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Analysis on Carbon Emission Situation of Chinese Export Industry Based on Input-Output Model

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Abstract: Low carbon economy development undoubtedly becomes the main trend of social development in future under the background of the global climate change and the increasing international pressure to reduce emissions. However, the international trade, as part of the global economy, will be carried out in accordance with the rules of low carbon economy. Therefore, it has important significance to study the relation between the carbon emission and export trade and deeply excavate carbon reduction potential of Chinese industry production for finding way to reduce carbon emission in China and striving for the carbon emission reduction space from the international. This paper constructed the input-output model to calculate the CO2 emission density of Chinese export industry according to the input-output theory, and then basically analyzed the situation of carbon emission of export industry.

Keywords: CO_2 emission, export trade.

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1. INTRODUCTION

When the industrialization level in human society is lower, the carbon resource scarcity often will not be attached great importance, but the environmental negative externality caused by carbon emission in industrial expansion has gradually highlighted with the successive deepening of the industrialization degree [1]. At present, it is imminent to promote coordinated development of social economy and environment for countries. Since the early 1990s, as a series of international climate regime or environment arrangement such as《United Nations Framework Convention on Climate Change》 and 《Kyoto Protocol》 gradually formed, especially, when entering the post period of financial crisis, low carbon economy which is provided with two mechanical bearings sprang up in all countries and gradually became the important strength [2] that the emerging market countries promoted the sustainable development of social economy under the double pressure of international climate change and industrial restructuring [3].

As the continuous improvement of international concern for carbon emission, the countries with different development levels began to implement emission reduction rules with different levels. In 2009, the CO_2 emissions in □United Nations Framework Convention on Climate Change□contracting parties decreased by 6.4% than that of in 1990, while CO_2 emission in other countries increased by 132.3% than that in 1990 (IEA, 2011). China attracts direct investment of huge foreign merchant, bears the "world factory" role. As the high-speed economic development, the CO_2 emission problem are increasingly serious. Under the above background, it not only has the theoretical significance to study the relation between the export trade and the carbon emission in our country, but also has the practical significance. China realizes the emission reduction and develops the low carbon economy, which embodies a commitment of the rising and responsible great power to the world. When Chinese being responsible, it should also be indicated to the world that the huge carbon dioxide emissions is not only due to the requirement to meet Chinese its own demands, but also to meet the needs of foreign customers. This is the implicit carbon emission problem in the export trade. So-called implicit carbon in export trade refers to the amount of carbon dioxide which is discharged during the process of domestic production, but avoided in the import countries. Based on the input-output theory, this study constructs input-output model to calculate the CO_2 emission density of Chinese export industries, and then fundamentally analyzes the status of carbon emission of export industries.

2. OVERVIEW CONCERNING DEMESTIC AND FOREIGN RESEARCHES

In summarization, the foreign researches on the relation between trade and carbon emission mainly include the relation between export trade and carbon emission, the implied carbon emission problem in foreign trade, the implied carbon emission driving factors in export trade, and etc.

2.1. Researches on the Relation Between Export Trade and Carbon Emission

On the relation between export trade and carbon emission, the foreign researches are mainly as follows. Wyckoff *et al*. (1994) found that the carbon emission implicit carbon emission in the finished products accounted

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for approximately 13% of the total emission by calculating the implicit carbon emissions in six OECD countries trade. Afterwards, Shui and Harriss (2006) calculated the implicit carbon emissions in the Sino-US trade. They found that the carbon emission contained in the export trade from China to the United States accounted for 7%□14% of the total carbon emissions in China, and these carbon emissions would be finally consumed by the U.S. people; Likewise, Weber *et al*. (2008) believed that the main factors that caused the increase of carbon emission in China were carbon leakage and carbon export, and this opinion proved the "pollution heaven hypothesis". From the theoretical perspective, Hillman (1978) adopted the classic 3×2×2 model in international trade to study the relation between energy consumption and trade, and expanded the input-output method of Leontief. Furthermore, Mongelli, Tassielli and Notarnicola (2006) also used the input-output technique to study the energy consumption problem in Italian merchandise trade based on the product department by calculating the energy and CO_2 contents in Italian merchandise trade. In addition, Lenzen and Mungsgaard (2002) proposed a multi-region input-output model, which was used to calculate the quantity of energy contained in products which are finally consumed in Denmark in a form of value [4].

