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Article

Modeling the impact of structural changes in international trade on economic growth based on principal component analysis

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Abstract: China's domestic demand is weak, the growth of domestic demand is constrained, some industries are overproducing, and many enterprises are facing great challenges in production and operation. This paper focuses on analyzing the influencing factors of export trade structure, constructing a regression model according to the related theory of influencing factors, and analyzing the covariance of variables and determining the variable indicators affecting economic growth through principal component regression analysis. Based on the BEC criterion and the research experience of the previous researchers, the international trade structure indicator model applicable to China was established, and the least squares method in multiple linear regression was used, and the test was carried out according to the analytical steps of the Granger test. The adjusted R square is 0.4686, the regression variance F value is 7.198, the significance is 0.0245, less than 0.05 indicates that the regression equation is valid and the proposed variables can be used for role analysis. The results of regression analysis show that every 1% increase in the coefficient of comparative advantage raises economic growth by about 0.0635%. The change of international trade structure has a positive impact on economic growth, but the current change of international trade structure has a certain path dependence, so there is a lag in the performance of the response of the change of international trade structure to economic growth.

Keywords: trade structure change; principal component regression analysis; least squares; Granger test; economic growth

1. Introduction

The international trade structure, which is an indicator expressed in monetary terms reflecting the size of world trade over a certain period of time, is the sum of the export trade volume of all countries (regions) of the world over a period of time [1]. The international trade structure can reflect the status and role of the world's countries in international trade, as well as the degree of trade exchanges and economic interdependence between countries [2-4]. In recent years, the international trade structure has undergone some important changes. First, trade barriers have been gradually reduced, and countries have promoted trade liberalization and facilitation by signing free trade agreements and reducing tariffs [5-6]. Literature [7] examined the impact of trade liberalization on the export of environmental goods, based on the bilateral trade data of Asia-Pacific, and found that the impact of tariff reduction in exporting countries on the export of environmental goods is greater than the impact of tariff reduction in importing countries. Literature [8] analyzed the relevant literature on trade liberalization and economic development and reviewed the theory of comparative advantage, which is regarded as the justification basis for global trade liberalization under the framework of the World Trade Organization.

Secondly, there is the rise of cross-border e-commerce. With the popularization of the Internet and the progress of technology, e-commerce plays an increasingly important role in international trade [9-10]. For example, literature [11] takes China as an example and analyzes factors such as transportation costs and tariffs from the perspective of transaction cost economics combined with the traditional comparative advantage model, aiming to examine the impact of cross-border e-commerce on international trade, and the results show that cross-border e-commerce positively affects the growth of China's international trade every year. Literature [12] discussed the impact of cross-border e-commerce on international trade and economic growth in China and concluded that cross-border e-commerce positively affects both international trade and economic growth in both the short- and long-term scopes.

Again, trade patterns have changed and the rise of emerging market economies has shifted the center of gravity of international trade from traditional developed countries to emerging market countries [13-14]. In this regard, literature [15] explored the relationship between trade openness and economic growth in five emerging market economies, emphasizing that trade openness plays an important role in emerging market economies in terms of economic growth and also promotes their economic development. Literature [16] describes the relationship between emerging market economies and global trade, pointing out that emerging market economies are mainly export-oriented globalized economies, and therefore any downturn in global trade should have a direct negative impact on them.

Changes in the structure of international trade have had a profound impact on the global economy. The increase in global trade has led to the growth of the global economy, and trade liberalization has brought more opportunities and development space for countries [17-18]. Literature [19] analyzed the impact of trade openness on economic growth in a multiple regression framework, and the results show that trade openness in has a positive impact on economic growth. Literature [20] based on literature review shows that most of the studies recognize the contribution of trade organizations in promoting free trade, which is one of the important factors in promoting productivity and growth, and its contribution depends on the proportion of economic activity.

Changes in the structure of international trade have altered the global production pattern, and with the further deepening of the division of labor and the formation of global value chains, the advantageous industries of each country have been able to develop, and the relevant enterprises have gained a larger market share [21-23]. Literature [24] constructed a model aimed at examining the impact of trade costs on the industrialization process of developing countries when sequential production links are interconnected in global value chains (GVCs), and the study showed that reducing trade frictions induces developing countries to join GVCs due to wage differentials and low trade costs.Literature [25] emphasized the importance of exporting through GVCs for the industrial development in developing countries, and by analyzing the long-term impact of GVC participation in a large number of countries, shows that participation in GVCs has a significant positive impact on productivity growth in the formal manufacturing sector.

Structural changes in international trade have also had a significant impact on global employment. Globalization has led to the globalization of industrial chains, and some developing countries have attracted large amounts of foreign capital and inward investment through cheap labor, leading to an increase in employment opportunities [26-27]. Literature [28] analyzes the role of high-value export growth and global food value chains in contributing to rural labor market dynamics and rural development, and describes the future outlook for employment, agro-industrialization, and labor market dynamics in global value chains. Literature [29] describes GVCs and points out that they play an important role in promoting exports and increasing productivity, but their impact on labor markets varies significantly across developing countries. The change of international trade structure and global economic relations is a process of continuous adjustment and adaptation, and it is the common goal of all countries to rationally utilize the opportunities of international trade to promote global economic development [30-33]. In this process, countries need to strengthen cooperation, and jointly address the challenges to promote the further development of international trade and global economic relations [34-35].

