Journal of Economics and Management Sciences; Vol. 8, No. 2; 2025
ISSN 2576-3008 E-ISSN 2576-3016
https://doi.org/10.30560/jems.v8n2p44

The Impact of the Carbon Border Adjustment Mechanism (CBAM) on China's New Energy Vehicle Exports to the European Union

Wang Ziyue[1]

[1] School of Management, University of Shanghai for Science and Technology, China

Correspondence: Wang Ziyue, School of Management, University of Shanghai for Science and Technology, Shanghai, China. Tel: 86-199-0640-1194. E-mail: 2209384198@qq.com

Received: February 26, 2025; Accepted: March 16, 2025; Published: March 18, 2025

Abstract

With the increasingly strong call for energy conservation and emission reduction on the international stage, countries and regions such as the United States, the European Union, and Japan have begun to prepare for legislation on the collection of carbon tariffs. To address climate change, the European Commission has also proposed a series of proposals. The CBAM will open up another important track for global efforts to combat climate change. The product categories initially included in the CBAM's collection scope have been revised several times during the legislative process and have finally been determined to be cement, electricity, fertilizers, steel, aluminum, and chemical products (hydrogen). The automotive industry, including new energy vehicles, power batteries, auto parts, automotive metal raw materials, and the hydrogen fuel cell vehicle industry chain, will all be affected. As a key component of new energy vehicles, the carbon emissions during the manufacturing stage of power batteries typically account for about 30% of the total emissions of new energy vehicles, which will bring new export challenges to China's automotive industry enterprises. This paper uses the input-output method to calculate the embodied carbon emissions of new energy vehicle exports based on the input-output table and export data of automotive products, providing data support for calculating the carbon tariff rate imposed on China's new energy vehicle products. Subsequently, this paper analyzes the impact of the CBAM on the export volume, market price, and social welfare of China's automotive products from both theoretical and empirical perspectives. Finally, in the face of the challenges posed by the EU carbon tariff to China's new energy vehicle industry, several forward-looking measures are proposed from two levels: the government and the automotive enterprises.

Keywords: Carbon Border Adjustment Mechanism, new energy vehicles, GTAP Model

1. Introduction

In March 2021, the European Parliament approved the "Carbon Border Adjustment Mechanism" bill, deciding to impose carbon tariffs on goods exported from countries that do not meet its carbon emission standards. The scope of taxation covers all trade products under its carbon trading system. To protect the competitiveness of domestic industries and prevent "carbon leakage", the EU and other developed countries will implement the "Carbon Border Adjustment Mechanism" on imported goods or services from developing countries, that is, impose "carbon tariffs". The EU CBAM bill, which was finalized in April 2023, covers products such as steel, aluminum, and hydrogen, which are important raw materials for the automotive industry. As the world's largest automotive market, China has made significant investments in the new energy vehicle sector and achieved remarkable results. With technological progress and policy support, China's exports of new energy vehicles are also growing, becoming an important force for economic development and transformation. The imposition of CBAM will bring new export challenges to China's automotive industry enterprises.

Previous scholars have formed a preliminary theoretical framework regarding the impact of the Carbon Border Adjustment Mechanism (CBAM) on international trade, mainly focusing on the policy effect transmission mechanism, carbon tariff calculation methods, and social welfare distribution. At the theoretical level, scholars generally analyze the role path of CBAM from the dual perspectives of "cost internalization" and "rule barriers", revealing its driving logic for the reconstruction of the global value chain (Peters et al., 2021; Zhong & Zhang, 2023). Some studies have quantified the implicit carbon emissions of new energy vehicle exports through input-output models, providing methodological support for the calculation of carbon tariff rates (Li et al., 2022), and verified the moderating effect of price elasticity on trade diversion effects (Wang & Chen, 2023). However, existing literature still has significant limitations: First, most studies are based on static equilibrium assumptions and do not fully incorporate the interaction mechanism between policy dynamic games and enterprise strategic responses, making it difficult to depict the long-term impact of EU carbon price fluctuations and the evolution of carbon markets in developing countries. Second, the treatment of regional carbon emission factor heterogeneity is rather crude, especially lacking differentiated accounting for China's western clean energy-rich regions and eastern high-carbon power grid regions. Third, existing results mostly focus on macro trade volume and price changes, with insufficient empirical research on the low-carbon technology adoption behavior of micro enterprises and supply chain resilience improvement strategies. Future research needs to further integrate dynamic general equilibrium models (DSGE) and heterogeneous firm theory (HFT) to explore the co-evolution path of carbon tariffs, technological innovation, and international rule negotiations, while strengthening the adaptability research of climate policy toolboxes in developing countries to break the industrial upgrading dilemma under "carbon rule hegemony".

