How Digital Economy drive the Optimization and Upgrading of Industrial Structure? the Mediating Effect of Innovation and the Role of Economic Resilience

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Article

How Digital Economy drive the Optimization and Upgrading of Industrial Structure? the Mediating Effect of Innovation and the Role of Economic Resilience

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Abstract: The digital economy (DE) has become a major force driving the optimization and upgrading of industrial structures (ISOU), and research on the driving mechanism has yet to be verified. To this end, the driving influence of DE on the ISOU is targeted, and the role played by economic resilience (ER) and innovation is explored. Based on the panel data of 31 provinces in China from 2011 to 2020, the driving influence of the DE on the ISOU is analyzed using a two-way fixed-effects model. The empirical study finds that the DE presents a positive driving effect on both industrial structure advancement and rationalization, and the driving effect is still significant after the addition of control variables and the robust-type test with one period of lag; the DE presents regional differences in ISOU, with the driving effect of the DE on industrial structure advancement in the eastern region having a more significant performance than that of the central and western regions, and the driving influence on the rationalization of industrial structure in the eastern and western regions exceeds that in the central region; the impact of DE on the ISOU has a mediating role through innovation, ER has a moderating role in the process, and innovation as a partial mediator also has a threshold effect, and finally countermeasure suggestions are put forward.

Keywords: digital economy; industrial structure; Optimization and upgrading; economic resilience; innovation

1. Introduction

The global economy is slowing down in the post-epidemic era, and the optimization and upgrading of industrial structure (ISOU) plays an irreplaceable role in promoting the transformation of China's economic development to low-carbon and green. However, from the perspective of China's industrial development as a whole, there still exists an irrational industrial structure, which brings many structural problems to urban and rural development and regional economic balance 1. The optimization of China's industrial structure began with the 10th Five-Year Plan, which advocated a high priority for the development of the industrial sector, promoting the effective growth of the industrial manufacturing industry and the country's overall economy through the support of iron and steel production as the main industry, complemented by the development of other heavy industry support policies. Through the implementation of the 10th Five-Year Plan, China's industrial structure has been improved and rationalized to a certain extent, but there were relatively few support policies for the development of material trade and related economic industries, including the food industry, the textile industry, the service industry, etc., which led to the irrationality of China's economic ratios and industrial structure at that time, and the mismatch between the people's daily life needs and the country's economic growth rate. In response to the above situation, policies on the optimization and transformation of China's industrial structure have been continuously introduced, such as strengthening the basic position of the primary industry represented by agriculture, optimizing the structure of the secondary industry with manufacturing as the main industry, and accelerating the development of the tertiary industry.

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Under the current world environment of global economic slowdown and fluctuating globalization cooperation, the economic development of all countries is facing more severe challenges. Therefore, accelerating the strategic adjustment of industrial structure and promoting the release of structural potential is an inevitable choice for China's economic development. China's demographic dividend is gradually disappearing, and the benefits of "structural acceleration" brought about by the rapid development of industrialization are no longer apparent 2. In the face of this series of difficulties, accelerating the development of China's DE has become an important means of promoting the transformation and upgrading of the economic and industrial structure. Under the rapid development of DE, on the one hand, the traditional industry has received a huge impact, relying on the original mode of operation and industrial form has been unable to adapt to the market competition; on the other hand, most of the traditional industries along with the industrial digital transformation and upgrading, the combination of the traditional industry and the DE to promote the transformation and upgrading of the industrial structure has become a new development mode 3. Industry digitalization is creating several new industrial forms, for example, The integrated development of new media platforms and online logistics and trade constitutes a new digital economy trade network, which makes the development model of the digital economy and the mode of industrial operation more diversified, and brings a driving role to ISOU 4.

