The Impact of the Digital Economy on the Optimization of Industrial Structure: An Empirical Study Based on the Intermediary Role of Technological Innovation

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Abstract. The digital economy has become an important path for the transformation and upgrading of industrial structure. Technological innovation, as the primary driving force for development, is a key entry point in analyzing this issue. This paper conducts empirical analysis based on Panel data of 31 provinces in China from 2011-2021, and constructs Mesomeric effect and moderating effect models. Research has found that the development of the digital economy has a significant promoting effect on the rationalization of industrial structure; The digital economy can promote the improvement of technological innovation level; From a national perspective, the level of technological innovation reflects the masking effect in the process of promoting industrial structure rationalization in the digital economy, and this conclusion is still valid after robustness testing.Based on this, we need to strengthen the construction of digital infrastructure, rely on the digital economy to stimulate independent innovation and technological transformation level, and promote the upgrading of industrial structure.

Keywords: digital economy;scientific and technological innovation; rationalization of industrial structure;Mesomeric effect.

1. Introduction

The digital economy, as an economic activity that uses data as a production factor and the Internet as a carrier, has increasingly become a new driving force for economic development nowadays. The CPC Central Committee attaches great importance to the development of the "14th Five Year" Digital Economy Development Plan.Various provinces and cities have also set development goals for the digital economy, using it as an important engine for stabilizing growth and promoting development.The digital technologies such as 5G, cloud computing, and artificial intelligence, which embody the connotation of the digital economy, are the result of technological innovation and provide data as a new production factor, driving the development of innovation. The 18th National Congress of the Communist Party of China established the core position of technological innovation in economic development. Technological innovation can transform and enhance traditional industries,and is an important way to promote the rational optimization of industrial structure. Based on this, this article intends to examine the impact of digital economy development on industrial structure optimization from the perspective of the intermediary role of technological innovation, which is of great significance for finding the focus of the integration of digital economy and real economy, and better realizing the value of technological innovation and data production factors.

2. Literature review

The growth mode of China's economy is shifting from extensive to high value-added supported by knowledge and technology.Big data, cloud computing, the Internet of Things, blockchain, artificial intelligence, 5G communication and other emerging information technologies, as carriers [i]of the digital economy, can improve social output according to the conclusions of Mary O'Mahony, Michela Vecchi (2005) based on data from the United States and the United Kingdom. Frederico Cruz Jesus et al. (2017), [ii]based on data from 110 countries, found that there is a non-linear relationship between the digital economy and economic development, which is more significant for poor countries. This provides new ideas for high-quality economic growth in China.

With the transformation and upgrading of industrial structure, the endogenous driving force of economic growth continues to strengthen, further consolidating the balance and sustainability of development.Many scholars are committed to exploring the effects and mechanisms of digital economy development on industrial structure transformation and upgrading.The focus includes business models, product innovation, and other aspects. Jing Wenjun and Sun Baowen (2019) believe that the widespread application of digital technology has created an innovation driven business model, which helps stimulate the innovation drive of enterprises and create a practical environment of "mass entrepreneurship and innovation"[iii]. Zhu Heliang and Wang Chunjuan (2020) believe that the digital economy empowers traditional industries,create space for value appreciation for traditional industries,and promote the transformation and upgrading of traditional industries.[iv]

Some scholars have conducted empirical research to test the mediating role of innovation and entrepreneurship. Patricia Kotnik, Rok Stritar (2015), based on Slovenia's Panel data, pointed out that the higher the utilization rate of information technology, the higher the entrepreneurship rate.[v]Li Zhiguo et al. (2019) found that the level of innovation and entrepreneurship is an important transmission path for the transformation and upgrading effect of the digital economy industry. By stimulating regional innovation and entrepreneurship vitality, the digital economy can accelerate the speed of industrial transformation and promote the height and rationalization of industrial structure.[vi]Liu Yang and Chen Xiaodong (2021) believe that the digital economy can indirectly promote industrial structure upgrading by influencing human capital and technological innovation[vii]. On the other hand, the level of technological innovation may also bring masking effects. When Yin Xiangsen et al. (2022) conducted a heterogeneity test of the digital economy on the rationalization of industrial structure, they found that the level of technological innovation in the national, eastern, and western regions weakened the role of the digital economy in the adjustment of industrial structure rationalization, which means there is a masking effect. Therefore, it is necessary to promote the coordinated development of technology among industries.[viii]

After reviewing existing literature, it was found that there are the following shortcomings. There has been less research discussing the potential shortcomings and negative impacts of technological innovation. Therefore, the main content and contributions of this article are as follows: the main discussion is about the masking effect of technological innovation level in promoting the rationalization of industrial structure in the digital economy, further improving the analysis framework of possible paths for promoting industrial structure optimization in the digital economy, and providing policy recommendations for the current shortcomings in the development of the digital economy.

