

# The Impact of Digital Economy on the Development of Green Logistics under the Goal of Dual Carbon

-- An Empirical Study based on PVAR Modeling

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**Abstract.** Digital economy and industrial structure upgrading are the keys to realizing low-carbon economic development. Based on the data of 30 provinces in China from 2013 to 2020, this study constructs a PVAR model. It analyzes the dynamic relationship between the digital economy, industrial structure upgrading, and green logistics development through impulse response and variance decomposition. It conducts a comparative study of the eastern, central, and western regions. The study shows that from 2013 to 2020, China's green logistics will rise steadily, characterized by "high in the east and low in the central and western regions.". From a national point of view, industrial structure upgrading, digital economy, and green logistics have strong coordination, and they influence each other. From the perspective of the three regions, the digital economy and industrial structure upgrading in the eastern and central regions have achieved better-coordinated development, and both have a good role in promoting the development of green logistics. The upgrading of industrial structure and the digital economy in the Western region have failed to achieve better-coordinated development, and both have no obvious impact on the development of green logistics in the Western region. Therefore, it is proposed to accelerate the development of the digital economy, reasonably promote the upgrading of industrial structure, and promote the countermeasures for the green development of the logistics industry.

**Keywords:** Digital Economy; Industrial Structure Upgrading; Green Logistics; PVAR.

## 1. Introduction

China is the largest developing country in the world and also the largest carbon emitter. In 2023, China's carbon emissions reached 12.6 billion tons, accounting for one-third of global carbon emissions. To address this situation, China has committed to reaching peak carbon emissions by 2030 and achieving carbon neutrality by 2060, increasing its nationally determined contributions (NDCs) and promoting a green, low-carbon energy transition. As a major industry for energy consumption and carbon emissions, the logistics industry emitted 7.2 billion tons of carbon in 2020, making it a critical sector for achieving emission reduction targets. China's logistics industry started late and developed rapidly, with an incomplete industry system and significant regional disparities. The rapid and unregulated development of the logistics industry has led to an unreasonable energy structure and low energy efficiency, exacerbating pollution. Therefore, promoting a green and high-quality transformation of the logistics industry is crucial for achieving the "dual carbon" goals. China advocates for upgrading and transforming the industrial structure through the digital economy and other new, environmentally friendly economic models to reduce energy consumption. Industrial structure upgrading has become the primary driving force for carbon reduction in China. Currently, the digital economy accounts for more than 40% of China's GDP, making it the most promising and widely influential new form and growth pole of the national economy. Thus, promoting green logistics development through digital economy development and industrial structure optimization is not only an inevitable trend for modern logistics industry development but also an important measure for achieving the "dual carbon" goals.

The importance of green logistics for reducing carbon emissions has been widely recognized by all walks of life [1]. Green logistics is a new type of environmentally friendly logistics system that

promotes the greening of logistics processes such as transportation, warehousing, and distribution through friendly economic models such as the digital economy [2]. China pays particular attention to the development of the logistics industry and continues to explore the green and low-carbon development of the digital economy and the logistics industry. Zhang J et al. [3] found that the digital economy is becoming an important driver of low-carbon development. In addition, digitalization can promote green and sustainable economic development. The digital economy promotes the high-quality development of the logistics industry through technological innovation and the improvement of the efficiency of factor allocation [4]. Popkova E G et al. [5] found that the widespread application of digital technology and the digitization of logistics is an important driving force to promote the high-quality development of the logistics industry. Zhang J et al. [6] investigated the influence of the spatial effect of the digital economy on the efficiency of low-carbon logistics from the perspective of the spatial effect.

Some studies have found that industrial structure upgrading is also a major key element in promoting low-carbon development. Actively promoting advanced industrial structures can effectively alleviate the pollution effect brought about by resource mismatch [7]. In addition, the development of the logistics industry under low-carbon constraints requires low-carbon control of all links in the supply chain, and the strengthening of environmental regulations and the requirements of energy conservation and emission reduction can promote industrial structure adjustment, improve the low-carbon efficiency of the logistics industry, and force the industrial structure to be upgraded and adjusted. At the same time, the optimization of industrial structure is also an important driving force for the development of the logistics industry [8]. Yan B et al. [9] study the impact of the logistics industry on high-quality economic development under different levels of industrial structure development. The results show that high-quality green development of the logistics industry can be promoted through industrial structure upgrading to realize green economic transformation and upgrading.