DE provides rich growth space for innovation ability. On the one hand, DE provides basic support for exchanges and cooperation between cities and regions, and makes multiple innovation subjects in different regions work more closely together 5; on the other hand, DE gives traditional industries, especially the manufacturing industry, a broader innovation space, industrial manufacturing industry transformation and upgrading relies on digital technology, and the innovation of digital production and management of highly informatized and intelligent demand, and constantly promotes the transformation and upgrading of industrial structure, and brings driving effect to industrial structure and intelligent demand for innovative digital production and management of highly informative and intelligent, and constantly promote the innovation and breakthrough of production technology and operation technology 6. With the popularization and application of the Internet and digital industry in China, the development of tertiary industry has a new development opportunity. Due to the strong support of the state for the digital and informatization industry, the Internet and informatization industry has been developing rapidly, giving China the driving force to develop the tertiary industry and adjust and optimize the industrial structure 7. Since 2000, the proportion of China's tertiary industry in GDP has been increasing, with the average annual contribution rate of the tertiary industry to GDP exceeding 49%, and the proportion of the tertiary industry in GDP in 2021 will be 53.3%. With the innovative application of digital technology, a series of emerging digital technologies relying on the Internet, such as big data, cloud computing, artificial intelligence, etc., have gradually matured and begun to be applied in various industries. A series of new industrial forms, such as mobile payment, sharing economy, live broadcasting economy, etc., have appeared, and the ISOU has entered into a new stage driven by DE. DE has become an important driving force for the ISOU, the strengthening of economic development resilience, and the enhancement of high-quality development 8 11. In addition, the innovation capacity of cities or regions is a major driving factor in promoting the transformation and upgrading of industrial structures 12. How does the DE drive ISOU, and what role will innovation and economic resilience (ER) play? This article will explore and answer these questions.

The following parts of the paper include chapters as follows: the second part is the theoretical review and research hypotheses, the third part introduces the theoretical model and variable selection, the fourth part is the analysis of empirical results and robustness test, the fifth part is the analysis of the mechanism, and the last part is the conclusion with countermeasure suggestions.

2. Theoretical Review and Research Hypotheses

At present, extensive and in-depth research has been carried out in academia on the transformation and upgrading of industrial structure and the role of the DE and digitalization in the ISOU. ISOU belongs to the transformation of the economic growth mode, which contains three levels:

micro, meso, and macro; the micro level refers to the upgrading of the enterprise's overall structure or operation mode 1314; the meso level refers to the fact that the main enterprises in the industry rise to a higher level and form a more advanced industrial structure1516; and the ISOU at the macro level is the transformation of the country's economic growth mode, which is brought about by the social. ISOU at the macro level is the transformation of the national economic growth mode, which is brought about by the comprehensive upgrading of the internal elements and structure of the social production mode 1718. Strategic emerging industries, as a new industrial form, belong to the ISOU at the meso- and macro-levels, and it has a positive effect on the high-quality development of the economy. In addition, the ISOU includes two areas, advanced and rationalization 19. Industry advancement is to achieve higher production efficiency through the combined allocation of factors under the conditions of existing resources and factors; industry rationalization is to achieve balanced development through the optimization of the allocation of industrial structure by integrating the endowment of resources and scientific and technological level. We will analyze the ISOU from the perspectives of both advancement and rationalization.

The positive effects of the DE on economic development have gained academic consensus20. A measurement analysis using an instrumental variables approach found that a 10 percent increase in broadband penetration increases the annual economic growth rate per capita by 0.9-1.5 percent 21. According to a study by the United Nations Broadband Commission, it was found that every 10 percent increase in broadband penetration could lead to a 2.5 percent increase in China's GDP. The DE based on Internet technology has shown a significant contribution to economic growth; moreover, the significant growth of wages and employment in high-income, high-population, and high-skill regions is closely related to the degree of development of the DE22. Regarding the impact of the DE on the ISOU, the main purpose is to analyze the mechanism of action, including the inspiring framework of the technological innovation model in the technology-based production sector, the combination of innovative technology through the introduction of knowledge and locally applied knowledge to achieve the optimization and upgrading of the enterprise's industrial structure in the case of resource scarcity and technological backwardness, and the support of urbanization for industrial upgrading through the promotion of technological innovation in the industry23. At the same time, DE can also promote the high-quality development of the industry through the industrial innovation effect and integration effect. There is a lack of studies that consider the DE to promote the ISOU from the aspects of innovation and ER. Thus, we study the driving mechanism of the DE on the ISOU in terms of the moderating role of ER in DE and ISOU, and the mediating role of innovation in it.

DE has a positive and direct impact on ISOU. Represented by information technology, the Internet, and big data, the DE has promoted the development of traditional industries in the direction of digitalization, networking, and intelligence. Through the wide application of digital technology, enterprises are able to improve production efficiency, optimize resource allocation, and create new business models, thus promoting the overall development of industries in the direction of high value-added and high-technology content. The DE has not only led to the emergence of new industries but also accelerated the upgrading and transformation of traditional industries, forming a more complex and diversified industrial structure 24.

