Research on Measurement of China's Inter-Provincial Trade, International Trade and Low-Carbon Trade Competitiveness

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In this paper, Embodied carbon emission competitiveness in international trade and inter-provincial trade is measured and comparative analysis is conducted. Specifically the non-competitive input-output model and low-carbon trade competitiveness index are constructed to study the embodied carbon emission competitiveness of 31 Chinese provinces in international trade and inter-provincial trade from the perspectives of the whole, three industries and product sectors. We find that Shanghai is the most competitive in low-carbon trade, while Qinghai is the least; carbon leakage in international trade is severe; the performance of different product sectors differ widely in embodied carbon emission competitiveness in international trade and inter-provincial trade; the primary and secondary industries are competitive in low-carbon inter-provincial trade and the tertiary industry is competitive in low-carbon international trade. The innovations of this paper is as follows: methodology in low-carbon trade competitiveness index is innovated; macro, meso and micro perspectives are taken; factors in international trade and inter-provincial trade are combined in content. In the end, development of low-carbon trade is promoted and references for policy are provided for a new round of trade competition.

Keywords: international trade, inter-provincial trade, low-carbon trade competitiveness index, embodied carbon emissions, input-output model

1. Introduction

Since 1990s, foreign trade grew rapidly along with economic globalization, but ecological degradation was worsened as economic development was promoted. The relationship between trade and the environment attracted wide attention. China actively performed the responsibility of a major power. The Report to the 19th

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National Congress of the CPC attached great importance to ecological civilization and green development and identified the building of an ecological civilization as vital to sustain the Chinese development, which indicated China's resolution in addressing environmental pollution and climate change and defined our direction in developing low-carbon trade and taking the path of low-carbon economy.

Meanwhile, trade liberalization and economic globalization drove Chinese economy to grow rapidly, but subsequently, environmental problems were increasingly severe. In 2016, Global Carbon Project (GCP) issued the *Global Carbon Budget 2016* and pointed out that China emitted 10.4 billion tons of carbon annually, 29% of the world's total and 4% higher than the sum of the United States and EU. According to statistics of the World Bank (WB), if carbon tariffs are carried out comprehensively, export of China will plunge by nearly 21%. This implies that global climate change rules exert impact that cannot be underestimated on China's foreign trade and carbon emissions will become an important indicator for measuring a country's foreign trade competitiveness. In an open economic system, foreign trade intensifies the flow of carbon emissions globally and production and consumption of products in a country (region) are gradually separated. In this context, "low-carbon trade competitiveness" is born as an index for measuring international competitiveness of products of a country (region) in the era of low-carbon economy and it reflects both emission reduction effect of trade-engaged product sectors and their level of trade competitiveness (Zheng *et al*., 2015). At the same time, in China, the largest developing country, due to breadth of its territory, different areas differ widely in low-carbon trade competitiveness. Given so, what impact is exerted on low-carbon trade competitiveness in different areas by international trade and inter-provincial trade and what trend of changes is displayed are worth further analysis and research. On this basis, this paper constructs the environmentally non-competitive input-output model, develops the low-carbon trade competitiveness index based on the traditional trade competitiveness index and carbon productivity index, measures the embodied carbon emission competitiveness index in international trade, inter-provincial trade and general trade of 31 Chinese provincial-level administrative regions and analyzes their difference from the panoramic view, the three industries and product sectors, with the hope of offering empirical supports and reference for different areas in improving low-carbon trade competitiveness in the low-carbon economy.

2. Theoretical Basis and Literature Review

In the international division of labor and engagement in trade activities, traditional

theories, such as the theory of comparative advantage and the theory of factor endowment, take the environmental factor in trade growth as an exogenous variable. In fact, however, trade grows at the cost of massive consumption of energy and resources and environmental pollution. In the context of economic globalization, a country cannot develop without contribution of other countries or regions and environmental pollution generated by trade should be taken into re-consideration. This paper aims to enrich and develop theories on international trade and environment, identify China's level of low-carbon trade competitiveness and effectively avoid low-carbon trade barriers. In the meantime, based on the pollution haven hypothesis, the paper measures China's embodied carbon emissions in international trade and inter-provincial trade, analyzes if pollution havens exit in China and validates them, if any. According to the environmental Kuznets theory, it verifies whether the inverted U-curve proposed in the theory exists in China.

Trade and the environment have always been the focus of attention of domestic and foreign scholars. As researchers probe deeper into the issue, many scholars gradually integrate the factor of environment into traditional trade competitiveness and combine environmental changes and trade competitiveness in study. Their perspectives of study can be categorized into relationships of environmental regulation, efficiency of carbon emission reduction and carbon productivity with trade competitiveness. The first is the influence of environmental regulation on trade competitiveness. Scholars mainly take the angles of pollution haven hypothesis, factor endowment hypothesis and Porter hypothesis and they have different views. Some believe environmental regulation can improve resource utilization and trade competitiveness (Porter and Lindo, 1995; Song and Wang, 2013; Wang and Liu, 2014), while some others hold that environmental regulation can narrow down trade circulation and reduce trade competitiveness (Jaffe and Palmer, 1997; Li *et al*., 2014; Ren and Huang, 2015). The second is the relationship between efficiency of carbon emission reduction and trade competitiveness in the context of low-carbon economy differs in different product sectors due to impact of the efficiency on trade competitiveness (Kuik and Hofkes, 2010; Zhou and Yu, 2014; Zhang *et al*., 2016). The third is the relationship between carbon productivity and trade competitiveness. Trade of a country (region) affects carbon productivity mainly through technology effect and structure effect and further affects its trade competitiveness (Zheng *et al*., 2015; Zhao and Zhang, 2016).

Compared with previous research findings, this paper contributes in the following areas. First, having excluded factors of import and inflow from other provincial regions, it resorts to the non-competitive input-output model and measures embodied carbon emissions in international trade and inter-provincial trade in 31 Chinese provincial-level administrative regions. Also, it integrates carbon productivity and traditional trade competitiveness index and constructs a low-carbon trade competitiveness index

to measure embodied carbon emission competitiveness in international trade, inter-provincial trade and general trade of the 31 Chinese provincial-level administrative regions and make comparative analysis. Second, on the basis of the traditional trade competitiveness evaluation standard, the paper refers to the practice of scholars such as Huang (2006) in segmenting the trade competitiveness index and introduces it into the low-carbon trade competitiveness evaluation standard for better accuracy. Third, in measuring carbon emissions of product sectors in each provincial-level administrative region, the paper takes into full consideration the difference in technology. It not only analyzes the embodied carbon emission competitiveness of the 31 provincial-level administrative regions in international trade, inter-provincial trade and general trade from the panoramic view and product sectors, but also introduces the three industries to study their low-carbon trade competitiveness in the three industries from a meso perspective.

3. Measuring Methodology and Modeling

3.1. Input-Output Analysis

The paper measures embodied carbon emissions of Chinese product sectors in international trade and inter-provincial trade and on this basis, the low-carbon trade competitiveness index of 31 Chinese provinces. Based on the *Input-output Tables of Provinces in China in 2012*, it takes 31 Chinese provinces as object of study and refers to methodology of some scholars (Yan and Zhao, 2012; Nie and Li, 2016; Pan, 2017) to study the relationship between international trade, inter-provincial trade and low-carbon trade competitiveness in China. The measurement is as follows:

$$X = AX + Y + T^{e} + T^{ep} - T^{m} - T^{mp} \tag{1}$$

It can be further written as:

$$X = (I - A)^{-1}(Y + T^{e} + T^{ep} - T^{m} - T^{mp}) \tag{2}$$

In the formula, $(I - A)^{-1}$ is a Leontief inverse matrix; X and Y respectively refer to column vector of total output and final consumption of each provincial region; A represents a direct intermediate input coefficient matrix of each provincial-level region; T^{e} and T^{ep}respectively refer to each provincial-level region's export column vector and column vector of outflow from other provinces in China; T^{m} and T^{mp} respectively refer to each provincial-level region's import column vector and column vector of inflow from others in China.

3.2. Non-Competitive Input-Output Modeling

With the input-output model applied into the environmental sector, according to theoretical analysis, direct intermediate input coefficient matrix of each provincial region is $A_i=A_i^d+A_i^m(i=1,2,3)$. A_i^d is direct intermediate input coefficient matrix in the country or provincial-level regions and A_i^m is direct intermediate input coefficient matrix of product sectors imported or flowed from other provincial regions. By referring to the method of Li and Lu (2010) in excluding intermediate input of import A_i^m, we set $A_i^m = M_i \times A_i$ and M_i is coefficient matrix of import or inflow from other provincial regions, representing the proportion of intermediate inputs into products imported or flowed from other provincial regions in the overall intermediate inputs. Suppose the proportion of intermediate inputs imported or flowed from other provincial regions remains the same in the input of product sector *i* into another product sector *j*, and then

$$M_i = \begin{bmatrix} m_{11} & 0 & \cdots & 0 \\ 0 & m_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & m_{nn} \end{bmatrix}$$ is a diagonal matrix. Direct intermediate input coefficient matrix in China and 31 provincial-level regions is $A_i^d = (I - M_i)A_i(i = 1,2,3)$.

