

Impact of Digital Economy Development on Industrial Structure Upgrading—An Empirical Analysis Based on PVAR Model

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Based on the panel data of 248 prefecture-level cities in China from 2011-2021, a PVAR model is constructed to empirically compare and analyze the impact of national and regional digital economy development on industrial structure upgrading. The results show that: from the national level, the development of the digital economy can significantly promote the upgrading of industrial structure, the degree of influence rises and then decreases, and lasts longer; the upgrading of industrial structure also affects the development of the digital economy, and the influence changes from negative to positive; there is a long-term, continuous, and significant dynamic effect between the digital economy and the transformation and upgrading of industrial structure, and the two affect each other. From the perspective of each region, the impact of digital economy development on industrial structure upgrading is somewhat different. The industrial structure in the western region is the most sensitive to the digital economy changes, followed by the eastern region and the weakest in the central region. However, the industrial structure upgrading in all regions is significantly and positively influenced by the development of the digital economy.

Keywords: Digital economy, industrial structure upgrading, PVAR model

Introduction

The digital economy is a new economic form developed by human society and is increasingly becoming a key driver of global economic development. In 2020, the scale of China's digital economy value added reached 39.2 trillion yuan, accounting for 38.6% of the GDP. This shows that the digital economy is gradually gaining prominence in the national economy, and the digital economy has become a new engine to drive China's economic growth. The digital economy is not only a growth point for economic development but also a support point for industrial structure upgrading. The practice has proved that the process of upgrading the industrial structure is the process of primary, secondary, and tertiary industries in turn, and cannot be separated from the promotion of science and technology. Currently, in the context of the new round of technological revolution, the industrial structure is constantly changing and showing new features, among which the changes caused by the digital economy are the most significant. Therefore, the study of the influence effect between the digital economy and industrial structure upgrading is conducive to releasing the development potential of the digital economy, grasping the opportunity of the technological revolution, and implementing industrial structure upgrading.

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Existing studies on the impact of the digital economy on industrial structure upgrading mainly focus on the following aspects: First, the direct or indirect impact of the digital economy on industrial structure upgrading is studied. Secondly, the data analyzed are inter-provincial or industry-level panel data, and the models are mainly static panel data models and VAR or SVAR models. However, this research idea can be improved: first, it is not limited to discussing the unilateral impact of the digital economy on industrial structure upgrading but can further study the dynamic interaction between the digital economy and industrial structure upgrading. Second, although the panel model used by previous scholars can reduce the endogeneity using the IV-GMM method, it still cannot completely eliminate the endogeneity. The time series VAR model can eliminate endogeneity but cannot take into account the advantages of panel data. The panel VAR model (PVAR), on the other hand, has both the advantages of the panel data model and the advantages of the time series VAR model in eliminating endogeneity. Not only individual effects and time effects are considered, but also impulse response plots can be used to analyze the effects of variable shocks on other variables.

Therefore, the marginal contributions of this paper are: first, based on the data at the prefecture-level city level in China, the data panel is expanded to further analyze the relationship between the digital economy and industrial structure upgrading, making the conclusions more general. Second, by establishing a PVAR model, which takes into account the advantages of panel data while eliminating the effects of endogeneity, study the impact of the digital economy on industrial structure upgrading, and use impulse response plots to analyze the impact of variable shocks on other variables. Thirdly, the dynamic interaction between the development of the digital economy and industrial structure upgrading is further studied.

Review of the Literature

Research on the Impact of Digital Economy Development on Industrial Structure Upgrading

Regarding the impact of digital economy on industrial structure upgrading, scholars have conducted research from different perspectives, at the theoretical level. Pradhan et al. (2019) believe that digital economy can promote industrial transformation and upgrading by improving production efficiency and optimizing resource allocation; Jing and Sun (2019) point out that the development of digital economy can promote industrial structure upgrading, and then promote high-quality economic development; Ren and Dou (2021) pointed out that the development of digital economy has given rise to a series of new industries as well as new models such as platform economy and sharing economy, which brings new opportunities for industrial structure upgrading; in terms of empirical evidence, Guan, Guo, and Zhang (2022) found that the development of digital economy has a significant positive contribution to the quantity and quality of industrial structure upgrading based on empirical analysis at the prefecture-level city level. Li and Han (2021) argue that the development of digital economy can promote the optimization and upgrading of industrial structure when analyzed from the perspectives of different regions in east, middle, and west China. In terms of investigating the influence mechanism, Zhao (2020) found that there is an extremely positive interaction between digital economy, market behavior, and market performance, which is one of the driving forces to achieve the optimization and upgrading of industrial structure; Su, Su, and Wang (2021) pointed out that the digital economy can play a role in promoting industrial structure upgrading through the intermediary path of technological innovation. Zhao (2022) pointed out that the digital economy significantly contributes to technological progress and human capital upgrading in Chinese cities, thus promoting the upgrading of industrial structure. Liu (2021) analyzed using the mediating effect model and found that the

development of the digital economy can influence the level of human capital and technological innovation capacity and thus the advanced and rationalized industrial structure in China.