As a core policy tool for the EU to achieve its climate goals, the Carbon Border Adjustment Mechanism (CBAM) is profoundly impacting the global new energy vehicle industry chain by reconstructing the carbon cost function of international trade. As the world's largest exporter of new energy vehicles, China's exports to the EU face three major challenges: the explicitization of carbon tariff costs, the complication of rule barriers, and the intensification of competition in the industrial chain. This study quantitatively analyzes the differentiated impacts of three carbon tariff rates (6.09%, 12.14%, and 18.22%) on China's new energy vehicle exports by coupling the input-output model with the GTAP model: Based on the input-output method, it calculates the full life cycle implicit carbon emissions and reveals the erosion effect of changes in export cost structure on price competitiveness; it uses the GTAP dynamic model to simulate the interactive responses of trade flows, price systems, and social welfare between China and the EU under the impact of carbon tariffs. The results show that the high tariff rate scenario will lead to a sharp decline in exports to the EU, trigger domestic market supply and demand imbalances and low-price competition in the international market, and cause equivalent variation losses for both China and the EU. To this end, it is suggested that the government establish a differentiated accounting system for regional power grid factors and promote negotiations on the connection of international carbon markets; enterprises need to accelerate the layout of overseas zero-carbon production capacity and breakthrough technologies such as solid-state batteries, and reshape the discourse power of the global green supply chain with "rule adaptability".

2. Method

This study employs the input-output method to calculate the embodied carbon emissions of new energy vehicle (NEV) product exports based on input-output tables and automotive product export data, providing empirical support for determining the carbon tariff rates imposed on China's NEV products under mechanisms such as the EU Carbon Border Adjustment Mechanism (CBAM).

2.1 Application of the Input-Output Model

Based on the national or regional input-output table (IO table), estimate the carbon emissions of new energy vehicles, and identify the sectors directly related to the industrial chain, including battery manufacturing (lithium and cobalt processing), metal smelting (steel and aluminum), power supply (distinguishing the energy structure such as coal-fired power and hydropower), and vehicle assembly, etc. Integrate the sector-level carbon emission coefficients (tons of CO_2 per 10,000 yuan of output value) from *China Energy Statistical Yearbook* and the life cycle assessment database (such as Ecoinvent). At the same time, use the multi-regional input-output model (MRIO) to distinguish the carbon footprints of intermediate goods at home and abroad, ensuring that the accounting covers the direct and indirect emissions throughout the entire life cycle. According to the input-output method, this model is further expanded to incorporate the relationships among economic activities, fuel usage, and carbon dioxide emissions. According to the basic assumptions of input-output analysis, assume that there is a linear relationship between the total output of a sector and the amount of fuel used in the production process. The embodied carbon emissions can be calculated using the following formula:

$$ICE_i = R_i * B * Export_i \tag{1}$$

Here, *R* represents the matrix of direct carbon emission intensity coefficients per unit value output, *B* is the total consumption coefficient matrix, which represents the coefficients for directly and indirectly driving the output of various sectors in the entire economy to meet the final demand. "Export" represents the export value of sector *i*. There are a total of 153 sectors in China's *Input-Output Table* (2020). In this paper, according to the formulas of the input-output analysis method, Excel is used to calculate the direct consumption coefficient *A* and the total consumption coefficient *B* of the 153 sectors.

According to the calculation formula: *R*=Direct Emissions (tons)/Output (in ten thousand U.S. dollars), the following values need to be calculated. First, calculate the direct carbon dioxide emissions. According to the publicly available data from the National Bureau of Statistics, the total energy consumption of the "automobile manufacturing industry" in 2021 was approximately 120 million tons of standard coal, and the proportion of relevant production links of new energy vehicles (power batteries, motors, and vehicle manufacturing) was approximately 15-20%. Based on this, the total energy consumption of the new energy vehicle manufacturing industry is estimated to be 10,000 tons of standard coal.

Thus, R=Direct Emissions (tons)/Output (in ten thousand U.S. dollars)=0.787407. According to the National Bureau of Statistics, knowing the total export value of new energy vehicle products in China in 2021, substituting B and R into the formula, we can obtain that the result is 2302.32 tons.

2.2 Calculation of the Proposed Carbon Tariff Rate

According to the rules of the European Union's Carbon Border Adjustment Mechanism (CBAM), the carbon tariff rate is the percentage that "the carbon price difference × the embodied carbon emissions" accounts for in the export price. Since the CBAM does not clearly define the carbon price, this paper will introduce three possible levels of carbon prices and calculate the tariffs that may be imposed at these three levels.The calculation formula is as follows:

Tariff Rate=Export Price(EU Carbon Price−CN Carbon Price)×Embodied Carbon Emissions×100%

Where:

- EU Carbon Price: The carbon price (in euros per ton of $CO2$) in the European Union Emissions Trading System (EU ETS).
- CN Carbon Price: The carbon price (in euros per ton of $CO2$) in China's national carbon market.
- Embodied Carbon Emissions: The carbon emissions throughout the whole life cycle of new energy vehicles (in tons of $CO2$).
- Export Price: The sales price of vehicles in the European Union market (in euros per vehicle).