In this paper, after a theoretical overview of the structural aspects of international trade, a regression model is established based on six related theories to analyze the structural changes of international trade in terms of principal component regression. On the basis of previous research, a method applicable to studying the impact of changes in international trade structure on economic growth in China's national conditions is proposed, and the relevant indicators of changes in international trade structure are selected based on the BEC guidelines, and a simple regression equation is set out to examine the empirical relationship between trade structure and industrial structure. The least squares method of multiple linear regression is used, and the causal analysis is carried out sequentially according to the steps of Granger test. After obtaining the results, the AR root test is applied to test the stability of the model to ensure the accuracy of the conclusions.

2. Factors affecting changes in the structure of international trade based on principal component analysis

2.1. Variable selection and modeling

In this paper, when studying the structure of international trade, two parts of the structure of import and export trade are elaborated. Similarly, when analyzing the factors affecting the structure of international trade, the factors affecting the structure of export trade are analyzed first, and then the factors affecting the structure of import trade are analyzed. The following section focuses on the factors and mechanisms affecting the structure of export trade from the perspective of the structure of export trade, and only briefly lists the results of measurement and conclusions from the perspective of exports [36].

This paper provides an overview of the theories on international trade structure, namely comparative advantage theory, factor endowment theory, intra-industry trade theory, international direct investment, technology gap theory and protection trade theory. According to these six theories, this paper selects the coefficient of explicit comparative advantage, capital-labor ratio, intra-industry trade index, amount of outward foreign direct investment, proportion of R&D investment to GDP and trade openness as the basic factors affecting a country's merchandise trade structure, and establishes a regression model:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon \quad (1)$$

where Y is a variable factor measuring the structure of foreign merchandise trade. Since the export value of single categories of goods exported by SITC6, SITC7 and SITC8 does not change much as a proportion of the total value of export trade, but the change of the total value of China's exports of foreign manufactured goods as a proportion of the total value of exports after the inclusion of the category of goods of SITC5 is relatively large and basically accounted for the proportion of the total value of exports that accounted for more than 80% of the total value of exports, this paper chooses the proportion of the exports of foreign manufactured goods as a proportion of the total value of exports change as the dependent variable. X_1 denotes the coefficient of comparative advantage RCA, X_2 denotes China's capital-labor ratio, X_3 denotes the intra-industry trade index GL, X_4 outward foreign direct investment (OFDI) flows, X_5 China's R&D investment in GDP, and X_6 China's degree of openness to trade.

Table 1 shows the original data selected for the econometric model of this paper, and it can be seen that Y (change in international trade structure) shows a fluctuating upward trend, from 84.546 in 2016 to 92.485 in 2025, with an increase of 9.39%, and the independent variable indexes X1~X5 are all improved to different degrees, while X6 shows a downward trend. At 2025, the values of X1~X6 are 0.845, 7.264, 0.249, 56115, 2.148, and 0.348, respectively.

Table 1. The original data selected by the measurement model

/	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Y	84.546	88.962	88.249	83.745	85.396	85.748	88.348	90.485	91.048	92.485
X1	0.418	0.548	0.548	0.548	0.636	0.645	0.6485	0.748	0.748	0.845
X2	1.458	1.798	2.266	2.859	3.645	4.048	4.846	5.875	6.645	7.264
X3	0.125	0.096	0.148	0.128	0.148	0.178	0.248	0.245	0.245	0.249
X4	4348	11048	11966	11235	30485	18695	34948	48266	33245	56115
X5	1.425	1.499	1.545	1.648	1.748	1.848	1.948	2.048	2.084	2.148
X6	0.652	0.648	0.569	0.439	0.463	0.489	0.489	0.459	0.448	0.348

2.2. Correlation analysis

To study the regression problem, the first step is to examine whether there is any problem of multicollinearity among the independent variables. In this paper, SPSS 20.0 is used to analyze the covariance of each independent variable. Figure 1 shows the correlation analysis. Through the analysis, the correlation of the six variables, namely, coefficient of revealed comparative advantage, capital-labor ratio, intra-industry trade index, amount of outward foreign direct investment, share of R&D investment in GDP and trade openness, are all very high, among which the correlation coefficients of X1 and X2~X5 are 0.989, 0.896, 0.966, 0.914, respectively, and the correlation coefficients of X1 and X6 are -0.869, which show a negative correlation, all of them are close to 1/-1, and there is no serious covariance.