Total carbon emission coefficient (intensity) matrix of each product sector is:

$$F_i = E_i(I - A_i^d)^{-1} \tag{8}$$

3.3 Modeling for the Measurement of Embodied Carbon Emissions Exported and Flowed from Provincial-Level Regions

According to the non-competitive I-O model and the total carbon emission coefficient matrix, the measurement formula for embodied carbon emissions in export of China can be attained as:

$$C_e = E_1(I - A_1^d)^{-1}T^e \tag{9}$$

In the formula, C_e is embodied carbon emissions in export; $(I\text{-}A_1^d)^{-1}$ is Leontief inverse matrix with import and inflow from other provincial regions excluded; E_1 is direct carbon emission coefficient matrix exported and flowed out from provincial regions of product sectors; T^e is column vector of product value in export.

Similarly, embodied carbon emissions caused by outflow from provincial regions can be measured with the formula:

$$C_{ep} = E_1(I - A_1^d)^{-1} T^{ep} \tag{10}$$

C_{ep} is embodied carbon emissions flowed out from provincial regions and T^{ep} is column vector of product value flowed out from them.

3.4. Modeling for the Measurement of Embodied Carbon Emissions Imported and Flowed in from Other Provincial Regions

China imports products to meet its domestic demand and carbon dioxide embodied in the imported products saves carbon dioxide generated in domestic production for the country. According to the non-competitive I-O model and the total carbon emission coefficient matrix, the measurement model for embodied carbon emissions in import is attained as followed:

$$C_m = E_2(I - A_2^d)^{-1}\left[A_2^m(I - A_2^d)^{-1}Y + Y^{m1}\right] \tag{11}$$

In the formula, C_m is embodied carbon emission in import; $A^d{}_2$ is the intermediate input matrix with input inflows from other provinces excluded; E_2 is direct carbon emission coefficient matrix of product sectors in import; Y is the sum of final consumption.

Similarly, the measurement model for embodied carbon emissions caused by inflow from other provincial regions in the country is:

$$C_{mp} = E_3(I - A_3^d)^{-1}\left[A_3^m(I - A_3^d)^{-1}Y + Y^{m2}\right] \tag{12}$$

C_{mp} is embodied carbon emission flowed in from other provincial regions in the country; $A^d{}_3$ is the intermediate input matrix with imported inputs excluded; E_3 is direct carbon emission coefficient matrix flowed in from other provincial regions in product sectors; Y is the sum of final consumption.

3.5. Construction of Low-Carbon Trade Competitiveness Index

Before measuring the low-carbon trade competitiveness, it's necessary to understand the meaning of trade competitiveness. Trade competitiveness refers to the proportion of foreign trade balance in total foreign trade of a country (region) and is a common indicator for analyzing a country (region)'s international competitiveness. The trade competitiveness index (*TC*), compared with other methods such as international market share and index of revealed comparative advantage, better reflects if a country (region) enjoys competitive advantage in foreign trade and is more representative in reflecting trade competitiveness of product sectors (Greenaway and Milner, 1993). The formula is as follows:

$$TC = \frac{T^{ex} - T^{im}}{T^{ex} + T^{im}} \tag{13}$$

In the formula, TC means trade competitiveness; T^{ex} is the column vector of exported product value; T^{im} the column vector of imported product value. According to the formula (13), trade competitiveness index is valued between [–1,1].

By referring to Pan and Zhang (2001) and Huang (2006) for segmenting the trade competitiveness index, this paper develops the following evaluation standard and introduces it to the evaluation of low-carbon trade competitiveness.

Table 1. Trade Competitiveness Evaluation Standard

TC	*TC* Rating
0.8~1.0	High comparative advantage
0.5~0.8	Relatively high comparative advantage
0~0.5	Low comparative advantage
–0.5~0	Low comparative disadvantage
–0.8~–0.5	Relatively high comparative disadvantage
–1.0~–0.8	High comparative disadvantage

Besides, it's important to understand the meaning of carbon productivity which refers to economic value per unit of carbon dioxide emission, measures the GDP level per unit of carbon emission in a country (region) and mainly reflects the impact of carbon emission permits on the economy and society (Zhou and Yu, 2014; Zheng *et al*., 2015). The measurement formula is as follows:

$$CP_{ik} = \frac{Y_{ik}}{C_{ik}} \tag{14}$$

In the formula, CP_{ik} refers to carbon productivity of product sector k in the country (region) i; Y_{ik} is value added of product sector k in the country (region) i; C_{ik} is carbon dioxide emission of product sector k in the country (region) i. On such basis, the paper develops the low-carbon trade competitiveness index (*CTC*) model and in the model, the embodied carbon emission competitiveness index in international trade is calculated as follows:

$$CTC_f = \frac{\frac{T^e}{C_e} - \frac{T^m}{C_m}}{\frac{T^e}{C_e} + \frac{T^m}{C_m}} = 1 - \frac{2\frac{T^m}{C_m}}{\frac{T^e}{C_e} + \frac{T^m}{C_m}} = 1 - \frac{2T^m}{C_m \frac{T^e}{C_e} + T^m} \tag{15}$$

Similarly, the embodied carbon emission competitiveness index in inter-provincial trade is calculated as follows:

$$CTC_p = \frac{\frac{T^{ep}}{C_{ep}} - \frac{T^{mp}}{C_{mp}}}{\frac{T^{ep}}{C_{ep}} + \frac{T^{mp}}{C_{mp}}} = 1 - \frac{2\frac{T^{mp}}{C_{mp}}}{\frac{T^{ep}}{C_{ep}} + \frac{T^{mp}}{C_{mp}}} = 1 - \frac{2T^{mp}}{C_{mp} \frac{T^{ep}}{C_{ep}} + T^{mp}} \tag{16}$$

The embodied carbon emission competitiveness index in general trade is calculated as follows:

$$\begin{aligned} CTC &= \frac{\frac{T^e + T^{ep}}{C_e + C_{ep}} - \frac{T^m + T^{mp}}{C_m + C_{mp}}}{\frac{T^e + T^{ep}}{C_e + C_{ep}} + \frac{T^m + T^{mp}}{C_m + C_{mp}}} = 1 - \frac{2\frac{T^m + T^{mp}}{C_m + C_{mp}}}{\frac{T^e + T^{ep}}{C_e + C_{ep}} + \frac{T^m + T^{mp}}{C_m + C_{mp}}} \\ &= 1 - \frac{2(T^m + T^{mp})}{(C_m + C_{mp})\frac{T^e + T^{ep}}{C_e + C_{ep}} + (T^m + T^{mp})} \end{aligned} \tag{17}$$

It's inferred from the model that the low-carbon trade competitiveness index is similarly between [–1,1]. In the evaluation of low-carbon trade competitiveness of product sectors, the evaluation standard in Table 1 is equally applicable.

4. Data Source and Processing

In order to ensure reliability, thoroughness and accuracy of research materials, the paper adopts statistics mainly from the *Input-Output Tables of Provinces in China in 2012*, *China Energy Statistical Yearbook* and statistical yearbooks of all the provincial-level administrative regions. Besides, according to *Industrial Classification Standard for National Economic Activities (GB/T4754-2017)* and consolidated classification of input and output sectors in the *Input-Output Tables of Provinces in China in 2012*, the paper categorizes input and output sectors in 31 Chinese provincial-level administrative regions in 2012 into 28 types (Table 2~Table 7).

Table 2. Embodied Carbon Competitiveness Index in International Trade of 28 Product Sectors in 31 Chinese Provincial-Level Administrative Regions in 2012 (Top 14 Product Sectors)