ER refers to the ability of an economy to maintain stability and sustainability in the face of external shocks, and it is clear that the DE belongs to a kind of powerful shock, and the development of the DE may have differentiated impacts on different regions and industries, while ER can play a moderating role in this process. Resilient regions can better adapt to changes in the DE, mitigate adverse impacts, and promote the ISOU by playing the role of the DE. Such resilience thus helps the economy to maintain relative stability amidst uncertainty and promotes the evolution of industrial structure in a more sustainable direction. Innovation is an important driving force for economic growth and structural change, and the DE provides rich soil for innovation. In the era of DE, innovation not only includes the technical level but also gives rise to the emergence of business models, management styles, and other areas of change. Diversification of innovation in the era of DE accelerates ISOU, i.e., not only promotes the rise of new industries but also guides the renewal of

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traditional industries. Therefore, in the impact of DE on the ISOU, innovation can play a mediating role as a transmission bridge.

In short, the DE, ER, and innovation form a multifaceted relationship. The DE serves as the dominant force, ER as the regulator, and innovation as the mediator, and they synergize and work closely together to promote the ISOU. The interactions in this relationship reflect both the profound impact of the DE on the ISOU and highlight the key role of ER and innovation in this process. In summary, we propose the following hypotheses：

H1：DE has a driving influence on the ISOU；

H2：DE's driving influence on the ISOU is through innovation；

H3：ER has a moderating role in the DE and the ISOU.

3. Model Setting and Variable Selection

3.1. benchmark model

3.1.1. Fixed Effects Model

In order to verify and analyze the driving influence of DE on the ISOU, we set up the following model::

$$ind_{i,t} = \beta_0 + \beta_1 dig_{i,t} + \beta x_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

where i represents the region, t represents the period, ind represents the level of industrial structure optimization and upgrading, including advanced and rationalization, dig is the level of the DE, x represents a series of control variables, λ_i represents the i individual fixed effect, μ_t is the time fixed, and $\varepsilon_{i,t}$ represents the stochastic disturbance term.

3.1.2. Mechanistic Model

In order to explore the influence of DE on the ISOU through which path, we verify it through the moderating effect test and the mediating effect model. Among them, $inno_{i,t}$represents innovation ability, which is the mediator variable. $res_{i,t}$represents ER, which is the moderating variable, and $dig_{i,t} * res_{i,t}$is the interaction term between DE and innovation level. The effects of DE and ER on the ISOU are examined by establishing a moderating model, as shown in equation (2). The mediation effect model is built to explore the influence of innovation ability in the DE on the ISOU, as shown in equations (3), (4) and (5).

$$ind_{i,t} = a_0 + adig_{i,t} + a_2 res_{i,t} + a_3 dig_{i,t} * res_{i,t} + ax_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

$$ind_{i,t} = \beta_0 + \beta_1 dig_{i,t} + \beta x_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

$$inno_{i,t} = \beta_0 + \beta_1 dig_{i,t} + \beta x_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (4)$$

$$ind_{i,t} = \beta_0 + \beta_1 dig_{i,t} + \beta_2 inno_{i,t} + \beta x_{i,t} + \lambda_i + \mu_t + \varepsilon_{i,t} \quad (5)$$

3.1.3. Threshold Model

Innovation ability the DE on the ISOU effect will present two intervals to produce impact, beyond a certain threshold value, the Internet continues to promote the industrial structure of the advanced and rationalization. In order to explore the threshold effect of innovation ability, this paper designs the following equation to estimate the threshold effect of ER.

$$ind_{i,t} = \beta_1 dig_{i,t} * I(inno_{i,t} \leqq \gamma) + \beta_2 dig_{i,t} * I(inno_{i,t} \geqq \gamma) + \beta x_{i,t} + \mu_i + \varepsilon_{i,t} \quad (6)$$

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Where $I(\cdot)$ is an indicator function that takes the value of 1 when the corresponding condition is true and vice versa. The other variables are interpreted as above.

3.2. Variable Description

3.2.1. Explained Variables

Advancement and rationalization of industrial structure are indispensable processes for the ISOU, which are interrelated and affect each other, and jointly promote the ISOU. This paper measures the ISOU by constructing two indicators of industrial structure advanced (adv) and industrial structure rationalization (rat). This paper draws on the measurement method of CH Gan (2011) [1] to process and calculate the data of 31 provinces in China from 2011 to 2020, in which the ratio of the output value of the tertiary industry to that of the secondary industry is used to measure the advanced industrial structure, and the ratio of the output value of the tertiary industry to that of the secondary industry is used to measure the rationalization of industrial structure. The rationalization of industrial structure is measured by the inverse of the Thiel index measured by the ratio of the number of employees and output value among the three industries.

