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RESEARCH ARTICLE

Impact of the European Union's Carbon Border Adjustment Mechanism: Evidence from India and Other Selected Trading Partners of EU

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Abstract: The European Union (EU) recently introduced the Carbon Border Adjustment Mechanism (CBAM) with the intention to impose a pricing mechanism on carbon emissions, originating during the production process of emission-intensive products, imported by EU from its non-EU trading partners. However, CBAM is facing a lot of criticism – as an unfair, protectionist measure that threatens the principles of multilateral trading system and has a disproportionately biased impact on the overall welfare of the low-income developing countries. In this context, the paper empirically examines the impact of the EU CBAM on its trading partners by using the CGE GTAP-E model. The impact has been assessed across three pathways – export sales of the trading partners, the emission intensity of the products, and the overall impact on the welfare of the EU's trading partners using the GTAP-11 database. The impact varies across countries and sectors. The model estimates indicate that due to the imposition of CBAM, countries with existing domestic carbon pricing mechanism experience marginal increase in welfare with the UK being an exception. Contrastingly, countries with no carbon pricing mechanism will experience a decrease in overall welfare. Countries with a higher share of the EU in their total export basket are affected in terms of their export sales. India's cement sector export is affected the most due to the imposition of CBAM. However, India's total amount of exports of cement to the EU's market is negligible. India's export of iron and steel to the EU constitutes a larger share but the impact of CBAM is found to be negligible on the same.

Keywords: Carbon Border Adjustment Mechanism, computable general equilibrium modeling, Global Trade Analysis Project Energy-Environment models, India

1. Introduction

While global alliance is gaining momentum in achieving the target of carbon neutrality across nations by 2050 in accordance with the Paris Agreement, European Union's (EU) unilateral climate regulation[1], Carbon Border Adjustment Mechanism (CBAM), is highly contentious. While aiming to reduce carbon leakage and simultaneously ensure competitiveness, evaluating the welfare implications of CBAM across economies is critical [1]. As the implementation phase of CBAM will begin in October 2026, international policymakers, academicians, and business houses are struggling to apprehend the quantitative impact of CBAM on their respective domestic economy and the overall trade pattern across the globe. The present paper contributes to the literature firstly, estimating quantitatively the impact of CBAM by using an expanded version of the computable general equilibrium (CGE) Global Trade Analysis Project Energy-Environment (GTAP-E) models disaggregated at the sectoral level. Secondly, the paper provides a comprehensive picture by examining the impact of CBAM across the EU's major trading partners including both developed and developing countries. Thirdly, in the Indian context, this is the first paper to analyze the impact of CBAM at the sectoral level using CGE GTAP-E models. Unlike previous studies, the present paper used the GTAP-11 database and examined the impact of CBAM on the overall welfare, emission intensity, and export sales to the EU's market by the partner countries.

The CBAM is an essential part of the "Fit for 55 Package" – the EU's climate action plans to achieve the target of reducing 55% of the greenhouse gas (GHG) emissions by 2030 and net zero emissions by 2050. EU advocated the initiation of this unilateral legally binding climate regulation on the grounds of – firstly, reducing the global "carbon leakage" and secondly inducing its trading partners to adopt green technology in their production process. The carbon leakage will be addressed through a level playing field EU's domestic price of products (inclusive of the carbon prices) across the five emission-intensive industries – iron and steel, aluminium, cement, fertilizer, electricity, and hydrogen generation vis-à-vis the price (inclusive of the carbon prices, if any) of the imported variety of products belonging to these industries. Later, the coverage of CBAM will be expanded encompassing almost 50% of all the industries under the EU's Emission Trading System

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2023.130.01.0052.01.ENG&toc=OJ%3AL%3A2023%3A130%3ATOC

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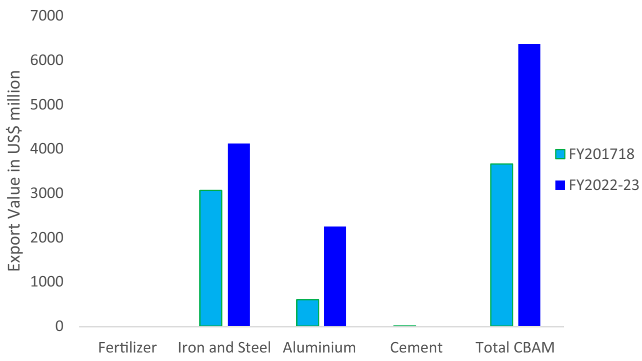
(ETS). The present documentation of the CBAM also declares a rebate to countries with the existing domestic carbon pricing mechanism (i.e., difference between the partner country's domestic carbon price and the EU's existing carbon price). Further, it will induce preferential treatment among the trading partners of the EU, giving an advantage to countries with an existing indigenous carbon pricing mechanism. This further threatens the Most Favored Nations (MFN) principle of the World Trade Organization (WTO), the basic tenet of international trade. Many developing and least-developed countries (LDCs) already lack in resources and technical skills to accentuate their transition towards a low-carbon pathway. The ambiguity in its implementation design and vexed legal framework has stirred up opposing voices across the world. According to the multidimensional CBAM opposition index[2], countries like Iran, Ukraine, the USA, the United Arab Emirates, Egypt, China, India, Kazakhstan, Russia, and Belarus are some of the major economies most likely to express their disagreement with EU's CBAM [2].