Provincial-level Administrative Region	Agriculture	Coal Mining, Washing and Dressing	Oil and Gas Extraction	Metallic Ore Mining and Dressing	Nonmetallic Ore and other Ore Mining and Dressing	Food Manufacturing and Tobacco Processing	Textile
Beijing	0.58	0.75	–0.53	0.78	0.44	0.73	0.41
Tianjin	–0.27	–0.72	0.94	–0.48	0.45	0.06	0.20
Hebei	–0.90	–0.89	–1.00	–1.00	–0.47	–0.32	–0.50
Shanxi	–0.49	1.00	0.00	–1.00	0.00	–0.50	–0.57
Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liaoning	–0.59	–1.00	–0.93	–0.80	0.04	–0.12	–0.38
Jilin	–0.54	–0.98	0.00	–0.89	0.26	0.27	–0.29
Heilongjiang	–0.23	–0.99	–1.00	–0.93	1.00	0.74	0.62
Shanghai	–0.16	–0.37	–1.00	–0.90	–0.45	0.24	–0.62
Jiangsu	–0.84	–0.94	0.74	–0.92	–0.39	0.05	–0.07
Zhejiang	–0.83	–1.00	0.84	–1.00	–0.34	0.07	0.08
Anhui	–0.55	–1.00	1.00	–1.00	–0.06	–0.10	–0.28
Fujian	0.74	–0.84	–1.00	0.76	–0.32	0.07	–0.50
Jiangxi	–0.79	–1.00	1.00	–1.00	–0.78	0.35	–0.45
Shandong	–0.88	–0.96	–0.99	–1.00	–0.41	0.94	0.64
Henan	–0.64	–1.00	–1.00	–0.99	–0.18	0.21	0.44
Hubei	0.86	–0.98	–0.76	–0.83	0.93	–0.06	0.81
Hunan	–0.37	–1.00	0.00	–0.99	0.41	0.11	–0.19
Guangdong	–0.56	–1.00	–0.76	–0.78	–0.43	0.06	–0.23
Guangxi	–0.70	–0.99	0.00	–1.00	1.00	0.33	–0.06
Hainan	0.20	0.00	–0.34	–1.00	0.32	0.28	–0.10
Chongqing	–0.76	–1.00	1.00	0.26	–0.82	0.20	0.09
Sichuan	–0.58	–1.00	–0.48	–1.00	–0.87	0.11	0.29
Guizhou	–0.77	–1.00	1.00	–0.99	–0.68	0.43	0.15
Yunnan	–0.37	–1.00	0.00	–1.00	–1.00	–0.22	0.75
Shaanxi	–0.33	0.00	1.00	–0.77	0.60	0.69	0.47
Gansu	–0.22	0.00	–1.00	–1.00	0.74	0.58	0.84
Qinghai	–0.30	–0.85	0.82	0.21	–0.92	–0.68	–0.65
Ningxia	–0.08	1.00	0.00	–0.73	–0.99	0.63	–0.40
Xinjiang	–0.92	–1.00	–1.00	–1.00	–0.94	–0.09	–0.23
Tibet	–0.14	0.00	0.00	0.00	0.00	0.00	0.99

Provincial-level Administrative Region	Manufacturing of Clothes, Leather, Down and others	Wood Processing and Furniture Manufacturing	Papermaking, Printing and Manufacturing of Stationery and Sporting Goods	Petroleum Processing, Coking and Nuclear Fuel Processing	Chemical Industry	Nonmetallic Mineral Products	Metal Smelting, Calendering and Processing
Beijing	0.63	0.80	0.60	0.97	0.87	0.56	0.25
Tianjin	0.54	0.57	0.42	–0.49	–0.13	0.42	0.18
Hebei	–0.02	0.55	–0.23	0.37	–0.23	–0.16	–0.03
Shanxi	–0.10	–1.00	–0.53	1.00	–0.24	0.18	–0.22
Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liaoning	0.41	0.34	0.45	–0.47	–0.31	0.14	–0.28
Jilin	0.59	0.37	0.72	–0.57	0.03	0.15	0.19
Heilongjiang	0.62	0.32	0.12	–0.84	0.20	0.91	0.62
Shanghai	0.41	0.52	0.07	–0.03	0.06	0.16	–0.13
Jiangsu	0.50	0.57	0.10	–0.64	–0.23	0.19	–0.16
Zhejiang	0.58	0.38	0.06	–0.51	–0.21	0.37	–0.30
Anhui	0.84	0.58	0.15	–0.89	0.04	–0.23	0.21
Fujian	0.51	0.61	0.47	–0.89	–0.08	0.15	–0.04
Jiangxi	0.87	0.92	0.34	–1.00	0.33	0.75	–0.56
Shandong	0.90	0.90	0.73	0.60	0.71	0.70	–0.87
Henan	0.88	0.93	0.17	–0.78	0.47	0.44	0.27
Hubei	–0.05	0.96	–0.47	–0.74	–0.15	–0.71	–0.70
Hunan	0.54	0.54	–0.16	0.65	0.24	–0.28	0.06
Guangdong	0.53	0.52	0.30	–0.17	–0.13	0.02	–0.57
Guangxi	0.43	0.98	0.02	–0.60	0.51	0.99	0.61
Hainan	1.82	0.24	0.53	0.17	0.22	–0.07	–0.01
Chongqing	0.15	0.42	0.28	–0.96	–0.06	0.10	0.18
Sichuan	0.56	0.70	0.22	–1.00	–0.14	0.07	–0.39
Guizhou	0.79	0.92	0.42	–0.99	–0.32	0.47	–0.42
Yunnan	0.98	0.18	–0.49	0.00	–0.05	0.78	0.38
Shaanxi	0.97	0.94	0.63	–0.91	–0.04	0.09	0.05
Gansu	0.94	0.99	0.88	–1.00	0.44	0.79	–0.77
Qinghai	–0.54	–1.00	–0.93	–0.99	–0.36	–0.64	0.44
Ningxia	0.71	–0.37	–0.57	–0.13	–0.52	–0.56	–0.67
Xinjiang	0.11	0.19	0.51	–0.95	0.02	0.00	–0.58
Tibet	–0.39	0.96	0.65	–0.34	0.52	–0.10	–4.06

Source: Calculated on the basis of the *Input-Output Tables of Provinces in China in 2012* and *China Energy Statistical Yearbook* with related formulas.

Table 3. Embodied Carbon Competitiveness Index in International Trade of 28 Product Sectors in 31 Chinese Provincial-Level Administrative Regions in 2012 (Last 14 Product Sectors)

Provincial-level Administrative Region	Metal Products	General and Special Equipment Manufacturing	Transport Equipment Manufacturing	Electrical Machinery and Equipment Manufacturing	Communication Devices, Computers and other Electronic Equipment Manufacturing	Instrumentation and Cultural and Clerical Machinery Manufacturing	Other Manufacturing
Beijing	0.84	0.76	0.79	0.89	0.86	0.63	0.05
Tianjin	0.74	0.56	0.56	0.73	0.51	0.49	–0.81
Hebei	0.48	0.09	0.25	0.37	0.26	0.03	–0.79
Shanxi	–1.00	0.04	0.31	–0.37	0.78	–1.00	–1.00
Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liaoning	0.50	0.29	0.43	0.60	0.48	0.27	–0.60
Jilin	0.36	0.30	0.27	0.53	0.34	0.30	0.47
Heilongjiang	0.97	0.55	0.78	0.60	0.91	0.47	0.42
Shanghai	0.52	0.60	0.65	0.77	0.59	0.69	0.77
Jiangsu	0.63	0.48	0.57	0.71	0.47	0.40	0.69
Zhejiang	0.73	0.56	0.81	0.73	0.74	0.41	–0.41
Anhui	0.62	0.37	0.77	0.74	0.47	0.30	0.11
Fujian	–0.05	0.31	0.52	0.67	0.72	0.44	0.47
Jiangxi	0.86	0.51	0.69	0.84	0.49	0.51	–0.35
Shandong	–0.78	0.83	0.07	0.91	0.49	–0.21	–0.48
Henan	0.84	0.42	0.69	0.58	0.40	–0.02	0.40
Hubei	0.92	0.57	0.36	0.59	0.28	0.24	–0.47
Hunan	0.58	0.47	0.50	0.73	0.54	0.66	–0.39
Guangdong	0.63	0.61	0.69	0.78	0.59	0.55	–0.51
Guangxi	1.00	0.47	0.85	0.73	0.44	0.06	–0.67
Hainan	0.67	0.41	0.58	0.88	0.99	0.54	0.98
Chongqing	0.54	0.68	0.50	0.61	0.49	0.75	0.35
Sichuan	0.55	0.44	0.38	0.72	0.46	0.38	0.26
Guizhou	0.70	0.17	0.63	0.67	0.72	0.14	1.00
Yunnan	0.87	0.57	0.43	0.92	0.48	–1.00	–1.00
Shaanxi	0.54	0.41	0.53	0.68	0.35	0.37	0.94
Gansu	0.88	0.49	0.36	0.93	0.27	0.26	1.00
Qinghai	–0.63	–0.26	–0.60	–0.57	–1.00	–1.00	–0.98
Ningxia	–0.14	–0.16	0.37	0.19	0.66	–0.23	–0.51
Xinjiang	0.38	0.12	0.60	0.64	0.88	0.37	0.47
Tibet	0.29	0.25	0.78	0.81	0.63	0.63	0.98

