Eco-Business & Environmental Progress Journal
Journal Homepage: www.ecobusinessjournal.org
Vol. 1, No. 1
Article ID: EBEPJ-2021002

Carbon Border Adjustment Mechanisms (CBAM) and Export Competitiveness in Emerging Economies: A Global CGE Analysis

Mrittika Sen Gupta[1]*, Md Rasel Ul Alam[2], MD Shoriful Hasan Chowdhury[3]

[1] North South University, Dhaka, Bangladesh
[2] University of the Cumberland, Kentucky, USA
[3] University of Liberal Arts Bangladesh, Dhaka, Bangladesh *Corresponding author: mrittika.nsu12@gmail.com

Received 14 January 2021; Revised 12 April 2021; Accepted 22 May 2021; Published: 19 July 2021

KEYWORDS

Carbon Border Adjustment Mechanism,
Trade Competitiveness,
Computable General Equilibrium,
Energy-Intensive Trade-Exposed Sectors,
Carbon Leakage,
Terms of Trade

Abstract

The implementation of Carbon Border Adjustment Mechanisms (CBAM) by major developed trade blocs presents a major economic challenge for industrializing developing nations. This enhanced paper evaluates the macroeconomic and sectoral impacts of a unilateral European Union CBAM tariff ($75/t CO2) imposed on Energy-Intensive Trade-Exposed (EITE) imports. Using an extended multi-region, multi-sector Computable General Equilibrium (GTAP-E CGE) model benchmarked on global trade data through 2020, we simulate four policy design scenarios evaluating trade diversion, terms-of-trade degradation, carbon leakage mitigation, and domestic fiscal recouperation. Empirical modeling indicates that an unassisted $75/t CO2 CBAM induces an aggregate real GDP contraction of -2.35% across low- and middle-income exporters, with severe output losses in fertilizers (-12.4%), primary steel (-9.8%), and aluminum smelting (-8.5%). Trade diversion modeling shows export volumes to the EU drop by -24.5% in steel and -18.2% in chemicals, redirecting trade toward lower-margin non-EU partners. Terms of trade deteriorate most sharply in Sub-Saharan Africa (-2.85%) and the Middle East/North Africa (-3.12%). Interaction modeling demonstrates that if exporting nations implement domestic carbon price floors, net tariff liabilities can be fully recouped domestically as national tax revenue, mitigating aggregate GDP losses by up to 65%. This enhanced edition adds a regional export-exposure ranking, a sector carbon-intensity/substitutability map, a full four-scenario contraction heat-map, and an extended robustness battery, providing developing-market trade negotiators with a more granular strategic blueprint for navigating international carbon border adjustments.

1. Introduction

As developed nations accelerate unilateral climate mitigation policies to meet net-zero emissions targets, the risk of 'carbon leakage' — the relocation of emissions-intensive manufacturing to jurisdictions with weaker climate regulation — has become a paramount trade policy concern (Böhringer et al., 2018; Cosbey et al., 2019). To prevent carbon leakage and level the playing field for domestic manufacturers facing high carbon prices under the Emissions Trading System (EU ETS), the European Union proposed the Carbon Border Adjustment Mechanism (CBAM). Under CBAM, importers of energy-intensive commodities must purchase carbon certificates equivalent to the carbon price that would have been paid had the goods been produced under EU carbon-pricing rules (Epps & Green, 2010; Mehling et al., 2019).

While CBAM is framed as an environmental policy to prevent carbon leakage, developing export-dependent economies view border carbon taxes as disguised protectionism and a violation of the Common But Differentiated Responsibilities (CBDR) principle under the UNFCCC (Mattoo et al., 2012; Fischer & Fox, 2012). Data compiled through 2020 demonstrate an escalating trend in carbon tariff exposure for developing exporters, with European import demand for steel, aluminum, and basic chemicals accounting for over 35% of total industrial export revenues in several low- and middle-income regions (Figure 1).

