The Impact of the EU Carbon Border Adjustment Mechanism on China's Exports and Suggestions on Countermeasures

Zhuo Chen[1,a,*]

[1]*Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, China*
a. zchengo@connect.ust.hk
**corresponding author*

Abstract: The European Parliament plans to gradually introduce the Carbon Border Adjustment Mechanism in 2023, with a complete implementation set for 2026. As an essential trading partner of the EU, China will shoulder an additional carbon border tariff due to the lack of low-carbon technology and the dependence on extensive development patterns. These extra costs will undermine the profit margins of China's carbon-intensive industry sectors, possibly resulting in decreased exports and a restructuring of production. The latest estimate of the exact costs of China's embedded carbon exports to the EU is a problem that has received limited academic attention. Using the IPCC carbon emission accounting methodology and non-competitive single-region input-output analysis, this research precisely measures the embedded carbon in China's exports to the EU for the nine most affected industries. Furthermore, this study quantifies the impact of the CBAM on China's exports of these nine industry sectors. The findings suggest that China should improve the domestic carbon emission trading system and take the initiative to participate in formulating a carbon pricing consultation and dialogue mechanism, mitigating the negative impact of the EU CBAM on exports.

Keywords: Carbon border adjustment mechanism, IPCC, Input-output analysis, Climate policy.

1. Introduction

The European Union has gradually implemented the Carbon Border Adjustment Mechanism (CBAM) since 2023. This mechanism requires exporters from states with less stringent carbon emission regulations to bear the carbon mitigation cost incurred by EU producers. By using the CBAM, the EU states domestic tax revenue neutral can be achieved [1].

China has been the world's largest carbon-emitting country for 18 consecutive years [2]. During the industrial and energy structure transformations, China faces many challenges, including the lack of independent innovation in low-carbon technology and the over-dependence on extensive development patterns [3]. Given that the EU is China's largest trading partner, the EU CBAM is both an opportunity and a challenge for China. The CBAM will impact the trade dynamics and climate governance cooperation between China and the EU, which has caused a heated debate over how many losses China will incur and what countermeasures it can implement [4]. Since the price of traded

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carbon emission allowance in the EU increased significantly in the last three years, the latest prediction of the precise cost of China's embedded carbon exports to the EU is an emerging area that has received limited academic attention. Therefore, the impact of the CBAM certificate on the cost of China's exports is the main problem that this research attempts to solve.

The significance of this research lies in four aspects: firstly, it accurately measures the carbon dioxide emissions of the nine most affected Chinese export industries faced with CBAM, using the carbon emission factor method from the Intergovernmental Panel on Climate Change (IPCC). Secondly, it calculated the embedded carbon in China's exports to the EU based on China's latest input-output table of 2020. Thirdly, by analyzing the standards and scope of tariff that the EU has planned to impose, it predicts the possible price of the CBAM certificate that would be levied on various China's industry sectors. The price of the CBAM certificate is then compared with the profits of these industries to assess if their exports are still profitable. Lastly, it discusses the policy recommendations for China regarding trade policy and climate governance.

2. Analysis of the Impact of European Union CBAM on China's Exports

In the long run, the European Union's carbon border adjustment mechanism encourages Chinese companies to invest in clean production technologies and reduce carbon emissions, ultimately facilitating the achievement of carbon peak by 2030 and carbon neutrality by 2060. Nevertheless, in the short term, the European Union CBAM tariffs have increased the cost of Chinese products and undermined the competitiveness of China's exports to the EU.

Specifically, the embedded carbon in China's exports to the EU varies significantly across industries. The carbon border adjustment tariff imposed by the EU depends on the industries' carbon intensity. In order to measure the scale of the impact from CBAM on Chinese trade, the export embedded carbon in the most affected industries will be calculated in this section.

2.1. The Accounting Method of Carbon Emissions

This section utilizes the carbon emission factor method from the Intergovernmental Panel on Climate Change to measure the carbon dioxide emissions of the Chinese export industries most affected by the EU Carbon Border Adjustment Mechanism (CBAM) [5]. Besides, the accounting method introduces a non-competitive single-region input-output model to obtain the direct and indirect emissions data for each industry in China. This thorough input-output analysis captures the direct emissions from the industries' production activities and the indirect emissions embedded in their intermediate inputs, providing a robust assessment of Chinese industries' carbon consumption.