The carbon tariff rate is the percentage that "the carbon price difference × the embodied carbon emissions" accounts for in the export price. As a result, three different tariff rate levels of 6.09%, 12.14%, and 18.22% are obtained.

Table 1. Prediction of the Proposed Carbon Tariff Rate to be Levied

Scenario	EU Carbon Price (€/t)	CN Carbon Price (€/t)	Carbon Price Difference (€/t)	Carbon Tariff (€)	Tariff Rate (%)
Low Tariff Rate	70	20	50	1,806	6.09%
Medium Tariff Rate	110	10	100	3,612	12.14%
High Tariff Rate	155	5	150	5,418	18.22%

2.2 GTAP Model Shock

2.2.1 Model Selection

The Global Trade Analysis Project (GTAP) model was developed from the Global Trade Analysis Project led by Professor Thomas Hertel at Purdue University in the United States. It is a global multi - sector Computable General Equilibrium (CGE) model designed on the basis of neoclassical economic theory. The data for the GTAP model comes from sources such as the World Bank, the UN Statistical Yearbook, the databases of the International Monetary Fund (IMF), and the Organization for Economic Co - operation and Development (OECD). This model has a well - developed basic data system and model framework. Its data indicators cover input - output tables, bilateral merchandise trade volumes, service trade, agricultural export subsidies, preferential tariff rates, and energy - related data.When simulating policy shocks within the GTAP model framework, countries or regions and various sectors under study can be initially classified. Based on this classification, the model can be used to explore the impacts of policies on variables such as imports and exports, commodity prices, terms of trade, gross domestic product (GDP), social welfare, and factor returns in different countries and sectors.

The GTAP - E model is an environmental - focused model built on the basis of the standard GTAP model by Bumiaux and Tmong in 2002. Here, the "E" stands for Energy - Environment. The GTAP - E model is largely consistent with the GTAP model in terms of theoretical assumptions and model architecture. First, sub - models are constructed to describe the production, consumption, and government expenditure behaviors of each country or region. Then, through international trade, these sub - models are combined to form a comprehensive multi - regional and multi - sector model.

Compared with the GTAP model, the main differences of the GTAP - E model are as follows: The GTAP - E model treats energy types as a new production factor. Energy is classified into five types: coal, oil, natural gas, refined petroleum products, and electricity. These are combined with the original five production factors in the GTAP model (land, capital, skilled labor, unskilled labor, and natural resources), and this combination is called the value - added - energy bundle. Meanwhile, in the construction of the GTAP - E model, a Constant Elasticity of Substitution Production Function (CES) is introduced and applied in the production stages of various energy products. Correspondingly, the model incorporates modules related to carbon trading, carbon taxes, and carbon emissions that reflect emission reduction policies, and differentiates between energy and non - energy products in the consumption process. The GTAP - E model mainly consists of a production module, a consumption module, a carbon emission module, and carbon tax variables. The main differences between it and the GTAP model lie in the production module and the carbon emission module.

2.2.2 Description of Data and Variables

1) Regional Classification

This paper uses the 11th version of the GTAP database for analysis. This version is the latest database supporting the GTAP model, with data updated to 2017. It covers relevant data of 160 countries and 65 production sectors. Before using this database, it is necessary to classify and set up countries, regions, and production sectors according to the research content.

Based on the current world economic and trade pattern, and considering that the EU's Carbon Border Adjustment Mechanism mainly affects energy-consuming countries such as developing countries and emerging markets, this thesis divides the world into three countries and regions: the 27 countries of the European Union (EU), China (CHN), and the Rest of the World (ROW) (see Table 6.1). Among them, the exempt regions of the EU's Carbon Border Adjustment Mechanism are the 27 EU countries and the EU ETS countries other than the 27 EU countries (Liechtenstein, Norway, Switzerland). The remaining countries and regions are all within the coverage of the EU's Carbon Border Adjustment Mechanism proposal this time.

The setting of countries or regions takes into comprehensive consideration information about the EU's major trading partners, the EU's Carbon Border Adjustment Mechanism, the European Emissions Trading System, the development direction of China's export industries, and relevant economic cooperation organizations. According to the data of countries and regions in the 11th version of the GTAP database, a total of 5 groups of countries (regions) and organizations are divided, namely China, the European Union (Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden), the United States, other EU - ETS participating countries (Switzerland, Norway, other countries of the European Free Trade Association), and other countries or regions in the world (countries and regions other than the above-listed countries and regions in the database.

2) Department Division

Secondly, in order to minimize the complexity of the model simulation, and drawing on the HS standards of the International Convention for the Harmonized Commodity Description and Coding System, the actual trade situation of countries, and the research situation of this paper, the original 6 sectors in GTAP 11.0 are re-integrated into 15 industries.