2.2. Researches on the Implicit Carbon Emission Problem in Foreign Trade

Since the 1990s, researches on climate change have drawn attention to the implicit carbon emission problem caused by foreign trade. The foreign researches on implicit carbon emission in trade started early, and at present, many countries use the input-output method to calculate the implicit carbon emission in their countries. For example, the research on implicit carbon emission in Brazilian trade conducted by Schaeffer and Leal (1996) showed that the developed countries transferred the carbon emission to developing countries such as Brazil through offshore manufacturing and production of domestic consumer goods, which caused that the consumed carbon in the export products in Brazil is 56% more than that in the import products. Ahmad and Wyckoff (2003) believed that the United States, Japan, Germany, France and Italy were the mainly implicit carbon import countries, and in 1995, the biggest implicit carbon export country in OECD was China, followed by Russia. The research conducted by Halicioglu (2008) showed that the foreign trade of Turkey was one of the reasons that affected its CO_2 emission. Halicioglu (2009) found that the development of bilateral trade can significantly increase CO_2 emission. In addition, Gavrilova *et al*. (2010) used the all-carbon calculation and life cycle analysis method to study the trade carbon emission of Austrian animal husbandry. At present, the common method used to calculate the implicit CO_2 content in product is the I-O model (input-output model), and the I-O model can also be divided into the unilateral I-O model (SRI-O) and multilateral I-O model (MRI-O). Sánchez-Chóliz and Duarte (2004) as well as Mongelli *et al*. (2006) used the SRI-O model to calculate the implicit pollutants in trade, and the SRIO model does not have high requirement for data, but it involves a narrow research scope. The MRI-O model can cover the flow issue of implicit pollutants in trade of multiple countries, but it has a higher requirement for the capacity and processing of data. Atkinson and Hamilton *et al*. (2010) used the MRI-O model, they calculated the CO_2 flow in global trade by using the data from 19 departments in 15 countries, and the empirical results show that CO_2 flowed to the developed countries from developing countries through foreign trade.

2.3. Researches on the Implicit Carbon Emission Driving Factors in Export Trade

During measurement and calculation of the implicit carbon emission in the export trade of China, some scholars began to analyze the driving factors. Yan and Yang (2010) used the structural decomposition analysis (SDA) method to decompose the change of implicit carbon emission into (1) Technical effect, i.e., the change of carbon emission intensity from product; (2) Structural effect, i.e., the change of trade structure; (3) Scale effect, i.e., the change of trade volume. The results show that the implicit carbon emission exported from China had increased by 449% from 1997 to 2007, among them, 450% resulted from scale effect, 47% resulted from structural effect, and -48% resulted from technical effect.

3. ANALYSIS OF CARBON EMISSIONSITUATION IN THE CHINESE EXPORT INDUSTRY

3.1. Input-Output Model

Under the economic globalization, the unit output of one country will not only cause CO_2 emission domestically, but also cause CO_2 emission in foreign countries through export of intermediate goods [5]. The input-output table provided by OECD does not only include the general application table, but also include the import and domestic application tables, which can separate the domestic CO_2 emission generated by the unit output of China and the implicit CO_2 emission from foreign countries [6]. Therefore, this paper uses the input-output table provided by OECD to calculate the domestic CO_2 emission generated by the unit output of Chinese industry. The input-output model is a model built in accordance with the balance relation of the input-output table. $X = AX + Y$, where X refers to the total output vector of various departments, A is the direct consumption coefficient matrix, Y refers to final demand vector. Through transposition, we can obtain $X = (I - A)^{-1}Y$, where $(I - A)^{-1}$ is Leontief inverse matrix. This is the basic form of input-output model, which means only the domestic elements are used for production, and the produced products are all used for domestic consumption. Under the background of global division of labor, China only participates in some links of the division of labor. Not only the import products are used for production and consumption, but the final products are also used for export in addition to the domestic production and consumption [7]. Therefore, by using the method of Julio *et al*. (2004), it is assumed that intermediate use of domestic production can be

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Table 1. CO2 emission coefficients of Chinese industrial divisions. Unit: wan tons CO_2 /hundred million yuan.