While assessing the quantitative impact of CBAM, the existing studies in the literature have used multi-regional input-output models [3, 4], multi-sector, multi-regional CGE model (MIRAGE models) [5, 6], CGE GTAP-E [7, 8], recursive dynamic GTAP models [9], and general equilibrium models of International-National Interactions between Economy, Energy, Environment (GEMINI-E3) models [10, 11]. These studies have concluded that CBAM may not be an effective policy in reducing the overall GHG emission at the global level. However, it can alter the industrial competitiveness, especially of the emission-intensive trade-exposed industries leading to the loss in export of developing and emerging economies to the EU's market. This is coupled with a trickle-down effect – the domestic output and employment of emission-intensive trade-exposed industries in the respective countries may suffer a loss. It has been observed in the context of the general equilibrium modeling framework, that unilateral climate policies reduce the output and export of emission-intensive-trade-exposed sectors [12]. However, they concluded that the margin of loss depends on the assumptions of the model. While developing and emerging economies are affected the most due to the CBAM, European countries like Germany, France, and Italy can increase their sales in the EU's market leading to the rise in within-EU trade [4]. In this context, the present study examines the impact of CBAM on the export, emission intensity, and overall welfare of the EU's major trading partners including India.

India's overall merchandise export to EU countries has grown by 70% over the last six years, i.e., between the year 2017–18 and 2022–23. In FY 2022-23, EU countries constitute 16% of India's total merchandise export [13]. The emission-intensive products covered under the present framework of CBAM and traded by India include cement (HS code 2523), fertilizers (HS code 3102), iron and steel (HS code 72) and aluminium (HS code 76). India's total export of these products amounts to US$ 22 billion in the year FY2022–23 in contrast to US$16 billion in the FY 2017–18. EU constitutes 28% of the total export of CBAM goods from India in the year FY2022–23. The overall export of CBAM products from India to the EU has increased by 74% between FY2017–18 and FY2022–23. Further decomposition indicates that the share of the EU in India's export of cement and fertilizer is negligible. However, India's export of iron and steel and aluminium to the EU's market amounts to US$ 4 billion and US$ 2 billion respectively in the year FY2022–23[3]. The exports of aluminium and articles of aluminium have experienced a dramatic growth of 24% over the last six years from FY2017–18 to FY2022–23. From the preliminary data analysis, it is evident that ferrous and non-ferrous metal export from India has a high dependence on the EU's market demand. In this context, it is pertinent to analyze the impact of CBAM on India's export to the EU market. Figure 1 [13] below illustrates India's trade in CBAM goods to the EU market.

Figure 1
India's export of CBAM goods to the European Union (EU) market for FY 2017–18 vs. FY 2022–23



Modeling CBAM entails the study of energy-economy-environment-trade linkages among the CBAM countries. The present paper has considered this linkage while estimating the impact of CBAM by using the GTAP-E model. GTAP-E incorporates carbon emissions from the combustion of fossil fuels generated during the production of a commodity, which is later traded across countries. The paper estimated the impact of the imposition of CBAM (*ex-ante*) on the major EU's trading partners in terms of exports, emissions, and welfare changes. The impact of the EU's CBAM on exports will be higher for countries with a higher share of exports to the EU, before the imposition of CBAM. The impact on emission intensity is negligible, particularly in the case of India, our result indicates that India's cement export to the EU will be hard hit due to CBAM; however, presently India's export value of cement is lower compared to other trading partners of the EU.

The rest of the paper has been organized. Section 2 presents a brief review of existing studies elucidating the impact of the carbon border adjustment regulations on international trade and the overall impact on the domestic economy of the EU and its trading partners. Section 3 illustrates some of the stylized facts – export of CBAM goods by different countries to the EU's market and carbon pricing heterogeneity across selected partners of the EU. Section 4 describes the methodology used in the study. Section 5 assesses the impact of CBAM on the export, overall welfare, and emission intensity of the EU's trading partners across the iron and steel, aluminum, cement, and fertilizer industries. Section 6 concludes the study.

2. Existing Studies

The international trade policies and climate policies are intertwined [14]. Nationally determined climate policies like

[2]The index encompasses five unique dimensions of cause of contest: a) trade, b) carbon intensity, c) previous records of non-compliance with WTO rules, d) public awareness about climate change, and e) capacity to innovate new technologies (green technologies).

[3]As accessed on 18.8.2023; Ministry of Commerce and Industry, Trade Statistics (Annual) https://tradestat.commerce.gov.in/eidb/ergncom.asp

energy subsidies/taxes, production/consumption side subsidies/taxes, and product standards need to be designed in sync with the international trading principles laid out by WTO. It has been observed that some of the existing multilateral trading rules for example MFN rules act as hindrances to multilateral coordination of climate policies. Environmentally sensitive trading system rules need to be formulated to enhance the coherence between trade and climate policies [15]. Policymakers across the globe find it hard to formulate policies encompassing the twin objectives of reducing carbon leakage and simultaneously ensuring international competitiveness [16]. Unilateral climate policies to reduce global carbon dioxide emissions, like border adjustment tax, sectoral exemption from carbon regulations, and emission permits based on the output of the industries, are found to be inefficient and inequitable in meeting the actual targets [17–20]. In a multi-sector multi-regional general equilibrium framework, it has been observed that among all the other unilateral climate policies, border carbon adjustment mechanisms can effectively reduce carbon leakage but it can increase regional inequality through the terms-of-trade effect causing the deterioration of the overall welfare of the countries across the world. The sensitivity analysis of the border carbon adjustment tax rate, using the GTAP7-based model, indicates that the emission reduction effect of the border carbon adjustment tax declines marginally with the higher rates [17]. Moreover, it can also cause fragmentation of the world into a coalition of countries with ambitious climate goals vs. non-coalition countries, majorly engaged in the export of emission-intensive products [6]. It has been argued that the coalition countries also strategically use high border carbon adjustment tax rates to distort international competitiveness rather than aiming at the reduction of global emissions [17]. Contrastingly, Lépissier and Mildenberger [21] have empirically shown in the context of the UK that unilateral climate policy (combination of the carbon tax and ETS) can reduce carbon emission even in the absence of a globally binding climate treaty. The empirical evidence is mixed in the existing literature and entails a deeper examination of the effectiveness of unilateral climate policies.