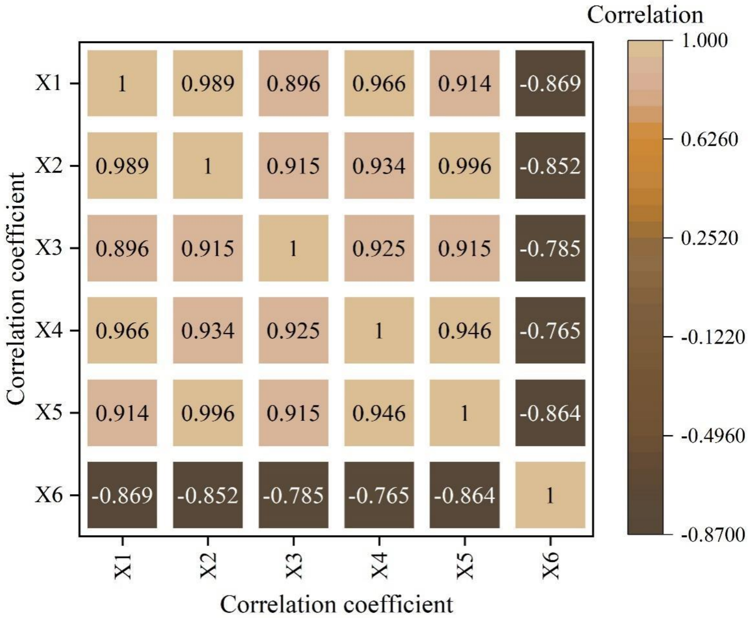

Figure 1. Correlation analysis

2.3. Principal component analysis

Before doing principal component analysis, factor analysis was done. Factor analysis refers to the study of statistical techniques for extracting common factors from groups of variables [37]. It was first proposed by a British psychologist. He found that there is a certain correlation between students' performance in various subjects, and students who perform well in one subject tend to perform better in other subjects as well, and thus hypothesized that there are some potential common factors, or some general intellectual conditions affecting students' academic performance. Factor analysis can find out the hidden representative factors among many variables, and group the variables with the same essence into one factor, which can reduce the number of variables and test the hypotheses of the relationship between variables. Table 2 shows the results of the test, KMO and Bartlett's Test for 6 indicators. The test was passed before the variables could be factor analyzed. According to the table KMO and Bartlett's Test results, it can be seen that the KMO value is 0.8265>0.7, and Bartlett'stTest Sig is 0 less than 0.05, so the variables are suitable for factor analysis.

Table 2. Test result

The test by KMO and Barlett		
The Kaiser-Meyer-Olkin measure of sampling adequacy		0.8265
Barlett's sphericity test	Approximate chi-square	77.9554
	Df	17
	Sig.	0.0000

Table 3 shows the test of variance of the public factors.From the results, it can be seen that the common degree of each variable is 0.9469,0.9758,0.8436,0.8869,0.9753, 0.8496 are higher than 0.5,which means that the public factors are highly correlated with each variable.

Table 3. Common factor variance

/	Initial	Extract
X1	1.000	0.9469
X2	1.000	0.9758
X3	1.000	0.8436
X4	1.000	0.8869
X5	1.000	0.9753
X6	1.000	0.8496
Extraction method: Principal component analysis		

Table 4 shows the total variance values of the solution, there is only one factor with eigenvalue greater than 1 in the correlation coefficient matrix of the explanatory variables, and its eigenvalue is 5.4154, this common factor includes 91.1645% of the variance of all the variables, and it explains 91.1645% of the total information of all the variables' variances. Therefore, one public factor was extracted, i.e., it is more reasonable to perform one principal component analysis.

Table 4. The total variance of the solution

Ingredients	Initial eigenvalue			Extract the sum of squares and load it		
	Total	Variance/%	Accumulation/%	Total	Variance/%	Accumulation/%
1	5.4154	91.1645	91.1645	5.4154	91.1645	91.1645
2	0.2969	4.2486	95.4131			
3	0.1648	2.7995	98.2126			
4	0.0864	1.3586	99.5712			
5	0.0166	0.2586	99.8298			
6	0.0199	0.1702	100			
Extraction method: Principal component analysis						

The principal component is named F. Table 5 shows the matrix of score coefficients of the public factors, through which the scores of the public factors can be found. According to the component data in the table:

F=0.1795 X_1 +0.1856 X_2 +0.16488 X_3 +0.1748 X_4 +0.1859 X_5 -0.1644 X_6

Table 5. The score coefficient matrix of the common factor

/	Ingredients
	1
X1	0.1795
X2	0.1856
X3	0.1648
X4	0.1748
X5	0.1859
X6	-0.1644
Extraction method: Principal component.	
Rotation method: Orthogonal rotation method with Kaiser standardization.	
Constitute the score.	

2.4. Principal Component Regression

The total value of international trade exports as a share of total exports, Y, is standardized and regressed with the public factors, and the results are expressed in Table 6. The adjusted R-square is 0.4686, indicating that the regression variance can explain 46.86% of the variance of the dependent variable, and the F-value of the regression variance is 7.1986. The significance is 0.0245, which is less than 0.05 indicating that the regression equation is valid.

Table 6. Public factor regression analysis

Model summary						
Model	**R**	**R^2**	**Adjust R^2**	**Error of standard estimation**	**F**	**Sig.**
1	0.6585a	0.4896	0.4686	2.2489	7.1986	0.0245b
a predictor variable: (Constant),REGR factor score 1 for analysis 1.						

Table 7 shows the table of coefficients, through the table of coefficients we can see the equation as: Y=2.0348-F

Adding the equation to the mean of the dependent variable, the standardized equation is changed back to the original model as: Y=87.9+2.0348-F is restored to the original metric value as:

Y=83.05+3.12·X1+0.17·X2+5.683·X3+0.00001·X4+1.362·X5-10.936·X6

Table 7. Internal coefficient table

Coefficient a					
Non-standardized coefficient					
Model	**B**	**Standard error**	**Standard coefficient**	**T**	**Sig.**
1 REGR factor score lfor analysis 1	3.30E-16	0.7196	0.6465	0	1
	2.0348	0.7529		2.345	0.0285
a. Dependent variable::Y					

3. Characterizing the changing structure of international trade

3.1. New approaches to the analysis of changes in international trade

3.1.1. Research methodology, data used

(1) Introduction to the methodology

The time series of a country's trade volume generally exhibits a fixed-trend process, and in addition to comparative advantage affecting a country's trade structure, it is also affected by factors such as inflation, economic growth, foreign trade dependence, macroeconomic imbalances, exchange rates, FDI, tariff and non-tariff barriers, and industrial policy. Therefore, analyzing a country's trade structure requires separating the above factors from the trade volume data. In order to portray the three conditions of a country's net imports, net exports, and trade balance, Gagnon and Roser proposed a standardized trade equilibrium index when considering imports and exports, as in the following equation:

$$NB_{it}^{j} = \left(\frac{X_{it}^{j}}{\sum_{i} X_{it}^{j}} - \frac{M_{it}^{j}}{\sum_{i} M_{it}^{j}} \right) \times 100 \tag{2}$$