Theoretical Analysis of the Digital Economy Affecting Industrial Structure Upgrading

Industrial structure upgrading refers to the process or trend of industrial structure transformation from lower to higher forms, and its intrinsic logic indicates that the intrinsic driving force of industrial structure upgrading is technological progress. As a new economic form, the digital economy optimizes resource allocation and promotes technological innovation based on the Internet platform, providing transformation and upgrading paths for traditional industries, while giving rise to new industries and influencing industrial structure upgrading. From the perspective of the conduction mechanism, the digital economy mainly has the following two mechanisms to influence the upgrading of industrial structure: First, the digital economy transforms traditional industries to promote the upgrading of industrial structure. The digital economy promotes the intelligent development of traditional industries, opens up the internal and external connection of each link of the industrial chain, forms the synergistic development relationship of upstream and downstream enterprises, strengthens the connection between various production sectors, improves the efficiency of factor resource allocation, and thus promotes the upgrading of industrial structure. Secondly, with the innovation and change of digital technology, industrial differentiation, and reorganization speed up, the process of integration among industries is greatly improved, new products and new modes of business are constantly formed, and the industrial ecology is reconstructed, meanwhile, the digital economy can give birth to new industries to promote industrial structure upgrading, and digital technology forms new industries through industrial development, such as Internet of Things, cloud computing, big data, artificial intelligence, biopharmaceuticals, new energy materials, high-end equipment manufacturing, etc. With the continuous innovation and maturity of digital technology, new industries will occupy an important position in the industrial ecosystem and drive the upgrading of industrial structure.

Model Setting

Data Source and Processing of Model Variables

The data in this study use the annual data of 248 prefecture-level cities in China from 2011 to 2021. Meanwhile, in order to eliminate heteroskedasticity, the indicators in this paper are taken as logarithms. The data in this paper are obtained from the China Urban Statistical Yearbook.

Variable Setting

Regional economic development level (RGDP): the local GDP per capita is used to measure the regional economic development level.

Industrial structure upgrading index (AIS): drawing on the method of Xu and Jiang (2015), the primary, secondary, and tertiary industries are included to construct the industrial structure upgrading index, and the measurement formula is:

$$\ln ais_{it} = \sum_{i=1}^{3} q_i \times i = q_1 \times 1 + q_2 \times 2 + q_3 \times 3$$
(1)

where, q_i is the proportion of the output value of *i* industry.

The development level of digital economy (ED): The digital economy index is calculated according to the approach of Zhao (2020), and the comprehensive index value is obtained by the entropy weighting method, as shown in Table 1.

Primary indicators	Secondary indicators	Units	Efficacy
Fundamentals of the digital economy	Number of internet broadband access users	Ten thousand households	+
	Number of employees in computer services and software industry	Ten thousand people	+
Digital economy applications	Telecommunications business revenue	Ten thousand yuan	+
Digital financial development	Number of cell phone subscribers	Ten thousand households	+
	Digital financial inclusion index	-	+

 Table 1

 Digital Economy Measurement System

Model Setting

This paper uses a panel VAR (PVAR) model to analyze the impact of the development of the digital economy on the upgrading of industrial structure and uses its impulse response to analyze the response of economic variables in the face of shocks. The general form of the PVAR model is:

$$\mathbf{y}_{it} = \alpha_{i} + \gamma_{t} + \sum_{j=1}^{k} \Gamma_{j} \, \mathbf{y}_{it-1} + \mu_{it} \tag{2}$$

where, y_{it} is the vector of endogenous variables of digital economy development, industrial structure upgrading, and regional economic development level. *i* represents each prefecture-level city, *t* represents the year, Γ is a 3 × 3 coefficient matrix, *j* is the lagged order of the model, α_i is a 3 × 1 vector of individual effects, which can reflect the individual differences of different prefecture-level cities, and γ_t is a 3 × 1 vector of time effects, which is used to reflect the differences of each prefecture-level city in different periods. The method used in this paper refers to the estimation method of Love (2006) for the PVAR model.

Empirical Analysis

Panel Unit Root Test

In time series, the purpose of the unit root test is to check the smoothness of the time series in order to avoid pseudo-regression. Since the panel data include both the characteristics of cross-sectional data and time series, it is necessary to test the stability of the panel data to overcome the small sample bias by the unit root test of individual time series, thus reducing the unobservable individual effects and the correlation of cross-section to some extent. In this paper, we adopt the LLC test for panel data to test the stability, and the results show that the data series of the digital economy (ED), industrial structure upgrading (AIS), and regional economic development level (RGDP) reject the original hypothesis of "existence of unit root", and the three variables are single integer series of the same order, so we can construct the panel autovector regression (PVAR) model. PVAR model can be constructed. The test results are shown in Table 2.