Some studies have suggested that border carbon adjustment policy should be accompanied by a compensatory fund transfer aimed at financing the adoption of green technologies, especially in low-income countries. This can incentivize low-income countries to join the climate coalition [17, 22]. Some alternative measures to unilateral climate policies have been also suggested by Galiffa and Bercero [22] like firstly, agreement on common decarbonization targets and giving individual countries the independence to decide the pathway to achieve it, secondly, a universal consensus on the product coverage and setting up common methods for calculating the embedded emission in the manufactured products, thirdly, enhancing the role of multilateral institutions to facilitate the implementation of climate policies and examining its compatibility with the WTO framework.

An emerging strand of literature has been assessing the impact of CBAM on EU's trading partners both developed as well as emerging and developing countries [3–5, 7, 10, 11, 23]. Given the present implementation framework, the magnitude of impact on the EU's trading partners will depend *firstly* on the share of EU in the exporting country's total value and volume of export[4] to the EU and *secondly* on emissions embedded in the exported product from partner countries to EU. Accordingly, the revenue generated from CBAM will be directly proportional to the emission content and the volume/value of export. The amount of revenue generated from CBAM will also vary across countries depending on the price elasticities of substitution and technical substitution of export among countries [3].

Using the multi-regional input-output table and trade data [3] estimated that maximum CBAM revenue[5] will be generated from countries like Russia, China, and Ukraine as their volume of exports to the EU is higher than the other countries. However, some of the developing countries like East European economies (Balkan region), Mozambique, Zimbabwe, and Cameroon in Africa are found to be the most vulnerable as their export dependence on the EU is higher than 2%. Further, CBAM has been observed to have an impact on the domestic output and employment of the trade-exposed emission-intensive industries across the EU's trading partners. It is estimated that output reduction in the exposed industries owing to the imposition of CBAM will lead to a risk of a wage cut by 0.5% accompanied by a 2% job loss in Moldova and Mozambique and a 1% job loss in Ukraine. The non-metallic mineral industries in China accounted for an export loss of $ US5,255 million to the EU accompanied by a 0.46% drop in the industrial output in the year 2012 [4].

Other countries like Turkey, India, and Indonesia suffer an export loss amounting to $US 2,437 million (drop by 6.30% of the sectoral output), $US771M (output declines by 0.72%), and $US402M (output declines by 0.80%), respectively. Similarly, in case of the chemical sectors, China will suffer the most in terms of its export to EU followed by other countries like US, Russia, and India. For the basic metal manufacturing industries, Russia's export to EU will be hard hit followed by a moderate decline in the export of China and Brazil to EU. In contrast to this, the estimates indicate that countries like Germany, Italy, and France will increase their sales in EU's market. Intra-EU trade across these industries will increase coupled with a decline in the amount of export from developing countries to EU's market [4]. Sectors with higher price elasticity and lower exposure to trade like power/energy generation sector are moderately affected by CBAM.

Kuik and Hofkes [5] using the GTAP-E model estimated that the imposition of CBAM can reduce carbon leakage in the iron and steel industry but the reduction in non-metallic mineral products manufacturing industries will be lower. They concluded that CBAM may not be effective in reducing the overall GHG emission at the global level. However, it can act as a signal for the countries to initiate the carbon pricing mechanism in their domestic economies; thereby moving towards low-carbon pathway. Chepeliev [7] by using a GTAP-E modeling technique observed that iron and steel and chemical industries are the two most affected sectors due to the imposition of CBAM. While analyzing cross-country impact, they observed that Ukraine' per capita income will drop by 0.4% due to CBAM, highest among all other trading partners of EU. The export of iron and steel industry from Ukraine and India will decline by 5.1% and 5.9% respectively. Moreover, countries like Russia and China will suffer in terms of their chemical export to EU by 4.3% and 1.3% respectively. The overall impact of CBAM on the global fossil fuel price will be lower. They concluded that the impact of CBAM at the global level is negligible.

The simulation results of GEMINI-E3 indicates that CBAM can only reduce carbon leakage by 1/3^{rd,} i.e., from 17 to 12.6% by 2040 [10]. However, this will be accompanied by a significant welfare loss across countries especially the LDCs which will be impacted the

[4]The exporters to EU across the five industries need to declare the emission content of their goods and this will be further verified through third-party auditing.

[5]Under the assumption that export from these countries is price inelastic i.e. imposition of CBAM will not affect the volume of export from these countries.

most. They discussed several complementary measures along with CBAM to limit the welfare loss in LDCs – for example lump sum transfer of fund – as a subsidy to finance the energy transition especially across emission-intensive sectors.

Clora et al. [23] use the GTAP power 10 database to analyze the quantitative impact of EU's CBAM on regional GHG emission, output, and trade flows. The results from the recursive dynamic CGE models indicate that the implementation of CBAM will lead to carbon leakage in the rest of the world if not supported by other precautionary measures and reduce the output of the emission-intensive trade-exposed sectors of EU. However, under the aggressive scenario, it has been observed that the carbon leakage may decrease but it can lead to initiation of retaliatory measures by the international partners. The study has also considered the scenario where all the countries have highly ambitious climate policy like EU; then, the global emission reduction achieved through CBAM is the highest.