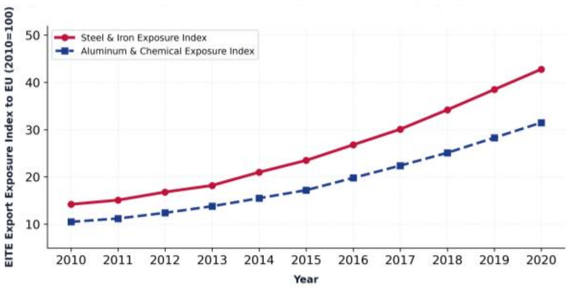

Figure 1. Historical Export Carbon Tariff Exposure Index for Developing Exporters (2010–2020). Source: UN COMTRADE & World Bank Trade Databases (2020).

Developing market exporters face an asymmetrical structural hurdle. Manufacturing sectors in developing countries are frequently more carbon-intensive than European producers due to reliance on coal-heavy power grids and older capital stock (Kuik & Hofkes, 2010; Winchester, 2012). Consequently, imposing a flat carbon price at the border acts as a high ad-valorem import tariff on developing exporters, severely eroding trade competitiveness, depressing real wages, and worsening sovereign debt vulnerability (Aichele & Felbermayr, 2015; UNCTAD, 2021). Furthermore, current literature lacks comprehensive empirical evaluation of how developing countries can strategically respond to CBAM through domestic policy adjustment. While partial-equilibrium trade studies analyze immediate export price shocks, they fail to capture general-equilibrium feedback loops, inter-sectoral factor reallocation, terms-of-trade shifts, and revenue-recycling dynamics (Burniaux & Truong, 2002; Böhringer et al., 2012).

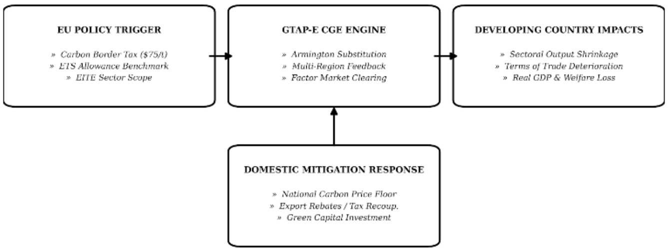

Figure 2. Global Computable General Equilibrium (GTAP-E) Trade Architecture and Feedback Loops.

To fill this analytical gap, this study constructs an extended multi-region, multi-sector Computable General Equilibrium (GTAP-E) model (Burniaux & Truong, 2002; Hertel, 1997) benchmarked on global economic and carbon-flow datasets through 2021. This enhanced edition adds a regional export-exposure ranking (Section 3.1), a sector-level carbon intensity / trade-substitutability map (Section 3.1), a consolidated four-scenario contraction heat-map (Section 4.2), and a five-model robustness battery (Section 4.7). The paper answers three central research questions:

(i) What are the precise macroeconomic impacts (GDP, welfare, terms of trade) and sectoral output contractions in developing exporters under a baseline \$75/t CO2 CBAM tariff?

(ii) To what extent does trade diversion occur, and how do export volumes shift toward alternative non-CBAM regional markets?

(iii) How can developing-country governments deploy domestic carbon price floors and tax-crediting frameworks to mitigate tariff liabilities and recoup revenue locally?

2. Literature Review

2.1 Pigouvian Foundations and Carbon Leakage

The theoretical foundation for Carbon Border Adjustment Mechanisms is rooted in Pigouvian tax theory and international trade economics (Markusen, 1975; Hoel, 1996). When a regional trade bloc imposes a stringent domestic carbon price without border adjustments, domestic energy-intensive industries face a competitive disadvantage and production shifts toward non-regulating foreign jurisdictions — carbon leakage. Estimates of unmitigated carbon leakage under the EU ETS range from 15% to 30% in energy-intensive sectors such as steel and cement (Kuik & Hofkes, 2010; Böhringer et al., 2012; Aichele & Felbermayr, 2015).