Low-carbon development is considered a crucial measure for achieving economic growth and environmental protection, requiring a fundamental transformation of the industrial structure [10]. The digital economy, as a new engine for economic growth, is deemed an essential driving force for optimizing the industrial structure. The digital economy drives green transformation, permeating all major aspects of the industrial chain, promoting industrial upgrading, and facilitating the optimization of the industrial structure[11]. This enhances the efficiency of the supply chain, thereby reducing carbon emissions[12]. Zhang J et al.[3] found that the upgrading of the industrial structure is the primary channel through which the digital economy impacts low-carbon development. Liu R et al.[13] discovered that the digital economy enhances green innovation efficiency and achieves emission reduction through industrial structure optimization.

In summary, in this context, the current research still lacks analysis of the dynamic relationship between industrial structure upgrading, digital economy, and green logistics development, and an in-depth discussion of the dynamic interaction mechanism among these three is of great practical significance to China's current and future period for upgrading the level of green logistics and accelerating the transformation of the development mode of the logistics industry and realizing the goal of "dual-carbon" in 2030. It is of great practical significance. Therefore, this paper attempts to empirically analyze the logical relationship among industrial structure upgrading, digital economy, and green logistics development under the perspective of a "dual-carbon" goal by constructing a panel vector autoregressive model to fill the gaps in the existing literature.

## **2. Measurement of Regional Green Logistics Development Level**

### **2.1 Regional Green Logistics Evaluation Index System**

Green development is a sustainable development in which the environment and the economy promote each other, and green development requires the transformation of the traditional logistics industry into a friendly industry, one that reduces energy consumption, protects the ecological

environment, and develops an efficient circular economy. Therefore, green logistics is a sustainable development of the logistics industry to ensure the quality of life of citizens, protect resources, and protect the ecological environment while maintaining the economic development of logistics, which can realize the sustainable development of the economy, environment, and society. By referring to the research results of several scholars, combining the requirements of green development, and according to the principles of availability, quantification, operability, and systematicity of indicator selection, this paper looks at technological innovation, structural efficiency, open development, environmental sharing, green and low carbon Five aspects to construct the evaluation index system of green development of China's logistics industry [14-16].

## 2.2 Regional Green Logistics Level Measurement Model

This paper adopts the entropy weight method to measure the level of China's regional green logistics development, The entropy weight method is an important information weighting model, which is widely used in a variety of empirical theoretical research. Compared with various other subjective weighting models, the entropy weighting method avoids the interference of human subjective factors and strengthens the objectivity of experimental conclusions [17].

## 2.3 Data Sources

To ensure the authenticity of the research results, as well as based on the reasonableness and availability of data, this paper selects the data of 30 provinces, autonomous regions, and municipalities directly under the central government in China, except for Tibet, Hong Kong, Macao, and Taiwan, from 2013 to 2020 as the research samples, and the data are mainly originated from the official website of the National Database of National Bureau of Statistics ([data.stats.gov.cn](http://data.stats.gov.cn)), and the China Labor Statistics Yearbook, etc. The energy consumption and CO2 emissions of the logistics industry were calculated from the China Energy Statistics Yearbook and the relevant data in the China Carbon Accounting Database (<https://www.ceads.net.cn/>).

## 2.4 Comprehensive Evaluation Results and Analysis of Regional Green Logistics Level

According to the aforementioned comprehensive evaluation method using the entropy weight method to calculate the green logistics development level of Chinese provinces, regions, and cities in 2013-2020, the comprehensive evaluation value is shown in Table 1.

As can be seen from Table 2, the comprehensive evaluation value of the national green logistics development level increased year by year from 2013 to 2020, with an average value of 0.2606, 0.2702, 0.2589, and 0.2533 in the eastern, central, and western regions, respectively. It can be seen that the development of green logistics in China is not coordinated, there are significant regional differences, showing a "high east, west and central low" situation: the level of green logistics development in the eastern region is higher than the national average, in the central and western regions is slightly lower than the national average, the western region is slightly lower than the central region, and the gap between the east and central regions is much higher than the middle, The gap between the eastern and central regions is much higher than the gap between the central and western regions. This shows that China has a long way to go in promoting the development of green logistics to narrow regional differences and coordinate development.

# 3. Empirical Analysis

## 3.1 Variable Setting and Empirical Modeling

The level of green logistics development is expressed by the comprehensive value measured by the entropy weight method adopted in the previous article. The optimization and upgrading of industrial structure are an important driving force to promote the high-quality development of the national economy, and this paper uses the ratio of the added value of the tertiary industry to the GDP

to indicate the level of upgrading of industrial structure. For the level of digital economy development. This paper constructs an indicator system containing three aspects infrastructure, digital industrialization, and industrial digitization.