3. Stylized Facts

3.1. EU's import of CBAM products

The present paper has used the export information of EU's major trade partners – India, Algeria, Brazil, Canada, China, Egypt, Indonesia, Japan, South Korea, Mozambique, Oman, South Africa, Tunisia, Turkey, Ukraine, Vietnam, United States of America (USA), United Kingdom (UK), Saudi Arabia and United Arab Emirates (UAE) from the World Bank WITS database for the year 2017. These countries are the EU's major trading partners accounting for 19% of the total share of the EU's import of CBAM goods. It has been observed that within-EU trade of CBAM goods is higher than the trade with non-EU partners. UK's (15.55%) export share of iron and steel in the EU's market is the highest followed by Ukraine (14.26%), China (12.65%), India (11.66%), and South Korea (10.46%) as shown in Figure 2 [24] below. In the case of aluminium, China's (25.70%) export share to the EU's market is the highest followed by the UK (15.94%), Turkey (11.95%), UAE (11.74%), and Mozambique (8.29%). UK's (32.86%) export share of cement in the EU's market is the highest followed by Vietnam (18.24%), China (11.80%), USA (9.13%), and Ukraine (9.07%). In the case of fertilizers, Egypt (67.92%) has the highest share of exports to the EU, followed by the USA (11.82%), and the UK (7.65%).

EU's share in the total export of Mozambique is 67.58% followed by the UK, Algeria, Egypt, and Tunisia. Any policy change in the EU will impact these countries as the share of the EU is higher in their trade value. This observation is corroborated by one of the empirical studies. Beaufils et al. [25] empirically concluded that the impact of CBAM will be disproportionately higher in the case of countries where the EU constitutes the bulk of their total export basket by using Multi-Regional Input-Output data.

The emission levels for various CBAM energy-intensive products produced per unit of output across the EU's major trading partners are shown in Figure 4 [26]. The developing countries are on the left side of the graph, and developed countries starting from Canada are on the right side. We can see that the developing countries have higher emission levels in their production processes of CBAM products. Notably, India's emission intensity is the highest in cement production followed by Tunisia, Vietnam, and Ukraine. Oman, China, Egypt, and Turkey have higher emissions levels in fertilizer production. In the developed countries, the emission level is higher in UAE and the US in cement production while the UK, Japan, and South Korea have very low emission levels in the production of CBAM products.

3.2. Heterogeneity in carbon pricing across the world

The carbon pricing mechanism is heterogeneous and presently exists in various forms – ETS, Emission Reduction funds, A Carbon

Figure 2
Share of export of CBAM products in EU's export basket

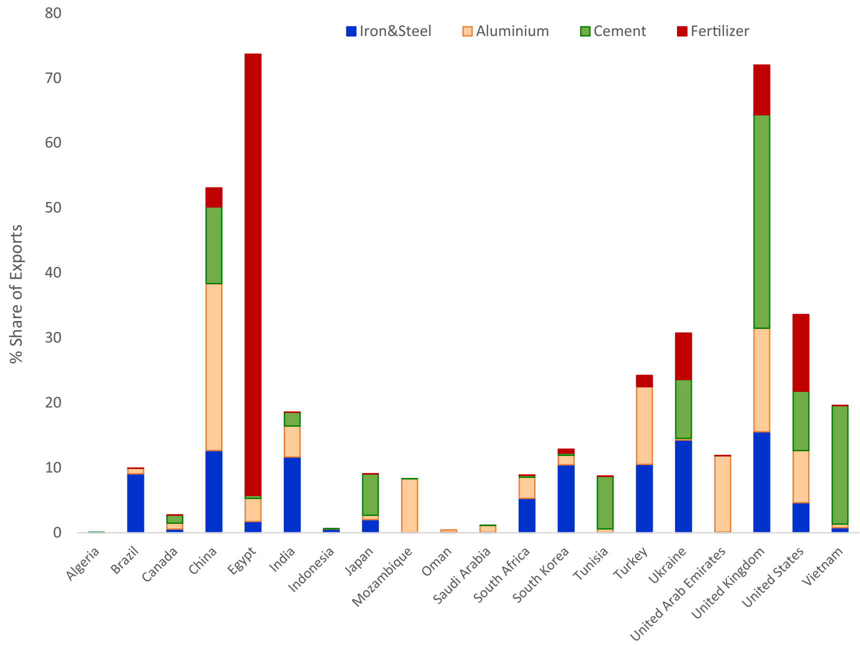


Figure 3
EU's share in the export basket of partner countries

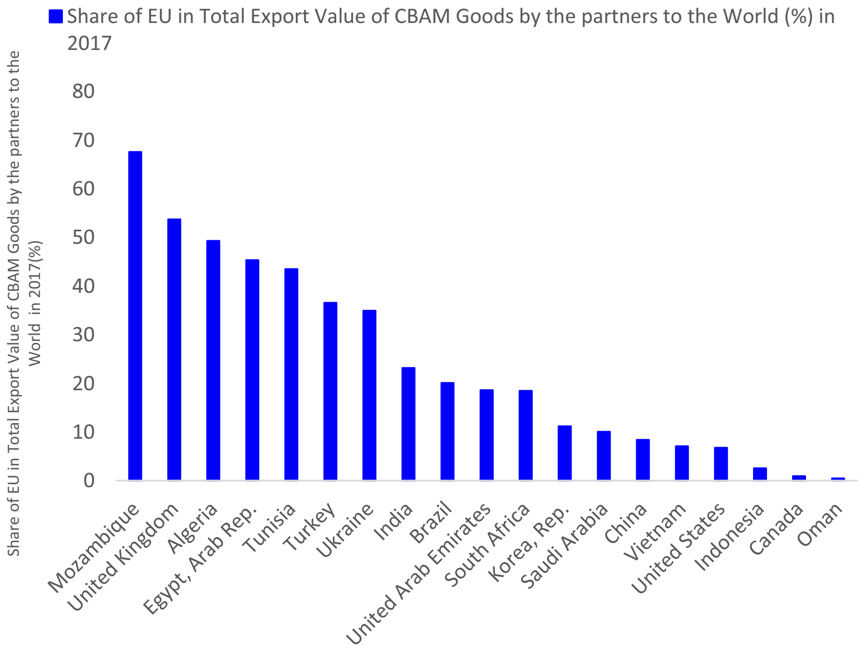
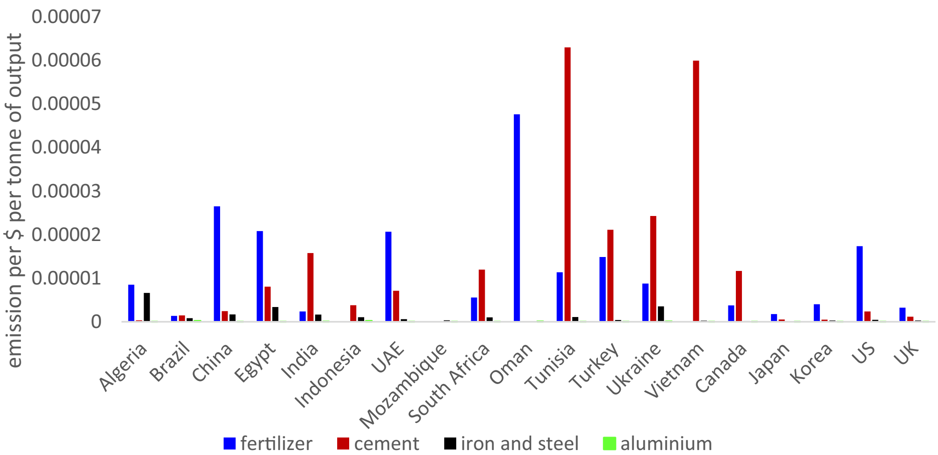


