvement of innovation level can promote the upgrading of industrial structure through technology diffusion effect. Finally, as a specific application of innovation, entrepreneurship enables the value of emerging technologies to be realized, drives the continuous emergence of high-end industries, optimizes resource allocation, promotes inter industry integration, and effectively promotes the upgrading of industrial structure.

Table 7. Test Results of Intermediary Effect of Regional Innovation Index

Variable	isu_1			isu_2		
	(1)	(2)	(3)	(5)	(6)	(7)
dge	0.133***	34.68***	0.059***	0.681***	34.68***	0.604***
	(0.040)	(7.64)	(0.038)	(0.188)	(7.64)	(0.194)
Regional innovation index (rii)			0.002***			0.002
			(0.000)			(0.001)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Regional effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.046***	24.853***	1.994***	-0.763***	24.853***	-0.818***
	(0.039)	(7.56)	(0.037)	(0.186)	(7.56)	(0.189)
R^2	0.756	0.650	0.797	0.765	0.650	0.767
Sample size	310	310	310	310	310	310
The value of F-statistic	105.226	62.793	117.620	110.570	62.793	98.975
(Prob>F)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 8. Test Results of Intermediary Effect of Regional Innovation Index

Variable	isu_3		
	(7)	(8)	(9)
dge	-0.076***	34.68***	-0.038***
	(0.012)	(7.64)	(0.008)
Control variable	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
Regional effects	Yes	Yes	Yes
Constant	0.154***	24.853***	0.181***
	(0.011)	(7.56)	(0.008)
R^2	0.664	0.650	0.846
Sample size	310	310	310
The value of F-statistic	66.879	62.793	164.542
(Prob>F)	(0.000)	(0.000)	(0.000)

4.4 Endogenous Problem

As for the impact of the development of digital economy on the upgrading of industrial structure, the

possible endogenous problems mainly stem from two aspects. First, there is a causal relationship between the explained variable and the explanatory variable, that is, the development of digital economy is an important driving force to promote the upgrading of industrial structure, and the upgrading of industrial structure will be conducive to the development of digital economy. The second is the problem of missing variables. There are many factors that affect the upgrading of industrial structure. In order to avoid the estimation error caused by missing variables, it is necessary to select appropriate instrumental variables to overcome this problem, so as to ensure that the effect of the development of digital economy on the upgrading of industrial structure is stable and reliable.

From the perspective of the concept of digital economy, any economic form that uses digital technology to guide resources to play a role and promote the development of productive forces can be included in its scope, while digital technology is a technology based on the Internet. From the perspective of the development history of China's digital technology, the early "online" information transmission and communication were realized through the post office, so people in many areas of the post office have developed the way and habit of "online" communication, and digital technology is easier to rise and develop in these areas. Therefore, taking the number of historical post offices as a tool variable for the development of digital economy can meet the requirements of correlation. At the same time, the tool variable still needs to meet the requirements of exclusivity. As a traditional information transmission intermediary, the impact of the number of historical post offices on the upgrading of industrial structure will inevitably weaken with the reduction of the frequency of use. Therefore, after controlling other factors unchanged, the number of historical post offices as a tool variable can meet the requirements of exclusivity.

Drawing on the existing research, this paper takes the number of post offices per million people in each province (city, autonomous region) in 1984 as a tool variable. However, the number of post offices in 1984 is cross-sectional data, so it is necessary to select a variable that changes with time and the number of post offices to construct an intersection item to generate panel tool variables. Drawing on the research of Nunn and Nancy (2014), this paper selects the intersection of the digital economy development level of provinces (cities, autonomous regions) and the number of post offices per million people in 1984 as the instrumental variable of the digital economy development level, and uses the Generalized Moment Estimation (GMM) for supplementary analysis.

The results of instrumental variable method and GMM estimation are shown in Table 9 and Table 10. From the first stage of the two-stage least square method (2SLS), the selected instrumental variables have a positive correlation with the development level of digital economy, and are significant at the significance level of 1%; The value of F statistic is 11.99, which is greater than the critical value of 10, so there is no need to worry about weak instrumental variables. It can be seen that whether 2SLS or GMM, the estimated parameters of digital economy development level (dge) and instrumental variable

(iv) are significant at the significance level of 1%, indicating that after considering the endogenous problem, the development of digital economy still has a significant role in promoting the upgrading of industrial structure.