In the GTAP Version 11 database, the new energy vehicle industry is not separately subdivided. Considering that there is no essential difference between new energy vehicle products and traditional vehicle products in the production process, and the proportion of new energy vehicles and their components exported to the EU has exceeded 50% of the overall vehicle exports. When the academic community uses this model to analyze the new energy vehicle industry, the automotive industry is often used as a substitute. Therefore, this paper also adopts this method for substitution. In terms of production factors, the default classification in the database is used in the GTAP Version 11 database, namely land, capital, unskilled labor, skilled labor, and natural resources. At the same time, it is assumed that labor (including skilled and unskilled labor) and capital are mobile production factors in the short term, while land and natural resources are fixed production factors in the short term.

2.2.3 Data Upgrading

Ianchovichina (2012) pointed out in their research that the GTAP dynamic model exhibits path dependence. When using this model to conduct future projections, it is necessary to select variables that impact the economy (such as capital stock, wealth accumulation, and labor force growth) to shock the data. This path dependence necessitates a comprehensive consideration of the degree of change in the shock variables and the time span of recursion.The dynamic recursive method draws on the research of Ianchovichina and Walmsley (2012). They integrated macro - economic forecasts and anticipated policy changes with the dynamic GTAP model and presented a basic case scenario. In this scenario, several key indicators that are of particular concern in macro - forecasting are mainly taken into account when recursively updating the data.

Given that the base year of the GTAP11 database is 2017, in order to better reflect the real - world situation of the European carbon border adjustment, this paper raises the base year of the GTAP11 database to 2025. That is, the economic development in 2025 is assumed to be in a state without any policy changes. Then, a comparative analysis will be carried out on the changes in relevant variables caused by the EU's implementation of the carbon border adjustment tax starting from 2026.

Therefore, to better reflect the changes in the natural endowments and economic development of various countries from 2014 to 2025, this paper conducts a dynamic recursion on the data from 2017 to 2026 using indicators such as GDP, capital stock, population, skilled labor, and unskilled labor from the CEPII - BACI database of the French Institute of International Economics for macro - forecasting. Based on this, a simulation analysis of the trade shock of the EU's carbon border adjustment tax on China's new energy vehicle exports to the EU will be carried out.

2.2.4 Scenario and Plan Setting

According to the rules of the EU's Carbon Border Adjustment Mechanism (CBAM), the carbon tariff rate is the percentage of "carbon price difference × embodied carbon emissions" in the export price. Since the CBAM does not clearly define the carbon price, this paper will introduce three possible levels of carbon prices and calculate the tariffs that may be imposed at these three levels.

Next, the RunGTAP software will be used to simulate the impact of the carbon tax, and the specific change rates of various economic indicators of China's automobile products under the three scenarios will be obtained. The carbon tariff rate is the percentage of "carbon price difference × embodied carbon emissions" in the export price. As a result, three different tariff rate levels of 6.09%, 12.14%, and 18.22% are obtained.Based on relevant academic research, there may be the following three scenarios when the EU imposes carbon tariffs.

Scenario 1 (A1): According to the "Legislative Proposal for the Establishment of a Carbon Border Adjustment Mechanism" issued by the European Commission, the EU will impose a carbon border adjustment tax on cement, electricity, fertilizers, steel, and aluminum imported into the EU from all regions except the exempted countries starting from 2026. We assume that the EU imposes a carbon tariff on China's exports of new energy vehicles and their components. The corresponding industry in the GTAP 10.0 database is the complete vehicles and components of automobiles. If the carbon price difference is 50 euros per ton, according to the previous calculations, the tariff rate imposed under this condition is 6.09%.

Scenario 2 (A2): Assume that the carbon price difference between the EU and China is 100 euros per ton. According to the previous calculations, the tariff rate imposed under this condition is 12.14%. The equivalent value of the tariff to be imposed will be calculated. Except for the different tax amounts, other assumptions are exactly the same as those in Plan 1.

Scenario 3 (A3): Assume that the carbon price difference between the EU and China is 150 euros per ton. According to the previous calculations, the tariff rate imposed under this condition is 18.22%. The equivalent value of the tariff to be imposed will be calculated. Except for the different tax amounts, other assumptions are exactly the same as those in Plan 1.

Table 2. Shock Settings

Tax Rate Level	Carbon Price Difference (Euros per Ton)	Carbon Tariff Rate Imposed by the EU
Low Tax Rate	50	6.09%
Medium Tax Rate	100	12.14%
High Tax Rate	150	18.22%

*Note.*Based on relevant academic research, there may be the following three scenarios when the EU imposes carbon tariffs.

3. Results

It is assumed that all EU countries impose three levels of carbon tariffs, namely 6.09%, 12.14%, and 18.22%, on China and other countries. Analyze the impact of the imposition of carbon tariffs on China's new energy vehicle products from three dimensions: trade competitiveness, market price, and social welfare.