3.2.2. Core Explanatory Variables

At present, there is less relevant literature involving the specific measurement of the DE, and it can be seen through the concept of the DE that the carrier of the development of the DE is the Internet, and at the same time, digital financial inclusion is also an important embodiment of the development of the DE. Therefore, this paper makes use of the China Digital Financial Inclusion Index, which is jointly woven by the Digital Finance Research Centre of Peking University and Ant Financial Services Group, to measure the index, which is a comprehensive measure of digital financial coverage, depth of use and degree of digitalization.

3.2.3. Mechanism Variables

The level of innovation is an important determinant for the quality of a city's economic development. Most of the traditional indicators of innovation level use the number of patents granted, which has the problem of a single dimension. Therefore, this paper adopts the calculation method of the FIND Report on City and Industrial Innovation in China (2017) published by the Fudan Institute of Industrial Development to measure the innovation level of the region. The specific measurement of ER (res) is more complicated, there is no accepted method, and it is mainly measured by a single indicator or a multi-dimensional composite indicator. When cities face external shocks, the diversification of their secondary and tertiary industries can reduce the instability caused by external shocks and make the economy sustainable. Therefore, this paper uses the inverse of the Herfindahl-Hirschman Index (HHI) excluding the primary industry to measure the level of ER, which is calculated as follows:

$$res_{i,t} = \frac{1}{HHI_{i,t}} = \frac{1}{\sum_{k=1}^{n}(L_{ki}/L_i)^2} \tag{7}$$

Where k denotes the kth industry sector, n is the total number of industries, i denotes the region, t denotes time, L_{ki} denotes the number of people employed in industry k in region i and L_i denotes the total number of people employed in region i.

3.2.4. Control Variables

Per capita GDP (p_gdp): The GDP per capita can be used to measure the level of economic development of a region, and also to control the possible non-linear effects of the ISOU. Foreign trade dependence (f_dep): The regional foreign trade dependence is measured through the proportion of total regional import and export trade. The proportion of fiscal expenditure (p_fexp): Measure the proportion of regional fiscal expenditure by the ratio of local current fiscal expenditure to local current GDP. The proportion of financial deposit and loan (p_fdloa): it is measured by the ratio of total loans to total deposits in the local area in the current period.

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3.3. Data Sources

This paper collects panel data from 31 provinces in China from 2011 to 2020 as the basis of empirical evidence, and the relevant data are obtained from the degree of digital financial inclusion in China, which is jointly compiled by the Digital Finance Research Centre of Peking University and Ant Financial Services Group, as well as the China Statistical Yearbook and China Science and Technology Statistical Yearbook. The definitions and statistical descriptions of all variables of the econometric model test in this paper are described in Table 1.

Table 1. Definition and statistical description of variables.

Variable	definition	Mean	SD	Min	Max
adv	advancing of the industrial structure	1.335095	0.719638	0.527055	5.24401
rat	rationalizing of industrial structure	0.111638	0.132257	0.013122	1.225598
dig	DE	0.371055	0.173589	0.077329	0.98219 7
inno	regional innovation	0.418143 8	0.618417 9	0.00047	4.5186
f_dep	foreign trade dependence	0.246938	0.264939	0.007164	1.457694
p_fexp	Proportion of fiscal expenditure	0.283898	0.209987	0.11027	1.37916 1
p_fdloa	Proportion of financial deposits and loans	3.298413	1.216584	1.517519	8.13103
p_gdp	Gross domestic product	5.56948	2.719076	1.6413	16.4889 5
res	Regional ER	0.493963 8	0.089262 9	0.326562 3	0.83731 6

4. Empirical Analysis

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

4.1. Correlation Test

As shown in Table 2, the absolute value range of the correlation coefficient is roughly located between 0.1-0.78, and the correlation coefficient is less than 0.8, thus determining that the model's multicollinearity may be small. The coefficients of DE and industrial structure advanced and rationalization are 0.496 and 0.483 respectively, showing a positive correlation and at the 1% significance level, so it is initially judged that there is a significant correlation between DE and industrial structure optimization and upgrading. The correlation coefficients of innovation and industrial structure advancement and rationalization are 0.113 and 0.526, and innovation shows a strong correlation to industrial structure rationalization and a weak correlation to industrial structure advancement, and it is initially judged that there is a relationship between innovation for industrial structure advancement. Similarly, ER shows strong significant positive correlation to both industrial structure advanced and rationalization, and it is preliminarily judged that there is a relationship between ER and industrial structure advanced and rationalization.

