Analysis of Implicit Carbon Emissions in Sino-EU Carbon-intensive Products Trade Based on Input-Output Model

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Abstract. In recent years, with the continuous deepening of China-EU trade partnership, EU countries have imported and consumed a large number of carbon-intensive products from China. In order to analyze the changes in China's carbon dioxide emissions caused by China's export of a large number of carbon-intensive products to the EU, this paper estimates the implied carbon emissions generated by the trade of carbon-intensive products between China and the EU by establishing the input-output models of China and the EU respectively. The results show that the future carbon emissions of China-EU carbon-intensive products will grow at a slower rate, which is due to the continued decline in China's carbon intensity.

1. Introduction

With the development of economic globalization and trade liberalization, international trade between various economies has become more frequent, and trade volume and trade volume have grown rapidly. China is the largest developing country in the world, and the EU is the largest developed region. As the two major economies, its trade relationship is increasingly close. In China's export trade to the EU, carbon-intensive products occupy an important position. EU countries import and consume a large number of carbon-intensive products from China. Although China also imports corresponding products from the EU, in general, the EU is in a net import status for China's carbon-intensive products. Trade Implied Carbon Emissions refers to carbon dioxide emitted by a trade product throughout the production chain, including direct and indirect carbon dioxide emissions. Regarding the measurement of implied carbon emissions in international trade, the current mainstream measurement method is input-output analysis. Input-output analysis is a top-down measurement method using input-output theory, which is suitable for large-scale measurement. Wyckoff and Roop first studied OECD for carbon emissions in trade from 1984 to 1986, and concluded that carbon emissions implied in imported manufactured products accounted for 13% of total carbon emissions in six OECD countries [1]. Ahmad and Wyckoff's conservative estimates found that some OECD countries have more than 50% of their domestic emissions in foreign trade, and an average of about 14% of all countries' emissions are trade implied carbon emissions [2].

Sanchez-Choliz and Duarte systematically analyzed the implicit carbon emissions of Spanish trade, including re-exports, using a single-region input-output model. Research shows that there is a net export of implicit carbon in Spain's international trade, although Net export carbon emissions account for only 1.31% of total domestic emissions, but implicit carbon emissions from imports and exports account for 36% and 37% of total demand emissions, respectively [3]. Mongelli et al. used the input-output method to obtain nearly 25% of the world's imported implied carbon, which is derived from developing countries and countries with economies in transition [4]. Lenzen used a mixed-unit input-
output model to analyze the implicit energy and implied carbon emissions in Australia's final consumption\cite{5}. Machad et al. further evaluated the impact of Brazilian international trade on its energy use and CO2 emissions by establishing a mix-unit input-output model\cite{6}.

In the future climate change negotiations, international trade will become an important factor in defining the carbon emissions responsibility of member states. Therefore, it is of great significance to analyze the changes in China's carbon dioxide emissions caused by the EU's import of large quantities of carbon-intensive products from China.

2. Model: input-output model
The basic formula of the input-output model is:

\[ X = (I - A)^{-1}Y \]

where \( X \) is the total output matrix, \( Y \) is the final use matrix, \( A \) is the technical coefficient matrix. \( A = \begin{bmatrix} a_{11} & \cdots & a_{1j} \\ \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} \end{bmatrix} \)

\( a_{ij} = \frac{x_{ij}}{x_{j}} \)

The formula is usually slightly deformed when calculating carbon dioxide emissions:

\[ C = c(I - A)^{-1}Y \]

where \( C \) is the direct carbon dioxide emission intensity for each sector, \( C \) is the carbon dioxide emission matrix, \( c(I - A)^{-1} \) is the complete carbon dioxide emission coefficient matrix.

