Online-Journals.org

iTDAF IETI Transactions on Data Analysis and Forecasting

iTDAF | eISSN: 2959-0442 | Vol. 2 No. 1 (2024) | OPEN ACCESS

https://doi.org/10.3991/itdaf.v2i1.49197

PAPER

# Research on China's Environmental Law and Low-carbon Emission Economy Trade Surplus under the Background of Carbon Neutrality

**Gaojing Gai**[1], **Yang Wang**[2](✉)

[1]School of International Trade and Economics, Shangdong University of Finance and Economics, Jinan, China

[2]Harbin Finance University, Harbin, China

wy9502@yeah.net

**ABSTRACT**

The significant presence of high-carbon industries in China's export trade and the substantial trade surplus in recent years are key factors contributing to the increase in China's carbon emissions. China's current export trade model does not align with the requirements of low-carbon economic development. Considering China's future emission reduction goals and responsibilities, we should aim to achieve a low-carbon trade transformation, establish a trading method that is compatible with developing a low-carbon economy, and actively promote the development of a low-carbon economy. Based on this premise, the paper utilizes the input-output model and low-carbon trade competitiveness indicators to empirically analyze China's foreign trade implied carbon emissions and low-carbon trade competitiveness. It also investigates China's foreign trade surplus.

**KEYWORDS**

carbon neutrality, low carbon trade competitiveness, trade surplus, environmental law

## 1 INTRODUCTION

In the 21st century, a "low carbon economy" has emerged as a significant response to global environmental challenges, attracting widespread attention from governments and citizens worldwide. This new economic paradigm, driven by the urgent need for sustainable development, has been underscored by a series of international agreements and protocols, such as the Kyoto Protocol and the Paris Agreement, which have played pivotal roles in fostering global consensus on climate change mitigation [1–2]. The transition to a low-carbon economy is considered a crucial pathway to achieving sustainable economic growth while addressing environmental concerns.

The shift towards a low-carbon economy has profound implications for international trade, necessitating a transition away from traditional and high-emission

Gai, G., Wang, Y. (2024). Research on China's Environmental Law and Low-carbon Emission Economy Trade Surplus under the Background of Carbon Neutrality. *IETI Transactions on Data Analysis and Forecasting (iTDAF)*, 2(1), pp. 23–32. https://doi.org/10.3991/itdaf.v2i1.49197

Article submitted 2024-01-19. Revision uploaded 2024-03-14. Final acceptance 2024-03-20.

industries towards more sustainable practices. This transformation is expected to lead to a new development trend in international trade, characterized by a focus on quality over quantity and a gradual increase in the export of low-emission, environmentally friendly products [3–4]. Moreover, the introduction of mechanisms such as carbon tariffs by developed countries could significantly impact the international competitiveness of high-carbon-emitting products, promoting exporting countries to innovate and adapt [5].

However, the transition to a low-carbon economy presents particular challenges for developing countries, which may lack the economic strength and technological capabilities of their developed counterparts. These countries face the dual challenge of promoting economic growth while adhering to stricter environmental standards, which often puts them at a disadvantage in the global market [6]. Nonetheless, the transition to a low-carbon economy is an inevitable step in addressing global ecological issues, with technological advancements and international cooperation being essential to overcoming these challenges [7].

Particularly, China has been at the forefront of this transition, with significant commitments to reducing carbon emissions and achieving carbon neutrality. Despite the challenges, such as less-developed legal frameworks for climate change mitigation, China's efforts exemplify the global shift towards more sustainable economic models. The country's emphasis on improving its legal and regulatory environment for climate change reflects a deeper recognition of the crucial role of governance in enabling this transition [8–9].

Against this backdrop, this paper aims to explore China's competitiveness in low-carbon trade and how it has evolved over time. By examining the carbon embodied in China's import and export trade and constructing a low-carbon trade competitiveness index, this study aims to offer insights into the effectiveness of China's low-carbon trade strategies and their implications for sustainable economic development [10].