Table 2. Correlation Test Results.

	adv	rat	dig	f_dep	p_fexp	p_fdloa	p_gdp	inno	res

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adv	1								
rat	0.485***	1							
dig	0.496***	0.483***	1						
f_dep	0.158***	0.601***	0.157***	1					
p_fexp	0.129**	-0.212***	-0.052	-0.310***	1				
p_fdloa	0.782***	0.523***	0.491***	0.310***	0.375***	1			
p_gdp	0.521***	0.720***	0.647***	0.573***	-0.310***	0.453***	1		
inno	0.113**	0.526***	0.483***	0.484***	-0.321***	0.160***	0.586***	1	
res	0.900***	0.590***	0.623***	0.337***	0.162***	0.845***	0.664***	0.251***	1

Note: ***, **, and *indicate the significance at the 1%, 5%, and 10% levels.

Further covariance test was conducted on the explanatory and control variables and the results of the test are shown in Table 3, the mean value of VIF is 2.29, which is significantly less than 10 and hence there is no problem of collinearity between the variables.

Table 3. Collinearity test results.

Variable	VIF	1/VIF
p_gdp	3.16	0.316555
p_fdloa	2.31	0.432626
dig	2.2	0.453711
p_fexp	1.9	0.527279
f_dep	1.89	0.529762
Mean VIF	2.29	

4.2. Benchmark Regression

The results of the ordinary panel data regression are shown in Table 4. From the results, it can be seen that the level of DE development has a significant positive effect on the industrial structure advanced and rationalization, and the effect of the DE on the industrial structure advanced is 0.953 when the control variables are not added, and the results are still significant after adding the control variables, the coefficient rises to 1.257, and the level of the DE has a significant positive effect on the industrial structure advanced , and the conclusion is consistent with the conclusion previously reached [15-16]. Meanwhile, the ratio of fiscal expenditure and GDP per capita also have significant positive effects on the industrial structure advanced and rationalization, and the ratio of deposit and loan has significant inhibiting effects on the industrial structure advanced and rationalization.

4.3. Tests for Regional Heterogeneity

Due to the differences in the level of development of industrial structure, the level of development of DE, the level of regional development and other realistic conditions in different regions, the ability and level of transformation and upgrading of the industrial structure in different regions show a large difference in reality. In order to examine the differences in the impact of the level of DE development on the ISOU in different regions, the 31 provinces in China are divided into three regions according to geographic location: east, central, and west, and the results of heterogeneity are shown in Table 5.

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Table 4. Benchmark regression result.

Explanatory variables	Explained Variables			
	FE	FE		
	adv	adv	rat	rat
dig	0.953*	1.257**	0.686***	0.876***
	(0.508)	(0.561)	(0.209)	(0.254)
f_dep		-0.0378		-0.00267
		(0.183)		(0.0829)
p_fexp		3.339***		0.597***
		(0.457)		(0.207)
p_fdloa		-0.0786**		-0.00988
		(0.0350)		(0.0158)
p_gdp		0.0467**		0.00407
		(0.0180)		(0.00816)
Observations	310	310	310	310
R-squared	0.685	0.748	0.252	0.279
Number of area	31	31	31	31

Note: ***, **, and *indicate the significance at the 1%, 5%, and 10% levels.

According to the results, it can be seen that the level of DE development has a significant positive propelling effect on industrial structure advanced in the economically developed regions in the east, but the effect on the central and western regions is not significant. This may be due to the digital divide in China's regional development, only in the more economically developed regions, the DE development will have a positive propelling effect on the industrial structure advanced, while in the more backward economic development, the DE development is not yet able to have an impact on the industrial structure advanced for the cities that have a late start in digitalization. In terms of the impact of the DE on the rationalization of industrial structure, the performance of the eastern region and the western region is more significant, and the positive propelling effect of the eastern region is stronger than that of the western region, while the central region does not have a more significant effect.

Table 5. Heterogeneity test results.

Explanatory variables	Explained Variables					
	east		central		west	
	adv	rat	adv	rat	adv	rat
dig	3.758***	1.864***	-2.391	0.307	-1.293	0.244***
	(0.854)	(0.582)	(2.376)	(0.448)	(0.898)	(0.0863)
f_dep	0.162	0.186	-1.402	-0.324	0.440	0.0289
	(0.262)	(0.179)	(1.105)	(0.208)	(0.360)	(0.0346)
p_fexp	2.116*	1.155	3.256*	0.717**	2.382***	0.131**
	(1.220)	(0.831)	(1.635)	(0.308)	(0.590)	(0.0567)
p_fdloa	0.0912	-0.0943**	-0.421***	-0.0529*	-0.191***	-0.00112
	(0.0660)	(0.0450)	(0.154)	(0.0291)	(0.0404)	(0.00388)
p_gdp	0.0397	-0.0236	-0.0976	-0.00392	-0.00703	0.00777**
	(0.0280)	(0.0191)	(0.0667)	(0.0126)	(0.0397)	(0.00381)
Observations	110	110	80	80	120	120
R-squared	0.835	0.390	0.849	0.653	0.725	0.664
Number of area	11	11	8	8	12	12

Note: ***, **, and *indicate the significance at the 1%, 5%, and 10% levels.