Figure 4
Emission intensity of EU's trading partners



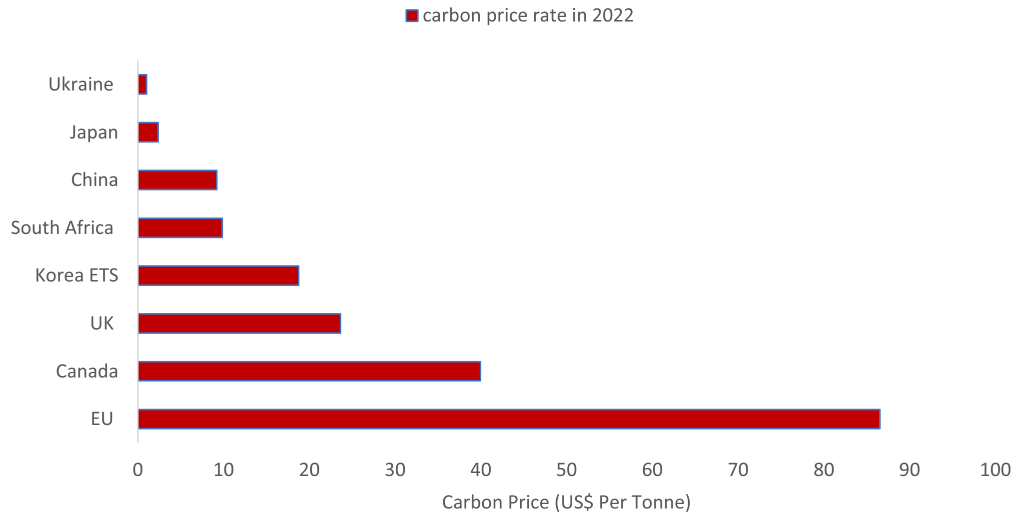
Tax, and sometimes hybrid approach[6] is also followed (combination of ETS and carbon tax, e.g., Switzerland) across the globe. Presently, only 46 countries have implemented carbon pricing mechanism covering 30% of total GHG emission and the global average is $6 per ton of CO_2 emission[7]. The information on the existing carbon pricing framework of all the countries included in the study has been extracted from the World Bank Carbon Pricing Dashboard for the year 2022. Among the selected 20 partners of EU, only seven countries already have domestic pricing mechanism – Canada, UK, Korea, South Africa, China, Japan, and Ukraine. Figure 5 [27] depicts the heterogeneity in the carbon pricing rates, and in comparison with EU's ETS, Ukraine has the lowest carbon pricing rate.

The EU ETS operates under the principle of cap and trade. Within the cap, emission allowances are traded among the emitters and the revenue from the sale of the allowances gets added to the member States' budget. Canada's carbon pollution pricing system has two parts: one, a regulatory charge on fuel (federal fuel charge) and two, a regulatory trading system for industry known as output-based pricing system. The carbon pricing system in UK includes both the ETS permit prices and carbon taxes while Korea initiated the Emission Trading Scheme (ETS) in the year 2015. The free allocation is provided to emission-intensive sectors based on production cost and trade

[6] https://unfccc.int/about-us/regional-collaboration-centres/the-ciaca/about-carbon-pricing#What-are-the-benefits-of-carbon-pricing?-

[7] https://www.imf.org/en/Blogs/Articles/2022/07/21/blog-more-countries-are-pricing-carbon-but-emissions-are-still-too-cheap#:~:text=To%20limit%20global%20warming%2C%20coverage,an%20IMF%20Staff%20Climate%20Note.

Figure 5
Heterogeneity in carbon price across selected countries in the year 2022



intensity benchmark. South Africa follows a carbon tax regime under the polluter's pay principle and includes the actual cost of GHG emission to the environment and society into the price of carbon-intensive production activities. China has an emission trading scheme mechanism to control the GHG emission. Japan's carbon pricing mechanism has two major components – carbon levy and carbon ETS. In the future, Japan is also planning to impose carbon levy on producers who are importing fossil fuels example, steel manufacturers. Ukraine has introduced carbon taxes to reduce the carbon emission and presently it is having the lowest carbon tax rate in the world; thus, may not be adequate to internalize the carbon emission externalities.