Table 9. Instrumental Variable Method and GMM Estimation Results

Variable	isu_1			isu_2		
	(1) 2SLS Stage I	(2) 2SLS Stage II	(3) GMM	(5) 2SLS Stage I	(6) 2SLS Stage II	(7) GMM
dge		0.856***	0.183***		1.800***	1.138***
		(0.152)	(0.031)		(0.755)	(0.240)
Instrumental variable(iv)	0.042*** (0.016)			0.042*** (0.016)		
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Regional effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.228***	1.758***	2.096***	0.228***	-1.208***	1.726***
	(0.085)	(0.070)	(0.035)	(0.085)	(0.346)	(0.000)
R^2	0.245	0.773	0.815	0.245	0.759	
Sample size	248	248	248	248	248	248
The value of F-statistic	11.990	115.320		11.990	106.765	
(Prob>F)	(0.000)	(0.000)		(0.000)	(0.000)	
The value of Wald statistic			1408.698			259.690
(Prob>Chi2)			(0.000)			(0.000)

Table 10. Instrumental Variable Method and GMM Estimation Results

Variable	isu_3		
	(7) 2SLS Stage I	(8) 2SLS Stage II	(9) GMM

dge		-0.238***	-0.067**
		(0.047)	(0.009)
Instrumental variable(^{iv})	0.042***		
	(0.016)		
Control variable	Yes	Yes	Yes
Time effect	Yes	Yes	Yes
Regional effects	Yes	Yes	Yes
Constant	0.228***	0.218***	0.129***
	(0.085)	(0.022)	(0.013)
R^2	0.245	0.643	
Sample size	248	248	248
The value of F-statistic	11.990	61.093	
(Prob>F)	(0.000)	(0.000)	
The value of Wald statistic			898.259
(Prob>Chi2)			(0.000)

5. Conclusion and Enlightenment

On the basis of theoretical analysis, this paper uses the panel data of 31 provinces (cities and autonomous regions) in China from 2011 to 2020 to build a digital economy development level index based on the development level of the Internet and the development level of digital Inclusive Finance. It measures the level of industrial structure upgrading from three dimensions: the speed of industrial transformation, the level of industrial structure upgrading, and the level of industrial structure rationalization. It studies the differential impact of the level of digital economy development on industrial structure upgrading from the perspective of regional differences, and takes the regional innovation index, which measures the level of regional innovation, as an intermediate variable to explore the path of the role of the level of digital economy development in industrial structure upgrading. At the same time, it selects the number of post offices per million people in 1984 as the instrumental variable of the level of digital economy development, and combines the GMM estimation method to analyze the research results. The robustness test is carried out. The main conclusions are as follows: the development of digital economy has significantly promoted the upgrading of China's industrial structure, which is the most obvious in the central region; The regional innovation index plays an intermediary role in the promotion process.

Based on the above analysis, we should pay more attention to and promote the development of digital economy in the future, lead the upgrading of industrial structure with the high-quality development of digital economy, and take digital industrialization and industrial digitization as an important starting point for the upgrading of industrial structure, so as to realize the high-quality development of China's economy. First of all, we should strengthen the construction of digital infrastructure, consolidate the

foundation for the development of the digital economy, adhere to the overall planning of "a game of chess for the whole country", take into account the coordinated development of regions, promote the construction of new digital infrastructure in favor of economically underdeveloped regions, and make up for the "digital divide" caused by uneven development. Secondly, we should continue to promote the implementation of the national big data strategy, cultivate new generation of information technology, new materials, high-end equipment manufacturing and other emerging industrial clusters, accelerate the deep integration of the three industries with digital technology and information technology, and release the demand vitality of information consumption, investment in the digital economy and digital trade. Finally, relying on the diversified innovation platform provided by the development of digital economy, we should seize the opportunity of a new round of industrial revolution, accelerate the independent innovation of core technologies, promote the formation of a new industrial system, and provide a channel for the digital economy to promote industrial upgrading through innovation from the perspective of mechanism and system.

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