	C^d			*E* (1)			*E* (2)		
Industry	**2002**	**2005**	**2008**	E^d	E^t	E^d/E^t	E^d	E^t	E^d/E^t
Agriculture	0.507	0.515	0.361	1.788	2.102	0.850	1.778	2.252	0.789
Mining industry(energy)	3.939	3.147	2.688	4.375	4.810	0.910	5.916	6.994	0.846
Mining industry (non-energy)	2.653	2.787	1.803	4.919	5.636	0.873	6.399	8.080	0.792
Food processing manufacturing	0.687	0.500	0.373	1.954	2.351	0.831	2.122	2.679	0.792
Textile industry and clothing industry	0.682	0.616	0.476	2.598	3.402	0.764	2.736	3.703	0.739
Wood-processing industry	0.834	0.830	0.495	3.236	4.129	0.784	3.342	4.281	0.781
Papermaking industry, printing industry	1.462	1.133	0.795	3.040	4.251	0.715	3.633	4.759	0.763
Petroleum processing industry	3.774	3.215	2.940	5.804	7.038	0.825	6.985	8.619	0.810
Chemical industry	4.200	3.288	2.404	6.646	7.948	0.836	7.055	8.755	0.806
Rubber and plastic product industry	0.807	0.815	0.572	3.699	5.131	0.721	4.082	5.305	0.769
Non-metallic production industry	4.966	4.521	2.974	7.670	8.552	0.897	6.960	7.873	0.884
Smelting processing industry of black metal	6.341	4.891	4.196	9.145	10.382	0.881	9.427	11.840	0.796
Metal product industry	0.958	0.809	0.531	5.206	6.505	0.800	4.942	6.673	0.741
Equipment manufacture industry	0.635	0.428	0.264	3.751	4.940	0.759	3.632	5.228	0.695
Instrument manufacture industry	0.331	0.141	0.113	1.620	3.449	0.470	1.808	4.036	0.448
Electrical machinery manufacturing industry	0.252	0.191	0.148	3.146	4.720	0.667	2.841	4.724	0.601
Communication equipment manufacturing industry	0.151	0.099	0.084	1.807	3.772	0.479	1.393	3.227	0.432
Transportation equipment manufacturing industry	0.396	0.251	0.168	3.178	4.233	0.751	2.896	4.267	0.679
Other manufacturing industries	1.459	0.905	0.518	3.242	4.375	0.741	3.067	4.251	0.721
Production and supply industry of electric power	4.033	2.037	1.524	4.038	4.945	0.817	4.319	5.186	0.833
Industry for production and supply of water	3.068	2.898	2.547	3.759	5.246	0.717	5.054	5.732	0.882
Construction industry	2.178	0.227	0.163	3.886	4.928	0.789	3.399	4.550	0.747
Wholesale, retail and catering industries	0.617	0.791	0.529	2.202	2.724	0.808	2.092	2.604	0.803
Transportation and postal service industries	2.514	3.218	2.753	4.882	5.591	0.873	4.945	5.728	0.863
Other service industries	0.468	0.383	0.310	1.823	2.322	0.785	1.827	2.463	0.742

E (1) denotes the complete discharge coefficient calculated according to input-output table (hereby, the direct consumption coefficient can be calculated) in 2000 and CO_2 direct emission coefficients in 2005. *E* (2) denotes the complete discharge coefficient calculated according to input-output table (hereby, the direct consumption coefficient can be calculated) in 2005 and CO_2 direct emission coefficients in 2005.