**Table 1.** Development level of green logistics by provinces, regions, and cities in China, 2013-2020.

| Logistics Score                  | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   | Mean   |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Beijing                          | 0.0558 | 0.0562 | 0.0560 | 0.1549 | 0.1575 | 0.1611 | 0.1646 | 0.3761 | 0.1478 |
| Tianjin                          | 0.1073 | 0.1039 | 0.1023 | 0.1003 | 0.1066 | 0.3487 | 0.5667 | 0.5698 | 0.2507 |
| Hebei                            | 0.0973 | 0.0968 | 0.0963 | 0.3151 | 0.3252 | 0.5690 | 0.5745 | 0.7875 | 0.3577 |
| Shanxi                           | 0.1280 | 0.1333 | 0.1237 | 0.1177 | 0.1254 | 0.2349 | 0.4687 | 0.4703 | 0.2253 |
| Inner Mongolia Autonomous Region | 0.1287 | 0.1169 | 0.1106 | 0.2094 | 0.2191 | 0.5844 | 0.8205 | 0.8137 | 0.3754 |
| Liaoning                         | 0.0626 | 0.0661 | 0.0694 | 0.1722 | 0.1773 | 0.1839 | 0.3988 | 0.4009 | 0.1914 |
| Jilin                            | 0.0616 | 0.0613 | 0.0564 | 0.0593 | 0.1859 | 0.2888 | 0.2928 | 0.5074 | 0.1892 |
| Heilongjiang                     | 0.0587 | 0.0573 | 0.1750 | 0.1787 | 0.1837 | 0.1897 | 0.1960 | 0.2001 | 0.1549 |
| Shanghai                         | 0.0813 | 0.0856 | 0.0858 | 0.1854 | 0.1917 | 0.2028 | 0.4181 | 0.4204 | 0.2089 |
| Jiangsu                          | 0.2358 | 0.2384 | 0.2357 | 0.3355 | 0.3487 | 0.5995 | 0.8140 | 0.8169 | 0.4531 |
| Zhejiang                         | 0.0869 | 0.0901 | 0.0910 | 0.1971 | 0.2008 | 0.2118 | 0.4278 | 0.4275 | 0.2166 |
| Anhui                            | 0.0806 | 0.0871 | 0.0827 | 0.1851 | 0.1900 | 0.1964 | 0.2016 | 0.4187 | 0.1803 |
| Fujian                           | 0.0658 | 0.0667 | 0.0667 | 0.1691 | 0.1772 | 0.4234 | 0.6405 | 0.6406 | 0.2812 |
| Jiangxi                          | 0.0553 | 0.0572 | 0.0579 | 0.0613 | 0.0657 | 0.2922 | 0.5076 | 0.5086 | 0.2007 |
| Shandong                         | 0.0919 | 0.0962 | 0.0939 | 0.1963 | 0.3300 | 0.3376 | 0.5570 | 0.5556 | 0.2823 |
| Henan                            | 0.1799 | 0.1842 | 0.1869 | 0.2888 | 0.2919 | 0.5428 | 0.7566 | 0.7561 | 0.3984 |
| Hubei                            | 0.1781 | 0.1821 | 0.1832 | 0.2842 | 0.2898 | 0.5358 | 0.7551 | 0.7507 | 0.3949 |
| Hunan                            | 0.1785 | 0.1807 | 0.1818 | 0.2851 | 0.2937 | 0.5426 | 0.7482 | 0.7492 | 0.3950 |
| Guangdong                        | 0.1589 | 0.1577 | 0.1525 | 0.3673 | 0.3760 | 0.6280 | 0.8426 | 0.8423 | 0.4406 |
| Guangxi Zhuang Autonomous Region | 0.0553 | 0.0603 | 0.0623 | 0.1629 | 0.1681 | 0.1753 | 0.3948 | 0.3963 | 0.1844 |
| Hainan                           | 0.0599 | 0.0519 | 0.0544 | 0.0572 | 0.0630 | 0.0642 | 0.0814 | 0.0745 | 0.0633 |
| Chongqing                        | 0.1688 | 0.1725 | 0.1713 | 0.2732 | 0.2748 | 0.2853 | 0.5044 | 0.5051 | 0.2944 |
| Sichuan                          | 0.1680 | 0.1726 | 0.1744 | 0.2768 | 0.2811 | 0.5288 | 0.7484 | 0.7474 | 0.3872 |
| Guizhou                          | 0.0532 | 0.0564 | 0.0574 | 0.1589 | 0.1635 | 0.1700 | 0.1683 | 0.3849 | 0.1516 |
| Yunnan                           | 0.0561 | 0.0609 | 0.0616 | 0.1682 | 0.1684 | 0.1761 | 0.1790 | 0.3901 | 0.1575 |
| Shaanxi                          | 0.0818 | 0.0770 | 0.0792 | 0.3019 | 0.3083 | 0.3140 | 0.5360 | 0.5382 | 0.2796 |
| Gansu                            | 0.0566 | 0.0577 | 0.1766 | 0.1813 | 0.1815 | 0.5256 | 0.7409 | 0.7409 | 0.3326 |
| Qinghai                          | 0.0783 | 0.0703 | 0.0605 | 0.2818 | 0.2866 | 0.2915 | 0.2971 | 0.5129 | 0.2349 |
| Ningxia Hui Autonomous Region    | 0.0948 | 0.0947 | 0.0944 | 0.0958 | 0.0943 | 0.3377 | 0.3444 | 0.3447 | 0.1876 |
| Xinjiang Uygur Autonomous Region | 0.0505 | 0.0571 | 0.0587 | 0.1862 | 0.1928 | 0.2043 | 0.4248 | 0.4354 | 0.2012 |
| Eastern Region                   | 0.1041 | 0.1044 | 0.1035 | 0.2078 | 0.2277 | 0.3546 | 0.5087 | 0.5511 | 0.2702 |
| Central Region                   | 0.1092 | 0.1121 | 0.1241 | 0.1814 | 0.2004 | 0.3341 | 0.4806 | 0.5291 | 0.2589 |
| Western Region                   | 0.0902 | 0.0906 | 0.1006 | 0.2087 | 0.2126 | 0.3266 | 0.4690 | 0.5281 | 0.2533 |
| Nationwide                       | 0.1005 | 0.1016 | 0.1086 | 0.2002 | 0.2140 | 0.3382 | 0.4857 | 0.5361 | 0.2606 |