4. Data and Methodology GTAP-E Model

4.1. GTAP-11 database

The GTAP-11 database has been compiled using data from different global sources. National input-output (I-O) tables are compiled for 141 countries which contain inter-sectoral linkages within each country, bilateral time-series merchandise from the United Nations Commodity Trade (UN-COMTRADE) Statistics and IEA, and services trade data from the recently developed dataset by OECD and WTO called the Balanced Trade in Services (BaTiS), macroeconomic data published as World Development Indicators by the World Bank, the UN Statistics Division and the CIA World Factbook. The energy volumes and energy subsidies are sourced from the IEA, CO_2 emissions, Non-CO_2 GHGs, and Air pollutants data from the Emissions Database for Global Atmospheric Research (EDGAR) and IEA. The protection data such as agricultural domestic support are sourced from the OECD. This database provides valuable insights into domestic transactions, global bilateral trade patterns, energy and environmental analysis, international transport margins, and protection matrices that link individual countries and regions.

4.2. Methodology

CGE models are powerful tools of ex-ante policy analysis. The GTAP model is impactful in performing a comprehensive evaluation of a policy or regulatory shock. On the production side, the model assumes perfect competition and there are constant returns to scale. Every sector and every region in the model are identified by a constant elasticity of substitution (CES) function. On the demand side of the model, total income is distributed following a fixed share across households, government, and savings expenditure. The model captures supply-demand linkages and equates them by accounting for changes in production, consumption, exports, and imports. Demand and supply equations for private-sector agents are derived from the solutions to the optimization problems (cost minimization, utility maximization, etc.,) which are assumed to underlie the behavior of the agents in conventional neoclassical microeconomics. Since there is perfect competition, each producer, firm, and industry is a price taker.

The underlying behavior for optimization of economic agents and the accounting relationship between them is captured in several behavioral equations. These equations dictate production, private consumption, exports, imports, and market-clearing conditions that equate supply with demand. The agents are assumed to be price-takers, with producers operating in competitive markets which prevent the earning of pure profits. Given a production technology, the producers try to minimize their costs to optimize their returns. Consumers try to optimize by price minimization and utility maximization. The model works based on Armington assumption and so, each firm employs a CES composite of domestic and imported intermediate goods in fixed proportions with endowment factors or value-added commodities like land, labor, capital, natural resources, etc. Elasticities determine the substitution between various input and output parameters in the production and consumption behavioral equation.

In this study, we have used GTAP-11 database with 2017 as the reference year and GTAP-E model [28] to analyze the macroeconomic, environmental and welfare impacts of the EU's CBAM. The GTAP database describes the domestic transactions, global bilateral trade patterns, international transport margins, and protection matrices that link individual countries and regions. For each country/region, the database provides values of production, in addition to intermediate and final consumption of goods and services measured in millions of current U.S. dollars. Many

Table 1
Regional and sectoral disaggregation of the GTAP-E model

Regions		Sectors	
1. China	12. Oman	1. Agriculture	12. Aluminium
2. Japan	13. Turkey	2. Coal	13. Other Non-ferrous metals
3. Korea	14. Algeria	3. Oil	14. Energy Intensive Industries
4. Indonesia	15. Mozambique	4. Gas	15. Other Industries
5. Vietnam	16. Egypt	5. Oil and Petroleum Products	16. Other Services
6. India	17. Tunisia	6. Electricity	
7. Canada	18. Turkey	7. Fertilizer	
8. USA	19. Ukraine	8. Other chemical	
9. Brazil	20 South Africa	9. Cement	
10. UK	21. Rest of the World	10. Other non-metallic minerals	
11. UAE		11. Iron and steel	

domestic policies are also captured by this database, including value-added taxes, producer subsidies, and consumption taxes [26].

Our aggregation had 21 regions and 13 sectors initially as shown in Table 1 but to understand the impact of CBAM on specific carbon-intensive sectors we have bifurcated the sectors further. This enables estimation of the impact on fertilizer, cement. and aluminium from chemical, non-metallic minerals, and non-ferrous metals respectively using their production and export as weights.

In the GTAP-E model, CO_2 emissions are available for different uses of commodities: government consumption, private consumption, and intermediate inputs – both domestic and imported. The aggregate CO_2 emission is the sum of all these types of emissions as shown in Equation (1),

$$\boldsymbol{CO_{2\,i,s}} = \sum(\boldsymbol{CO_2Industry_{i,j,s}} + \boldsymbol{CO_2Households_{i,s}} + \boldsymbol{CO_2Government_{i,s}}) \quad (1)$$

where commodity i is used in industry j in region s

For our purpose of knowing the impact of CBAM on EU trade partners, we consider only the firm-level emissions to know the emissions in the production of a commodity exported to EU.

4.3. Carbon pricing shock

For those countries that have enforced carbon prices till 2022, their carbon prices have been taken from the World Bank's Carbon Pricing Dashboard[8]. Since the GTAP-11 database has the reference year of 2017, we take the carbon prices of countries and deflate to the prices of 2017 to maintain parity with the export data. As per the present framework of CBAM, the countries without the existing carbon pricing mechanism will get a rebate, i.e., they get an exemption of the total amount of carbon tax already paid in their own country.

Let us assume if a country (say India) exports cement (industry covered under CBAM framework) equal to a value of **X US$** value and volume of **Y ton.** Then, the unit price of export will be $\boldsymbol{A} = \left(\frac{X}{Y}\right)\boldsymbol{US\$/ton}$. The carbon emission embodied per ton of output has been calculated by using the standard concept of multiplying total quantity of goods produced and the carbon emission factor. We assume that the carbon embodied in per ton of cement produced in India is "***c.***" Therefore, the total amount of carbon embodied in cement exported by India to Europe is given by $\boldsymbol{C} = \boldsymbol{c} \times \boldsymbol{Y}$. The total carbon revenue (per ton) received by EU from India under the CBAM is $\boldsymbol{R} = \boldsymbol{c}\times$ **(US$86.5**[9]**)**. The margin of level playing field per ton for countries with the already existing carbon pricing mechanism is calculated as $\boldsymbol{l} =$ **(R - U$86.5)**. While introducing the carbon shock in our model, we treat it as an import tariff shock, where EU is treated as the importing country.