Provincial-level Administrative Region	Production and Supply of Power and Heat	Gas Production and Supply	Water Production and Supply	Construction	Transport, Warehousing and Postal Service	Wholesale and Retail and Catering	Other Services
Beijing	1.00	0.00	0.00	0.00	0.34	0.89	0.61
Tianjin	0.00	0.00	0.00	0.88	–0.02	–0.14	0.22
Hebei	0.00	0.00	0.00	0.80	–0.53	–0.40	–0.44
Shanxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liaoning	–1.00	0.00	0.00	0.90	–0.27	–0.38	–0.04
Jilin	1.00	0.00	0.00	0.00	–0.27	–0.27	0.38
Heilongjiang	–1.00	0.00	0.00	0.00	–0.55	–0.32	0.00
Shanghai	0.00	0.00	0.00	0.96	0.03	0.07	0.25
Jiangsu	0.00	0.00	0.00	0.89	0.00	0.00	–0.45
Zhejiang	0.00	0.00	0.00	0.00	–0.15	0.00	–0.07
Anhui	0.00	0.00	0.00	0.00	1.00	1.00	0.97
Fujian	0.92	–1.00	–1.00	0.76	–0.39	0.13	–0.09
Jiangxi	0.00	0.00	0.00	0.00	0.46	0.25	0.95
Shandong	0.00	–1.00	0.00	–1.00	–0.97	0.06	–0.32
Henan	0.00	0.00	0.00	0.82	–0.56	–0.20	–0.69
Hubei	–1.00	–0.95	–0.93	0.00	0.00	0.00	–0.80
Hunan	0.00	0.00	0.00	0.92	–0.78	0.00	–0.50
Guangdong	0.46	0.00	0.00	0.96	0.19	0.39	0.22
Guangxi	0.00	0.00	0.00	0.68	0.28	0.88	0.27
Hainan	0.00	0.00	0.00	0.19	0.14	0.43	0.08
Chongqing	0.00	0.00	0.00	1.00	0.80	1.00	0.10
Sichuan	0.00	0.00	0.00	0.00	0.00	0.00	–0.32
Guizhou	0.00	0.00	0.00	0.00	0.00	0.00	–0.12
Yunnan	0.00	0.00	0.00	0.00	1.00	0.00	0.82
Shaanxi	0.00	0.00	0.00	0.00	0.29	–0.02	–0.40
Gansu	0.00	0.00	0.00	0.00	0.78	0.90	–0.13
Qinghai	–0.71	–0.86	–1.00	–0.57	–0.88	–0.73	–0.94
Ningxia	0.00	0.00	0.00	0.00	–0.78	–0.53	0.19
Xinjiang	1.00	0.00	0.00	0.00	–0.64	–0.57	–0.75
Tibet	0.00	0.00	0.00	1.00	0.00	1.00	0.91

Source: Calculated on the basis of the *Input-Output Tables of Provinces China in 2012* and *China Energy Statistical Yearbook* with related formulas.

Table 4. Embodied Carbon Competitiveness Index in Inter-Provincial Trade of 28 Product Sectors in 31 Chinese Provincial-Level Administrative Regions in 2012 (Top 14 Product Sectors)

Provincial-level Administrative Region	Agriculture	Coal Mining, Washing and Dressing	Oil and Gas Extraction	Metallic Ore Mining and Dressing	Nonmetallic Ore and other Ore Mining and Dressing	Food Manufacturing and Tobacco Processing	Textile
Beijing	0.50	–0.06	0.74	0.91	0.11	0.10	0.18
Tianjin	–0.85	0.97	0.59	0.93	0.00	–0.06	–0.16
Hebei	–0.59	–0.99	–1.00	0.28	–0.99	–0.35	–0.10
Shanxi	–0.79	0.39	–0.70	–0.86	–1.00	–0.70	–0.82
Inner Mongolia	–0.81	0.52	0.99	0.31	–0.84	–0.34	–0.36
Liaoning	–0.62	–0.86	–0.98	0.12	–0.53	0.00	–0.59
Jilin	1.00	–1.00	1.00	1.00	–1.00	1.00	–1.00
Heilongjiang	–0.18	–0.24	1.00	0.15	–0.03	–0.09	–0.03
Shanghai	–0.30	–1.00	–0.16	0.99	–1.00	–0.05	0.32
Jiangsu	0.06	–1.00	–1.00	–1.00	–1.00	–0.15	0.04
Zhejiang	–0.55	–0.14	–1.00	0.96	–0.19	–0.04	–0.11
Anhui	–0.18	–0.24	–1.00	0.08	–0.36	–0.11	–0.21
Fujian	–0.82	–1.00	–0.03	–0.84	–0.89	0.04	–0.22
Jiangxi	–0.01	–0.84	–1.00	0.08	–0.97	–0.06	–0.05
Shandong	–0.99	–0.97	–0.99	–0.90	–0.94	0.97	0.76
Henan	–0.23	–0.43	–1.00	–0.56	–0.89	0.26	0.15
Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hunan	0.19	–0.99	0.00	–0.87	–0.29	0.05	–0.03
Guangdong	–0.84	0.13	–0.33	–0.18	0.27	0.31	–0.04
Guangxi	0.57	–1.00	0.00	0.51	–0.76	–0.01	0.10
Hainan	–0.19	0.00	0.98	0.42	–0.20	–0.23	0.16
Chongqing	–0.12	0.91	–0.40	–0.13	–0.87	–0.12	–0.13
Sichuan	–0.66	0.28	–0.92	0.55	–0.22	0.04	0.26
Guizhou	–0.26	0.75	–1.00	–0.64	–0.57	–0.45	–0.24
Yunnan	–0.09	0.69	0.00	–0.73	–0.84	–0.25	–0.32
Shaanxi	0.05	0.25	0.04	0.65	–0.24	–0.18	–0.07
Gansu	–0.10	–0.81	–1.00	–0.67	–0.44	–0.48	–0.36
Qinghai	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ningxia	–0.57	–0.66	–0.78	–1.00	–0.88	–0.67	–0.68
Xinjiang	0.69	0.66	1.00	–0.13	–0.44	–0.27	–0.43
Tibet	0.33	0.00	0.00	0.00	0.00	0.00	–0.99

Provincial-level Administrative Region	Manufacturing of Clothes, Leather, Down and Others	Wood Processing and Furniture Manufacturing	Papermaking, Printing and Manufacturing of Stationery and Sporting Goods	Petroleum Processing, Coking and Nuclear Fuel Processing	Chemical Industry	Nonmetallic Mineral Products	Metal Smelting, Calendering and Processing
Beijing	0.11	0.12	0.17	–0.49	0.12	0.07	–0.06
Tianjin	–0.07	–0.51	–0.34	–0.55	0.35	–0.28	0.12
Hebei	–0.41	–0.45	–0.97	–0.56	–0.49	0.66	0.08
Shanxi	–0.93	–0.99	–0.96	–0.50	–0.81	–0.72	–0.86
Inner Mongolia	–0.97	–0.41	–0.95	–0.67	–0.32	–0.26	0.19
Liaoning	–0.35	0.24	–0.73	0.14	–0.17	0.24	–0.23
Jilin	–1.00	1.00	–1.00	–1.00	1.00	1.00	–1.00
Heilongjiang	0.13	0.05	–0.38	–0.03	–0.18	–0.05	–0.21
Shanghai	0.08	0.01	0.20	–0.62	0.30	–0.12	–0.06
Jiangsu	0.67	–0.12	–1.00	–0.61	0.03	–0.37	–0.85
Zhejiang	0.01	0.01	0.30	–0.08	0.00	–0.29	–0.37
Anhui	–0.16	–0.17	–0.47	–0.25	–0.26	0.07	–0.26
Fujian	–0.03	0.14	0.20	–0.89	–0.44	0.51	–0.69
Jiangxi	–0.13	0.10	–0.18	–0.53	0.04	–0.08	0.15
Shandong	0.77	0.84	0.56	0.87	0.88	0.79	–0.99
Henan	–0.08	0.15	–0.01	–0.49	–0.20	0.78	–0.06
Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hunan	–0.45	0.30	–0.36	–0.71	–0.10	0.12	–0.04
Guangdong	0.24	0.24	0.23	0.08	0.22	0.46	0.08
Guangxi	0.02	0.40	0.05	–0.96	–0.35	0.65	0.69
Hainan	–0.07	–0.16	–0.17	0.16	–0.18	–0.46	–0.38
Chongqing	–0.21	–0.17	–0.34	–0.35	–0.12	–0.21	–0.25
Sichuan	–0.39	–0.18	–0.79	–0.83	–0.10	–0.09	–0.25
Guizhou	1.43	–0.46	–0.64	–0.53	–0.43	–0.37	–0.29
Yunnan	–0.44	–0.55	–0.93	–0.41	–0.31	–0.80	0.49
Shaanxi	–0.11	0.00	–0.30	0.49	–0.27	–0.01	–0.15
Gansu	–0.46	–0.74	–0.83	–0.11	–0.51	–0.59	–0.20
Qinghai	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ningxia	–0.66	–0.69	–0.69	–0.29	–0.61	–0.71	–0.59
Xinjiang	–0.96	–0.67	–0.60	0.89	–0.38	–0.52	–0.31
Tibet	–0.69	–0.79	0.99	–1.00	0.72	–0.59	–1.00

Source: Calculated on the basis of the *Input-Output Tables of Provinces in China in 2012* and *China Energy Statistical Yearbook* with related formulas.