## 2 MODEL BUILDING

The input-output analysis method was created by Leontief through his research, and it is widely utilized in the fields of national economic accounting, industrial structure linkage, and energy and environment studies. The input-output table (extension table) is constructed based on the fundamental principle of the input-output method, which states that total output = intermediate input + final use. The formula can be expressed as:

$$X_i = \sum_{j=1}^{n} a_{ij} X_j + Y_i (i, j = 1, 2, \ldots, n) \tag{1}$$

Among them, $a_{ij}$ refers to the direct consumption coefficient of the total output $X_j$ of the production unit $j$ to the product sector $i$, $\sum_{j=1}^{n} a_{ij} X_j$ represents the sum of the intermediate inputs, $Y_i$ is the final use of product sector $i$ in the current period, and $X_i$ is the total output of the i-th product sector.

Expand the analysis of the product sector i to include all product sectors. Let $I$ be the unit matrix, $A$ be the direct consumption coefficient matrix, $X$ be the column vector of the total output of each product department, and $Y$ be the column vector of the final use. Each determinant can be expressed as follows:

$$A = \begin{bmatrix} a_{11} & a_{22} & \dots & a_{1,n-1} & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2,n-1} & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n-1,1} & a_{n-1,2} & \dots & a_{n-1,n-1} & a_{n-1,n} \\ a_{n1} & a_{n2} & \dots & a_{n,n-1} & a_{nn} \end{bmatrix} Y = [\begin{matrix} Y_1 \\ Y_2 \\ \vdots \\ Y_{n-1} \\ Y_n \end{matrix}]$$

$$I = \begin{bmatrix} 1 & 0 & \dots & 0 & 0 \\ 0 & 1 & \dots & 0 & 0 \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 1 & 0 \\ 0 & 0 & \dots & 0 & 1 \end{bmatrix} X = [\begin{matrix} X_1 \\ X_2 \\ \vdots \\ X_{n-1} \\ X_n \end{matrix}] \tag{2}$$

Then (1) can be expressed as:

$$X = AX + Y$$

After further sorting, the basic model of input and output can be obtained, namely:

$$X = (I - A)^{-1}Y \tag{3}$$

## 3 CARBON EMISSION CALCULATION MODEL IN FOREIGN TRADE

### 3.1 Construction of a non-competitive input-output model

In China, production and consumption take place within a closed economic system. Trade effects may not be considered at this time. In the current open economic system, a country efficiently allocates factor resources and products through trade based on its comparative advantage. This separation of a country's production, and consumption leads to the international flow of embodied carbon emissions. Therefore, when calculating the implied carbon emissions of the product sector, the implied carbon emissions caused by trade factors should be fully considered. The intermediate inputs should be categorized as either produced in China or imported from other countries. Based on this, the paper constructs a non-competitive input-output model.

Currently, the corresponding direct consumption coefficient matrix is $A = A^d + A^m$, $A^d$ is still the direct consumption coefficient matrix, and $A^m$ is the direct consumption coefficient matrix of the imported product sector. Drawing on the method of removing the intermediate input $A^m$ from scholars such as, set $A^m = M \times A$, $M$ is the import coefficient matrix, which refers to the proportion of imported products in the intermediate input. Assuming that the intermediate input ratio of imported products remains unchanged, $M$ is a diagonal matrix, and the diagonal matrix elements $m_{ij} = \frac{IM_i}{(X_i + IM_i - EX_i)}$ $(i, j = 1, 2, \dots, n)$; and when $i \neq j$, $m_{ij} = 0$, $IM_i$ is the import value of the i-th product sector, and $EX_i$ is the export value. Then China's direct consumption coefficient matrix is $A^d = (I - M)A$, and the implied carbon emission coefficient of each product sector can be expressed as:

$$F = E(I - A^d)^{-1} \tag{4}$$

Among them, $E$ represents the direct carbon emission coefficient matrix, and $(I - A^d)^{-1}$ represents the inverse Leontief matrix excluding imports.