NB_{it}^{j} denotes the normalized net trade in i products under j categories of goods in a country in year t, and X_{it}^{j} and M_{it}^{j} denote the exports and imports of i products in year t, respectively. Since the value of imports and exports of each product in each year is based on 100 and the arithmetic sum of all products is zero (3). Therefore, it is possible to make cross-section comparisons between different time years, and the effect of exchange rate factors can also be eliminated, so that the normalized value of NB_{it}^{j} is only affected by structural factors and not by trend factors:

$$\sum NB_{it}^{j} = 100\sum\left(\frac{X_{it}^{j}}{\sum_{i} X_{it}^{j}} - \frac{M_{it}^{j}}{\sum_{i} M_{it}^{j}}\right) = 100\left(\frac{\sum X_{it}^{j}}{\sum X_{it}^{j}} - \frac{\sum M_{it}^{j}}{\sum M_{it}^{j}}\right) = 0 \quad (3)$$

In order to further measure the relative importance of i -products in j -categories of goods, a standardized trade share indicator is constructed, as in the following equation:

$$NV_{it}^{j} = \frac{1}{2}\left(\frac{X_{it}^{j}}{\sum_{i} X_{it}^{j}} - \frac{M_{it}^{j}}{\sum_{i} M_{it}^{j}}\right) \times 100 \quad (4)$$

NV_{it}^{j} denotes the share of import and export of i products in j categories of goods in year t in total trade.

(2) Use of data

Therefore, this paper draws on the construction of intra-industry trade competition indicators to improve the above indicators, as follows equation (5):

$$R = 1 + \frac{NB_{it}^{j}}{2 \times NV_{it}^{j}} = 1 + \frac{\left|\frac{X_{it}^{j}}{\sum_{i} X_{it}^{j}} - \frac{M_{it}^{j}}{\sum_{i} M_{it}^{j}}\right|}{\left|\frac{X_{it}^{j}}{\sum_{i} X_{it}^{j}} + \frac{M_{it}^{j}}{\sum_{i} M_{it}^{j}}\right|} \quad (5)$$

The range of values of the improved trade balance indicator and the trade proportion indicator is set to $[0,2]$, and 0.85 and 1.15 are taken as the dividing line; if the R indicator is at $[0,0.85]$, it indicates that the commodity is in the state of net import, if the R indicator is at $[0.85,1.15]$, it indicates that the commodity is in the state of trade balance, and if the R indicator is at $[1.15,2]$, it indicates that the commodity is in the state of net export.

3.1.2. New research methodologies

For developing countries, the effect of changes in the international trade structure on economic growth extends to 25 per cent. Drawing on endogenous economic growth models, this paper establishes a new methodology for examining a country's trade structure by analyzing changes in the types of goods it exports and imports. It specifically involves the following four indicators:

(1) An indicator of the value of changes in the types of goods imported and exported in bilateral trade between China and the sample countries. This indicator is used to examine the overall status of the change in commodity categories in China's trade with the sample countries.

(2) The absolute value of changes in the types of goods imported and exported in the bilateral trade between China and the sample countries in the three groups of goods according to the customs statistics of primary products SITC 0-4 categories of goods, capital-intensive goods SITC 5+7 categories of goods: labor-intensive goods SITC 6+8 categories of goods and other absolute value of changes in the types of goods imported and exported. This indicator examines the dynamic changes in the types of goods in each of the three groups of goods.

(3) The relative value of each imported (exported) commodity category within the above three groups of commodities to the total categories of China's imports (exports) indicator.

(4) Construct indicators of structural change in the variety category of capital-intensive

commodities (ZBMZB) and the variety category of labor-intensive commodities (LMZB) in China's manufactured goods. the LMZB indicator is greater than 1, which indicates that China is a labor-intensive commodity exports of categories greater than the types of imports of labor-intensive products, and the ZBMZB indicator is greater than 1, which indicates that China's exports of capital-intensive commodities of categories greater than the imports of this type of commodity types of goods.

$$LMZB = \frac{\dfrac{\text{Labor-intensive export commodity categories}}{\text{Capital-intensive export commodity categories}}}{\dfrac{\text{Labor-intensive import commodity categories}}{\text{Capital-intensive import commodity categories}}} \tag{6}$$

$$ZBMZB = \frac{\dfrac{\text{Capital-intensive export product categories}}{\text{Labor-intensive export product categories}}}{\dfrac{\text{Capital-intensive import product categories}}{\text{Labor-intensive import product categories}}} \tag{7}$$

3.2. Construction of international trade structure indicators

3.2.1. Existing international trade structure indicators

According to the BEC guidelines, the trade structure indicator is constructed as the following equation.

$$COMPO = \frac{41EX + 521EX / 112EX + 122EX + 522EX + 6EX}{41IM + 521IM / 112IM + 122IM + 522IM + 6IM} \tag{8}$$

where EX indicates exports and IM imports. The indicator has a cut-off of 1, with a value greater than 1 indicating that the country is an exporter of capital goods and an importer of consumer goods, and a value less than 1 indicating that the country exports consumer goods and imports capital goods.