3.1 Impact on Total Export Value

Table 3. Changes in the Total Export Value of Main Countries and Regions under the Scenario of Carbon Tariff Implementation Unit: %

Tax Rate Level	EU	Other EU - ETS	USA	ROW	Total Export Value
Low Tax Rate	-8.20	-3.20	-2.98	2.5	-5.1
Medium Tax Rate	-16.7	-9.43	-7.43	4.8	-9.3
High Tax Rate	-27.5	-19.22	-16.58	7.3	-15.6

Note. Simulation Results of RunGTAP

Looking at the data of China's new energy vehicle products exported to the European Union, when the European Union forcibly imposes carbon tariffs on China, the export value of China's new energy vehicle products to foreign countries will be significantly reduced due to the tariff barriers. There is a positive correlation between the reduction range and the level of the imposed tax rate. As the carbon tariff rate rises from the low level to the high level, the decline rate of China's total export value to the European Union expands from -8.20% to -27.5%, and the export decline rate of other EU - ETS participating countries (such as Norway and Iceland) increases from -3.20% to -19.22%. The main reason is that carbon tariffs directly raise the export costs of China's high-carbon products (such as steel and aluminum materials), weaken price competitiveness, and lead to the transfer of the EU's import demand to domestic or low-carbon suppliers. Although the United States has not implemented a policy similar to the CBAM, China's exports to the United States are still affected incidentally. This may reflect the carbon cost transmission effect of the global supply chain, or it is assumed that the environmental compliance requirements of American importers for Chinese products have increased.

There is a structural growth in exports to non-carbon tariff markets. Under the pressure of carbon tariffs, China's exports are transferred to countries that have not implemented similar policies, and the export value has increased against the trend. For example, regions such as Southeast Asia and Africa may undertake part of the production capacity due to their low-cost advantages, or China may tap into emerging demands through market diversification strategies. The total export value as a whole shrinks. The intensification of the policy strength non-linearly expands the decline rate of the total export value, from -5.1% at the low tax rate level to -15.6% at the high tax rate level, indicating that the losses in high-value markets such as the European Union cannot be fully offset by the growth in other regions. The marginal effect increases: the marginal impact of the high tax rate on exports to the European Union is greater than that on other regions, suggesting that the EU market has a higher degree of dependence on China's high-carbon supply chain and is more sensitive to policies.

Since the export volume of China's new energy vehicle products accounts for a relatively small proportion of the entire industry's output, under the condition of high tariffs, Chinese new energy vehicle manufacturers are not inclined to spend a large amount of costs to maintain a foreign market that cannot maximize their profits. Therefore, in this situation, the exports of automotive products to various countries will decline.

3.2 Impact on the Price of New Energy Vehicles

Table 4. Change Rates of the Market Prices of New Energy Vehicles in Main Countries and Regions under the Scenario of Carbon Tariff Implementation Unit: %

Tax Rate Level	CHN	EU	Other EU - ETS	USA	ROW
Low Tax Rate	-1.5	4.8	2.4	1.22	-2.2
Medium Tax Rate	-2.3	9.5	4.9	3.10	-3.7
High Tax Rate	-3.8	15.2	9.2	6.24	-5.4

Note. Simulation Results of RunGTAP

From Table 4, we can observe the changes in the market prices of new energy vehicle products between China and the EU under three types of simulation scenarios. According to the data comparison, the simulation results of this paper are consistent with the conclusions of the above theoretical analysis section: Under these three scenarios, affected by both the increase in product costs and the decrease in production volume, the production volume of domestic new energy vehicle products is bound to decline. However, due to the collection of carbon tariffs, assuming that the demand remains unchanged, the export demand will be replaced by the demand of domestic consumers, resulting in a situation of in short supply

The supply of new energy vehicle products in the domestic market will increase significantly in a short period. If the demand remains unchanged, the equilibrium price of automotive products in the Chinese domestic market will decrease. The simulation results show that the prices of automotive products in the Chinese domestic market will decrease by 1.5% - 3.8%. With the study of the potential impact of carbon tariffs on China's automotive product exports, the tariff rate will gradually increase. But as an importing country, the EU will see a decrease in the supply of imported automotive products due to the imposition of carbon tariffs, and then the prices of similar products will also rise. According to the simulation results, the maximum increase rate in the EU is 15.2%. And with the gradual intensification of the contradiction between supply and demand, the price increase rates of automotive products in these countries and regions are also gradually increasing.

After the implementation of the carbon tariff (CBAM), the market prices of new energy vehicles in different countries and regions show significant differentiation, with the following specific patterns:

1)The price in the Chinese market continues to decline: The price in the Chinese market decreases by -1.5% under the low tax rate, the decline expands to -2.3% under the medium tax rate, and further drops to -3.8% under the high tax rate. The carbon tariff has raised the export costs, causing enterprises to shift more production capacity to the domestic market. The imbalance between supply and demand triggers price competition. At the same time, some enterprises may take the initiative to reduce prices to maintain the capacity utilization rate and avoid inventory backlogs caused by blocked exports.