4.4. Robustness Test

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In order to verify the reliability of the research results, this part of the robustness test was carried out, due to the economic cyclicality of the development of the DE, the lag one period of the data economy was used as an instrumental variable for the original explanatory variables, and the results of the test are shown in Table 6. The direction and significance of the DE's influence on the advanced industrial structure and the rationalization of the industrial structure are consistent with the benchmark model, proving that the research results of this paper are reliable.

Table 6. Robustness test result.

Explanatory variables	**Explained Variables**			
	adv	**adv**	**rat**	**rat**
L.dig	1.949***	2.349***	1.126***	1.303***
	(3.24)	(3.72)	(4.25)	(4.25)
f_dep		0.275		-0.039
		(1.43)		(-0.42)
p_fexp		3.195***		0.486**
		(7.44)		(2.33)
p_fdloa		-0.060*		0.000
		(-1.68)		(0.01)
p_gdp		0.056***		0.002
		(3.22)		(0.28)
Constant	0.826***	-0.251	-0.066*	-0.220**
	(10.14)	(-1.14)	(-1.84)	(-2.06)
Observations	279	279	279	279
R-squared	0.693	0.756	0.278	0.304
Number of area	31	31	31	31

Note: ***, **, and *indicate the significance at the 1%, 5%, and 10% levels.

5. Mechanism Analysis

5.1. Mediating Effect

In this paper, we follow the analysis of Baron 25 to test the mediation effect, and the mediation effect regression results are shown in Table 7, in which model (1) to model (3) present the role played by the innovation level in the DE on the advanced industrial structure, and model (4) to model (6) present the role played by the innovation level in the DE on the rationalization of industrial structure. From model (1) and (4), it can be seen that the DE has a significant positive impact on the advancement and rationalization of industrial structure. Secondly, by testing the relationship between the mediator variable and the dependent variable, it can be seen from models (2) and (5) that the DE has a significant positive impact on the level of innovation. Finally, from model (3) and (6), it can be seen that the coefficient and significance of the DE's influence on the industrial structure advancement and rationalization decreased significantly after the innovation level was added as a mediator variable, and this phenomenon shows that the innovation level partially mediates the relationship between DE and advancement and rationalization of industrial structure.

Table 7. Mediating effect regression results.

Explanatory	**Explained Variables**					
variables	**adv(1)**	**inno(2)**	**adv(3)**	**rat (4)**	**inno (5)**	**rat (6)**

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dig	1.257**	19.07***	1.051*	0.876***	19.07***	0.645**
	(0.561)	(5.821)	(0.570)	(0.254)	(5.821)	(0.250)
inno			0.0108*			0.0121***
			(0.00590)			(0.00258)
f_dep	-0.0378	-8.340***	0.0524	-0.00267	-8.340***	0.0981
	(0.183)	(1.899)	(0.189)	(0.0829)	(1.899)	(0.0827)
p_fexp	3.339***	14.52***	3.182***	0.597***	14.52***	0.421**
	(0.457)	(4.740)	(0.463)	(0.207)	(4.740)	(0.203)
p_fdloa	-0.0786**	0.178	-0.0805**	-0.00988	0.178	-0.0120
	(0.0350)	(0.363)	(0.0348)	(0.0158)	(0.363)	(0.0153)
p_gdp	0.0467**	1.182***	0.0339*	0.00407	1.182***	-0.0102
	(0.0180)	(0.187)	(0.0193)	(0.00816)	(0.187)	(0.00843)
Constant	0.0453	-8.316***	0.135	-0.178*	-8.316***	-0.0775
	(0.221)	(2.297)	(0.226)	(0.100)	(2.297)	(0.0989)
Observations	310	310	310	310	310	310
R-squared	0.748	0.677	0.751	0.279	0.677	0.334
Number of area	31	31	31	31	31	31

Note: ***, **, and *indicate the significance at the 1%, 5%, and 10% levels.