Note: Table East Central, West Central and Central regions according to the classification criteria of the National Statistical Office

(2) Empirical modeling. The panel vector autoregressive model (PVAR) is used in the experiment. It combines the advantages of both panel data and vector autoregressive model analysis, both without the need to set the causal relationship between the variables in advance, and also allows cross-section and time series analysis, which can reflect the complex interrelationships between the variables more

robustly [18]. Therefore, to verify the impact relationship between industrial structure upgrading, digital economy, and green logistics, this paper applies the PVAR model to the indicators. The model is set as follows:

$$Y_{it} = a_0 + \sum_{j=1}^n a_j Y_{i,t-j} + \beta_i + \gamma_i + \varepsilon_{it}$$

**Table 2.** Indicator system

| Primary Indicators        | Secondary indicators                                     | Unit                           |
|---------------------------|----------------------------------------------------------|--------------------------------|
| Infrastructure            | Internet broadband access ports per capita               | 10,000 ports per 10,000 people |
|                           | Length of fiber optic lines per capita                   | Kilometers per 10,000 people   |
| Digital Industrialization | Employment in the Information and Communication Industry | million people                 |
|                           | Per capita income from information technology services   | million yuan/person            |
| Industrial Digitization   | E-commerce sales                                         | Billions of dollars            |
|                           | Websites per 100 enterprises                             | per hundred                    |
|                           | Share of enterprises with e-commerce trading activities  | %                              |
|                           | Domestic Patent Applications Received                    | /                              |

Y is a  $1 \times 3$ rd order column vector containing three endogenous variables: digital economy (TE), industrial structure upgrading level (TE), and green logistics (GL).GL is the level of green logistics, ST is the industrial structure upgrading, and TE is the level of digital key economic development.