2)The prices in the EU and other EU - ETS participating countries rise significantly: When the carbon tariff rate in the EU market rises from the low level to the high level, the price increase rate soars from 4.8% to 15.2%. The main reason is that the prices of imported new energy vehicles increase due to the increase in carbon costs, and local enterprises take the opportunity to raise prices to make up for the costs of low-carbon transformation. In other EU - ETS participating countries (such as Norway), the prices rise synchronously, reflecting the policy linkage with the EU market and a high degree of dependence on imported products.

3)The prices in the United States and other countries show differentiation: Affected by the carbon cost transmission in the global supply chain, the prices still rise moderately, which may be due to the increase in the import costs of some raw materials or the active adjustment of pricing strategies by enterprises. For other countries/regions (ROW), the prices continue to decline (from -2.2% under the low tax rate to -5.4% under the high tax rate). The main reason is that the transfer of China's exports leads to oversupply in these regions, or local enterprises compete for the market by lowering prices.

From the perspective of the nonlinear relationship between the policy intensity and price fluctuations, the marginal effect in the EU market is significant: The price increase rate in the EU under the high tax rate (15.2%) is nearly three times that under the low tax rate, indicating that the policy intensity has an accelerating effect on price transmission, which may trigger consumers' resistance to high-priced green products and suppress demand in the long term. The domestic demand market in China is under pressure: The price decline expands as the tax rate increases. However, if the domestic demand growth is insufficient, it may lead to a contraction of industry profits and increase the risk of overcapacity. The global market pattern is being reconstructed, and the EU has become a high-price market: The carbon tariff has pushed up the import costs, which may accelerate the technological substitution and capacity expansion of the EU's domestic new energy vehicle industry (such as German and French car companies).

China faces challenges in export diversification: Although the price decline in other countries (ROW) provides alternative markets for China's exports, these regions have weak purchasing power and low added value, making it difficult to compensate for the losses in high-value markets such as the EU.

The increase in the prices of domestic automotive products in the EU will generate a certain amount of excess profits, and car manufacturers will increase the supply of automotive products, which will enable manufacturers without price advantages to re-enter the market. Due to the return of funds, the supply of products in the corresponding domestic production will increase slightly. Taking the EU as an example, the cost of the carbon tariff imposed by the EU on China will be transferred to consumers in various forms. Therefore, the export price of automotive products will inevitably increase. Compared with the prices of domestic cars in the United States, domestic cars in the EU do not have a competitive advantage. Therefore, although the EU protects its domestic market in the short term, the trade balance between China and the EU will be broken, which is bound to lead to the occurrence of some trade frictions.

3.3 Impact on Social Welfare

In the short term, the imposition of the CBAM may reduce China's social welfare by increasing the export costs of China's high-carbon products, squeezing corporate profits and employment opportunities. At the same time, industries within the EU can enhance their competitiveness and achieve environmental benefits due to the reduction of carbon leakage. However, in the long run, if China accelerates its low-carbon transformation and the EU bears the dual pressures of rising import prices and intensified trade frictions, both sides may gradually move towards a welfare rebalancing of "environmental improvement and technological upgrading", but it is necessary to balance the short-term conflict between emission reduction costs and economic growth.

Table 5. Change Rates of the Market Prices of New Energy Vehicles in Main Countries and Regions under the Scenario of Carbon Tariff Implementation Unit: %

Macroeconomic Variables	Research Region	Low Tax Rate	Medium Tax Rate	High Tax Rate
GDP	CHN	-0.08	-0.15	-0.27
	EU	0.05	0.11	0.20
	Other EU - ETS	0.02	0.05	0.13
	USA	0.01	0.02	0.04
	ROW	-0.01	-0.01	-0.02
Social Welfare	CHN	-0.18	-0.35	-0.62
	EU	0.12	0.25	0.43
	Other EU - ETS	0.04	0.12	0.25
	USA	0.02	0.03	0.05
	ROW	-0.02	-0.04	-0.07

Note. Simulation Results of RunGTAP

From Table 5, we can observe the changes in the social welfare levels of China and other countries and regions after the imposition of carbon tariffs under the three established scenarios. China's gross national product will be affected by the imposition of carbon tariffs, and it may even lead to negative results. When the carbon tariff is at the low tax rate, China's GDP will decline by 0.08%. When the carbon tariff rate is at the medium tax rate, China's GDP will decline by 0.15%. Based on considerations of social welfare, also under these three scenarios, there is an obvious negative correlation between China's social welfare level and the implementation of carbon tariffs. The degree of decline in China's welfare is within the range of 0.12% to 0.43%. On the contrary, as the economy that formulates carbon tariffs, the EU shows an obvious positive correlation between its social welfare and the increase in the carbon tariff rate. Therefore, some developed countries are always the beneficiaries of the implementation of carbon tariffs, and the increase range of their social welfare varies from 0.12% to 0.43%.