### 3.2 Construction of a calculation model for embodied carbon in export trade

According to the implied carbon emission coefficient, the calculation formula for the embodied carbon in export trade can be obtained, namely

$$C_{ex} = E(I - A^d)^{-1}T^{ex} + E(I - A^d)^{-1}A^m(I - A^d)^{-1}T^{ex} \quad (5)$$

Among them, $C_{ex}$ is the embodied carbon emissions in export trade; $E(I - A^d)^{-1}$ is the matrix of implied carbon emission coefficients for export products; $E(I - A^d)^{-1}T^{ex}$ is the carbon embodied in domestic exports; $E(I - A^d)^{-1}A^m(I - A^d)^{-1}T^{ex}$ is re-exported embodied carbon; $T^{ex}$ is a column vector of export product values.

### 3.3 Construction of a calculation model for the embodied carbon in import trade

China imports products from other countries to meet its final demand. From the perspective of import substitution, it can be seen that the carbon emissions associated with products imported from other countries are equivalent to reducing the carbon emissions that would have otherwise been generated in China. Therefore, it can be assumed that the embodied carbon emission intensity per unit of the output value of other countries is equal to that of China (Caihong and Liyan, 2014; Jianbo and Feng, 2018). From this, the calculation formula for carbon embodied in import trade can be derived, namely:

$$C_{im} = E(I - A^d)^{-1}A^m(I - A^d)^{-1}Y^d + E(I - A^d)^{-1}Y^m + E(I - A^d)^{-1}A^m(I - A^d)^{-1}T^{im} \quad (6)$$

Among them, $C_{im}$ is the embodied carbon emissions in import trade; $E(I - A^d)^{-1} A^m(I - A^d)^{-1}Y^d$ is the implicit carbon used in the import for intermediate inputs; $E(I - A^d)^{-1}Y^m$ is the embodied carbon in imports for final consumption; $E(I - A^d)^{-1} A^m(I - A^d)^{-1}T^{ex}$ is the embodied carbon generated in import for re-export; $Y^d$ is the column vector of intermediate input product value; $Y^m$ is the final consumer product value column vector; $T^{im}$ is the column vector of imported product value.

### 3.4 Construction of low-carbon trade competitiveness index

According to the concept of low-carbon trade competitiveness, this paper develops the low-carbon trade competitiveness index by combining the implied carbon emission productivity index with the traditional trade competitiveness index. Among them, embodied carbon emission productivity measures the economic output level of the embodied carbon emissions per unit of a country or region. It mainly measures the impact of embodied carbon emissions on the economy and society (Lingling and Jinping, 2014), which can be expressed as:

$$CP_k = \frac{Y_k}{C_k} \quad (7)$$

Among them, $CP_k$ refers to the implied carbon emission productivity of China's k-product sector, $Y_k$ refers to the added value of China's k-product sector, and $C_k$ refers to the implied carbon emissions of China's k-product sector. In the product sector, the higher the value of embodied carbon emission productivity, the greater the economic value of embodied carbon emissions per unit in the product sector. Traditional trade competitiveness refers to the proportion of a countries' or region's products and industries in the total foreign trade balance. It is a common method to analyze the international competitiveness of a country or region (Dongwei and Guoming, 2009; Lan, 2014). It can be expressed as:

$$TC = \frac{T^{ex} - T^{im}}{T^{ex} + T^{im}} = 1 - \frac{2T^{im}}{T^{ex} + T^{im}} \tag{8}$$

Among them, $TC$ represents traditional trade competitiveness, $T^{ex}$ is the value column vector of export products, and $T^{im}$ is the column vector of import product value. From formula (8), it can be inferred that the value of the trade competitiveness index falls within the range of (–1, 1). The traditional evaluation standard of trade competitiveness states that $TC = 1$ indicates that the product sector only exports and does not import, possessing an absolute advantage in trade competitiveness; $TC = 0$ indicates that exports are equal to imports, resulting in average trade competitiveness; $TC = -1$ indicates that the product sector only imports and does not export, indicating an absolute disadvantage in trade competitiveness. Regarding the embodied carbon emission productivity index and the traditional calculation method of the trade competitiveness index, the low-carbon trade competitiveness index of China's import and export product sector can be determined. The proportion of the total economic value contained in the unit of embodied carbon can be expressed as follows:

$$CTC = \frac{\frac{T^{ex}}{C_{ex}} - \frac{T^{im}}{C_{im}}}{\frac{T^{ex}}{C_{ex}} + \frac{T^{im}}{C_{im}}} = 1 - \frac{2\frac{T^{im}}{C_{im}}}{\frac{T^{ex}}{C_{ex}} + \frac{T^{im}}{C_{im}}} = 1 - \frac{2T^{im}}{C_{im}\frac{T^{ex}}{C_{ex}} + T^{im}} \tag{9}$$

Among them, $C_{ex}$ is the carbon embodied in China's product sector's export trade and $C_{im}$ is the carbon embodied in the import trade of China's product sector. Compared with the traditional trade competitiveness calculation model, the comprehensive analysis of formulas (8) and (9) shows that when the carbon embodied in import trade equals the embodied carbon in export trade, the traditional trade competitiveness index and the low-carbon trade competitiveness index can be understood as a special form of the low-carbon trade competitiveness index when $C_{ex} = C_{im}$.

It can be seen from the model that the low-carbon trade competitiveness index of China's import and export product sector ranges from –1 to 1. When evaluating China's import and export product sector's low-carbon trade competitiveness, the traditional trade competitiveness index is subdivided for reference (Wenqing and Wei, 2001; Xianhai, 2006). Introducing it into the evaluation criteria of low-carbon trade competitiveness can more accurately measure the level of low-carbon trade competitiveness of China's import and export product sector. The evaluation criteria are presented in Table 1.

**Table 1.** Evaluation criteria for low-carbon trade competitiveness

| Low Carbon Trade Competitiveness Index | Low Carbon Trade Competitiveness Rating |
|---|---|
| 0.8~1.0 | High comparative advantage |
| 0.5~0.8 | Higher comparative advantage |
| 0~0.5 | Low comparative advantage |
| –0.5~0 | Low comparative disadvantage |
| –0.8~–0.5 | Higher comparative disadvantage |
| –1.0~–0.8 | High comparative disadvantage |

## 4 DATA SOURCE AND PROCESSING

This paper analyzes all input-output tables (including extended tables) from China after its accession to the WTO, with a specific focus on "China's input-output tables" (including extended tables) from 2002 to 2015. It estimates China's import and export products using a non-competitive input-output model. On this basis, the low-carbon trade competitiveness of China's import and export products sector is studied using the low-carbon trade competitiveness index. The primary data are mainly sourced from the "China Statistical Yearbook," "China Energy Statistical Yearbook," the National Bureau of Statistics database, and the Commerce Data Center of the Ministry of Commerce over the years.

### 4.1 Empirical results and analysis

**Analysis of China's foreign trade embodied carbon emissions.** Figure 1 illustrates the trends in China's embodied carbon emissions from 2002 to 2015, focusing on export trade, import trade, and total foreign trade. The embodied carbon emissions from import trade have consistently increased over the years, leading to a rise in total foreign trade emissions. Notable yearly figures reached up to 10.168 billion tons by 2015, indicating an average annual growth rate of 7.75%. This significant increase, particularly after China's accession to the WTO, highlights the substantial impact of China's total carbon emissions, demonstrating a remarkable overall growth of 184.50% during this period.

The total embodied carbon emissions in China's foreign trade also showed a steady increase, reaching 13.460 billion tons by 2015, with an average annual growth rate of 7.47%. The most significant growth occurred from 2002 to 2005, indicating a rapid expansion in the early years following China's entry into the WTO.

Conversely, the carbon emissions from China's export trade exhibited a more fluctuating trend, peaking in 2007 before declining in 2010 and subsequently recovering. The overall growth rate from 2002 to 2015 was 146.90%, with the period from 2002 to 2005 experiencing the highest growth rate in export trade emissions. These dynamics reflect the complex interplay of economic activities, global trade participation, and environmental impacts over the analyzed period.