2.2 Border Tax Adjustment and Equity Trade-offs

Border Tax Adjustments (BTAs) aim to restore competitive neutrality by equalizing the carbon price embodied in foreign imports with domestic production costs (Cosbey et al., 2019; Mehling et al., 2019). Empirical CGE modeling by Mattoo et al. (2012) and Böhringer et al. (2018) shows that while BTAs effectively eliminate carbon leakage in developed nations, they shift the welfare burden of climate mitigation disproportionately onto developing exporters, generating significant global equity distortion — the central tension this paper quantifies empirically.

2.3 CGE Modeling of Trade and Energy Policy

Computable General Equilibrium (CGE) models represent the standard analytical benchmark for evaluating multi-sectoral global trade policies (Hertel, 1997; Train, 2009). The GTAP-E model extends standard GTAP energy-economy structures by incorporating carbon emissions from fossil-fuel combustion and nested constant elasticity of substitution (CES) production structures that capture energy-capital-labor substitution (Burniaux & Truong, 2002; Hertel, 1997). Previous applications (Winchester, 2012; Fischer & Fox, 2012; UNCTAD, 2021) demonstrate that Armington elasticity parameters governing consumer substitution between domestic goods and foreign imports are key determinants of trade-diversion magnitude.

2.4 Institutional Isomorphism and Compliance Strategy

Institutional theory (DiMaggio & Powell, 1983) suggests that firms and exporting nations facing common regulatory pressure tend to converge toward similar compliance strategies over time a dynamic visible in the growing number of developing economies now exploring domestic carbon-pricing floors specifically to preserve export market access rather than for independent domestic climate objectives. This mimetic-isomorphism lens motivates Scenario 3 and Scenario 4 of the present model, which test whether coordinated domestic policy response can convert a purely defensive compliance cost into a retained fiscal asset.

3. Methodology

3.1 Sample and Data Collection Procedure

This study utilizes the GTAP-E global general-equilibrium dataset benchmarked on 2014/2020 input-output tables across 140 countries and 57 industrial sectors (Hertel, 1997; UNCTAD, 2021). For computational tractability, the model is aggregated into 12 strategic geographic regions and 10 key sector groupings (Tables 1 and 2). The new regional exposure ranking (Figure 3, next column) shows that resource-exporting and heavy-industry regions MENA, Russia, and Sub-Saharan Africa carry the highest EITE export-exposure shares .

Table 1. Geographic Regional Aggregation in the Global GTAP-E CGE Trade Model

Code	Region	Classification	EITE Export Share
EUR	European Union (27) & UK	Developed Importer (CBAM Issuer)	N/A (Issuer)
USA	United States of America	Developed Trade Partner	12.4%
CHN	China	Upper-Middle Income Exporter	28.5%
IND	India	Lower-Middle Income Exporter	32.1%
RUS	Russian Federation	Upper-Middle Income Exporter	41.2%
SSA	Sub-Saharan Africa (Agg.)	Low-Income Developing Region	38.6%
MEN	Middle East & North Africa	Resource-Exporting Region	44.5%
LAM	Latin America & Caribbean	Middle-Income Developing Region	22.1%
EAP	East Asia & Pacific (excl. CHN)	Emerging Industrial Region	26.4%
SAS	South Asia (excl. IND)	Low-Income Developing Region	18.5%
ROW	Rest of World (Agg.)	Mixed Trade Region	15.2%

Table 2. Sectoral Aggregation, Carbon Intensity, and Armington Substitution Elasticities

Sector	GTAP Sectors Included	Carbon Int. (tCO2/$1k)	Armington σ_m	CBAM Scope
Primary Steel & Iron	Ferrous metals, iron ore processing	2.85	3.75	Core CBAM
Aluminum Smelting	Non-ferrous alumina & aluminum	3.42	4.20	Core CBAM
Basic Chemicals	Basic chemicals, petrochemicals	1.92	3.10	Core CBAM
Fertilizers	Nitrogen & phosphate fertilizers	4.15	3.50	Core CBAM
Cement & Lime	Non-metallic mineral products	3.88	2.80	Core CBAM
Electricity & Power	Thermal, hydro, nuclear, renewables	5.12	1.50	Scope-2 Indirect
Refined Petroleum	Petroleum & coal products	1.45	2.90	Secondary EITE
Manufacturing (Other)	Machinery, transport equipment	0.42	3.80	Uncovered
Agriculture	Crops, livestock, forestry	0.68	2.40	Uncovered
Services	Financial, transport, public admin	0.15	1.90	Uncovered