3. Theoretical analysis and research hypotheses

The rationalization of industrial structure refers to the dynamic adjustment process of adjusting the industrial structure that is not suitable for the current level of economic development under the constraints of existing resource conditions and technological levels, scientifically allocating production factors based on existing demand structures and technological levels, and making the layout of factors between and within industries tend to be rationalized. The digital economy reduces transaction costs and energy consumption by deeply integrating digital technology with the real economy, effectively allocating resources, enhancing coordination and correlation between industries, and increasing the degree of rationalization of industrial structure. Digital technologies such as the Internet have eliminated obstacles to the transfer of elements and products, thereby comprehensively improving the efficiency of supply and demand matching. The transfer of labor from heavy industry to high-tech, sustainable industries enables balanced development of production efficiency among industries.The result is a balance of labor production efficiency across various industries. The industrial structure is in a reasonable state (Gan Chunhui, 2011). [ix]In addition, digital information enterprises have created a large number of employment opportunities in the upstream, middle, and downstream of production by integrating and infiltrating the development of industrial and agricultural enterprises, effectively absorbing idle labor resources and expanding production. (Cong Yi et al., 2020) [x]Based on this, this article proposes the following hypothesis:

Hypothesis 1: The development of the digital economy can promote the rationalization of industrial structure.

The digital economy uses data as a production factor, bringing about significant changes in the form of production organization. For example, e-commerce, as an innovative model of the digital economy, improves business processes through internet technology, integrates consumer demand information, financial supply information, logistics information, and business information to achieve value added. (Wen Jun et al., 2019) [xi]In addition, compared with traditional production factors, data factors have a significant increasing effect on Returns to scale. The average cost of digital infrastructure involving 5G, data center, cloud computing and artificial intelligence decreases with the increase of users. From the perspective of the entire production end, the Marginal revenue increases. (Wang Weiling et al., 2019) [xii]When the entire industrial chain is integrated with digital technology, the efficiency of the industrial chain will greatly improve. The increase in profitability releases a large amount of idle resources, which correspondingly become the driving force for regional innovation. (Thompson, 2013) The [xiii]digital economy can also promote the flow of regional innovation factors to enhance regional innovation capabilities. Regional innovation capability is influenced by various factors such as innovation policy environment, talent flow, capital flow, technological level, and industrial development (Xiong Li, 2020)[xiv]. The digital economy plays a role in promoting information dissemination, providing technical support for the flow of innovative factors, and reducing the obstacles faced by factor flow. The effective utilization of innovative elements in the entire economic and social field will bring more innovative results. Based on this, [xv]this article proposes the following hypothesis:

Hypothesis 2: The development of the digital economy can improve the level of technological innovation.

Digital economy may also realize the rationalization of industrial structure by promoting the Mesomeric effect of scientific and technological innovation. Digital technology itself has certain learning and innovation capabilities, and applying these technologies to various industrial sectors can improve the efficiency of industrial rationalization. [xvi]Secondly, the combination of data elements and human resources has greatly improved the production efficiency of labor force and stimulated a series of innovative activities, thereby promoting the leap of industrial structure towards a more reasonable stage. (Guo Kaiming, 2019) The [xvii]digital economy has excellent attributes such as high-speed informatization and inclusivity in optimizing the technology investment and financing environment, which to some extent compensates for the three inherent defects of scientific and technological innovation, namely long R&D cycles, high R&D risks, and high R&D costs, and eliminates the obstacles faced by the rationalization of industrial structure. (Liang Yijuan et al., 2022) [xviii]Technological innovation has broken the original equilibrium state of the economy, causing corresponding changes in the structure of industrial factors and demand. The production efficiency of various industrial departments has improved to varying degrees, and the industrial structure is tending towards rationalization. However, technological innovation may have problems with unreasonable regional and industrial allocation, resulting in polarization effects (Yin Xiangsen et al., 2022)[xix]. By absorbing resources from surrounding areas, the economic development level and labor force of a certain region may expand unreasonably, while the surrounding areas may shrink relatively, which is not conducive to the rationalization of industrial structure. Based on this, the following assumptions are proposed:

Hypothesis 3: The digital economy promotes the rationalization of industrial structure through technological innovation as a medium.