### 3.2 Descriptive Statistics of Variables

**Table 3.** Results of descriptive statistics for variables

|          | Variables | Sample size | Mean   | Standard deviation | Minimum value | Maximum value |
|----------|-----------|-------------|--------|--------------------|---------------|---------------|
| National | TE        | 240         | 0.2054 | 0.1385             | 0.0490        | 0.8167        |
|          | GL        | 240         | 0.2606 | 0.2084             | 0.0505        | 0.8426        |
|          | ST        | 240         | 0.5057 | 0.0848             | 0.3466        | 0.8373        |
| East     | TE        | 88          | 0.3091 | 0.1719             | 0.0640        | 0.8167        |
|          | GL        | 88          | 0.2702 | 0.2193             | 0.0519        | 0.8426        |
|          | ST        | 88          | 0.5538 | 0.1134             | 0.3978        | 0.8373        |
| Central  | TE        | 64          | 0.1483 | 0.0565             | 0.0524        | 0.2803        |
|          | GL        | 64          | 0.2589 | 0.2083             | 0.0553        | 0.7566        |
|          | ST        | 64          | 0.4664 | 0.0498             | 0.3466        | 0.5376        |
| West     | TE        | 88          | 0.1431 | 0.0603             | 0.0490        | 0.3231        |
|          | GL        | 88          | 0.2533 | 0.1992             | 0.0505        | 0.8205        |
|          | ST        | 88          | 0.4862 | 0.0353             | 0.3787        | 0.5531        |

### 3.3 Smoothness Test

This paper constructs a PVAR model containing digital economy, industrial structure upgrading and green logistics development and estimates it. The data in this paper is characterized by wide cross-section and short time data, which can generally be regarded as smooth data, but in order to ensure the accuracy of the results of the later analysis, the LLC (Levin-Lin-Chu) method and IPS (Im-Pesaran-Shin) method are further adopted to test. As in Table 4.

**Table 4.** Results of the stability test

| Variables | Test Method | National | Eastern Region | Central Region | Western Region |
|-----------|-------------|----------|----------------|----------------|----------------|
| TE        | LLC         | -20.8785 | -11.4173       | -1.6675        | -4.9076        |
|           | IPS         | -2.3873  | -1.3033        | -1.5334        | -1.0699        |
| GL        | LLC         | -14.3807 | -6.3741        | -9.1085        | -8.3731        |
|           | IPS         | -4.0773  | -2.7394        | -1.7791        | -2.8948        |
| ST        | LLC         | -20.0338 | -2.4039        | -7.7595        | -7.9066        |
|           | IPS         | 0.1652   | 0.7187         | 1.0638         | -0.0017        |
| dTE       | LLC         | -21.0927 | -4.5504        | -2200          | -16.5287       |
|           | IPS         | -4.4495  | -2.1105        | -2.9099        | -3.1172        |
| dGL       | LLC         | -73.8009 | -18.3765       | -550           | -21.5098       |
|           | IPS         | -3.0639  | -2.5086        | -1.3944        | -1.8689        |
| dST       | LLC         | -18.1057 | -12.2885       | -14.4703       | -10.7417       |
|           | IPS         | -3.6832  | -1.7511        | -1.9349        | -1.8948        |

Note: \*\*\* denotes significant at a 1% confidence level, and the data in the table represent the corresponding statistics in the LLC test and IPS test, respectively.

According to the results in Table 4, it can be seen that some of the series do not pass the unit root test, indicating that the original series is not smooth. The first-order differencing is applied to all the variables, and the dTED, dGL, and dST obtained after the transformation are all smooth, indicating that all the variables are first-order single integers.

### 3.4 Lag Order Establishment

**Table 5.** Comparison of AIC, BIC and HQIC results in three regions

| Lag Order | National  |           |           | East      |          |           |
|-----------|-----------|-----------|-----------|-----------|----------|-----------|
|           | AIC       | BIC       | HQIC      | AIC       | BIC      | HQIC      |
| 1         | -12.4734* | -10.4864* | -11.6662* | -12.6357* | 11.1028* | -12.0429* |
| 2         | -11.66    | -9.15     | -10.64    | -11.88    | -9.82    | -11.12    |
| 3         | -8.24     | -4.99     | -6.92     | -8.55     | -5.83    | 7.63      |
|           | Central   |           |           | Western   |          |           |
|           | AIC       | BIC       | HQIC      | AIC       | BIC      | HQIC      |
| 1         | -12.322*  | -10.9287* | -11.8182* | -12.9849* | -11.452* | -12.3921* |
| 2         | -11.35    | -9.42     | -10.71    | -11.53    | -9.46    | -10.76    |
| 3         | -4.39     | -1.88     | -3.72     | -9.15     | -6.43    | -8.24     |

In this paper, the lag order of the model is determined concerning the three criteria of AIC, BIC, and HQIC. Table 5 shows that the AIC, BIC, and HQIC of lag order 1 of the PVAR model are the smallest, therefore, it is more appropriate to take 1 as the lag order of the PVAR model.

### 3.5 Robustness Test

To ensure the validity of the subsequent model estimation, impulse response, and variance decomposition, the model needs to be tested for robustness, i.e., whether the mode of the eigenvalues of the dynamic matrix is less than 1 (within the unit circle) or not, as can be seen from Fig. 1, the PVAR model constructed in this paper is robust.