China's economy and social welfare are under double pressure. The decline in GDP expands step by step: When the carbon tariff rate rises from the low level to the high level, China's GDP loss expands from -0.08% to -0.27%, indicating that the impact of rising export costs on the high-carbon-intensive supply chain (such as the production of upstream raw materials for new energy vehicles) intensifies, combined with the effect of the transfer of EU market demand. Social welfare declines rapidly, and the decline in social welfare increases from -0.18% (low tax rate) to -0.62% (high tax rate), reflecting the combined effect of the decline in corporate profits, the loss of jobs, and the reduction of government tax revenue caused by the shrinkage of exports.

For the EU: Significant short-term benefits, but long-term risks loom. GDP and welfare grow simultaneously: The EU's GDP grows by 0.05% and social welfare increases by 0.12% under the low tax rate; they increase to 0.20% and 0.43% respectively under the high tax rate. The core reason is that carbon tariffs reduce "carbon leakage", protect the competitiveness of domestic industries, and at the same time, the revenue from carbon tariffs supplements public finances. If the tax rate is too high, it may push up the production costs of EU domestic enterprises (such as industries that rely on imported low-carbon components), and in the long term, it may trigger inflationary pressures and trade frictions, offsetting some of the short-term benefits.

Other EU - ETS participating countries are marginal beneficiaries following the EU. GDP and social welfare grow moderately. The GDP grows by 0.02% and social welfare increases by 0.04% under the low tax rate; they increase to 0.13% and 0.25% respectively under the high tax rate. Their benefits come from policy coordination with the EU (such as Norway's participation in the CBAM through the European Economic Area Agreement), but the increase is small, reflecting the limitations of market size and the right to speak in the industrial chain.

The United States is slightly positively affected. GDP and social welfare increase slightly. The GDP grows by 0.01% and social welfare increases by 0.02% under the low tax rate, and they increase to 0.04% and 0.05% respectively under the high tax rate. The possible reasons include that US enterprises gain some market share due to the increase in China's export costs, and the carbon cost transmission in the global supply chain promotes the investment in domestic low-carbon technologies in the United States.

Other countries/regions are "victims" passively involved. Both GDP and social welfare decline. The GDP decreases by -0.01% and social welfare decreases by -0.02% under the low tax rate; they expand to -0.02% and -0.07% respectively under the high tax rate. The main reason is that China's exports shift to these markets, leading to oversupply and price competition, depressing corporate profits and residents' consumption capacity.

The asymmetry of carbon cost transmission: Carbon tariffs are transferred layer by layer through the supply chain, putting cost pressure on high-carbon producing countries, while generating a double dividend of "domestic protection + tax revenue gain" for the policy-making country (the EU). The damage of the high tax rate to China shows an accelerating trend, while the growth rate of benefits for the EU slows down, indicating that a unilateral high tax rate may trigger trade countermeasures and weaken the sustainability of the policy. The shift of China's exports to non-carbon tariff markets may trigger low-price competition and overcapacity in emerging markets, exacerbating global trade imbalances.

In conclusion, the research results of this paper show that China's social welfare level will decrease with the implementation of carbon tariffs by countries such as the EU. At the same time, this also presents an unfair situation. There is not always an equilibrium state among the countries imposing carbon tariffs, and this unbalanced situation needs to be jointly determined by other factors, such as changes in consumer welfare, production welfare, and government revenue. Therefore, the emergence of carbon tariffs as a form of green trade barrier does not conform to the principle of free trade popular in the international community. Especially when the standards for formulating tariffs cannot be defined fairly and effectively, it will undoubtedly cause economic fluctuations in some countries and even the whole world, damage the interests of other countries, and aggravate the unbalanced development situation among countries.

4. Discussion

4.1 Increased Costs of Entering the EU Market and Decreased Export Volume

The taxation under the CBAM directly increases the costs for Chinese new energy vehicles to enter the EU market. During the production process of Chinese new energy vehicles, especially in the battery manufacturing stage, the carbon emissions are relatively high. Therefore, the CBAM will impose higher carbon taxes on these vehicles. Take new energy vehicles like Tesla and BYD manufactured in China as examples. These vehicles involve a large amount of battery manufacturing during the production process, and this process often relies on fossil fuels, resulting in higher carbon emissions. Thus, the imposition of the CBAM will significantly increase the prices of these vehicles when they enter the EU market, which will directly affect their market competitiveness.

Taking battery manufacturing as an example, the production of lithium-ion batteries is a highly energy-consuming and carbon emission-intensive process. In particular, the extraction and processing of materials involve a large amount of electricity and chemical treatment, and most of this electricity comes from high-carbon emission energy sources such as coal. Therefore, the implementation of the CBAM will directly increase the production costs and the final selling prices of electric vehicles, thus having a negative impact on the competitiveness of Chinese electric vehicles.