Table 5. Embodied Carbon Competitiveness Index in Inter-Provincial Trade of 28 Product Sectors in 31 Chinese Provincial-Level Administrative Regions in 2012 (Last 14 Product Sectors)

Provincial-level Administrative Region	Metal Products	General and Special Equipment Manufacturing	Transport Equipment Manufacturing	Electrical Machinery and Equipment Manufacturing	Communication Devices, Computers and other Electronic Equipment Manufacturing	Instrumentation and Cultural and Clerical Machinery Manufacturing	Other Manufacturing
Beijing	0.04	0.09	–0.65	0.14	0.19	0.16	0.19
Tianjin	–0.10	–0.06	0.00	–0.18	0.40	0.14	0.74
Hebei	0.99	–0.46	–0.47	–0.33	–0.98	–0.99	–0.74
Shanxi	–0.99	–0.87	–0.91	–0.96	–0.90	–0.96	–0.98
Inner Mongolia	0.34	–0.51	–0.52	–0.49	–0.70	–0.97	–0.75
Liaoning	–0.29	–0.15	–0.24	–0.17	–0.40	–0.51	–0.56
Jilin	–1.00	–1.00	1.00	–1.00	–1.00	1.00	–1.00
Heilongjiang	–0.19	–0.20	–0.15	–0.06	–0.19	–0.25	–0.42
Shanghai	–0.04	0.19	0.02	0.05	0.32	0.60	–0.03
Jiangsu	1.00	–0.02	0.87	0.47	0.29	1.00	–0.34
Zhejiang	0.41	0.29	0.05	0.21	–0.13	0.44	0.19
Anhui	–0.09	–0.31	–0.17	0.00	–0.18	–0.03	–0.42
Fujian	0.29	–0.16	–0.09	0.11	–0.11	–0.01	0.42
Jiangxi	–0.13	–0.38	–0.14	0.19	–0.09	–0.08	–0.10
Shandong	–0.66	0.86	–0.44	0.64	0.52	–0.53	–0.87
Henan	–0.40	–0.30	–0.24	–0.17	–0.10	–0.11	–0.58
Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hunan	0.51	–0.01	–0.28	0.06	–0.03	–0.23	–0.42
Guangdong	0.33	0.24	0.10	0.35	0.42	0.33	0.81
Guangxi	–0.57	–0.27	–0.19	–0.11	–0.38	–0.19	–0.74
Hainan	–0.23	–0.10	–0.26	–0.15	–0.04	–0.18	–1.00
Chongqing	–0.37	–0.28	–0.10	0.03	–0.06	0.73	–0.11
Sichuan	–0.85	–0.38	–0.11	–0.40	–0.04	–0.68	–0.84
Guizhou	–0.45	–0.48	–0.48	–0.46	–0.47	–0.43	–0.70
Yunnan	–0.91	–0.54	–0.44	–0.67	–0.49	–1.00	–0.93
Shaanxi	–0.23	–0.19	–0.21	–0.10	0.12	0.39	–0.46
Gansu	–0.72	–0.59	–0.51	–0.48	–0.50	–0.54	–0.54
Qinghai	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ningxia	–0.74	–0.67	–0.68	–0.66	–0.56	–0.66	–1.00
Xinjiang	–0.99	–0.51	–0.51	–0.53	–0.50	–0.73	–0.32
Tibet	–1.00	–1.00	–1.00	–1.00	–1.00	–1.00	–1.00

Provincial-level Administrative Region	Production and Supply of Power and Heat	Gas Production and Supply	Water Production and Supply	Construction	Transport, Warehousing and Postal Service	Wholesale and Retail and Catering	Other Services
Beijing	0.09	–0.07	1.00	–0.57	0.15	0.11	0.53
Tianjin	–1.00	0.86	–0.48	–0.21	0.32	0.90	–0.10
Hebei	–0.99	–0.60	–0.94	–0.82	–0.36	0.01	–0.76
Shanxi	–0.04	–0.95	–1.00	0.00	–0.37	–0.81	–0.91
Inner Mongolia	0.52	–1.00	–1.00	–0.50	0.47	0.77	–0.68
Liaoning	–0.83	–0.79	–1.00	–0.34	–0.39	–0.04	–0.20
Jilin	–1.00	–1.00	–1.00	–1.00	–1.00	–0.91	–0.29
Heilongjiang	0.98	1.00	1.00	–0.24	0.56	0.97	–0.43
Shanghai	–1.00	–1.00	–1.00	0.02	0.05	0.80	–0.03
Jiangsu	0.00	–1.00	0.00	–0.11	–0.25	0.98	–0.12
Zhejiang	–0.69	1.00	0.00	0.00	0.03	–0.04	0.07
Anhui	0.69	–0.32	–0.69	–0.36	–0.22	–0.22	–0.20
Fujian	0.00	0.00	0.00	0.00	1.00	1.00	–0.55
Jiangxi	–0.85	–1.00	–1.00	–0.18	–0.20	–0.15	–0.27
Shandong	–0.97	0.48	–0.88	–1.00	–0.84	0.33	–0.42
Henan	–0.51	–0.82	0.00	–0.24	–0.10	–0.45	–0.40
Hubei	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hunan	–1.00	–1.00	0.00	–0.17	–0.44	–0.84	0.28
Guangdong	–0.30	0.15	0.00	–1.00	0.38	0.27	0.00
Guangxi	–0.45	–1.00	0.00	–0.29	0.37	0.03	–0.52
Hainan	–0.13	–1.00	–1.00	–0.20	–0.15	0.05	–0.32
Chongqing	–0.75	–0.14	–0.13	–0.14	–0.10	–0.04	–0.16
Sichuan	0.78	0.95	0.00	–1.00	–0.52	0.08	0.56
Guizhou	1.00	–1.00	0.00	–0.63	–0.43	–0.13	–0.43
Yunnan	0.96	–1.00	0.00	–0.42	–0.25	–0.05	–0.06
Shaanxi	–0.46	–0.92	–0.93	–0.44	–0.15	–0.21	–0.44
Gansu	0.87	–0.94	–1.00	–0.52	–0.51	0.63	–0.54
Qinghai	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ningxia	–0.56	–0.94	–0.82	1.00	–0.61	–0.82	–0.86
Xinjiang	1.00	–0.60	0.00	–1.00	–0.40	–0.96	–0.60
Tibet	–1.00	–1.00	0.00	–1.00	0.00	0.99	0.74

Source: Calculated on the basis of the *Input-Output Tables of Provinces in China in 2012* and *China Energy Statistical Yearbook* with related formulas.

Table 6. Embodied Carbon Competitiveness Index in General Trade of 28 Product Sectors in 31 Chinese Provincial-Level Administrative Regions in 2012 (Top 14 Product Sectors)

Provincial-level Administrative Region	Agriculture	Coal Mining, Washing and Dressing	Oil and Gas Extraction	Metallic Ore Mining and Dressing	Nonmetallic Ore and other Ore Mining and Dressing	Food Manufacturing and Tobacco Processing	Textile
Beijing	0.45	0.13	0.03	0.83	0.16	0.23	0.39
Tianjin	–0.75	0.47	0.64	0.15	0.04	0.02	–0.10
Hebei	–0.60	–0.97	–1.00	–0.66	–0.96	–0.35	–0.15
Shanxi	–0.78	0.39	–0.70	–0.94	–1.00	–0.69	–0.72
Inner Mongolia	–0.81	0.52	0.99	0.31	–0.84	–0.34	–0.36
Liaoning	–0.61	–0.88	–0.97	–0.44	–0.52	–0.03	–0.52
Jilin	0.10	–1.00	1.00	0.50	–0.98	0.81	–0.50
Heilongjiang	–0.20	–0.28	–0.04	0.04	–0.02	–0.05	–0.02
Shanghai	–0.27	–0.22	–0.13	0.49	–0.20	0.03	0.13
Jiangsu	–0.24	–0.99	–1.00	–0.96	–0.97	–0.06	0.00
Zhejiang	–0.63	–0.15	–0.04	0.82	–0.25	–0.02	–0.01
Anhui	–0.18	–0.24	–0.47	–0.13	–0.35	–0.11	–0.23
Fujian	–0.19	–0.87	–0.19	–0.59	–0.52	0.06	–0.55
Jiangxi	–0.02	–0.86	–0.25	–0.34	–0.97	–0.06	–0.15
Shandong	–0.92	–0.97	–0.99	–0.95	–0.81	0.95	0.71
Henan	–0.25	–0.44	–1.00	–0.60	–0.88	0.27	0.15
Hubei	0.86	–0.98	–0.76	–0.83	0.93	–0.06	0.81
Hunan	0.19	–0.99	0.00	–0.92	–0.29	0.06	–0.05
Guangdong	–0.66	–0.11	–0.48	0.13	–0.02	0.24	–0.14
Guangxi	–0.09	–1.00	0.00	–0.38	–0.29	0.06	–0.01
Hainan	–0.18	0.00	0.25	0.36	–0.20	–0.19	0.08
Chongqing	–0.12	0.91	–0.39	–0.13	–0.86	–0.12	–0.13
Sichuan	–0.66	0.17	–0.93	0.29	–0.33	0.07	0.19
Guizhou	–0.29	0.72	–0.56	–0.69	–0.53	–0.45	–0.27
Yunnan	–0.25	0.56	0.00	–0.89	–0.85	–0.24	–0.29
Shaanxi	0.02	0.27	0.07	–0.09	–0.22	–0.13	–0.06
Gansu	–0.10	–0.81	–1.00	–0.78	–0.45	–0.47	–0.34
Qinghai	–0.30	–0.85	0.82	0.21	–0.92	–0.68	–0.65
Ningxia	–0.43	–0.67	–0.78	–0.81	–0.88	–0.67	–0.68
Xinjiang	0.40	0.53	–0.26	–0.48	–0.46	–0.27	–0.46
Tibet	0.23	0.00	0.00	0.00	0.00	0.00	–0.50