5.2. Moderation Effect

Based on the previous theoretical analysis of ER as a moderating variable to construct the moderating effect model, the empirical results are shown in Table 8. From model (1) and model (2), it can be seen that after adding ER as a mediating variable into the model, both the DE and ER show significant negative effects with industrial structure advanced, but the interaction term of the two shows a significant positive correlation with industrial structure advanced. This result suggests that the effects of DE and ER on industrial structure advancement are interpenetrating and substituting each other. From model (3) and model (4), it can be seen that both DE and ER present a significant positive influence on industrial structure rationalization, but the interaction term of the two presents a significant negative correlation with industrial structure rationalization. This result shows that the effects of DE and ER on industrial structure rationalization are also interpenetrating and substituting each other. In regions with higher ER, the impact of DE on industrial structure rationalization is significantly enhanced and the impact on industrial structure advanced is significantly weakened. Therefore, ER is not simply a moderating role in DE driving industrial optimization and upgrading, but has an antagonistic role.

5.3. Threshold Effect

The innovation level is set as a threshold variable, and 500 bootstrap iterations are used to calculate the statistical value of F and the threshold critical value of the innovation level, and the random seed 1234567 is set to achieve the reproducibility of the regression results, and the results of the threshold effect are shown in Tables 9 and 10. When the explanatory variable is the rationalization of the industrial structure, there is a single threshold effect with a threshold value of 0.1072. When the explanatory variable is rationalization of industrial structure, there is a triple threshold effect between DE and rationalization of industrial structure, and the threshold values are 6.3667, 10.7746, and 12.8330 respectively.

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Table 8. Moderating effects test.

Explanatory variables	Explained Variables			
	adv (1)	adv (2)	rat (3)	rat (4)
dig*inno	0.232***	0.233***	-0.0226**	-0.0410***
	(0.0171)	(0.0164)	(0.00906)	(0.00954)
dig	-1.729***	-2.430***	0.385***	1.520***
	(0.442)	(0.495)	(0.0847)	(0.288)
res	-0.0401***	-0.0382***	0.00962**	0.0153***
	(0.00822)	(0.00791)	(0.00436)	(0.00461)
f_dep		-0.606***		0.0948
		(0.143)		(0.0834)
p_fexp		1.730***		0.965***
		(0.371)		(0.216)
p_fdloa		-0.0683**		-0.0212
		(0.0275)		(0.0160)
p_gdp		0.0188		0.00559
		(0.0139)		(0.00810)
Constant	1.355***	1.270***	-0.0411	-0.448***
	(0.0859)	(0.195)	(0.0375)	(0.114)
Observations	310	310	310	310
R-squared	0.813	0.859	0.236	0.332
Number of areas	31	31	31	31

Note: ***, **, and *indicate the significance at the 1%, 5%, and 10% levels.

Based on the test results in Table 9, the threshold model regression results are derived by regressing the threshold effect model, as shown in Table 10. When the explanatory variable is industrial structure advancement, when the innovation level is below the threshold value of 0.1072, DE is not significant to industrial structure advancement, and when the ER is above the threshold value of 0.1072, the impact of the DE on the industrial structure advancement has a negative to positive, with a more significant positive impact. When the explanatory variable is the rationalization of industrial structure, the change of the four intervals shows an inverted "U" shape, when the innovation level is below the threshold value of 6.3667, DE has a significant positive impact on the rationalization of industrial structure; when the innovation level is located between the threshold value of 6.3667 and 10.7746, DE has a significant positive impact on the rationalization of industrial structure; when the innovation level is located between the threshold value of 6.3667 and 10.7746, DE has a negative impact on the rationalization of industrial structure. The promotion effect of DE on the rationalization of industrial structure is significantly enhanced; when the innovation level is located between the threshold value of 10.7746 and 12.8330, the promotion effect of DE on the rationalization of industrial structure is the most obvious; when the innovation level is located above the threshold value of 12.8330, the promotion effect of DE on the rationalization of industrial structure has been weakened, and the coefficient becomes 0.398, but it is still significantly positive.

Table 9. Threshold effect test.

Explained Variables	Model	Threshold	F-value	P-value	1%	5%	10%	95 % Confidence Interval

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	Singl			0.032	47.820	37.28	32.09	
adv	e	0.1072	39.26	0	5	11	50	[0.0097, 0.1194]
	Singl			0.044	121.74	57.60	39.70	
rat	e	6.3667	63.01	0	93	55	41	[4.9472, 6.6191]
	Dou			0.024	89.370	59.51	36.36	
	ble	10.7746	66.63	0	0	91	33	[6.6191, 12.8330]
	Thre	12.83		0.062	132.02	39.97	27.24	
	e	30	34.94	0	00	65	37	[5.3027, 13.9832]

Table 10. Threshold effect regression.