3.2.2. Indicators of the international trade structure in this paper

Although the construction of trade structure indicators according to the BEC classification is not suitable for China's national conditions, it helps to think about the problem. By the same token, it is possible to construct indicators of changes in the structure of China's merchandise trade according to the STTC standard, which has been revised four times to become more comprehensive and rationalized. China's customs statistics are based on the SITC caliber of merchandise import and export statistics. Therefore, the calculation with SITC classification can minimize the distortion in data transformation. What's more, SITC divides commodities into two major categories, primary products and industrial manufactured products, of which categories 0-4 are primary products and categories 5-10 are manufactured products, which are more attributes of capital goods compared to primary products. In addition, the classification does not count spare parts separately but includes them in manufactured goods, so it is more in line with the national conditions of China. The trade structure variable I (hereinafter denoted by MYJG) constructed in this paper is as follows:

$$MYJG = \frac{\text{Exports of Industrial Manufactured Goods} \Big/ \text{Exports of Primary Goods}}{\text{Imports of Industrial Manufactured Goods} \Big/ \text{Imports of Primary Goods}} \tag{9}$$

$MYJG > 1$ indicates that the ratio of manufactured exports to primary exports is greater than the ratio of manufactured imports to primary imports, the country is a net exporter of manufactured goods, and $MYJG < 1$ the country is an importer of manufactured goods. Generally speaking, the greater the trade structure of a country is above 1, the higher the share of its exports of manufactured goods.

3.3. Selection of indicators and data

3.3.1. Trade structure variables

Appropriate changes are made in the light of the criteria adopted for the classification of China's trade commodities. China's foreign trade commodities adopt the SITC classification standard, under which they are categorized into primary products and manufactured products to construct indicators of dynamic changes in the structure of trade commodities. The TSVs of foreign trade commodity structure variables constructed in this paper are as follows:

$$TSV = \frac{EX_{\text{Made}} / EX_{\text{Initial}}}{EM_{\text{Made}} / EM_{\text{Initial}}} \tag{10}$$

EM_{Made} , EM_{Initial} denote imports of manufactured goods and primary products respectively, $TSV > 1$ indicates that the ratio of imports of manufactured goods to primary products is smaller than the ratio of exports, and that the country is a net importer of primary products and a net exporter of manufactured goods, $TSV < 1$. The opposite is true, indicating that the ratio of exports of manufactured goods to primary products is less than the ratio of imports, and the country is a net exporter of primary products and a net importer of manufactured goods.

3.3.2. Model setup

The changes between trade structure and China's economic growth rate over the years have been briefly analyzed in Chapter 2, and a certain correlation has been found between the two. The process of economic growth relies on the shape of the production function, and in order to study the relationship between trade structure and economic growth so that a clear numerical comparison can be made, the neoclassical $C-D$ production function will be used:

This production function satisfies the following conditions:

(1) The returns to scale are constant.

$$F(\lambda K, \lambda L) = \lambda F(K, L) \tag{11}$$

That is, by putting in λ times the amount of labor and capital, the amount of output obtained is also λ times the original amount of output.

(2) The returns to private inputs are positive and decreasing.

$$\frac{\partial F}{\partial K} > 0, \frac{\partial^2 F}{\partial K^2} < 0; \frac{\partial F}{\partial L} > 0, \frac{\partial^2 F}{\partial L^2} < 0 \tag{12}$$

At constant levels of technology and labor, output increases with each additional unit of capital, but decreases as the amount of capital increases, and labor has the same properties.

(3) Rice field conditions.

$$\lim_{K\to\infty}\left(\frac{\partial F}{\partial K}\right)=\lim_{L\to\infty}\left(\frac{\partial F}{\partial L}\right)=\infty;\lim_{K\to 0}\left(\frac{\partial F}{\partial K}\right)=\lim_{L\to 0}\left(\frac{\partial F}{\partial L}\right)=\infty \tag{13}$$

That is, as capital (or labor) input tends to zero, its marginal output tends to infinity, and as capital (or labor) input tends to infinity, its marginal output tends to zero.

The dynamic behavior of the neoclassical economy was analyzed on the basis of the above assumptions and the Solow-Swan model was formed. The model is set to have a constant stock of human capital, i.e. $h=1$ and $L=M$. The form is a Cobb-Douglas production function:

$$Y = AK^{\alpha}L^{1-\alpha} \tag{14}$$

where Y denotes the increment in GNP, A denotes total factor productivity, K denotes the amount of capital input, L denotes the increase in labor employment, and α and $1-\alpha$ are the contribution of labor and capital, respectively. Taking natural logarithms on both sides of equation (15) simultaneously yields:

$$\ln Y = A + \alpha \ln K + (1-\alpha)\ln L \tag{15}$$

In this paper, we want to examine the impact of trade structure on economic growth, so we consider adding two new variables, trade structure and foreign direct investment, to (15), and the model is constructed as follows:

$$\ln GDP = c_1 + \beta_1 \ln LBOR + \beta_2 \ln TK + \beta_3 \ln FDI + \beta_4 \ln TSV + u_1 \tag{16}$$

Since the structure of industrial structure reflects the quality of economic growth, a simple regression equation is thus set out to examine the empirical relationship between trade structure and industrial structure, and to further find the path through which trade structure affects economic growth.

$$\ln TSV = c + \beta \ln STR1 + u \tag{17}$$

Thus, in this paper, the impact of trade structure on economic growth is tested using multiple linear regression ordinary least squares model and following the analytical steps of Granger test [38-39].

4. Study on the impact of structural changes in international trade on economic growth

4.1. Granger causality test results

4.1.1. Unit root test

When modeling the time series, the first need to consider the smoothness of the series, many time series are non-smooth, linear mainstream test is to carry out the unit root test, commonly used extended Dickey-Fuller (ADF) and non-parametric PP unit root test. In this paper, the ADF test is used, and the test formula is [40]:

$$\Delta y_t = c + \alpha t + \rho y_{t-1} + \sum\nolimits_{i=1}^{k} \gamma_i \Delta y_{t-i} + u_t \tag{18}$$

Where y_t is the time series to be tested, c is the constant term, t is the time trend, k is the lag, and u_t is the random error term. The original hypothesis is $\mathrm{H0}{:}\rho = 0$ and the alternative hypothesis is $\mathrm{H1}{:}\rho < 0$. The single integer order of y_t is determined by taking a sufficient number of differencing of y_t to ensure that the sequence under test is a smooth sequence, and then sequentially performing a unit root test each time with a sequence that reduces the number of differencing by one until the original hypothesis is accepted.