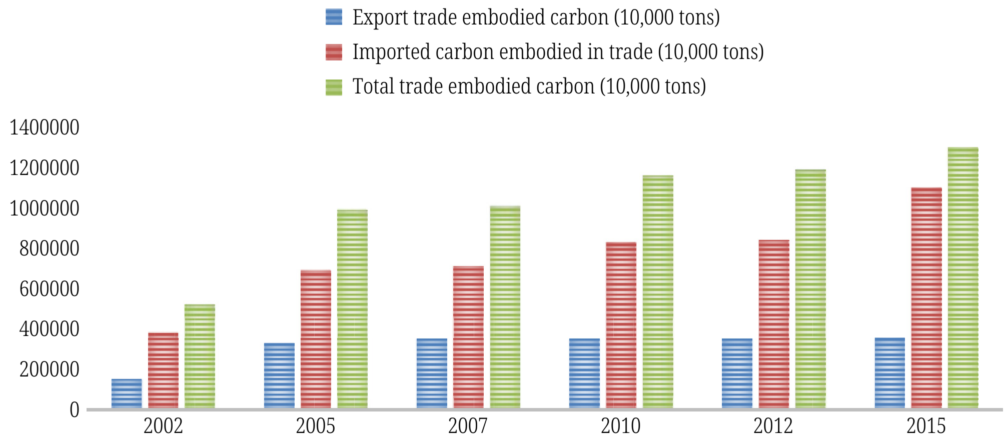


**Fig. 1.** China's overall foreign trade embodied carbon emissions (2002–2015)

*Note:* "China input-output table (extended table)," "China Statistical Yearbook," "China Energy Statistical Yearbook," the national Statistical Bureau.

Between 2002 and 2015, China's three major industries witnessed a consistent rise in embodied carbon emissions in both export and import trades. Specifically, the carbon emissions associated with the primary industry's export trade increased by 14.03 million tons, rising from 6.58 million tons in 2002 to 20.61 million tons in 2015, with intermittent decreases in 2010 and 2012. The import trade for this sector experienced a more significant increase of 62.72 million tons. The carbon emissions from the secondary industry's export trade surged by 1,803.2 million tons, while its import trade emissions increased by nearly 5.98 billion tons over the same period, both displaying consistent upward trends. The tertiary industry's export trade emissions increased by 142.81 million tons, and its total emissions increased by 562.57 million tons, showing continuous growth. The growth rate analysis revealed that, except for the primary industry, the carbon emission growth rates in the secondary and tertiary industries of import trade were higher than those in the export trade. This indicates a significant carbon leakage issue in China, with import trade playing a crucial role in the rapid increase of the country's carbon emissions.

**Table 2.** The embodied carbon emissions of China's three industries in foreign trade (2002–2015) Unit: 10,000 tons

| Industry Years | Primary Industry | | Secondary Industry | | Tertiary Industry | |
|---|---|---|---|---|---|---|
| | Export Embodied Carbon | Imported Embodied Carbon | Export Embodied Carbon | Imported Embodied Carbon | Export Embodied Carbon | Imported Embodied Carbon |
| 2002 | 658 | 3812 | 123351 | 326550 | 8981 | 24926 |
| 2005 | 1642 | 5975 | 288234 | 630060 | 17730 | 41431 |
| 2007 | 1726 | 6166 | 314897 | 650788 | 19030 | 42163 |
| 2010 | 1658 | 6784 | 295192 | 767174 | 17945 | 48506 |
| 2012 | 1505 | 7463 | 292759 | 792374 | 21662 | 60065 |
| 2015 | 2061 | 10084 | 303671 | 924353 | 23262 | 81183 |

*Note:* "China input-output table (extended table)," "China Statistical Yearbook," "China Energy Statistical Yearbook," the National Bureau of Statistics.