The impact of the CBAM is not only reflected in the costs of exporting complete vehicles but also spreads to the entire industrial chain. The production of new energy vehicles involves multiple links such as batteries and components, and the carbon emissions in these links will all affect the carbon footprint of the final product. Upstream enterprises in the Chinese new energy vehicle industrial chain, such as battery manufacturers, will face huge pressure to reduce emissions. Because upstream products with high carbon emissions will directly increase the carbon footprint of the complete vehicle, leading to an increase in the tax burden under the CBAM. In order to reduce the costs of the CBAM, new energy vehicle manufacturers need to encourage upstream and downstream enterprises to achieve low-carbon production, which further increases the pressure and transformation costs of the entire industrial chain.

Therefore, the negative impacts of the Carbon Border Adjustment Mechanism on the export of Chinese new energy vehicles to the EU are mainly reflected in aspects such as increased costs, weakened price competitiveness, changed consumer preferences, increased compliance pressure, and greater emission reduction requirements for the industrial chain. These factors, acting together, may significantly affect the market share and export revenue of Chinese new energy vehicles in the short term.

4.2 Weakened Price Competitiveness of Chinese New Energy Vehicles in the EU Market

The competitiveness of Chinese new energy vehicles in the EU market is mainly reflected in their relatively low prices. However, the implementation of the CBAM will lead to an increase in the selling prices of these vehicles in the EU market, thus weakening their price advantage over local brands. For example, European local brands such as Volkswagen and Renault, due to their production facilities in the EU being bound by the EU Emissions Trading System (EU ETS), have lower carbon emissions and thus will not face the same carbon border adjustment tax burden. In this situation, Chinese new energy vehicles may lose their price competitiveness due to the increased costs.

Data shows that in 2023, Chinese new energy vehicles accounted for about 20% of the EU's electric vehicle market share. Based on this market share, the EU launched an anti-subsidy investigation into Chinese electric vehicles, believing that the low prices of Chinese electric vehicles are supported by government subsidies, which also reflects the importance of price competitiveness for Chinese electric vehicles. The additional carbon tax costs brought by the CBAM may further increase this challenge and make it more difficult to enter the market.

4.3 Weakened Price Competitiveness of Chinese New Energy Vehicles in the EU Market

The CBAM has strict requirements for the accounting of carbon emissions. Exporting enterprises are required to provide detailed carbon emission data of the production process and meet the EU's accounting standards. For many Chinese new energy vehicle manufacturers, how to comprehensively and accurately track the carbon emission data throughout the production process is a challenge. If enterprises cannot meet these compliance requirements, it may lead to their products being unable to enter the EU market smoothly.

In addition, the complexity of compliance also increases the operating costs of enterprises. For example, Chinese enterprises must establish a complete carbon footprint tracking and reporting system to ensure data transparency in the production and export links, which undoubtedly increases the burden on enterprises that have not fully adapted to international carbon emission standards. Especially for small and medium-sized new energy vehicle enterprises, they may find it difficult to bear these compliance costs, thereby affecting their willingness and ability to enter the EU market.

The impact of the CBAM is not only reflected in the costs of exporting complete vehicles but also spreads to the entire industrial chain. The production of new energy vehicles involves multiple links such as batteries and components, and the carbon emissions in these links will all affect the carbon footprint of the final product. Upstream enterprises in the Chinese new energy vehicle industrial chain, such as battery manufacturers, will face huge pressure to reduce emissions. Because upstream products with high carbon emissions will directly increase the carbon footprint of the complete vehicle, leading to an increase in the tax burden under the CBAM. In order to reduce the costs of the CBAM, new energy vehicle manufacturers need to encourage upstream and downstream enterprises to achieve low-carbon production, which further increases the pressure and transformation costs of the entire industrial chain.

Acknowledgments

Once bathed in the kindness of teachers, one always cherishes and remembers their grace. I would like to express my sincere gratitude to my supervisor, Professor Liu Shengti, for his guidance and assistance in my graduation thesis. His help has been of great significance in enabling me to complete my thesis. I am also grateful to all the teachers for their tolerance and patience. They answered my questions and helped me to finish my graduation thesis. May my beloved teachers be blessed with numerous outstanding students and their teachings have a long - lasting influence.

Even if a tree grows a thousand feet high, it never forgets the fertile soil that nourishes its roots. I am deeply thankful to my parents and family. In our lives, we meet countless people, yet only our parents have been with us since birth while constantly facing the prospect of separation. I want to thank my parents for their love and support over the past twenty - odd years. They have warmed my life with their constant care and words. May they enjoy peace and happiness year after year.

No matter how many words I use, I still feel that they cannot fully convey my feelings. I am grateful for all the encounters during my postgraduate years. I believe that everything is the best arrangement. Although my university days are coming to an end, our real lives are just beginning.

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