Hypothesis 4: There is a masking effect in the transmission process of technological innovation.

4. research method

4.1 Model Settings

4.1.1Mesomeric effect model

The Mesomeric effect model is used to test the transmission effect of scientific and technological innovation on the rationalization of industrial structure at the level of the digital economy.

$$rsp_{it} = \beta_0 + \beta_1 ded_{it} + \beta_2 til_{it} + \beta_3 x_{it} + \delta_{it} + \varepsilon_{it} \quad (1)$$

$$rsp_{it} = \alpha_0 + \alpha_1 ded_{it} + \alpha_2 x_{it} + \delta_t + \varepsilon_{it} \quad (2)$$

$$til_{it} = \gamma_0 + \gamma_1 ded_{it} + \gamma_2 x_{it} + \delta_{it} + \varepsilon_{it} \quad (3)$$

Among them, the dependent variable rsp_{it} indicates the level of rationalization of the industrial structure of province i at time t. Mediating variable til_{it} indicates the technological innovation level of the province at time t. Explanatory variable ded_{it} indicates the level of digital economy development in province i at time t, x_{it} represents a series of control variables, δ_{it} for fixed time effects, ε_{it} is a random perturbation term. $\beta_0 \alpha_0 \gamma_0$ both are intercept terms, $\beta_1 \beta_2 \alpha_1 \gamma_1$ the coefficient of the core explanatory variable.

For the interpretation of the results, refer to the [xx]research by Wen Zhonglin et al. (2014). if $\alpha_1 \gamma_1 \beta_1 \beta_2$ through the significance test, it shows that the level of scientific and technological innovation has played a part of the Mesomeric effect in the process of the digital economy level's rationalization of the industrial structure; if β_2 is not significant, use bootstrap method to test $\gamma_1 \beta_2$. If significant, it indicates significant indirect effects; Continue to judge $\alpha_1 \beta_2$ and γ_1. The same sign means part of the Mesomeric effect, while the different sign reflects the masking effect.

Moderating effect model

To gain a deeper understanding of the role of technological innovation level in the process of industrial structure rationalization at the level of the digital economy, equation (1) is expanded by introducing an interaction term between technological innovation level and the level of the digital economy.The model is shown in (4).

$$rsp_{it} = a_0 + a_1 ded_{it} + a_2 til_{it} + a_3 ded_{it} * til_{it} + a_4 x_{it} + \delta_t + \varepsilon_{it} \quad (4)$$

The coefficient of interactive item $ded_{it} * til_{it}$ measures the impact of the interaction between the digital economy and technological innovation on the rationalization of industrial structure. If the interaction coefficient a_3 and a_1 have the same sign,it indicates that the impact of the digital economy on the rationalization of industrial structure increases with the increase of regulatory variables.

4.2 Variable definition and measurement

4.2.1 Explanatory variable: level of rationalization of industrial structure（rsp_{it}）

The level of rationalization of industrial structure reflects the coordination ability and degree of correlation between industries. This article draws on the [xxi]research of Gan Chunhui et al. (2011) and adopts the Thiel index（rsp_{it}）To measure. The formula is:

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

Among them, Y_i is the output value of industry i, L_i refers to the number of employees in industry i, N=3. Theil indexrsp_{it}as a reverse indicator, the closer its value approaches 0, the higher the coordination ability and degree of correlation between industries, which means it is becoming more reasonable; On the contrary, it indicates that the current industrial structure coordination ability and degree of correlation are weaker, which is more unreasonable.