## 4.2 Analysis of China's low carbon trade competitiveness

Figure 2 illustrates China's overall low-carbon trade competitiveness index from 2002 to 2015. Firstly, regarding the absolute quantity of the low-carbon trade competitiveness index, in 2002, 2005, 2007, 2010, 2012, and 2015, China's overall low-carbon trade competitiveness index showed a trend of initially decreasing and then rising. The values are 0.51, 0.43, 0.46, 0.49, 0.51, and 0.57 across the years. Generally, the growth rate of low-carbon trade competitiveness is exceeding the decline rate, indicating an overall upward trend. Secondly, from the perspective of the growth rate of the low-carbon trade competitiveness index, between 2002 and 2015, China's overall low-carbon trade competitiveness index increased by 0.06, with a growth rate of 12.07%. The overall competitiveness of low-carbon trade has improved. Specifically, from 2002 to 2005, China's overall low-carbon trade competitiveness increased by –0.08, with a growth rate of –16.48%. During this period, China's overall low-carbon trade competitiveness index declined. For the following periods: 2005–2007, 2007–2010, 2010–2012, and 2012–2015. China's overall low-carbon trade competitiveness index showed a positive change, with added values of 0.03, 0.03, 0.02, and 0.06 in each period and growth rates of 7.68%, 5.84%, 4.40%, and 12.77%, respectively. Finally, when combined with China's overall low-carbon trade competitiveness index and evaluated according to the criteria outlined in Table 1, we can determine China's status regarding low-carbon trade competitiveness over the years. That is to say, China's low-carbon trade competitiveness index was between 0 and 0.5 in 2005, 2007, and 2010. During these years, China's low-carbon trade competitiveness showed a low comparative advantage. It was between 0.5 and 0.8 in 2002, 2012, and 2015, indicating a relatively high comparative advantage during these years. This indicates that China's overall low-carbon trade competitiveness is showing a positive development trend.

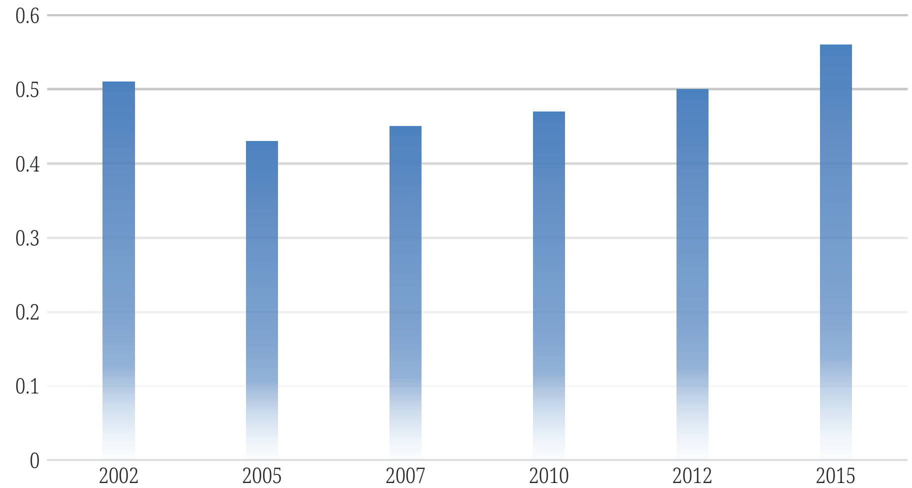


**Fig. 2.** China's overall low-carbon trade competitiveness index (2002–2015)

*Note:* According to the "China input-output table (extended table)," "China Statistical Yearbook," "China Energy Statistical Yearbook," and the National Bureau of Statistics.

## 5 DISCUSSION

Despite the comprehensive analysis provided, this study acknowledges certain limitations and identifies avenues for future research. The input-output method employed here, while effective in quantifying direct and indirect carbon emissions, has its constraints, such as the classification of industrial sectors and the assumptions regarding constant prices and consumption coefficients. Additionally, the data used, derived from various "China input-output tables," may not constitute a stable time series, potentially leading to biases. Furthermore, the complexity of global carbon emission flows, exacerbated by economic globalization and trade liberalization, presents a challenge that transcends national borders and necessitates a collective global response.