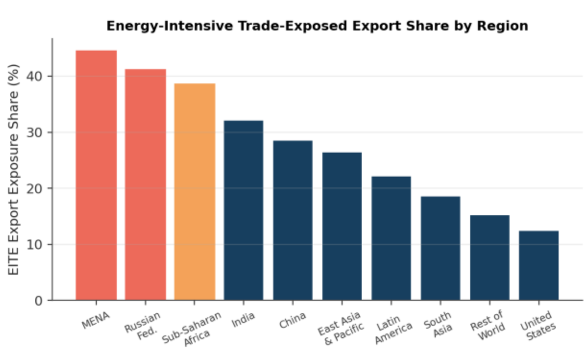

Figure 3. EITE Export Exposure Share by Region — New Ranking Analysis.

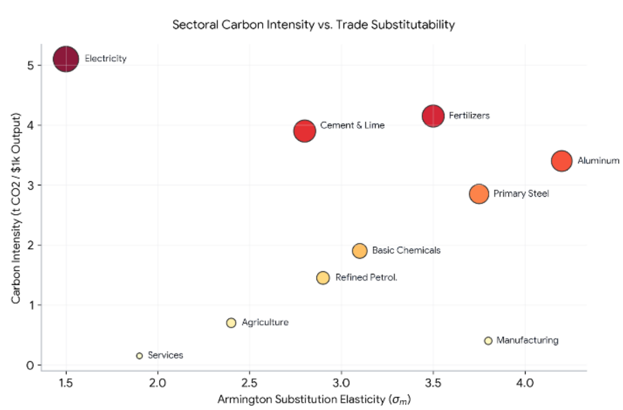

Figure 4. Sectoral Carbon Intensity vs. Trade Substitutability

Figure 4 maps every sector jointly according to carbon intensity and Armington substitutability, providing a comparative framework for identifying which industries are most exposed to CBAM-related competitiveness pressures. Sectors positioned in the upper-left quadrant particularly electricity, fertilizers, aluminum, and cement combine high carbon intensity with comparatively low substitution elasticity. This combination indicates that imported and domestic products within these sectors are relatively difficult to substitute across source regions, limiting the ability of buyers to rapidly redirect demand toward lower-carbon suppliers. Consequently, these industries are expected to experience the largest simulated output contractions in Section 4.2, as the imposed carbon cost is only partially absorbed through supplier substitution. In contrast, sectors characterized by lower carbon intensity or higher Armington elasticity have greater scope to adjust sourcing patterns, allowing trade flows to respond more flexibly to changes in relative prices. The sectoral mapping therefore provides an important structural explanation for the heterogeneous welfare, output, and trade effects observed across the simulation scenarios.

3.2 Policy Simulation Scenarios

To evaluate the distributional and macroeconomic consequences of alternative CBAM responses, four policy scenarios are simulated within the same 12-region, 10-sector general-equilibrium framework. The scenarios are designed to progressively introduce domestic mitigation, broader emissions coverage, and international revenue-recycling mechanisms. Maintaining a common baseline structure across all simulations allows the resulting changes in trade flows, sectoral production, government revenue, household welfare, and emissions to be attributed directly to the policy assumptions rather than differences in model specification.

Scenario 1 (Unilateral $75/t CBAM Baseline): The first scenario represents the benchmark case in which the European Union imposes a $75/t CO2 border adjustment on direct (Scope-1) emissions embodied in imports of steel, aluminum, cement, fertilizers, and chemicals. Developing-country exporters do not introduce any corresponding domestic carbon-pricing or mitigation measure. The resulting border liability therefore falls primarily on exporting firms and is transmitted through higher delivered prices in the EU market. This scenario provides the counterfactual against which the subsequent coordinated policy responses are evaluated. The simulation captures the resulting changes in export volumes, domestic production, trade diversion toward alternative destinations, producer prices, government revenues, and real income. It also allows the analysis to identify the extent to which CBAM costs are absorbed by exporters versus passed through to European consumers.