In order to avoid the pseudo-regression phenomenon in the establishment of the model, first of all, it is necessary to carry out a smoothness test on the time series data from 2016 to 2025, if there is no unit root, then the data are smooth and can be directly carried out to determine whether there is a causal relationship between the variables, and then directly establish the vector autoregressive model, if the data are not smooth, it is necessary to change into a smooth series through differencing and carry out cointegration test. Where GEX denotes the effect of structural change in export commodities, GIM denotes the effect of structural change in import commodities, and GIN denotes the effect of structural change in international trade in the study interval from 2016 to 2025.

The results of unit root test are shown in Table 8, at 1% significance level, the time series of the three variables reject the original hypothesis, and the P-values are 0, 0.0084 and 0 respectively indicating that there is no unit root, and all of them are smooth time series, in which the industrial structure and imported goods structure change effect are smooth series containing intercept term, and the exported goods structure change effect is a smooth series without intercept term and time trend term. Thus, there is no need to carry out cointegration test and the vector autoregressive model can be built directly.

Table 8. ADF test results

Variable	1% critical value	5% critical value	ADF value	P value	Test Form (c,t,k)	Lag order	Conclusion
GIN	-3.6485	-2.9458	-8.4355	0.0000	c	0	Reject
GEX	-2.6314	-1.9485	-2.6468	0.0084	K	3	Reject
GIM	-3.6245	-2.9439	-10.1468	0.0000	c	0	Reject

4.1.2. Granger causality tests

In order to ensure that the established vector autoregressive model is both statistically and economically significant, Granger causality test is needed before modeling to test whether the variables have causal relationships with each other, i.e., whether they have the ability to predict each other in the economic sense. Generally speaking, the longer the lag period can better reflect the dynamic characteristics of the model, but if the lag period is too long, there will be more parameters to be estimated, which will reduce the degree of freedom of the model and affect the validity of parameter estimation. Therefore, first of all, we need to use Eviews to determine the optimal lag order according to the relevant information criteria, Table 9 shows the results of the optimal lag order judgment, “*” in the case of lagging the 4th order of the number of 4, which is the most frequent in all the lagging cases, so it can be judged that the optimal lag order of the 4th order. Then in the case of lagging 1-4 periods, the causality test is carried out for the three variables respectively.

Table 9. The optimal hysteresis number is the result

Lag	LogL	LR	FPE	AIC	SC	HQ
0	432.4258	NA	1.88E-16	-27.485	-27.569	-27.642
1	449.6695	29.5485	1.12E-16	-28.234	-27.648*	-28.048
2	456.4897	12.1695	1.24E-16	-28.148	-27.169	-27.829
3	469.7852	16.5485	1.05E-16	-28.345	-26.948	-27.846
4	485.3158	18.8668*	7.38E-18*	-28.485*	-26.948	-28.487*
5	492.5897	6.5264	9.97E-17	-28.648	-26.458	-27.964

Note: * indicates the optimal order under the corresponding standard.

Table 10 shows the results of the Granger causality test, where GIN is the Granger cause of GEX and GIM is the Granger cause of GIN in the lagged 1-period scenario, with p-values of 2.452e-09 and 0.0248, respectively. In the 2-period lag scenario, only GIN can be used as a Granger cause of GEX, with a p-value of 0.0452. In both the lagged 3- and 4-period scenarios, GEX rejects the original hypothesis as a Granger cause of GIN, with p-values of 0.0005 and 0.0025, respectively. To summarize, the structural change effect of imported and exported commodities can be the Granger cause of industrial structure change effect. The structural change effect of imported goods can be the Granger cause of industrial structure change effect only in the case of lagging 1 period, reflecting that imported goods can make up for the scarce elements of industrial development most quickly and promote its optimization and adjustment, in addition, there is only a unidirectional causality between the two, and they do not form a mutually complementary interactive relationship. The effect of industrial structure change in the lag 1-2 period can be used as the Granger cause of the effect of changes in export structure, the effect of changes in the structure of export goods in the lag 3-4 period can be used as the Granger cause of the effect of changes in industrial structure, the two have a bi-directional causality in different lags, reflecting that the industrial structure of the current period determines the structure of export goods, and the later period is the time when the structure of foreign trade brings the international market demand. It reflects the development logic that the international market demand brought by the foreign trade structure leads to the optimization and adjustment of the industrial structure, and it is also a reflection of the formation of the interactive relationship of mutual promotion.

Table 10. Granger causality test results

Original hypothesis	Lag order	P Value	Conclusion
GEX does not Granger Cause GIN	1	0.5485	No refuse
GIN does not Granger Cause GEX	**1**	**2.452e-09**	**Refuse**
GIM does not Granger Cause GIN	**1**	**0.0248**	**Refuse**
GIN does not Granger Cause GIM	1	0.8469	No refuse
GEX does not Granger Cause GIN	2	0.7966	No refuse
GIN does not Granger Cause GEX	**2**	**0.0452**	**Refuse**
GIM does not Granger Cause GIN	2	0.4268	No refuse
GIN does not Granger Cause GIM	2	0.1458	No refuse
GEX does not Granger Cause GIN	**3**	**0.0005**	**Refuse**
GIN does not Granger Cause GEX	3	0.4185	No refuse
GIM does not Granger Cause GIN	3	0.6748	No refuse
GIN does not Granger Cause GIM	3	0.0966	No refuse
GEX does not Granger Cause GIN	**4**	**0.0025**	**Refuse**
GIN does not Granger Cause GEX	4	0.5758	No refuse
GIM does not Granger Cause GIN	4	0.7496	No refuse
GIN does not Granger Cause GIM	4	0.1549	No refuse

4.2. Vector autoregressive modeling

4.2.1. Empirical analysis of structural changes in international trade on economic growth

In this paper, the least squares method is used to estimate the four models separately, and the analysis software is Eviews 6.0.The statistic descriptions and final calculation results are shown in Table 11. The results of empirical analysis show that the goodness of fit of all four equations is above 95%, the regression coefficient of the independent variable X2 is greater than 1, and the capital-labor ratio is still the most critical driving force of economic growth in the test region, and there is the effect of increasing returns to scale.