Using the IPCC carbon emission accounting methodology and the detailed input-output analysis ensures emissions calculations are in strict alignment with internationally accepted principles and guidelines. This adherence to global standards enhances the credibility and robustness of the research findings, providing a solid foundation for further analysis of the economic implications of the carbon border tariff.

2.1.1. Carbon Emission Calculation Model

Since the embedded carbon in export includes both direct emissions from production and indirect emissions from intermediate inputs from other industries [6], the latest single-region input-output table for the year 2020 is used to calculate the embedded carbon in China's export to the EU (27 countries).

The basic structure of the input-output model can be expressed as intermediate consumption + final demand = gross output, namely in mathematic notation:

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$$DX + Y = X \tag{1}$$

D is the input-output matrix. Y is the vector of final demand. X is the vector of gross output. The equation (1) can be further transformed into:

$$X = (I - D)^{-1}Y \tag{2}$$

$(I - D)^{-1}$ is the Leontief inverse matrix. Let $e_i = E_i \div X_i$ (X_i is the gross output of the i^{th} industry sector. E_i is the gross carbon emission of the i^{th} industry sector). e_i is the carbon dioxide emissions per unit of the production from the i^{th} industry sector, which is called the direct carbon emission intensity coefficient. The $1 \times n$ matrix of all the e_i values is defined as the carbon emission intensity coefficient matrix, denoted as E. Therefore, the calculation formula of the carbon dioxide emission is:

$$C = E(I - D)^{-1}Y \tag{3}$$

Let $D = D_t + D_i$ (D_t is the technical coefficients for domestic intermediate inputs. D_i is the technical coefficients for imported intermediate inputs). Similarly, Y is composed of domestic final demand Y_t and foreign final demand Y_f for export. The final formula to calculate the embedded carbon in domestic production and exports is:

$$C^f = E(I - D_t)^{-1}Y_f \tag{4}$$

2.1.2. Data Source and Process

In previous literature, the IPCC carbon emission factor method was commonly used to calculate various industry's domestic carbon emissions. The IPCC carbon emission factor method involves multiplying the activity energy consumption data by the corresponding emission factor to estimate the CO_2 emissions, which requires the consumption data of various energy sources by industry, the standard coal conversion coefficients of different energy sources, and the carbon dioxide emission coefficients of these energy sources.

Firstly, the consumption data of various energy sources by industry is obtained from the China statistical yearbook [7]. Secondly, according to Liao, the standard coal conversion coefficients of different energy sources are displayed in Table 1. Thirdly, the carbon dioxide emission coefficients of China's primary energy sources are collected from Chinese Product Life Cycle Greenhouse Gas Emission Coefficients, Chen and Liao, which are displayed in Table 2.

Table 1: Standard coal conversion coefficients [8].

Raw coal	Coke	Crude oil	Petrol	Kerosene	Diesel oil	Fuel oil	Natural gas	Power
0.7143	0.9714	1.4286	1.4714	1.4714	1.4571	1.4286	1.3300	1.2290

Unit: standard coal/t

Table 2: The carbon dioxide emission coefficients of China's primary energy sources [8][9][10].

Raw coal	Coke	Crude oil	Petrol	Kerosene	Diesel oil	Fuel oil	Natural gas	Power
2.763	0.8550	2.145	0.5538	0.5714	0.5921	0.6185	1.642	26.2287

Unit: kg of CO_2 / kg of standard coal

The industries most affected by the CBAM are the ones with the largest amount of embedded carbon in the exports from China to the EU. Based on the research of Liu and Zhao, the top five industries in the amount of embedded carbon in China's exports to the EU are the chemical products industry, the general and special-purpose equipment industry, the machinery industry, the textile

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products industry and the metal products industry [4]. Apart from the top five industries in exporting embedded carbon, the EU will also probably sell the CBAM certificate to the non-metallic mineral industry, gas production and supply industry, metal smelting and rolling industry, and non-metallic mineral mining and quarrying industry [4]. Therefore, these nine industries are the main research subjects of this research.

To match the data of these nine industry sectors from China's input-output table and UNcomtrade, Table 3 lists the correspondence between the industry sectors in the China's input-output table and the chapters in UNcomtrade based on the HS code [11, 12]. Refer to the data processing method by Liu and Zhao, the coal mining and selection industry is incorporated into the non-metallic mining industry. Besides, the petroleum and nuclear fuel processing industry is incorporated into the chemical industry. The data of the general equipment industry and the special-purpose equipment industry are merged [5].

Table 3: Correspondence of China's export key industry sectors.