5. Impact of CBAM on EU's Trading Partners

This section elaborates the impacts of CBAM on export value, emission intensity, and overall welfare across EU's selected trading partner across all the sectors like iron and steel, cement, fertilizer, and aluminium.

5.1. Impact on export value of EU's trade partners

EU accounts for 23.19% share in India's total export value of CBAM products to the World in 2017 as Figure 3 [24] shows. India's greatest decline is in cement at (−0.62%) which accounts for 2.11% (Figure 3 [24]) of its share of exports to EU (Figure 2 [24]). Cement is also the highest emitter per unit of output amongst all the CBAM products (Figure 4 [26]). Though iron and steel forms 11.66% share of exports to EU (Figure 3 [24]), its decline in exports is only −0.06% and its emissions in per unit of output are also very low as seen in Figure 4 [26].

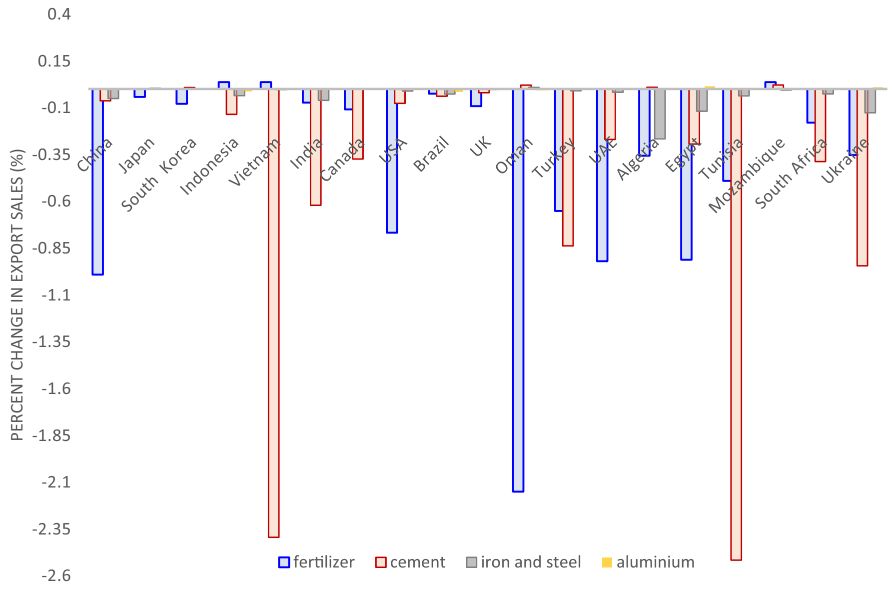
As per Figure 6, Algeria has the largest decline (−0.27%) in the iron and steel exports followed by Ukraine (−0.13%) and Egypt (−0.12%). Algeria has the highest emissions in per unit of output of iron and steel (Figure 4 [26]) followed by Egypt and Ukraine. United Kingdom's share of export sales of iron and steel is the highest (15.55%) but its emission rate of iron and steel is very much lower than most of the countries (Figure 4 [26]). It also has a carbon pricing mechanism in place as seen in Figure 5 [26]. UK's exports of iron and steel are not affected by CBAM and its export sales of iron and steel to EU hardly decline (−0.002%) as seen in Figure 6.

The hardest hit in cement exports is Tunisia (−2.52%) and Vietnam (−2.4%) (Figure 6) and they also have the highest emissions in their per unit of output (Figure 4 [26]). Vietnam exports 43.51% of its exports to EU (Figure 4 [26]), hence any policy shock by EU would have a greater impact on Vietnam.

[8] https://carbonpricingdashboard.worldbank.org/

[9] As in 2022, the carbon price rate under EU's ETS is US$86.3. As last updated till 31st March 2023, the updated EU ETS carbon price rate is US$96.3.

Figure 6
Impact of CBAM on export sales across EU's trading partners



Though UK's export share of cement is high at 32.86%, but its emissions are very low in cement production. It also has a carbon price as seen in Figure 5 [26]. Hence, it is not affected by CBAM and its export sales of cement declines only by −0.02%. Figure 6 shows that Egypt has been greatest hit in fertilizer exports to EU by 0.91%, followed by China (−0.99%) and USA (0.77%). Oman's percentage decline in fertilizer exports to EU is −2.5% but its share of exports of fertilizers to EU is negligible. 68% of Egypt's and 11.82% of US' share of exports of fertilizers is to EU (Figure 3 [24]).

There is negligible decline in aluminium in all trading partners of EU by imposition of CBAM. The highest decline is in Brazil by −0.013% (Figure 6) but its export share to EU is very low at 0.84% (Figure 2 [24]). The highest share is that of China at 25.70% (Figure 2 [24]) but its decline is −0.0012% (Figure 6). Its emission per unit of output of aluminium is also very low (Figure 4 [26]).

5.2. Impact on emission intensities of EU's trade partners

As seen in Figure 7, the marginal decline in emission is −0.01475% in Egypt primarily with the decline in its fertilizer export sales to EU. UK's export sales would not be affected by CBAM significantly; hence, its emissions continue to show a very negligible rise of 0.003%. India registered a decline in the emission intensity.