Explanatory variables	**Explained Variables**	
	adv	**rat**
0.dig	-0.237	0.237***
	(0.263)	(0.0717)
1.dig	0.530*	0.397**
	(0.310)	(0.162)
2.dig		0.909**
		(0.341)
3.dig		0.398***
		(0.125)
p_gdp	0.0694	-0.0147
	(0.0438)	(0.00909)
f_dep	-0.131	0.0289
	(0.340)	(0.114)
p_fexp	2.481***	0.238
	(0.842)	(0.194)
p_fdloa	0.0281	-0.0209
	(0.0721)	(0.0155)
Constant	0.0136	0.0875
	(0.406)	(0.0796)
Observations	310	310
R-squared	0.755	0.525
Number of area	31	31

Note: ***, **, and *indicate the significance at the 1%, 5%, and 10% levels.

5. Conclusions and Discussion

Under the high-speed development of DE, traditional industries have received a huge impact, and most traditional industries are transformed and upgraded along with the trend of industrial digitalization, which is a new driving force to promote the ISOU by combining the traditional industries with the DE, and it is also the key to the emergence of new development pathways for the traditional industries in the new era.

This paper collects panel data from 31 provinces in China from 2011 to 2020, analyzes the effect of DE on the ISOU as well as regional differences by using a two-way fixed-effects model, and selects ER as a moderator variable and innovation level as a mediator, and constructs an econometric model

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to investigate the driving mechanism between the DE and the ISOU. The results of the study show that: firstly, DE has a significant positive effect on the rationalization and advanced industrial structure; secondly, DE has a significant positive effect on the advanced industrial structure in the eastern economically developed regions, but not in the central and western regions, where there is a big difference in economic development. The DE has a significant positive propelling effect on the rationalization of industrial structure in the eastern region and the western region, and the positive propelling effect in the eastern region is significantly stronger than that in the western region, and there is not a more significant effect in the central region; thirdly, the impact of the DE on the advanced industrial structure can be realized through innovation, which plays a partly intermediary role, and has a similar impact on the rationalization of industrial structure; fourthly, the DE and ER on industrial structure advanced and rationalization present the characteristics of antagonistic, in the region with higher ER, the impact of the DE on industrial structure rationalization will be significantly strengthened, and the impact on industrial structure advanced will be significantly weakened; Fifthly, taking the level of innovation as a threshold variable, it is found that there is a significant threshold effect of the DE to promote the optimization and upgrading of the industrial structure, in which the There is a single threshold effect of DE on industrial structure advancement, and the threshold value of ER is 0.8650, which can better promote industrial structure advancement than this threshold value, and there are four intervals of changes in the impact on industrial structure rationalization, with an overall inverted "U" shape.

Based on the above research conclusions, combined with the actual development of China's DE and innovation capacity, we propose countermeasures in the following aspects to better promote the ISOU:

First, tap China's advantages as a mega-market and its application advantages to promote digital industrialization and industrial digitalization, bringing sustainable momentum to the ISOU. Vigorously develop the DE, accelerate the construction of digital infrastructure, strengthen the scope of Internet penetration in backward areas, strengthen the construction of public information service platforms, guide the industry to shift from the traffic dividend to the technological dividend, encourage the innovation capacity of enterprises, grow and cultivate the digital market, and effectively enhance the growth potential and resilience of the real economy.

Second, based on the characteristics of the local market, the development of the DE according to local conditions. The development of the DE has a significant impact on the industrial structure, and it is necessary to investigate the structure and details of the local industrial structure, to transform and upgrade the local industrial structure, and to maximize the release of the impact of the DE on the local industrial structure. At the same time, China's central and western regions have large differences in economic development, slow development of the DE, the impact of the ISOU is not significant, therefore, we need to vigorously support the development of the digital industry in the central and western regions, to drive the development of the local DE, to avoid the digital divide brought about by the digitalization of the industry as well as the differences in the regional development of the problem.

Third, grasp the new opportunities of DE development and build a high-quality industrial structure layout. All regions should grasp the historical opportunities brought by the DE for the ISOU, develop the local DE and innovation capacity, follow the law of coordinated development of the regional economy, identify the layout and positioning of the digital industry, and reasonably formulate the development plan for the transformation and upgrading of the industrial structure, so as to promote the advancement, rationalization and digitization of the local industrial structure, and push forward the formation of the high-quality economic development layout with complementary advantages.

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