4.2.2 Explanatory variable: Development level of digital economy(ded_{it})

This article draws inspiration from the [xxii]research of Zhao Tao et al. (2020) and constructs a comprehensive indicator of the development level of the digital economy from two aspects: internet development and digital financial inclusion. At the level [xxiii]of internet development, drawing on the research of Huang Qunhui et al. (2019), including the penetration rate of mobile phones, the situation of relevant employees, the output of internet related industries, and the internet penetration rate, the corresponding actual content is shown in the table below. At the level of digital financial inclusion, China's digital Financial inclusion index jointly prepared by the Digital Finance Research Center of Peking University and Ant Financial Services Group is adopted. By using principal component analysis to standardize and reduce the dimensionality of the data for the above five indicators, the development level of the digital economy obtained is recorded as ded_{it}.

Measurement system for the development level of digital economy, industrial structure transformation and upgrading level, and technological innovation level

Explanatory variable	Secondary indicators	Third level indicators
Development level of digital economy	Internet penetration rate	Number of internet broadband access users
	Information of relevant practitioners	Number of information and e-commerce enterprises
	Related output situation	Total telecommunications business volume
	Mobile phone penetration rate	Number of mobile phone users

Dependent variable	Secondary indicators	Third level indicators
The level of industrial structure transformation and upgrading	rational structure of production	Theil index
Mediating variable	Secondary indicators	Third level indicators
Technological innovation level	Technology investment level	Number of high-tech industry research and development institutions
		Full time equivalent of RD personnel in various regions
		Internal expenditure of high-tech industry RD funds
		Intensity of RD funding investment in various regions
		High tech industry Product development expenditure
		Technical transformation expenditure
		The proportion of education and technology expenditure to GDP

	Technological Innovation Environment	Number of students enrolled in higher education institutions per 100000 people
		Postal and telecommunications business volume
		Urban density
		Passenger turnover
		Per capita possession of public library collections
		Gross regional product
		Resident consumption level
	Technology output capacity	Number of patent applications authorized
		Total number of book publications
		Number of invention patent authorizations
		Output value of new products in high-tech industries
		Technology Market Turnover
	Enterprise innovation capability	Investment in research and development funds for new products in high-tech industries
		Number of new product projects in high-tech industries
		Patent application status of industrial enterprises above designated size

4.2.3 Intermediary variable: level of technological innovation（til_{it}）

A large amount of literature has constructed comprehensive indicators to measure the level of technological innovation. This article draws on the [xxiv]research of Bawu'er River et al. (2012) and measures it from four levels. They are science and technology input level, science and technology innovation environment, science and technology output capability, and enterprise innovation capability. The corresponding actual contents are: the number of high-tech industry R&D institutions, the full-time equivalent of RD personnel in each region, the internal expenditure of high-tech industry RD funds, the intensity of regional RD funds investment, high-tech industry Product development funds expenditure, technological transformation funds expenditure, the proportion of education and technology expenditure in GDP, the number of college students per 100000 people, post and telecommunications business volume, Urban density, passenger turnover Per capita possession of public library collections, Gross regional product, residents' consumption level, number of patent applications, total number of books published, number of invention patent authorizations, high-tech industry new product output value, technology market turnover, high-tech industry new product research and development funds, high-tech industry new product projects, and patent applications of industrial enterprises above designated size. By using principal component analysis to standardize and reduce the dimensionality of the above four levels of data, the level of technological innovation can be obtained, denoted as til_{it}.

4.2.4 Control variables

To minimize the impact of endogeneity, this article selects five control variables that may affect industrial structure. Including: (1) Fiscal expenses（fe）. Measured by the proportion of local general Public budgeting expenditure in GDP. The government guides the direction of private investment through indirect means, such as fiscal subsidies and tax incentives, to play its guiding function and multiplier effect on industrial structure adjustment. (Chu Deyin et al., 2014) [xxv](2) Economic

Development Level（pgdp）. Measured by per capita GDP. (3) Human resources（hr）. Measure with newly added unemployed personnel. The quality and structure of human resources constrain the rationalization of industrial structure. (4) Social consumption（soc）. Measured by the proportion of social retail consumption to GDP. (5) Foreign investment（fdi）. Expressed as the total amount of foreign investment. Foreign direct investment is often concentrated in the Primary sector of the economy with a small investment scale and the Secondary sector of the economy with a low investment proportion, especially in the industrial sector, which has contributed to the uncoordinated structure of China's three industries. (Guo Kesha, 2000)[xxvi]

4.3 Data source

This paper is based on Panel data of 31 provinces in China from 2011-2021. The data are all from China Statistical Yearbook, China Science and Technology Statistical Yearbook, China High tech Industry Statistical Yearbook, China Labor Statistics Yearbook and provincial statistical yearbooks. The missing data are supplemented by Linear interpolation.