5.3. Impact on welfare of EU's trade partners

Figure 8 shows the percent change in welfare in trading partner countries due to the imposition of CBAM. Most of the developing countries shown on the right side of the graph experience a marginal decline in the welfare index called "equivalent

Figure 7
Impact of CBAM on emission intensity across EU's trading partners

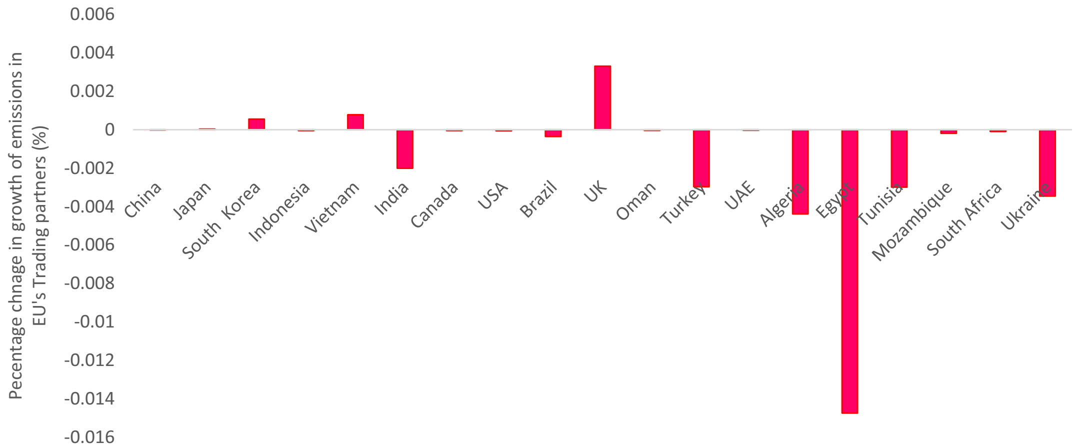
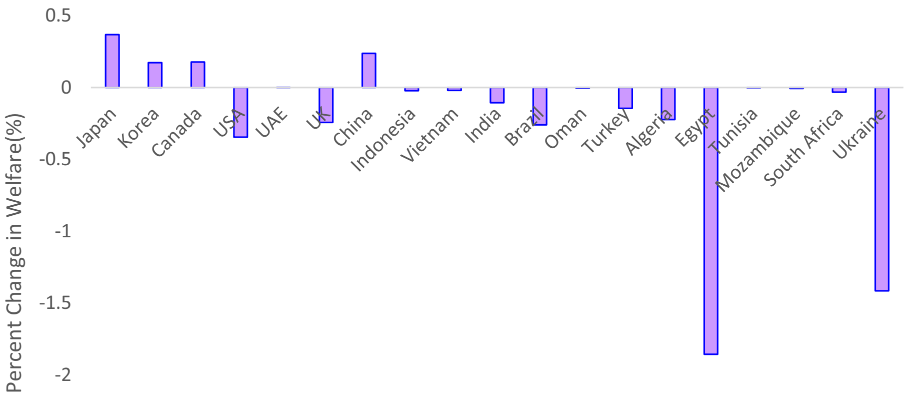


Figure 8
Impact of CBAM on welfare across EU's trading partners



variation." Most of the developed countries shown on the left side of the graph experience a very marginal rise in the welfare index. These countries already have carbon pricing enforced as seen in Figure 5 [26]. Only USA experienced a very marginal decline of −0.35%. But it does not have a carbon pricing mechanism in place and hence its welfare index would be impacted; the UK is the only outlier; however, despite having a carbon pricing mechanism, it experiences a −0.24% fall in the welfare index. Only China in developing and emerging economies experiences a rise of 0.24% in welfare primarily due to the carbon pricing mechanism already in place. Hence it won't be affected in terms of welfare index.

6. Conclusion and Policy Implications

The paper has assessed the macroeconomic impacts of CBAM across three major indicators – export value, the emission intensity of the total output, and welfare implications on EU's trading partners, including both developed and developing countries. The paper has used the GTAP-11 database and estimated the impact of CBAM across all four intensive traded goods-fertilizer, cement, aluminium, and iron and steel, presently covered under the EU's CBAM framework. The study concludes that with the imposition of CBAM in the EU, the impact on the EU's trading partners is primarily governed by three factors, the volume of exports before the imposition of CBAM, the domestic carbon pricing mechanism in each partner country, and the level of emissions embodied in the CBAM products.

While the EU's CBAM is a unilateral climate policy, it has been observed to have a negligible impact on reducing the emission intensity of the goods produced by countries. Contrary to the objective of CBAM, some countries are observed to experience a rise in their emission intensity after the imposition of the EU's CBAM. The welfare implications indicate that countries like India, Egypt, Algeria, US, and Ukraine will experience a decline in the overall welfare in their respective domestic economy. This indicates that countries without domestic carbon pricing mechanisms or lower carbon price rate will experience a decline in welfare. Results also indicate that most of the countries will also experience a decline in their export sales to the EU's market.

The EU is India's highest export market destination of Iron and steel but, from the result, the impact of CBAM on the amount of export sales is marginal in this sector. The cement industry in India experiences the maximum fall in export sales. However, the amount of cement exported to EU's market is negligible, so Indian exporters will be affected marginally in terms of the revenue generated from their export to the EU.

The legal framework and implementation design of CBAM need to be revisited as it is threatening the existence of the basic principle of WTO. This observation corroborates the conclusion of Lim et al. [9], which expressed concerns about legal compatibility issues with the existing international trade principles. Moreover, each economy differs in terms of its resource endowment, availability of financial resources, technology frontier or stage of development, and the level of skill development to facilitate the transition process towards a low-carbon economy. In this context, each country should use its discretion to determine its pathways to achieve global commitments. EU's unilateral climate policy through the imposition of CBAM will distort trade patterns and affect the domestic welfare across countries. One future scope of the study is to further disaggregate the sectors in terms of their product qualities to analyze the impact of CBAM.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Piyali Majumder: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – Original Draft, Writing – Review & Editing, Visualization. **Somya Mathur:** Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization. **Sanjib Pohit:** Conceptualization, Methodology, Validation, Writing – Review & Editing, Supervision.

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