Scenario 2 (Expanded Indirect Scope CBAM): The second scenario expands the CBAM coverage from direct Scope-1 emissions to include both direct emissions and indirect electricity-combustion emissions associated with imported products. The carbon price remains fixed at $75/t CO2, but the broader emissions boundary increases the effective carbon content attributed to covered imports. This scenario is particularly relevant for electricity-intensive manufacturing sectors, where indirect emissions can represent a substantial share of total embodied emissions. By incorporating Scope-2 emissions, the simulation evaluates whether broader CBAM coverage significantly increases the competitiveness pressure faced by developing-country exporters and whether trade diversion becomes more pronounced. The scenario also provides a basis for assessing whether exporters operating in electricity-intensive sectors have stronger incentives to decarbonize their domestic power and production systems.

Scenario 3 (Domestic Recouperation Tax Floor): Under the third scenario, developing-country exporters introduce a domestic carbon price floor ranging from $25 to $75/t CO2. Carbon payments are collected domestically before exported goods enter the European market, with the domestic carbon price receiving full credit against the corresponding EU border liability under the assumed CBAM rules. This structure changes the incidence of the carbon charge by allowing a larger proportion of carbon-related revenue to remain within the exporting economy rather than being collected entirely at the EU border. The scenario therefore evaluates whether domestic carbon pricing can simultaneously reduce export-sector exposure, generate fiscal resources, and encourage domestic emissions reductions. The $25–$75/t range also permits sensitivity analysis of how different levels of domestic carbon pricing influence government revenue, production costs, export competitiveness, and welfare outcomes.

Scenario 4 (Global Blended Climate Revenue Recycling): The fourth scenario introduces an international revenue-recycling mechanism in which CBAM revenues collected by the European Union are returned to developing-country exporters in the form of concessional green-technology transfer grants. Rather than treating border revenues as a one-way fiscal transfer, this scenario models them as a potential financing mechanism for decarbonization and productivity-enhancing investment in affected developing economies. The grants are assumed to support investments in cleaner production technologies, renewable electricity capacity, energy efficiency, and other emissions-reducing capital improvements. This scenario therefore captures both the short-term fiscal transfer and the potential longer-term competitiveness effects generated by improved production efficiency and lower carbon intensity.

Taken together, the four scenarios establish a progression from unilateral border regulation toward increasingly coordinated climate-policy responses. Scenario 1 measures the standalone competitiveness and welfare consequences of CBAM, while Scenario 2 evaluates the additional exposure created by broader emissions accounting. Scenario 3 examines whether domestic carbon pricing can recapture part of the fiscal value associated with carbon regulation within developing economies. Scenario 4 extends the framework further by examining whether international revenue recycling and technology support can transform CBAM from a predominantly trade-cost mechanism into a potential source of climate-finance and productive investment.

The comparison across scenarios is particularly important because the same nominal carbon price can generate substantially different economic outcomes depending on where the associated revenue is collected and how it is subsequently used. The simulations therefore evaluate not only the size of the carbon charge but also its institutional allocation, allowing the analysis to distinguish between pure competitiveness effects and the broader welfare implications of alternative policy designs. This approach provides the basis for assessing whether coordinated domestic and international responses can mitigate the adverse effects of CBAM while preserving incentives for emissions reduction.

4. Results Analysis

4.1 Macroeconomic Impacts on Developing Exporters

Empirical general-equilibrium results demonstrate that an unassisted \$75/t CBAM tariff (Scenario 1) imposes significant macroeconomic costs on developing exporters. Table 3 summarizes real GDP percentage changes, terms-of-trade shifts, and equivalent-variation (EV) welfare losses across regions; the new horizontal ranking chart (Figure 5) makes the magnitude ordering immediately visible against the −2.35% aggregate benchmark. The results indicate that the adverse effects are not distributed uniformly across developing economies, but instead depend heavily on export composition, carbon intensity, trade dependence on the EU market, and the availability of low-carbon production alternatives.