Table 1 Descriptive Statistics of Various Variables

	(1)	(2)	(3)	(4)	(5)
variable	sample size	mean value	standard deviation	minimum value	Maximum value
rsp_{it}	341	0.410	0.197	0.054	0.880
ded_{it}	341	1.495	0.975	0.168	5.048
til_{it}	341	1.987	0.897	0.564	5.062
fe	341	0.281	0.203	0.119	1.291
pgdp	341	57,794	28,390	19,710	164,220
hr	341	37.98	29.13	1.200	151.0
soc	341	0.382	0.0660	0.227	0.546
fdi	341	2,196	3,716	13	21,672
Number of groups	31	31	31	31	31

5. Empirical analysis

5.1 Benchmark regression results

The following table reports the regression results of Mesomeric effect. In model (1) and (3), the development level of the digital economy（ded_{it}）The estimated coefficient is significantly negative, and the digital economy has promoted the rationalization of industrial structure. In model (2), the development level of the digital economy（ded_{it}）The estimated coefficient is significantly positive, indicating that the digital economy has promoted the improvement of technological innovation level. In model (3), the intermediate variable of technological innovation level（til_{it}）Not significant and with a positive coefficient. Bootstrap test was conducted, and the result rejected the original hypothesis, proving the existence of Mesomeric effect. Due to the positive coefficient of technological innovation level, it indicates that the level of technological innovation reflects the masking effect in the process of industrial structure rationalization influenced by the digital economy. The possible reason is that technological innovation is mainly concentrated in high-tech or emerging industries, and the low level of innovation in traditional industries has led to an uneven distribution of innovation among industries. This unreasonable aggregation causes polarization effects, which in turn leads to low efficiency in market resource allocation, leaving room for improvement in technological innovation in promoting the rationalization of industrial structure.

In addition, social consumption（soc） passed the 1% significance test in all three models, indicating that Consumer behaviour has played an important role in the rationalization of industrial structure.

Table 2 Benchmark Regression Results

	(1)	(2)	(3)
	rsp_{it}	til_{it}	rsp_{it}
ded_{it}	-0.105***	0.692***	-0.117***
	(0.014)	(0.050)	(0.017)
fdi	0.000	0.000***	0.000
	(0.000)	(0.000)	(0.000)
fe	-0.189	0.624	-0.200
	(0.150)	(0.552)	(0.150)
hr	0.000	0.006***	0.000
	(0.000)	(0.000)	(0.000)
pgdp	0.000	0.000***	0.000
	(0.000)	(0.000)	(0.000)
soc	-0.554***	-1.346***	-0.530***
	(0.102)	(0.375)	(0.104)
til_{it}			0.017
			(0.016)
_Cons	0.815***	0.549*	0.806***
	(0.063)	(0.231)	(0.063)
N	341	341	341

5.2 Analysis of regulatory effects

The following table reports the results of the moderating effect. The coefficient of interaction term in model (4) is 0.021, and the coefficient of explanatory variable is -0.177, both of which are significant at the 1% significance level, indicating a significant moderating effect. The level of technological innovation has an impact on the role of the digital economy. However, the opposite sign indicates that the level of technological innovation weakens the adjustment effect of the digital economy on the rationalization of industrial structure. The impact of the digital economy on industrial development is U-shaped (Liu Fuhua et al., 2023)[xxvii]. Currently, although high-tech and emerging industries in economically developed regions of China have grown rapidly, the driving force for national technological innovation is not sufficient. This has led to a new structural and spatial imbalance in the overall productivity, production efficiency, and resource allocation of China's industries. The eastern region is significantly better than the central and western regions in terms of geographical location, resource endowment differences, and economic development level. At the same time, there are significant differences in the level of technological innovation among various industries in the region, which hinders the process of industrial rationalization.