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divided into the two parts of domestic input and import input, and $A^d = \left\{ x_{ij}^d / x_j \right\}$ represents the direct consumption matrix of domestic input among the intermediate use, in which, x_{ij}^d refers to the domestic input of department i consumed for the production of x_j output, and x_j refers to the total output of department j ; $A^m = \left\{ x_{ij}^m / x_j \right\}$ represents the direct consumption matrix of import input among the intermediate use, where x_{ij}^m refers to the import input of department i consumed for the production of x_j output. $A = A^d + A^m$. Then, the input-output model can be written as:

$$X^d = (I - A^d)^{-1}(Y^x + Y^d) \quad (1)$$

$$X^m = A^m X^d + Y^m = A^m (I - A^d)^{-1}(Y^d + Y^x) + Y^m \quad (2)$$

where Y^d and Y^x represent the domestic demand and export demand in the final demand respectively; Y^m refers to the part of import products directly used for domestic consumption.

$C^d = \left\{ C_j^d / x_j \right\}$ represents the direct emission coefficient of CO_2 in unit output of various industries, where C_j^d refers to direct emission amount of CO_2 in department j . Then, the complete emission of domestic part in domestic unit output (i.e., the complete emission coefficient) is

$E^d = C^d (I - A^d)^{-1}$ in accordance with the input-output theory.

From the perspective of import substitution, the implicit CO_2 emission in the import products of China can be equivalent to saving the CO_2 emission in domestic production [8]. Therefore, it is assumed that the CO_2 complete emission coefficients of unit product manufactured in foreign countries are the same as that in China, then, the CO_2 emission saved for China through import is $E^m = X^m E^d$, and the domestic CO_2 emission generated by export is $E^x = Y^x E^d$.

3.2. Simulation Results and Analysis of Discharge Coefficient

OECD input-output table includes 48 departments, which is different from the division of Chinese economic department. Hence, with reference to the international standard industrial classification (ISIC) method, the classification and docking are conducted on the input-output table and the economy sectors, and finally they are merged to 25 departments (industry). Table **1** is the CO_2 emission coefficients of Chinese industrial divisions calculated according to the input-output model.

It is concluded from Table **1** that first CO_2 emission coefficient displays an obviously decreased trend. In the 25 industries in China, except "wholesale, retail and catering industries" and "transportation and postal service industries", CO_2 emission coefficient has an obviously decreased trend in other industries. Moreover, the reduction range of discharge coefficients are especially obvious for three industries such as“smelting processing industry of black metal”, “metal product industry” and "chemical industry" with the highest direct discharge coefficients. It shows that energy conservation and emission reduction measures in various industries, especially, in the high discharge industries make obvious progress after Chinese accession to WTO. Secondly, complete discharge coefficient is significantly higher than that of direct discharge coefficient, and complete discharge coefficients in some industries increase. This suggests that degree of correlation among various Chinese domestic industries is higher, and unit output in each industry implies higher CO_2 emission of other industries. Because the complete discharge coefficients are calculated by the input-output table in 2000, input-output table in 2005, and direct emissions coefficients in 2005. Hence, the rise of complete discharge coefficient show that the correlation in some industries has a tendency to improve. Furthermore, this means that it may be one of the reasons for the reduction of direct emission coefficient in each industry that the CO_2 is shifted to other industries. Thirdly, except a few industries, the proportion of CO_2 emission abroad implied in unit output of each industry obviously increases. Except the four industries of “papermaking and printing industries”, “non-metallic products industry”, “electric power production and supply industry” and “industry for production and supply of water”, the proportion of CO_2 emission abroad implied in unit output of other industries to the all CO_2 emission is significantly increases. This shows that the degree that Chinese industries participate in the international vertical specialization obviously increases.

CONCLUSION

This paper divides Chinese industrial CO_2 emission into two parts which are domestic emission and implicit carbon of import trade, and calculated carbon emission of export industry in China according to OECD input-output table. It shows that in China complete discharge coefficient is significantly higher than that of direct discharge coefficient, Chinese industries participate in the international vertical specialization obviously increases.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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