Table 2

Panel Unit Root Test Results		
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Variables	Statistic	Results
lnED	-44.4008***	Stable
lnAIS	-15.2724***	Stable
lnGDP	-17.0803***	Stable

Notes. *, **, *** represent the statistical values of the results that are significant at the 10%, 5%, and 1% levels respectively.

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Selecting the Optimal Lag Order

In this paper, AIC, BIC, and HQIC information criteria are used to select the optimal lag order according to the minimum value of indicators in the criteria. The results of lag order selection are shown in Table 3.

Table 3

White House East Order Selection Results				
Lag	AIC	BIC	HQIC	
1	-3.89769	-1.97239	-3.19454	
2	-4.20691*	-2.06019*	-3.41819*	
3	-4.0421	-1.61893	-3.1458	

PVAR Model Lag Order Selection Results

Notes. *, **, *** represent the statistical values of the results that are significant at the 10%, 5%, and 1% levels respectively.

The results of the above table show that the AIC criterion, BIC criterion, and HQIC criterion all choose a lag of two periods as the optimal choice.

Panel Impulse Response Plot Analysis

This paper studies the impact of digital economy development on industrial structure upgrading, at the same time, considering the macro variables of regional economic development level will also have some impact on industrial structure upgrading, therefore, this paper puts ED, AIS, and RGDP into PVAR model for analysis, in addition, in order to facilitate comparison, this paper will list the impulse response plots for the whole country and the three regions of East, West, and Central.

National impulse response analysis.



Figure 1. Impulse response diagram for national regions.

To analyze the dynamic influence between the development of digital economy and industrial structure upgrading, impulse response results with a lag of six periods were obtained after 1000 Monte Carlo simulations, as shown in Figure 1, when industrial structure upgrading is impacted by the development of digital economy, industrial structure upgrading responds rapidly in the short term and obtains positive influence, reaching a peak of 0.011 in the first period and gradually weakening, and with the increasing number of periods. The response value gradually tends to a stable positive value, indicating that the impact of digital economy development on industrial structure upgrading is becoming more and more stable, in a positive response state, with a continuous and significant dynamic promotion effect. When the development of the digital economy is impacted by the upgrading of industrial structure, it is initially affected negatively, and in the second periods. It can be seen that the impact of industrial structure upgrading on the digital economy is not transient and has a positive promoting effect in the long run.

For the impact of the regional economic development level on industrial structure upgrading, it can be seen from Figure 1 (c) that after the regional economic development level gives a negative shock in the current period, the national level of industrial structure upgrading shows a negative response by first decreasing and then increasing. In terms of the response level, the response level reaches the maximum in the third period, and then gradually stabilizes. Analyzing the reason, probably from the national level, to promote the regional economic development level, resources, factors, and financial support have to be invested in many aspects, thus the input for industrial structure upgrading related aspects will be reduced accordingly, and the national policies at the macroeconomic level will be adjusted timely according to the actual situation, so this negative impact will gradually decrease over time and finally tends to level off.



Impulse response analysis of east, central, and western regions.

Figure 2. Impulse response plot of east, central, and western regions.

First, in terms of the direction of change, after giving a positive shock to the level of digital economy development in the current period, the changes of industrial structure upgrading in the east, central, and west regions all show a positive response by first rising and then falling. In terms of response intensity, the highest value in the eastern region is 0.02 in the first period, the highest value in the central region is 0.01 in the first

period, and the highest value in the western region is 0.035 in the first period. In terms of response time, both the eastern, central, and western regions can reach after the sixth period or even longer. From the above three aspects, the upgrading of industrial structure in different regions is not affected by the development of the digital economy in the same way. In the eastern region, the level of economic development is higher, the construction of digital economy already has a certain scale, and the upgrading of industrial structure is significantly affected by the digital economy in comparison. In the central region, the impact of digital economy development on industrial structure upgrading is the least significant compared with other regions, probably because the secondary industry accounts for the highest proportion of GDP in the central region, and the impact of digital economy development on industrial structure upgrading is the most significant compared to other regions, indicating that in the western region, where the economic development is relatively backward, the industrial structure is still dominated by primary and secondary industries, and the marginal utility of digital economy to promote industrial structure upgrading is still at a high level, so the state promotes the development of the digital economy through various policies to help upgrade the industrial structure.

For the impact of regional economic development, it can be seen from Figure 2 that in the eastern region, when the upgrade of industrial structure is impacted by the level of regional economic development, it will have a negative impact, and the negative impact will gradually weaken and become positive as time goes by. In the central region, regional economic development has a negative impact on industrial structure upgrading, which gradually weakens and tends to be stable after the fourth period. In the western region, the regional economic development level in the current period has a weak negative impact on the upgrading of industrial structure, and then changes to a positive impact, and gradually tends to be stable over time. It can be seen that in different regions, the regional economic development level is different, and the government has different aspects for economic factors and production factors input, which also causes the different impact of economic development level on industrial structure upgrading.