Provincial-level Administrative Region	Manufacturing of Clothes, Leather, Down and Others	Wood Processing and Furniture Manufacturing	Papermaking, Printing and Manufacturing of Stationery and Sporting Goods	Petroleum Processing, Coking and Nuclear Fuel Processing	Chemical Industry	Nonmetallic Mineral Products	Metal Smelting, Calendering and Processing
Beijing	0.23	0.37	0.26	–0.28	0.33	0.12	0.20
Tianjin	0.07	0.06	–0.16	–0.53	0.10	–0.20	0.13
Hebei	–0.36	–0.39	–0.91	–0.56	–0.44	0.65	0.07
Shanxi	–0.92	–0.99	–0.93	–0.49	–0.73	–0.66	–0.73
Inner Mongolia	–0.97	–0.41	–0.95	–0.67	–0.32	–0.26	0.19
Liaoning	–0.19	0.27	–0.48	0.05	–0.20	0.24	–0.24
Jilin	–0.34	0.83	–0.72	–0.99	0.68	0.99	–0.97
Heilongjiang	–0.10	0.13	–0.32	–0.06	–0.15	–0.04	–0.21
Shanghai	0.23	0.20	0.12	–0.46	0.15	–0.10	–0.08
Jiangsu	0.56	0.07	–0.28	–0.59	–0.07	–0.33	–0.73
Zhejiang	0.11	0.20	0.21	–0.16	–0.08	–0.31	–0.42
Anhui	–0.13	–0.15	–0.33	–0.25	–0.24	0.06	–0.25
Fujian	0.31	0.49	0.40	–0.88	–0.20	0.22	–0.38
Jiangxi	–0.06	0.14	–0.06	–0.56	0.05	–0.05	0.06
Shandong	0.87	0.89	0.73	0.81	0.81	0.80	–0.94
Henan	–0.03	0.21	0.01	–0.50	–0.18	0.77	–0.06
Hubei	–0.05	0.96	–0.47	–0.74	–0.15	–0.71	–0.70
Hunan	–0.12	0.32	–0.35	–0.71	–0.09	0.11	–0.03
Guangdong	0.43	0.36	0.28	0.05	0.06	0.32	–0.19
Guangxi	–0.10	0.45	0.05	–0.53	–0.24	0.65	0.69
Hainan	–0.17	0.01	–0.10	0.17	–0.14	–0.43	–0.34
Chongqing	–0.21	–0.17	–0.33	–0.35	–0.11	–0.21	–0.25
Sichuan	–0.13	–0.06	–0.35	–0.88	–0.12	–0.08	–0.30
Guizhou	–0.45	–0.46	–0.54	–0.53	–0.41	–0.34	–0.30
Yunnan	–0.39	–0.46	–0.93	–0.41	–0.29	–0.71	0.49
Shaanxi	–0.19	–0.10	–0.22	0.45	–0.21	–0.01	–0.14
Gansu	–0.47	–0.45	–0.57	–0.10	–0.49	–0.52	–0.29
Qinghai	–0.54	–1.00	–0.93	–0.99	–0.36	–0.64	0.44
Ningxia	–0.64	–0.63	–0.68	–0.30	–0.61	–0.71	–0.60
Xinjiang	–0.44	–0.40	–0.46	0.67	–0.38	–0.43	–0.32
Tibet	–0.71	0.39	0.61	–0.28	0.20	–0.06	0.93

Source: Calculated on the basis of the *Input-Output Tables of Provinces in China in 2012* and *China Energy Statistical Yearbook* with related formulas.

Table 7. Embodied Carbon Competitiveness Index in General Trade of 28 Product Sectors in 31 Chinese Provincial-Level Administrative Regions in 2012 (Last 14 Product Sectors)

Provincial-level Administrative Region	Metal Products	General and Special Equipment Manufacturing	Transport Equipment Manufacturing	Electrical Machinery and Equipment Manufacturing	Communication Devices, Computers and other Electronic Equipment Manufacturing	Instrumentation and Cultural and Clerical Machinery Manufacturing	Other Manufacturing
Beijing	0.35	0.61	0.61	0.64	0.56	0.55	0.28
Tianjin	0.18	0.29	0.44	0.39	0.49	0.37	0.04
Hebei	0.87	–0.36	–0.39	–0.19	–0.44	–0.52	–0.75
Shanxi	–0.99	–0.71	–0.83	–0.93	–0.62	–0.96	–0.98
Inner Mongolia	0.34	–0.51	–0.52	–0.49	–0.70	–0.97	–0.75
Liaoning	0.08	0.04	–0.01	0.15	–0.11	–0.16	–0.57
Jilin	–0.75	–0.81	0.32	–0.59	–0.46	0.36	–0.97
Heilongjiang	–0.16	–0.16	–0.12	0.08	–0.13	–0.10	–0.38
Shanghai	0.30	0.53	0.47	0.56	0.51	0.65	0.11
Jiangsu	0.61	0.30	0.59	0.69	0.46	0.50	–0.33
Zhejiang	0.53	0.43	0.23	0.57	0.11	0.40	–0.10
Anhui	–0.03	–0.19	–0.14	0.15	–0.04	0.08	–0.41
Fujian	0.24	0.22	0.33	0.62	0.27	0.30	0.49
Jiangxi	–0.09	–0.27	–0.10	0.50	0.22	–0.01	–0.12
Shandong	–0.73	0.85	–0.33	0.84	0.51	–0.36	–0.42
Henan	–0.37	–0.25	–0.22	0.01	0.21	0.00	–0.56
Hubei	0.92	0.57	0.36	0.59	0.28	0.24	–0.47
Hunan	0.53	0.08	–0.09	0.19	0.11	–0.02	–0.40
Guangdong	0.52	0.52	0.41	0.72	0.57	0.52	–0.03
Guangxi	–0.28	–0.16	–0.17	0.12	0.05	–0.07	–0.72
Hainan	–0.13	–0.02	0.27	0.09	0.12	0.01	–0.95
Chongqing	–0.34	–0.25	–0.05	0.11	0.10	0.73	–0.10
Sichuan	–0.11	–0.06	0.16	–0.02	0.28	–0.04	–0.66
Guizhou	–0.45	–0.45	–0.46	–0.45	–0.46	–0.38	–0.68
Yunnan	–0.69	–0.42	–0.41	–0.59	–0.38	–1.00	–0.93
Shaanxi	–0.12	0.11	–0.06	0.30	0.29	0.38	–0.42
Gansu	–0.55	–0.49	–0.47	–0.42	–0.45	–0.45	–0.51
Qinghai	–0.63	–0.26	–0.60	–0.57	–1.00	–1.00	–0.98
Ningxia	–0.70	–0.63	–0.67	–0.59	–0.59	–0.57	–0.90
Xinjiang	–0.48	–0.49	–0.51	–0.51	–0.49	–0.35	–0.36
Tibet	–0.13	–0.32	0.39	0.04	0.11	0.18	–0.15

Provincial-level Administrative Region	Production and Supply of Power and Heat	Gas Production and Supply	Water Production and Supply	Construction	Transport, Warehousing and Postal Service	Wholesale and Retail and Catering	Other Services
Beijing	0.22	0.13	1.00	0.50	0.22	0.23	0.57
Tianjin	–1.00	0.88	–0.49	–0.17	0.23	0.44	–0.02
Hebei	–0.99	–0.60	–0.94	–0.79	–0.37	–0.03	–0.74
Shanxi	–0.04	–0.95	–1.00	0.00	–0.37	–0.81	–0.90
Inner Mongolia	0.52	–1.00	–1.00	–0.50	0.47	0.77	–0.68
Liaoning	–0.85	–0.81	–1.00	–0.31	–0.37	–0.11	–0.16
Jilin	–1.00	–1.00	–1.00	–1.00	–0.95	–0.82	–0.25
Heilongjiang	0.74	1.00	1.00	–0.24	0.40	0.42	–0.42
Shanghai	–1.00	–1.00	–1.00	0.59	0.03	0.39	0.11
Jiangsu	0.00	–1.00	0.00	–0.04	–0.29	0.98	–0.06
Zhejiang	–0.80	1.00	0.00	0.00	–0.02	–0.05	0.01
Anhui	0.68	–0.32	–0.70	–0.36	–0.20	–0.21	–0.19
Fujian	0.93	–1.00	–1.00	0.74	–0.30	0.30	–0.26
Jiangxi	–0.86	–1.00	–1.00	–0.09	–0.20	–0.13	–0.29
Shandong	–0.98	0.56	–0.94	–1.00	–0.91	0.23	–0.41
Henan	–0.52	–0.82	0.00	–0.20	–0.13	–0.42	–0.39
Hubei	–1.00	–0.95	–0.93	0.00	0.00	0.00	–0.80
Hunan	–1.00	–1.00	0.00	–0.17	–0.44	–0.84	0.29
Guangdong	–0.40	–0.02	0.00	–0.07	0.31	0.31	0.26
Guangxi	–0.47	–1.00	0.00	–0.29	0.37	0.05	–0.46
Hainan	–0.13	–1.00	–1.00	–0.18	–0.13	0.07	–0.27
Chongqing	–0.75	–0.14	–0.13	–0.14	–0.10	–0.03	–0.16
Sichuan	0.71	0.95	0.00	–1.00	–0.60	0.01	0.55
Guizhou	1.00	–1.00	0.00	–0.63	–0.44	–0.16	–0.43
Yunnan	0.96	–1.00	0.00	–0.42	–0.24	–0.04	–0.04
Shaanxi	–0.50	–0.92	–0.94	–0.45	–0.12	–0.19	–0.43
Gansu	0.87	–0.94	–1.00	–0.51	–0.47	0.65	–0.52
Qinghai	–0.71	–0.86	–1.00	–0.57	–0.88	–0.73	–0.94
Ningxia	–0.57	–0.94	–0.83	1.00	–0.61	–0.81	–0.85
Xinjiang	1.00	–0.58	0.00	–1.00	–0.39	–0.79	–0.63
Tibet	–1.00	–1.00	0.00	0.91	0.00	0.99	–0.26

Source: Calculated on the basis of the *Input-Output Tables of Provinces in China in 2012* and *China Energy Statistical Yearbook* with related formulas.