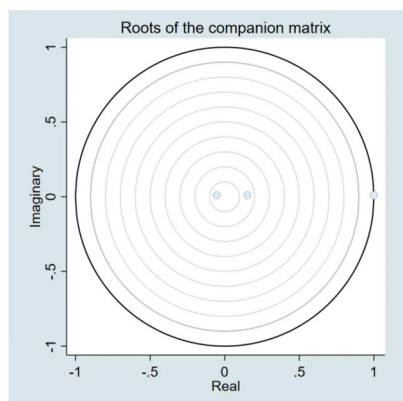


Figure 1. Dynamic matrix eigenvalues

### 3.6 Impulse Response Functions

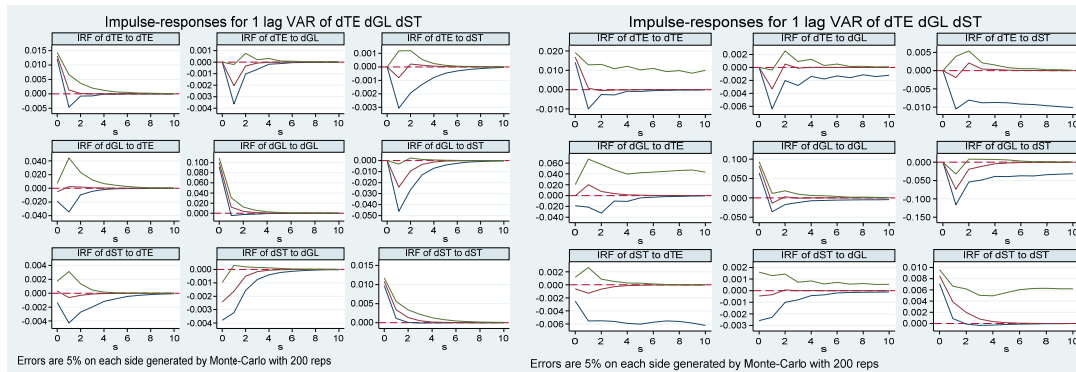


Figure 2a. national impulse response results

Figure 2b. Eastern impulse response results

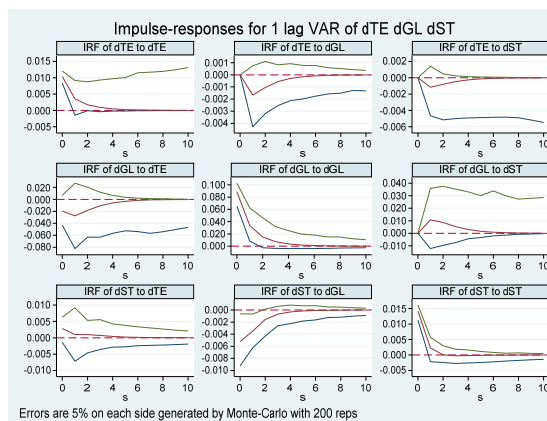


Figure 2c. central impulse response results

The impulse response results show that none of the three systems in the western region responds significantly to a given shock, and the following focuses on analyzing the impulse response results in the eastern and central regions. The research group further analyzes the interrelationship between industrial structure upgrading, digital economy, and green logistics by conducting impulse response. It can be seen from the impulse response results in Fig.2a-c.

(1) Shock effect on itself

When industrial structure upgrading, digital economy, and green logistics face a standard deviation shock themselves, the positive reaction to themselves in the current period is the largest, and then gradually weakened and converged to 0, indicating that green logistics, digital technology, industrial structure upgrading have relative economic inertia.

(2) The impact of green logistics

In the face of a standardized impact of green logistics development, the response value of the digital economy in the country and the central region presents a "U" type of less than zero, first decreasing and then increasing, and the negative response is the largest in the first period, and then gradually weakened and tended to 0. The reason may be: When the eastern region is subjected to a standardized impact of green logistics development, the response value of the digital economy also shows a "U" shape of less than zero, first decreasing and then increasing, with the largest negative response in the first period, but a positive impact in the second period, followed by a gradual weakening and convergence to zero.

In the face of a standardized impact of the development of green logistics, the industrial structure of the country, the central region of the upgrading of the negative reaction immediately, followed by a gradual increase to zero. First, the overall development level of China's logistics industry is not high, logistics infrastructure is still relatively backward, the green transformation of the logistics industry requires a large amount of capital investment, and the return period of investment is long, forming a "crowding out" effect on productive capital; second, the logistics industry has a certain degree of vulnerability and is easily affected by economic conditions; third, the green transformation of the logistics industry has fewer relevant policies, and the degree of policy influence is small. In general, green logistics has not been able to play a good role in promoting the upgrading of industrial structures.