Industry sector in input-output table	UNcomtrade (HS4)
Non-metallic mineral mining and quarrying industry	Chapter 25
Gas production and supply industry	Chapter 27
Chemical products	Chapter 28-40
Textile products	Chapter 50-63
Non-metallic mineral products	Chapter 68-72
Metal Smelting and Rolling industry	Chapter 72
Metal products	Chapter 73-83
General and special-purpose equipment products	Chapter 84
Machinery products	Chapter 85

2.1.3. Embedded Carbon in China's Exports to EU by Industry

Utilizing the data from the China input-output table and UNcomtrade database, this research calculated the carbon intensity coefficients for China's key industries and embedded carbon in China's exports to the EU. The formula and results are demonstrated in Table 4.

The total amount of embedded carbon in these nine industries' exports to the EU was 198 million tons in 2020. The largest five industries are the chemical products industry (54.6 million tons), textile products industry (51.1 million tons), general and special-purpose equipment industry (30.4 million tons), machinery industry (30.2 million tons), and metal products industry (13.9 million tons). The metal smelting and rolling industry had the highest carbon intensity coefficient, at 3.29 kg of CO2 per US dollar.

Table 4: Embedded carbon in China's exports to the EU in 2020.

Industry sector in input-output table	Carbon intensity coefficients for each industry (Carbon emission/ output value) (Kg of CO_2/USD)	Embedded carbon in China's exports to the European Union (10,000 tons)
Non-metallic mineral mining and quarrying industry	0.56402023	16.25437427
Gas production and supply industry	0.87293602	0.072258938

Table 4: (continued).

Chemical products	1.54831213	5467.053633
Textile products	0.98929121	5115.710099
Non-metallic mineral products	1.71118594	1267.454994
Metal Smelting and Rolling industry	3.29119726	485.6237821
Metal products	0.70048497	1385.991622
General and special-purpose equipment products	0.390621254	3048.395062
Machinery products	0.304521285	3020.408233

The average exchange rate between RMB and USD in 2020: 1 RMB = 0.14498 USD

2.2. The Impact of the CBAM Certificate on the Cost of China's Exports

This section further analyzes the potential losses that China may incur when the EU imposes a carbon border adjustment tariff on the embedded carbon in China’s exports. According to the EU regulations, the CBAM will mirror the Emissions Trading System (ETS). The price of CBAM certificates will be determined based on the weekly average auction price of the EU ETS allowances, measured in euros per-ton of CO_2 emitted [13].

The price of traded carbon emission allowances in Figure 1 is collected from the European Energy Exchange database [14]. During the last three years, the price of trade carbon emission allowances has first increased from 49.78 USD/t to 100.92 USD/t and then fell back to 79.98 USD/t. Given this trend, the price of the CBAM certificate will likely be between $80 and $100 per ton of carbon dioxide.

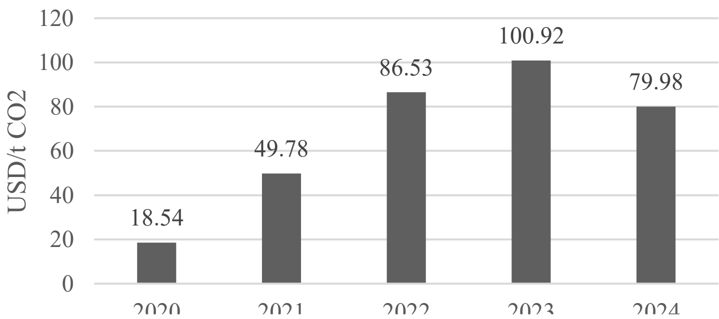

Figure 1: The price of traded carbon emission allowances.

As is demonstrated in Table 5, when the EU sells a CBAM certificate of the embedded carbon dioxide in China’s key industries’ exports at $80 per ton, China will have to incur an additional CBA tariff of $158.46 billion annually. This tariff value accounts for 5.4% of China’s key industries’ exports value to the EU, which means that China’s average export cost to the EU will increase by at least 5.4%. When the EU sells a CBAM certificate of the embedded carbon dioxide in China’s key industries’ exports at $100 per ton, China will have to incur an additional CBA tariff of $198.07 billion annually, accounting for 6.76% of China’s key industries’ exports value to the EU. By comparing the proportion of the CBA tariff in the export value and the corresponding industry operating profit margin, it is found that five out of nine sectors will no longer be profitable to export with the CBAM certificate at $80 per ton. Moreover, six of nine sectors will no longer be profitable to export with the CBAM certificate at $100 per ton.