Also, it divides product sectors into the three industries for analysis, with those numbered 1 as the primary industry, those numbered 2~25 as the secondary industry and those numbered 26~28 as the tertiary industry (Figure 2).

5. Empirical Results and Analysis

5.1 Analysis on Low-Carbon Trade Competitiveness: A Holistic View

Figure 1 shows the embodied carbon emission competitiveness index of 31 Chinese provincial-level administrative regions in international trade, inter-provincial trade and total trade in 2012. The index in international trade is generally lower than that for inter-provincial trade. As to the index in international trade, Beijing ranks first with an index of 0.5~0.8 and enjoys relatively high comparative advantage, while Qinghai ranks last with an index ranged between –1.0 and –0.8 and shows high comparative disadvantage. Apart from Inner Mongolia that is excluded for import and export statistics, five provincial regions range from 0 and 0.5 with low comparative advantage, 17 range from –0.5 and 0 with low comparative disadvantage, and six range from –0.8 and –0.5 with relatively high comparative disadvantage. It indicates that the majority of Chinese provincial regions suffer the comparative disadvantage in embodied carbon emission competitiveness for international trade and take a disadvantaged position in international trade, with carbon emission productivity in export being lower than the productivity in import. In international trade, carbon leakage is a serious problem. For reasons, foreign carbon emission intensity is lower due to more advanced technology overseas and China is always in trade surplus, with its export far exceeding import in volume. For the embodied carbon emission competitiveness index in inter-provincial trade, Tibet ranks first with an index of 0~0.5 and enjoys low comparative advantage, while Shanxi ranks last with an index ranged between –0.8 and –0.5 and suffers relatively high comparative disadvantage. Apart from Hubei and Qinghai that are excluded from statistics on inflow from other provincial regions and outflow, 10 range from 0 and 0.5 with low comparative advantage, 12 range from –0.5 and 0 with low comparative disadvantage, with five range from –0.8 and –0.5 with relatively high comparative disadvantage. The majority of Chinese provincial regions similarly suffer comparative disadvantage in embodied carbon emission competitiveness for inter-provincial trade. In inter-provincial trade, carbon emissions are transferred among the provincial regions and carbon leakage cannot be neglected. The embodied carbon emission competitiveness index in total trade covers both international trade and inter-provincial trade. Shanghai ranks first with an index of 0~0.5 and enjoys low comparative advantage, while Qinghai ranks last with an index ranged between –1.0 and –0.8 and suffers high comparative disadvantage. Nine provincial regions range from 0 and 0.5 with low comparative advantage, 14 from –0.5 and 0 with low comparative disadvantage, and six from –0.8 and –0.5 with relatively

high comparative disadvantage. Embodied carbon emission competitiveness in total trade is comparatively disadvantaged and carbon emission productivity in export and outflow from the provincial regions remains to be improved.

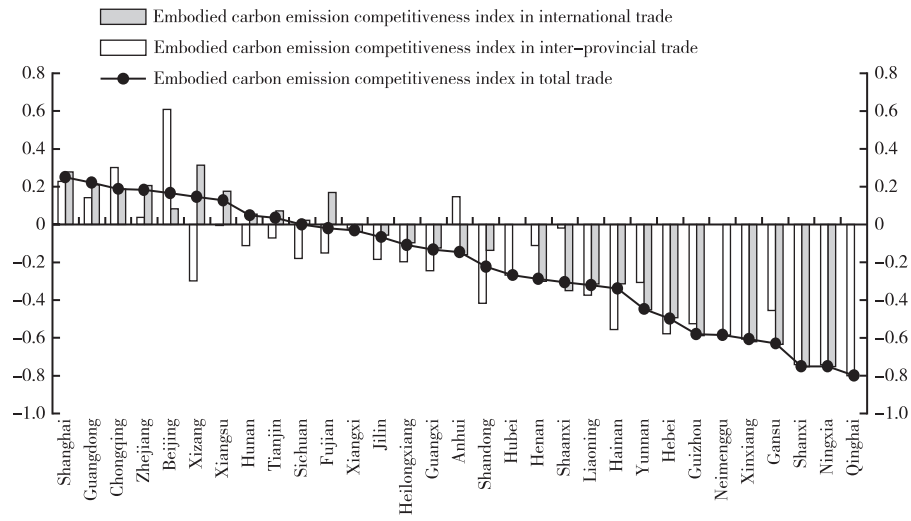

Figure 1. Embodied Carbon Emission Competitiveness Index in International Trade, Inter-Provincial Trade and Total Trade in 31 Chinese Provincial-Level Administrative Regions in 2012

Note: Provinces are ranked from high to low according to the embodied carbon emission competitiveness index in total trade and the right axis refers to the index in total trade.

5.2. Analysis on Low-Carbon Trade Competitiveness: From the Perspective of Product Sectors

The paper categorizes product sectors into 28 types and embodied carbon emission competitiveness index for their trade is shown in Table 2~7. Moreover, in order to facilitate analysis, product sectors numbered 2~5 are named mining herein, those numbered 6~21 named manufacturing, those numbered 22~24 production and supply of power, gas and water, those numbered 26~28 services, and those numbered 1 and 25 indicate agriculture and construction, respectively. Regarding agriculture, 26 provincial regions have an embodied carbon competitiveness index of lower than 0 for international trade and 21 for inter-provincial trade, with Shandong ranking last with an index between –1.0 and –0.8. For total trade, 24 provincial regions have an index of lower than 0, with Shandong ranking last with an index between –1.0 and –0.8. It shows that the agriculture sector has relatively high competitiveness in embodied carbon emission for inter-provincial trade. With respect to mining, embodied carbon emission competitiveness index in international trade is lovoer than 0 for 27 provinces, index in inter-provincial trade is lower than 0 for 16 provinces, and 21 for total trade.

The mining sector has relatively high competitiveness in embodied carbon emission in inter-provincial trade. As for manufacturing, 31 provincial regions generally enjoy comparative advantage and are highly competitive in embodied carbon emission for international trade. Shanxi suffers high comparative disadvantage in the competitiveness for trade. About production and supply of power, gas and water, since related statistics on import and export is not available for the majority of provincial regions, the embodied carbon emission competitiveness index in international trade for most of them is not available, either. This is relevant to the characteristics of the product sector. Most players in the production and supply of power, gas and water are state-owned/controlled enterprises, which engaged in international trade only at a low level. For inter-provincial trade, 22 provincial regions have an embodied carbon emission competitiveness index of lower than 0; for total trade, 25 have an index of lower than 0. In this product sector, most provincial regions suffer comparative disadvantage for embodied carbon emission competitiveness in trade in general. With regard to construction, the sector is relatively highly competitive in embodied carbon emission in international trade and Ningxia enjoys high comparative advantage in embodied carbon emission competitiveness in trade. Services are relatively highly competitive in embodied carbon emission in trade, but the competitive advantage is not impressive; services in Qinghai generally suffer high comparative disadvantage in embodied carbon emission competitiveness in trade.