China, as the largest developing country, faces numerous development challenges, such as the need for sustainable industrialization, urbanization, and the establishment of an ecological civilization. The establishment of a global mechanism for sharing responsibility for carbon emissions is considered urgent to ensure a fair carbon emission space that supports the sustainable development of China's foreign trade and enhances its low-carbon trade. However, research in this domain remains sparse, highlighting the need for further investigation into the principles of responsibility determination, their impact on the trajectory of China's foreign trade, and their potential to enhance China's low-carbon trade competitiveness.

## 6 CONCLUSION

The analysis of China's low-carbon trade competitiveness index across various product sectors reveals a general upward trend, indicating an improvement in the overall low-carbon trade competitiveness within China's product sector. Notably, sectors such as the metal smelting and rolling processing industry, along with the general and special equipment manufacturing industry, have transitioned from a low comparative disadvantage to a low comparative advantage, indicating a positive developmental trajectory. However, certain sectors, such as agriculture and coal mining, have experienced a decline in their low-carbon trade competitiveness, transitioning from a high comparative advantage to a significant disadvantage. This suggests a need for strategic adjustments in the foreign trade and production structures of these sectors to enhance the development of low-carbon trade levels.

## 7 DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## 8 CONFLICT OF INTEREST

The authors declare that the research was conducted without any commercial or financial relationships that could be seen as a potential conflict of interest.

## 9 ACKNOWLEDGEMENT

This work was supported by the fund project: Basic Scientific Research Expenses of Provincial Undergraduate Universities 2021-KYYWF-E018; 2023-KYYWF-E030; WCMY20230701.

## 10 REFERENCES


[1] D. R. Lugo-Morin, "Global future: Low-carbon economy or high-carbon economy?" *World*, vol. 2, pp. 175–193, 2021. https://doi.org/10.3390/world2020012

[2] M. Mohsin *et al.*, "Developing low carbon economies: An aggregated composite index based on carbon emissions," *Sustainable Energy Technologies and Assessments*, vol. 35, pp. 365–374, 2019. https://doi.org/10.1016/j.seta.2019.08.003

[3] C. Perroni and T. F. Rutherford, "International trade in carbon emission rights and basic materials: General equilibrium calculations for 2020," *The Scandinavian Journal of Economics*, pp. 257–278, 1993. https://doi.org/10.2307/3440355

[4] K. Li and S. Qi, "Trade openness, economic growth and carbon dioxide emission in China," *Economic Research Journal*, vol. 11, pp. 60–72, 2011.

[5] W. Benyong *et al.*, "Research on carbon emissions of China's international trade based on input-output analysis," *Journal of Beijing Normal University: Natural Science Edition*, pp. 413–419, 2009.

[6] Z. Zhang, “China in the transition to a low-carbon economy,” *Energy Policy*, vol. 38, pp. 6638–6653, 2010. https://doi.org/10.1016/j.enpol.2010.06.034
[7] T. J. Foxon, “A coevolutionary framework for analyzing a transition to a sustainable low carbon economy,” *Ecological Economics*, vol. 70, pp. 2258–2267, 2011. https://doi.org/10.1016/j.ecolecon.2011.07.014
[8] B. Jiang, Z. Sun, and M. Liu, “China’s energy development strategy under the low-carbon economy,” *Energy*, vol. 35, pp. 4257–4264, 2010. https://doi.org/10.1016/j.energy.2009.12.040
[9] N. Wang and Y.-C. Chang, “The development of policy instruments in supporting low-carbon governance in China,” *Renewable and Sustainable Energy Reviews*, vol. 35, pp. 126–135, 2014. https://doi.org/10.1016/j.rser.2014.03.021
[10] S. Aijun, F. Jingtao, and W. Qunwei, “The temporal and spatial evolution of carbon emission efficiency of China’s export trade from 2000 to 2012,” *Resource Science*, pp. 1230–1238, 2015.

## 11 AUTHORS

**Gaojing Gai,** School of Intenational Trade and Economics, Shangdong University of Finance and Economics, Jinan, China (E-mail: 15628812013@163.com).

**Yang Wang,** Harbin Finance University, Harbin 150030, China (E-mail: wy9502@yeah.net).