Table 5: The impact of the CBAM certificate on the cost of China's exports to the EU.

Industry sector in input-output table	Export value between China and the EU (USD)	CBAM certificate at 80 USD/t	The proportion of the CBA tariff in the export value	CBAM certificate at 100 USD/t	The proportion of the CBA tariff in the export value	Industry operating profit margin
Non-metallic mineral mining and quarrying	288187789	13003499.42	4.51%	16254374.27	5.64%	9.33%
Gas production and supply	827769	57807.15005	6.98%	72258.93756	8.73%	7.69%
Chemical products	35309764184	4373642907	12.39%	5467053633	15.48%	6.52%
Textile products	51710861719	4092568079	7.91%	5115710099	9.89%	4.85%
Non-metallic mineral products	7406880594	1013963995	13.69%	1267454994	17.11%	8.52%
Metal Smelting and Rolling	1475523172	388499025.6	26.33%	485623782.1	32.91%	3.07%
Metal products	19786172185	1108793298	5.60%	1385991622	7.00%	4.58%
General and special-purpose equipment	78039661943	2438716050	3.12%	3048395062	3.91%	7.81%
Machinery products	99185455349	2416326586	2.44%	3020408233	3.05%	5.90%

3. Suggestions on China's Trade and Climate Policy

With respect to trade policy, it is suggested that China establish a low-carbon product list by referencing the WTO environmental product list to adjust the structure of exports to EU, encouraging the priority exports of low-carbon products and China's advantageous products such as new energy vehicles. Besides, China should explore including environmental and climate-related rules in the Regional Comprehensive Economic Partnership (RCEP) as a beneficial attempt to address the issue of carbon leakage in international trade. The proportion of intermediate goods trade in China's global trade is gradually increasing [15]. During cross-border trade, the embedded carbon in added value from upstream production processes is repeatedly calculated, thereby obscuring the carbon consumption and carbon emission footprints from various countries in bilateral and multilateral trade. China has been an important “transit point” for the global exports of embedded carbon. Therefore, the cost brought by the CBA tariff should be shared among China and its upstream trading partners.

In terms of climate policy, China should take the initiative to participate in formulating a carbon pricing consultation and dialogue mechanism. Adhering to the principle of “common but differentiated” emission reduction, it would be equitable and reasonable if China proposed to differentiate the carbon price criteria between developed and developing countries. While striving for more favourable carbon border adjustment rules, it is necessary for China to accelerate the construction of a domestic carbon emissions trading system. By piloting carbon pricing reforms in carbon-intensive sectors, such as cement, chemicals, iron and steel, and aluminium sectors, the gap between the price of domestically traded carbon emission allowance and the CBAM certificate can be narrowed, thereby avoiding large flows of money into the EU in the form of border taxes.

4. Conclusion

This research provides a comprehensive analysis of the potential impact of the European Union’s Carbon Border Adjustment Mechanism (CBAM) on China’s exports of key industry sectors. By utilizing the IPCC carbon emission accounting methodology and non-competitive input-output analysis, the study accurately quantifies the embedded carbon in China’s nine carbon-intensive industries’ exports to the EU. The findings reveal that the CBAM will significantly increase the costs for Chinese exporters, undermining the competitiveness of their products in the European market. The carbon-intensive industries, such as metal smelting and rolling, non-metallic mineral products, and chemicals, will shoulder the greatest burden from the CBAM tariffs. These additional costs may erode the profit margins of the affected sectors, potentially leading to declined exports or even restructure of production. However, the research also recognizes the long-term benefits of the CBAM for China’s transition towards a low-carbon economy. The mechanism pushes Chinese companies to invest in clean production technologies and reduce their carbon emission. This alignment with China’s own climate goals of peaking emissions by 2030 and achieving carbon neutrality by 2060 could ultimately strengthen the country’s global competitiveness in the green economy. To mitigate the short-term challenges posed by the CBAM, the study suggests that China should explore policy options such as providing targeted industry support and negotiating with the EU on the scope and implementation of the CBAM. Strengthening climate cooperation and harmonizing carbon pricing mechanisms between China and the EU could help minimize trade frictions and pave the way for mutually beneficial climate governance. The limitation of this research is that only carbon dioxide emissions are calculated into the total carbon emissions and embedded carbon in trade. In future studies, the calculation of carbon emissions and embedded carbon can include more greenhouse gases than carbon dioxide, such as methane, nitrous oxide, and hydrofluorocarbons, which also contribute significantly to global warming.

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