Granger Test

In this paper, the Granger causality test is adopted to further determine the changing relationship between variables, and the test results are shown in Table 4.

Table 4

Area	Original hypothesis	Cardinality statistic	Hysteresis order	<i>p</i> -value
National	lnED is the reason of lnAIS	10.278	2	0.006
National	lnGDP is the reason of lnAIS	11.02	2	0.004
National	lnAIS is the reason of lnED	9.3732	2	0.009
East	lnED is the reason of lnAIS	0.7964	1	0.372
East	lnGDP is the reason of lnAIS	5.6422	1	0.018
Central	lnED is the reason of lnAIS	5.1826	2	0.075
Central	lnGDP is the reason of lnAIS	32.473	2	0.000
Western	lnED is the reason of lnAIS	0.1026	1	0.749
Western	lnGDP is the reason of lnAIS	4.5601	1	0.033

By analyzing the data in the above table, for the whole country, for the Granger causality hypothesis that the change in digital economy development is the cause of industrial structure upgrading, the probability of rejecting the first type of error is 0.006 in the case of two lags, indicating that the digital economy development is the Granger cause of industrial structure upgrading at 5% level of significance, indicating that the digital economy development in China has a relatively significant impact on industrial structure upgrading. Similarly, the influence of regional economic development level on industrial structure upgrading is also significant at the 5% level.

Analysis of Variance Decomposition

For the national level, the industrial structure upgrading is mainly influenced by its own factors, and in the early period, the contribution is over 80%, which gradually decreases with time and reaches 76.5% in the 15th period, and the contribution of digital economy development and regional economic development level on industrial structure upgrading gradually increases with time and reaches 8.1% and 15.4%. The specific variance decomposition results are shown in Table 5.

Table 5

Variance Decomposition Results

Pasponso variable	Impulse variable				
	Prediction period	lnED	lnAIS	lnGDP	
lnAIS	1	0.000	1.000	0.000	
lnAIS	5	0.073	0.818	0.108	
lnAIS	10	0.080	0.770	0.150	
lnAIS	15	0.081	0.765	0.154	

Main Findings and Policy Recommendations

Based on the data of 248 prefecture-level cities in China from 2011-2021, a PVAR model is constructed, and the relationship between digital economy development and industrial structure upgrading is studied empirically at the national level and in the eastern, central, and western parts of the country respectively through impulse response function and variance decomposition, and the following research conclusions are mainly obtained:

(1) From the national level, digital economy development can significantly promote industrial structure upgrading, industrial structure upgrading also affects digital economy development, there is a long-term, continuous, and significant dynamic effect between the digital economy and the transformation and upgrading of industrial structure, and they influence each other.

(2) At the level of each region, the impact of the development of the digital economy on industrial structure upgrading, however, varies. According to the impulse response diagram, the development of digital economy can have a positive impact on the upgrading of industrial structure, but the intensity of the response is different, with the central region having the weakest response to the development of the digital economy, and the east and west having little difference.

(3) From the perspective of regional economic development level, the impact of regional economic development level on industrial structure upgrading is not the same in different regions, in the eastern and western regions, the economic development level will first have a negative impact on industrial structure upgrading, and then change to a positive impact and stabilize. From the national and central regions, the economic development level will have a negative impact on industrial structure upgrading.

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Based on the above research findings, the following policy recommendations are put forward: First, grasp the opportunities of digital economy development, give full play to the advantages of digital platforms in resource allocation and information transmission, steadily promote the development of digital economy, improve the efficiency of resource utilization, promote the transformation and upgrading of traditional industries, and in turn, it will promote the upgrading of industrial structure. Second, the development of strategies by region, for the implementation of digital technology applications, and industrial layout is not reasonable in the western region, to take full advantage of the backward areas of the development of the digital economy in the early stage of the special advantages of increasing marginal rewards, in order to accelerate the elimination of the digital divide, break the industry barriers and local restrictions, break the industrial development dilemma, and stimulate the upgrading of industrial structure. For the eastern regions where the digital economy has developed to a certain extent and the industrial infrastructure is more perfect while making good use of the digital economy, we should further consider the influence of other factors, invest more production factors and economic support in the relevant aspects of industrial structure upgrading, make reasonable use of the high level of regional economic development, and strive to provide some support for industrial structure upgrading. For the central region, there is no longer the advantage of incremental marginal compensation at the early stage of digital economy development, it is necessary to actively explore the new mode of digital economy development, realize the orderly and free flow of digital elements between regions, and form an innovative industrial technology system.

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