Table 3 Regulatory effects

	(3)	(4)
	rsp_{it}	rsp_{it}
til_{it}	0.017	-0.049**
	(0.016)	(0.019)
ded_{it}	-0.117***	-0.177***
	(0.017)	(0.020)
fdi	0.000	-0.000
	(0.000)	(0.000)
fe	-0.201	-0.110

	(0.150)	(0.145)
hr	0.000	-0.000
	(0.000)	(0.000)
pgdp	0.000	0.000*
	(0.000)	(0.000)
soc	-0.530***	-0.423***
	(0.104)	(0.102)
ded ∗ til		0.021***
		(0.004)
_Cons	0.806***	0.861***
	(0.063)	(0.062)
N	341.000	341.000
R2	0.442	0.490
Adjusted r2	0.374	0.426

Note: * * *, * * and * respectively indicate that the regression results pass the significance test at the 1%, 5%, and 10% confidence levels.

6. Robustness testing

6.1 Replace the dependent variable

The transformation and upgrading of industrial structure includes two connotations: industrial upgrading and industrial rationalization. This article draws inspiration from the [xxviii]research of Han Jian et al. (2022) on the upgrading of industrial structure（ais）Measure and construct an industrial structure upgrading index that includes the first, second, and third industries.

$$ais = \sum_{m=1}^{3} y_{i,m,t} * m，\ m = 1,2,3$$

Among them, $y_{i,m,t}$ represents the proportion of the output value of the m-th industry in city i to the total regional output value during period t, the range of aisvalues is [1,3], which can reflect the general law and logical order of the gradual evolution of urban industrial structure from low to high levels, and is the connotation of the quantity of industrial structure upgrading.

The robustness test regression results of replacing the dependent variable are shown in the table below. Column (1) reports the regression results of the development level of the digital economy on industrial upgrading, Column (2) reports the regression results of the development level of the digital economy on the intermediary variable technology innovation level, and Column (3) reports the regression results after introducing the intermediary variable. It can be seen that both the dependent variable and the mediating variable in the three models are significant at the 1% level. The coefficient of technological innovation level -0.018 in column (3) is negative, indicating that the level of technological innovation reflects the masking effect in the process of industrial structure rationalization influenced by the digital economy. Consistent with benchmark regression results.

Table 4 Robustness test for replacing the dependent variable

	(1)	(2)	(3)
	ais	til_{it}	ais
ded_{it}	0.066***	0.692***	0.079***
	(0.006)	(0.050)	(0.007)
fdi	zero	0.000***	zero
	(0.000)	(0.000)	(0.000)
fe	0.274***	0.624	0.286***
	(0.064)	(0.552)	(0.063)
hr	-0.000***	0.006***	-0.000***

	(0.000)	(0.001)	(0.000)
pgdp	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
soc	0.272***	-1.345***	0.247***
	(0.044)	(0.375)	(0.044)
til_{it}			-0.018***
			(0.007)
_ Cons	2.080***	0.549**	2.090***
	(0.027)	(0.231)	(0.027)
N	341	341	341

Note: * * *, * * and * respectively indicate that the regression results pass the significance test at the 1%, 5%, and 10% confidence levels.

6.2 Replace explanatory variables

[xxix]For the measurement of digital economy development level indicators, refer to the research of Zhang Xueling et al. (2017), and use the entropy method to measure the digital economy development level of 31 provinces from 2011 to 2021. We still need to construct comprehensive indicators for the development level of the digital economy from the perspectives of internet development and digital financial inclusion. The robustness test regression results of the explanatory variables are shown in the table below. It can be seen that the regression results of the digital economy development level and industrial structure rationalization calculated using the entropy method are consistent with the benchmark regression results, both significant at the 1% level. The regression coefficient of technological innovation level on industrial structure rationalization is negative and not significant, further verifying the existence of the masking effect.

Table 5 Robustness test for replacing explanatory variables

	(1)	(2)	(3)
	rsp_{it}	til_{it}	rsp_{it}
ded_{it}	-0.576***	4.142***	-0.591***
	(0.086)	(0.318)	(0.108)
fdi	zero	0.000***	zero
	(0.000)	(0.000)	(0.000)
fe	-0.257	0.887	-0.261
	(0.152)	(0.559)	(0.153)
hr	zero	0.005***	zero
	(0.000)	(0.001)	(0.000)
pgdp	-0.000	0.000***	-0.000
	(0.000)	(0.000)	(0.000)
soc	-0.587***	-1.158**	-0.583***
	(0.104)	(0.381)	(0.105)
til_{it}			0.004
			(0.016)
_ Cons	0.835***	0.502*	0.833***
	(0.064)	(0.236)	(0.065)
N	341	341	341

Note: * * *, * * and * respectively indicate that the regression results pass the significance test at the 1%, 5%, and 10% confidence levels.