5.3. Analysis on Low-Carbon Trade Competitiveness: Three Industries

As displayed in Figure2, Figure 3 and Figure 4, in the primary industry, for embodied carbon emission competitiveness index in international trade of the 31 provincial regions, it is lower than 0 in 26 of them, with Shandong, Hebei and Xinjiang ranking as the last three; for the index in inter-provincial trade of the 31provincial regions, it is lower than 0 in 21 of them; for the index in total trade, it is lower than 0 in 24 provincial regions, with Hubei ranking first with an index of 0.8~1.0. The 31 Chinese provincial-level administrative regions are generally weak for embodied carbon emission competitiveness in trade in the primary industry; embodied carbon emission competitiveness in inter-provincial trade is generally higher than that in international trade and inter-provincial trade can help promote the carbon emission productivity in the primary industry to improve. In the secondary industry, for embodied carbon emission competitiveness index in international trade of the 31 provincial regions, it is lower than 0 in 23 of them, with Beijing ranking first with an index of 0.5~0.8; for the index in inter-provincial trade, it is lower than 0 in 17 of them; for the index in total trade, it is lower than 0 in 21 of them. The 31 provincial regions generally suffer comparative disadvantage in embodied carbon emission competitiveness in trade in the secondary industry and similarly as in the primary industry, their embodied carbon emission competitiveness in inter-provincial trade is

generally greater than that for international trade. In the tertiary industry, for embodied carbon emission competitiveness index in international trade of the 31 provincial regions, it is lower than 0 in 18 of them, with Hubei and Qinghai ranking as the last two with an index between -1.0 and -0.8; for the index in inter-provincial trade, it is lower than 0 in 19 of them, with Inner Mongolia, Ningxia and Xinjiang ranking as the

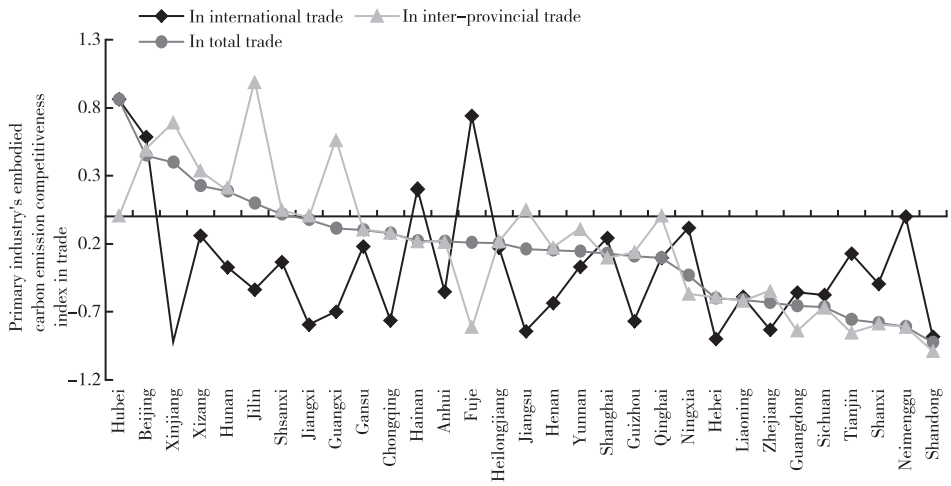

Figure 2. Embodied Carbon Emission Competitiveness Index in International Trade, Inter-Provincial Trade and Total Trade in the Primary Industry of 31 Chinese Provincial-Level Administrative Regions in 2012

Note: The sequence in the figure is by embodied carbon emission competitiveness index in total trade in the primary industry.

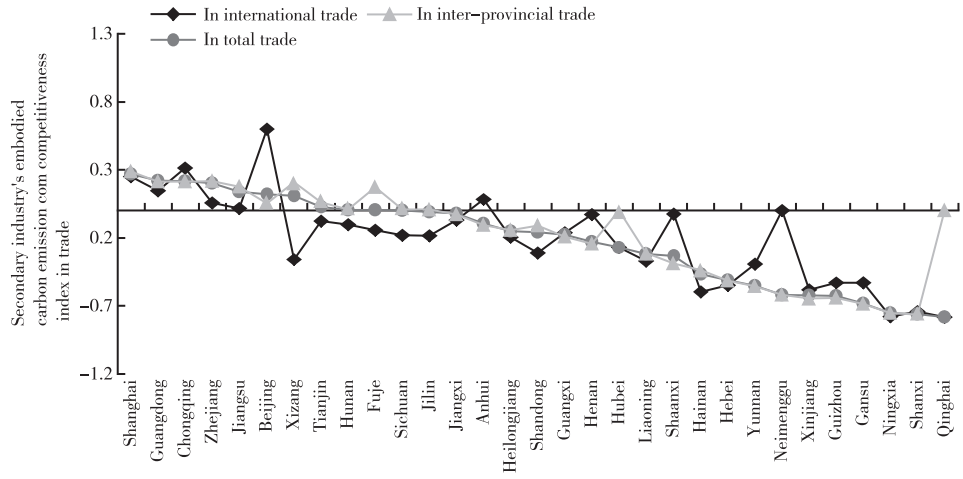

Figure 3. Embodied Carbon Emission Competitiveness Index in International Trade, Inter-Provincial Trade and Total Trade in the Secondary Industry of 31 Chinese Provincial-Level Administrative Regions in 2012

Note: The sequence in the figure is by embodied carbon emission competitiveness index in total trade in the secondary industry.

last three; for the index for general trade, it is lower than 0 in 21 of them, with Hubei and Qinghai ranking as the last two with an index between −1.0 and −0.8 and Tibet with an index of 0.8~1.0. Tibet enjoys high comparative advantage in embodied carbon emission competitiveness in trade in the tertiary industry mainly because its import and inflow from other provincial regions are relatively small and its industrial structure is incomplete. Besides, the 31 Chinese provincial-level administrative regions are relatively highly competitive in embodied carbon emission for international trade in the tertiary industry, but the competitive advantage is not distinct.

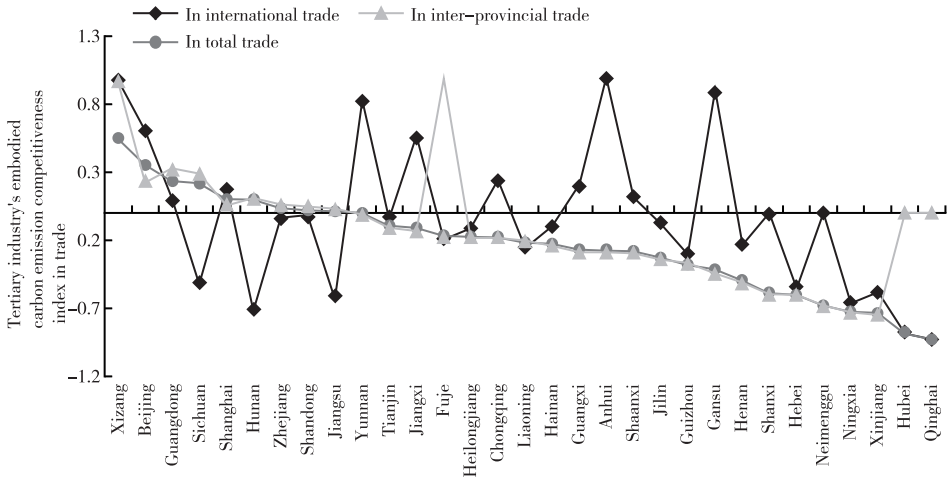

Figure 4. Embodied Carbon Emission Competitiveness Index in International Trade, Inter-Provincial Trade and Total Trade in the Tertiary Industry of 31 Chinese Provincial-Level Administrative Regions in 2012

Note: The sequence in the figure is by embodied carbon emission competitiveness index in total trade in the tertiary industry.

6. Conclusions

This paper measures the embodied carbon emission competitiveness index in international trade, inter-provincial trade and total trade of 31 Chinese provincial-level administrative regions from the perspectives of the whole, three industries and product sectors and draws the conclusions as follows. First, for embodied carbon emission competitiveness index in total trade, Shanghai ranks first, while Qinghai ranks last, and embodied carbon emission competitiveness in international trade of the 31 Chinese provinces is generally lower than that for inter-provincial trade. Besides, as international trade causes serious carbon leakage, embodied carbon emission

productivity in export is low. Second, various product sectors in the 31 provincial regions differ widely in embodied carbon emission competitiveness in international trade and inter-provincial trade. Some sectors enjoy certain comparative advantage, but the advantage is not obvious; for agriculture and mining, the competitiveness in international trade is lower than that for inter-provincial trade, but in manufacturing and services, the competitiveness for international trade is greater than that for inter-provincial trade. Third, the three industries in the 31 provincial regions have a wide gap in embodied carbon emission competitiveness in international trade and inter-provincial trade. The primary and secondary industries enjoy greater competitiveness in inter-provincial trade than that in international trade and inter-provincial trade helps promote carbon emission productivity in the primary industry to improve; the tertiary industry has greater competitiveness in international trade than that in inter-provincial trade, but the competitive advantage is not apparent.

References

Greenaway, D., & Milner, C. (1993). *Trade and Industrial Policy in Developing Countries*. UK: Palgrave Macmillan.

Halicioglu, F. (2009). An Econometric Study of CO2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey. *Energy Policy*, 37 (3), 1156-1164.

Jaffe, A., & Palmer, K. (1997). Environmental Regulations and Innovations: A Panel Study. *The Review of Economics and Statistics*, 79 (4), 610-619.

Kuik, O., & Hofkes, M. (2010). Border Adjustment for European Emissions Trading: Competitiveness and Carbon Leakage. *Energy Policy*, 38 (4), 1741-1748.

Porter, A., & Van der Linde, C. (1995). Towards a New Conception of the Environment Competitiveness Relationship. *Journal of Economics Perspectives*, 9, 97-118.