The coefficient of comparative advantage, the index of intra-industry trade, the amount of outward foreign direct investment, the share of R&D investment in GDP and trade openness have differentiated characteristics in their contribution to economic growth. The regression results of model (1) show that the intra-industry trade index has a significant driving effect on economic growth, and every 1% increase in the comparative advantage coefficient raises economic growth by about 0.0635%. The regression results of model (2) show that the amount of foreign direct investment does not have a significant driving effect on economic growth. The regression results of model (3) show that the share of R&D investment in GDP has a significant driving effect on economic growth, and every 1% increase in the share of R&D investment in GDP raises economic growth by about 0.1348%, which is twice as much as that of general product exports. The regression results of model (4) show that trade openness has an unfavorable effect on economic growth, but its effect is not significant.

Table 11. The relationship between foreign trade and economic growth

/	Indicator	Model(1)	Model(2)	Model(3)	Model(4)
Independent variable	X1	1.6425*** (3.0489)	1.2452** (2.3485)	1.3456** (3.0448)	0.7165 (1.0554)
	X2	1.3483*** (11.7985)	1.2489*** (10.9452)	1.2485*** (12.7496)	1.4168*** (7.9452)
	X3	0.0635** (2.7965)			
	X4		0.0348 (1.0542)		
	X5			0.1348** (2.7456)	
	X6				-0.0448 (-0.5136)
	AR(1)	0.9645*** (6.6485)	1.0485*** (5.3422)	0.4125 (0.9426)	
	AR(2)	-0.2485* (-1.8468)	-0.3452* (-1.8456)	-0.5423 (-1.2498)	
Evaluation statistic	Adj-R^2	0.9485	0.9485	0.9452	0.9845
	Mean square error	4.3454	4.3485	4.4463	4.4369
	Sum of squared residuals	0.0012	0.0026	0.0059	0.0025
	D-W statistical value	2.1245	2.0485	1.8455	1.4495
	F-statistic	443.4896	292.3464	49.3486	88.5564

Note: AR represents the coefficient estimates of the autoregressive model. The numbers in parentheses are t-statistical values. The ***, **and* next to the coefficient estimates indicate significant validity at the 1%, 5%, and 10% significance levels, respectively.

4.2.2. Model Stability Tests

In order to complete the further analysis of the above vector autoregressive model, it is necessary to carry out the stability test of the model. Figure 2 shows the AR root test, the characteristic roots all fall within the unit circle, thus it can be considered that the above established vector autoregressive model passes the stability test.

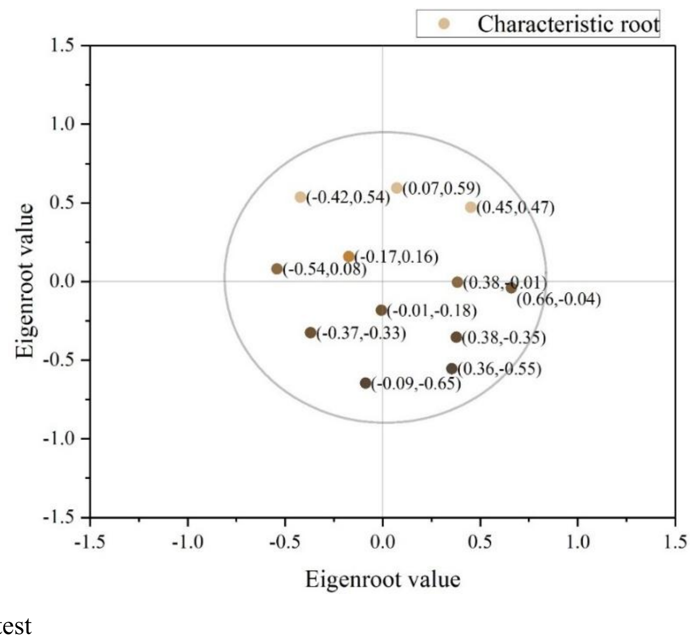

Figure 2. AR root test

4.3. Impulse Response Function Analysis

When a positive shock of standard deviation size is applied to the effect of international trade structure change, Figure 3 shows the impulse response result, which has a large positive impact on itself in the current period, and then drops sharply, and fluctuates down after period 2, and then produces a smaller negative impact from period 6, and the function value of the negative impact is about -0.00005 period 7 reaches the lowest point and then picks up slowly, and after that, it has been in the negative After that, it has been in a fluctuating state of negative and positive influence, but the influence is gradually weakening.

When the effect of changes in the structure of imported goods is given a standard deviation of the size of the positive shock, the effect of changes in the structure of international trade in the current period is affected by the impact of 0, and then the negative response to the shock is more sensitive to the lowest point in the 4th period, about -0.0003 after the rapid rise in the 6th period after the presentation of positive and negative impacts of the alternately fluctuating and progressively weaker phenomenon, in general the impacts of the structure of imports of goods are negative. In general, the impact of imported goods structure is negative.