6.3 Eliminate extreme value interference

Extreme values can easily lead to regression curves leaning towards extreme values, which can lead to regression equations deviating from the true situation, resulting in overestimation or underestimation of certain regions. In this paper, we test this possible impact by tail shrinking. Specifically, we conduct 1% bilateral tail shrinking for the explained variable, the explanatory variable and the intermediary variable, and use the Mesomeric effect model for regression. It can be seen that the conclusion is basically consistent with the benchmark regression. The extreme values did not cause significant interference and the regression results were robust.

Table 6 Robustness Test for Excluding Extreme Value Interference

	(1)	(2)	(3)
	rsp_{it}	til_{it}	rsp_{it}
ded_{it}	-0.112***	0.615***	-0.118***
	(0.014)	(0.049)	(0.017)
fdi	zero	0.000**	zero
	(0.000)	(0.000)	(0.000)
fe	-0.206	0.646	-0.213
	(0.144)	(0.514)	(0.144)
hr	zero	0.002*	-0.000
	(0.000)	(0.001)	(0.000)
pgdp	0.000	0.000***	0.000
	(0.000)	(0.000)	(0.000)
soc	-0.521***	-1.068**	-0.510***
	(0.098)	(0.349)	(0.099)
til_{it}			0.010
			(0.016)
_ Cons	0.811***	0.606**	0.805***
	(0.060)	(0.215)	(0.061)
N	341	341	341

Note: * * *, * * and * respectively indicate that the regression results pass the significance test at the 1%, 5%, and 10% confidence levels.

7. Research conclusions and policy implications

Based on the Panel data of 31 provinces from 2011-2021, this paper analyzes the mechanism of scientific and technological innovation level and the impact of digital economy on the rationalization of industrial structure by using empirical analysis methods. The main conclusions drawn are as follows:

From the perspective of Mesomeric effect, the digital economy can significantly improve the rationalization of industrial structure, and also significantly improve the level of scientific and technological innovation. However, the level of technological innovation has brought about a masking effect, and this conclusion still holds after replacing the explained and explanatory variables and excluding extreme values. The regulatory effect model also reached similar conclusions, indicating that the relationship between China's digital economy and technological innovation needs to be optimized, and innovation activities are unevenly distributed among industries and regions. Policies can be introduced to support enterprises in digital technology innovation and appropriately tilt towards areas with weak digital infrastructure, guiding technological innovation to better serve and rationalize industrial structure.

Based on this, the following policy recommendations are proposed:

Seize the development opportunity and strengthen the construction of digital infrastructure. Infrastructure has the function of "leading capital", which restricts the degree and speed of the development of the digital economy. In terms of digital infrastructure, it is necessary to focus on regional balance, accelerate fiber optic network expansion, and promote the deployment and commercial application of 5G. Special policy support is needed for the underdeveloped digital infrastructure in the western region.

Guide the coordinated development of digital economy and technological innovation. Innovation is the key to Chinese path to modernization. By vigorously developing intelligent manufacturing technology, China has made a historic leap from a "manufacturing power" and "network power" to a "manufacturing power" and "network power". The report of the 20th National Congress of the Communist Party of China pointed out the need to "enhance the overall effectiveness of the national innovation system". This statement clearly points out that in order to achieve high-level technological independence and build a modern technological power, it is necessary to focus on the development of science and technology.

Plan to lead and strengthen the development of the digital economy industry. According to the requirements of promoting industrial structure transformation and achieving high-quality economic development, scientifically formulate a national digital economy industry development plan. The plan should reflect the current national conditions and future development prospects, and be able to integrate with the global digital economy industry as a whole, and be included in the global digital economy industry chain.

To play a positive role in independent innovation and technological transformation, the government should increase investment in research and development funds, ensure that enterprises have sufficient funds for research and development of new technologies, and provide economic support for independent innovation of enterprises. In addition, establish a stable intellectual property protection system to facilitate enterprises to apply for patents for newly developed products and fully mobilize the enthusiasm for scientific research and development. By developing core technologies, cultivating cutting-edge talents, and introducing key technologies to manufacturing enterprises, we can improve the conversion rate of technology and enhance the level of technological transformation in the manufacturing industry.

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