3. Data source and processing
The text of your paper should be formatted as follows: The EU-ETS industry that incorporates a carbon trading system consists of three parts: the first part includes power generation and heating; the second part is energy-intensive; the third part is commercial aviation. Since the first and third parts generally do not involve international trade, this paper mainly considers the second part of the industry, which is summarized as seven industries of cement lime, organic chemistry, pulp paper board, ceramics, glass, steel and aluminum. Based on the selected seven carbon-intensive industries, this article focuses on the following four sectors: paper, printing, cultural and educational sporting goods manufacturing, corresponding to pulp, paper and cardboard; chemical industry, corresponding organic chemistry; non-metallic mineral products industry. This paper takes the proportion of exports to Europe in the ceramics, cement lime and glass industries as the weight, and splits the hidden carbon dioxide emissions of these three industries. According to the same method, the implicit carbon dioxide emissions of steel and aluminum. China's input-output table data comes from the input and output tables of China in 2007, 2010 and 2012, including the complete consumption matrix and the intermediate flow matrix; the export data of each department comes from the 2007-2015 China Trade Foreign Economics Statistical Yearbook and the United Nations Data Center; energy consumption data for various industries in China comes from the 2009-2014 China Statistical Yearbook. The input-output table data of the EU is derived from the Input-Output Tables under ESA 2010 methodology of the European Union Statistics website. At the same time, this paper selects the departments that are also calculated according to the ESA 2010 method. Carbon dioxide emissions data for 2012, and calculated the intensity of carbon dioxide emissions in various sector.

4. Result and analysis
Based on data on carbon dioxide emission intensity in various sectors, and the 41-sector China IO model from 2007 to 2012, the EU imports carbon-intensive products from China, and calculates China's carbon-intensive exports to the EU in 2007, 2010 and 2012, the implied carbon dioxide emissions in the product are shown in Table 1.
As can be seen from Table 1, the export carbon emissions of paper, organic chemistry, ceramics and aluminum are rising. The implied carbon emissions of cement lime, glass and steel are available in 2010. After a brief decline, it rose again in 2012. However, among the two types of products, glass and cement lime, the export carbon emissions in 2012 almost reached or exceeded the level of 2007, and the export carbon emissions of steel in 2012 are still much lower than the 2007 level, a decrease of 53.3% from 2007.

**TABLE 1. Implicit CO2 emissions from carbon-intensive products to EU export trade (10,000 tons)**

| Category       | 2007     | 2010     | 2012     |
|----------------|----------|----------|----------|
| Paper products | 274.97   | 292.13   | 366.03   |
| organic chemistry | 2101.13 | 2105.57 | 2356.07 |
| cement,lime    | 772.14   | 594.19   | 769.61   |
| ceramics       | 688.76   | 803.79   | 1236.66  |
| glass          | 793.36   | 723.30   | 1097.16  |
| steel          | 6496.73  | 2979.15  | 3032.52  |
| aluminum       | 696.54   | 723.99   | 746.08   |
| total          | 11823.64 | 8222.12  | 9604.12  |

The ratio of China's implicit carbon dioxide emissions to EU carbon-intensive exports to China's total carbon dioxide emissions is shown in Table 2. As can be seen from Table 2, the ratio of implied CO2 emissions to EU-exported carbon-intensive products to China's CO2 emissions is 1.11%-1.83%, while net implicit CO2 emissions from EU-exported carbon-intensive products. The proportion of China's CO2 emissions is 0.98%-1.70%. Whether it is the implied CO2 emissions or the net implied CO2 emissions caused by the export of EU carbon-intensive products, it accounts for a higher proportion of China's total CO2 emissions.

**TABLE 2. Implied CO2 emissions from trade in carbon-intensive products in the EU as a percentage of total CO2 emissions in China**

|                  | 2007     | 2010     | 2012     |
|------------------|----------|----------|----------|
| China's carbon dioxide emissions (Mt) | 6468.57  | 7707.05  | 8620.97  |
| Implicit CO2 emissions proportion     | 1.83%    | 1.07%    | 1.11%    |
| Net implicit CO2 emissions proportion | 1.70%    | 0.93%    | 0.98%    |

China’s implicit CO2 emissions from exports of carbon-intensive products to the EU accounted for 1.11%-1.83% of China’s total CO2 emissions in 2007, 2010 and 2012. The EU adopted carbon-intensive products imported from China in 2007. In 2010 and 2012, the EU reduced its CO2 emissions by 2.28%-3.06%. The trade in carbon-intensive products between China and Europe increased China's net CO2 emissions by 0.98%-1.70%. In the next few years, the trade volume between China and the EU will continue to increase, but due to the continuous decline in China's carbon dioxide emission intensity, the implicit CO2 emissions from trade will increase at a slower rate. At the same time, the proportion of implicit CO2 emissions from trade to China's total CO2 emissions will increase slightly and begin to decline.

The main policy recommendations are: controlling investment in carbon-intensive industries, introducing green environmental protection industries, improving energy efficiency in carbon-intensive industries, improving their energy structure, establishing a carbon emissions trading market that comprehensively covers carbon-intensive industries, and improving the environment rules.

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