(3) Shock effect of digital economy

When green logistics face a standard deviation impact of the digital economy, the national green logistics response value in the current period is negative, and then gradually increases, in the first period to reach the maximum, indicating that the digital economy on the promotion of green logistics has a lagging effect, maybe because of the results of innovation needs to be transformed after a certain period, the digital economy can be a very good impetus to the green transformation of the logistics industry. The eastern region shows a positive impact of the inverted "U" type that first expands and then shrinks, and the digital economy effectively promotes the improvement of the development level of green logistics by improving the efficiency of resource allocation and giving birth to high-tech enterprises. The central region also shows a "U" shape of less than zero, which decreases and then increases, and gradually tends to zero in the 6th period, probably because there are fewer high-tech enterprises and insufficient investment in innovation in the central region, and it is difficult for the development of the digital economy to play a role in promoting the development of green logistics.

When industrial structure upgrading faces a standard deviation impact of the digital economy, the response value of industrial structure upgrading in the country presents a negative impact of less than 0 firstly decreasing and then increasing, and gradually tends to 0 in the 4th period, which may be because the digital economy in the early stage, the upgrading of industrial structure will have a negative impact. The central region presents a positive impact, and the response value reaches the maximum in the current period.

(4) The impact of industrial structure upgrade

Facing a standardized impact of industrial structure upgrading, the green logistics in the whole country and the eastern region show a consistent response, showing a "U" shape of less than zero, decreasing first and then increasing, with the largest negative response in the first period, then

gradually converging to 0. The mismatch between the upgrading speed of the industrial structure and the speed of development of green logistics will constrain the development of green logistics. In the central region, green logistics shows a positive impact and reaches the maximum value in the first period. The industries in the central region have more urgent needs for structural upgrading, which can present a pilot impact in the current period.

Facing a standardized impact of industrial structure upgrading, the digital economy in the whole country and the eastern region embodies a consistent response, presenting a gradually weakening positive impact, with the largest response in the current period.

### 3.7 Variance Decomposition Function

**Table 6.** Contribution of different structural shocks

| Variable | Period | National |       |       | East    |       |       |
|----------|--------|----------|-------|-------|---------|-------|-------|
|          |        | dTE      | dGL   | dST   | dTE     | dGL   | dST   |
| lnTE     | 2      | 0.973    | 0.023 | 0.004 | 0.952   | 0.036 | 0.012 |
| lnGL     | 2      | 0.003    | 0.944 | 0.054 | 0.031   | 0.548 | 0.421 |
| lnST     | 2      | 0.004    | 0.062 | 0.935 | 0.023   | 0.004 | 0.974 |
| lnTE     | 4      | 0.972    | 0.024 | 0.004 | 0.937   | 0.037 | 0.027 |
| lnGL     | 4      | 0.003    | 0.935 | 0.062 | 0.035   | 0.525 | 0.440 |
| lnST     | 4      | 0.004    | 0.063 | 0.933 | 0.027   | 0.003 | 0.970 |
| lnTE     | 6      | 0.972    | 0.024 | 0.004 | 0.936   | 0.037 | 0.027 |
| lnGL     | 6      | 0.003    | 0.934 | 0.062 | 0.035   | 0.524 | 0.440 |
| lnST     | 6      | 0.004    | 0.063 | 0.933 | 0.027   | 0.003 | 0.969 |
| Variable | Period | Central  |       |       | Western |       |       |
|          |        | dTE      | dGL   | dST   | dTE     | dGL   | dST   |
| lnTE     | 2      | 0.967    | 0.022 | 0.011 | 0.979   | 0.010 | 0.011 |
| lnGL     | 2      | 0.111    | 0.878 | 0.011 | 0.019   | 0.942 | 0.039 |
| lnST     | 2      | 0.035    | 0.154 | 0.811 | 0.012   | 0.069 | 0.918 |
| lnTE     | 4      | 0.951    | 0.032 | 0.017 | 0.976   | 0.011 | 0.014 |
| lnGL     | 4      | 0.143    | 0.838 | 0.020 | 0.019   | 0.932 | 0.049 |
| lnST     | 4      | 0.040    | 0.163 | 0.797 | 0.013   | 0.070 | 0.917 |
| lnTE     | 6      | 0.950    | 0.033 | 0.018 | 0.975   | 0.011 | 0.014 |
| lnGL     | 6      | 0.146    | 0.834 | 0.020 | 0.019   | 0.932 | 0.049 |
| lnST     | 6      | 0.041    | 0.163 | 0.796 | 0.014   | 0.070 | 0.917 |