When a positive shock of standard deviation size is given to the effect of export commodity structure change, it has no effect on the effect of industry structure change in the current period, but the effect is rapidly highlighted after the 1st period, the positive effect reaches a peak of 0.00058 in the 3rd period and then decreases rapidly, the negative effect reaches a minimum in the 6th period and then slowly rebounds, and then it has been in the fluctuating state of the negative effect and the positive effect, but the effect after the 11th period Weakness. In addition, the Granger causality test shows that there is a bidirectional causality between the two, so the same positive shock with a standard error of the size of the effect of changes in industrial structure is also applied, which has a more obvious positive impact on the structure of export commodities in the first period, and reaches a maximum in the second period, then declines rapidly in the third period, and then exhibits a more moderate fluctuation trend after the fourth period, with the positive impact gradually weakening to disappear.

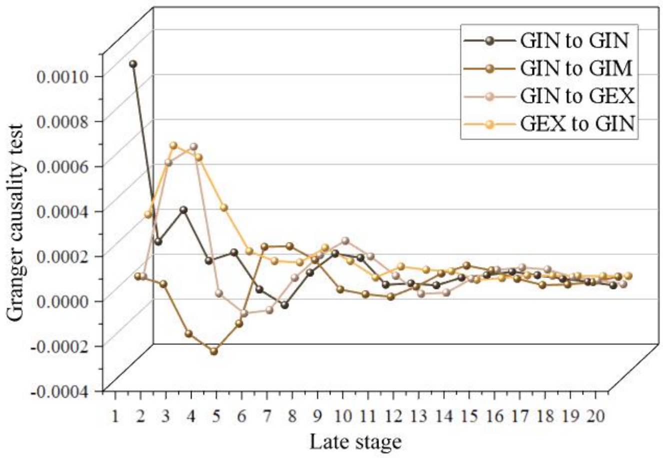

Figure 3. Pulse response

4.4. Variance Decomposition

In order to further analyze the explanatory role of structural shocks of different variables on GIN and to clarify the contribution of each variable to each other, a variance decomposition of GIN is needed. Figure 4 shows the variance decomposition of GIN, with GIN contributing the most to the structural change in international trade, GEX the second most, and GIM the least. The predicted variance of the industrial structure change effect is completely explained by itself in the current period, the contribution of the import and export commodity structure change effect starts to rise significantly in the 2nd period, and the contribution of the industrial structure change effect itself decreases, and the changes of the three tend to be stable in the 4th period, in which the contribution of GIN is 55.516%, the contribution of GEX is 33.359%, and the contribution of GIM is 10.95%. It can be seen that in the process of adjusting the changes in the international trade structure of the test area, it is most affected by its own changes, and the overall impact of the changes in the structure of trade in goods is relatively small, of which the impact of exports is greater than that of imports, which has a certain relationship with the volume of exports of goods in the test area is greater than imports.

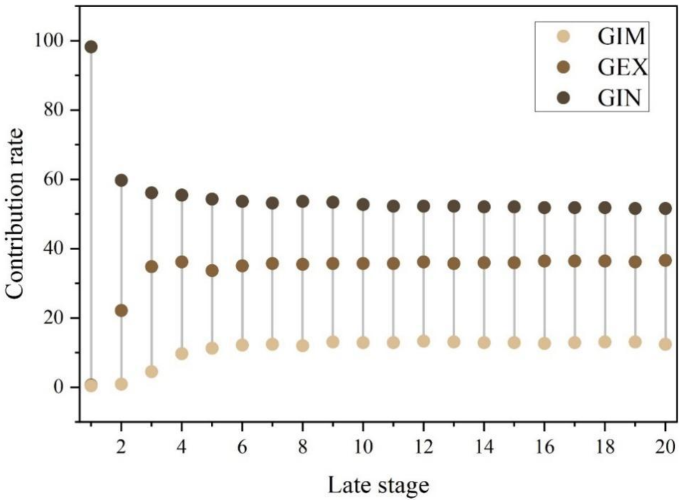

Figure 4. GIN variance decomposition

Combined with the results of empirical analysis, it can be seen that changes in the international trade structure of the test area have a certain degree of impact on economic growth. However, the current international trade structural adjustment is path-dependent, and thus there is a time lag in the response to changes in economic growth.

5. Conclusion

This study divides the international trade structure into two parts: imports and exports, discusses the influencing factors and mechanisms from the perspective of trade structure, selects the relevant independent variables and establishes a regression model, and analyzes the degree of its influence on economic growth through the principal components. Subsequently, combined with the previous methods of analyzing the changes in international trade, this paper proposes a new research method to construct the international trade structure indicators applicable to China's national conditions. Finally, Granger causality test, AR root test and impulse response function analysis are utilized in turn to explain the role of international trade structure changes in influencing economic growth. The experimental results are as follows:

(1) The principal component regression analysis shows that the adjusted R-square is 0.4686, and the regression variance can explain 46.86% of the dependent variable, and the significance is 0.0245,which is less than 0.05, indicating that the regression equation is valid.

(2) In order to avoid pseudo-regression phenomenon in modeling, the time series data of this paper are tested for smoothness, and at 1% significance level, the time series of export trade commodity structure change, import trade commodity structure change and industry trade structure change reject the original hypothesis, and the P-value is 0, 0.0084, 0, respectively, and the test period are all smooth time series.

(3) The variance decomposition of international trade structure changes, the contribution of GIN is 55.516%, the contribution of GEX is 33.359%, the contribution of GIM is 10.95%, and the contribution of GIN to international trade structure changes is the largest.

To summarize, the change of international trade structure has a certain impact on economic growth, but there is a certain time lag in the response to the change of economic growth.

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