To more deeply understand and portray the interaction effects of industrial structure upgrading, digital economy, and green logistics, this paper uses the variance decomposition function to measure the contribution of different structural shocks (Table 6). As shown in Table 6, the variables tend to stabilize in the 6th period, so the 6th period is taken for analysis:

(1) As far as the whole country is concerned, the contribution rate of green logistics development variance is mainly influenced by itself, which is still 93.4% in period 6, followed by the level of upgrading of industrial structure and the level of development of digital economy. The result of the variance decomposition of green logistics development in the western region is similar to that of the whole country, which is 93.2% at the lag of 6 periods. The contribution rate of the green logistics development variance in the eastern region and the central region is 52.4% and 83.4% respectively, and the level of digital economy development and the level of industrial structure upgrading have a large contribution. The variance contribution rate of green logistics development in the eastern region is influenced by the level of industrial structure upgrading at 44%, and the level of digital economy development is influenced by 3.5%. The variance contribution rate of green logistics development in the central region is influenced by the level of digital economy development at 14.6%, while the level of industrial structure upgrading is less than 2% to the level of green logistics development.

(2) A large part of the contribution to the upgrading of industrial structure in the national, eastern, and western regions comes from the industrial structure itself, with 93.3%, 96.9%, and 91.7% respectively, and the influence from the development level of green logistics and digital economy is smaller. The upgrading of industrial structure in the central region also relies mainly on itself, with a contribution of 79.6%, but the level of green logistics development also has a large impact on the upgrading of industrial structure, with a contribution of 16.3%, and the development of the digital economy contributes to the upgrading of industrial structure with a contribution of 4.1%.

(3) The most important impact of the nationwide digital economy is the digital economy itself, with the contribution of technological innovation of 97.2% in the national and central regions, and 93.6%, 95%, and 97.5% in the eastern region, central region, and western region respectively. The impact of green logistics development and industrial structure upgrading on the development of the digital economy is relatively small.

#### 4. Conclusion and Policy Recommendations

This paper uses the PAVR model to empirically analyze the dynamic relationship between the digital economy, industrial structure upgrading, and green logistics, and the specific conclusions are as follows: China's green logistics development level is constantly improving, but there are significant regional differences, showing the trend of "high in the east and low in the middle and west", and the gap between the eastern region and the central and western regions is widening. The upgrading of industrial structure, digital economy, and green logistics at the national and regional levels all exhibit self-reinforcing mechanisms. In the eastern and central regions, industrial structure upgrading and the digital economy have achieved well coordinated development and can mutually promote each other. Across all regions of the country, the development of green logistics and industrial structure upgrading have formed a positive bidirectional interactive relationship. The upgrading of the industrial structure promotes green logistics and the digital economy nationwide and regionally, but it has a certain lag effect on green logistics. The digital economy has a lag effect on promoting green logistics nationwide and regionally. In the central region, the digital economy has a significant effect on industrial structure upgrading.

Promote the comprehensive development of the digital economy in all regions. Increase investment in digital infrastructure construction, improve Internet penetration and network quality nationwide, and promote the application of emerging technologies such as 5G, big data, and artificial intelligence (AI) in the logistics industry. Accelerate the upgrading of the industrial structure, encourage the transformation and upgrading of traditional industries, and support the development of high-tech industries to improve technology and productivity. Accelerate the promotion of green logistics technology and equipment, support logistics enterprises to implement energy-saving and emission-reduction technology transformation, and improve green logistics. (1) The eastern region should continue to deepen the application of the digital economy. Strengthen the synergistic development of industries, enhance the synergistic development of the digital economy and

traditional industries, promote information sharing and collaborative operation of upstream and downstream enterprises in the supply chain, and improve the operational efficiency of the entire industrial chain. (2) The central region should enhance digital infrastructure construction. It should support the transformation and upgrading of traditional industries, promote the development of green logistics, and push logistics enterprises to implement green transformation and reduce environmental pollution in the logistics process. (3) The Western region should continue to increase support for the development of the digital economy, improve infrastructure construction, raise the level of digitization, and promote the application of digital technology in the logistics industry. Promote industrial restructuring, encourage green logistics demonstrations in the western region, promote the application of green logistics technologies and models, and enhance green logistics development.

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