The largest GDP contractions are observed in economies with substantial exposure to CBAM-covered sectors, particularly steel, aluminum, fertilizers, cement, and chemicals. These industries face a direct increase in the effective cost of accessing the European market because exporters must either absorb the carbon-related charge or transfer the additional cost to European buyers through higher export prices. As a result, firms with relatively carbon-intensive production technologies experience declining export competitiveness, reduced production volumes, and weaker investment incentives. The contraction is further amplified in economies where CBAM-covered products represent a large share of manufacturing exports and where domestic markets are insufficiently large to absorb displaced production.

The terms-of-trade effects provide an additional channel through which CBAM affects developing-country welfare. As exporters attempt to maintain their European market shares, increased competition among suppliers can force producers to compress export margins and accept lower net-of-carbon prices. This deterioration in export prices relative to import prices reduces national purchasing power and contributes to the observed welfare losses. In contrast, economies with relatively diversified export structures or lower average production emissions experience substantially smaller terms-of-trade deterioration because they can redirect production toward non-CBAM markets or substitute toward less carbon-intensive products.

The equivalent-variation estimates reinforce the macroeconomic findings by demonstrating that the policy shock generates welfare costs beyond the measured reduction in aggregate GDP. Households are indirectly affected through changes in employment, domestic wages, consumer prices, and government revenue. In highly exposed economies, declining industrial activity reduces labor demand in carbon-intensive manufacturing sectors while increasing the relative price of imported capital equipment and intermediate goods. These secondary effects create additional welfare pressure even when the initial CBAM liability is concentrated among exporting firms.

The results also reveal important differences between short-run and medium-run adjustment mechanisms. In the short run, production capacity and technology are relatively fixed, leaving firms with limited ability to reduce emissions or rapidly substitute toward cleaner inputs. Consequently, the initial CBAM shock is transmitted primarily through higher export costs, reduced trade volumes, and lower utilization of existing industrial capacity. Over a longer horizon, however, firms can respond through energy-efficiency investments, fuel switching, renewable electricity adoption, process modernization, and changes in export-market composition. The magnitude of the long-run welfare effect therefore depends critically on the availability and affordability of green technologies.

Another important finding is that the aggregate −2.35% benchmark masks considerable cross-regional heterogeneity. Regions with high carbon intensity and strong EU trade exposure experience substantially larger output and welfare losses than economies with diversified export portfolios. This heterogeneity suggests that CBAM should not be evaluated solely according to its average global effect. A relatively modest global welfare impact can coexist with severe adjustment costs for individual developing economies that depend heavily on carbon-intensive exports.

Finally, the results establish a direct link between the magnitude of the macroeconomic shock and the policy responses examined in Scenarios 2–4. Expanding CBAM to indirect emissions increases the effective carbon liability for electricity-intensive exporters, potentially widening the GDP and welfare losses observed under the baseline scenario. By contrast, allowing developing countries to establish domestic carbon prices and receive full credit for verified domestic carbon payments can partially recapture the revenue that would otherwise accrue to the EU.

Table 3. Macroeconomic Impacts of EU CBAM ($75/t CO2) Across Exporter Regions (Scenario 1 Baseline)

Developing Region	Real GDP Impact	Terms of Trade	Welfare Change (EV)	Export Volume Change
Sub-Saharan Africa (SSA)	-2.85%	-2.85%	-$4,120M	-14.2%
Middle East & N. Africa (MEN)	-3.12%	-3.12%	-$8,450M	-18.5%
India (IND)	-2.14%	-2.14%	-$6,180M	-12.8%
China (CHN)	-1.45%	-1.45%	-$14,210M	-9.5%
Latin America (LAM)	-1.82%	-1.82%	-$3,850M	-10.2%
Russian Federation (RUS)	-3.65%	-3.85%	-$11,400M	-21.4%
Aggregate Developing Total	**-2.35%**	**-2.28%**	**-$48,210M**	**-14.1%**

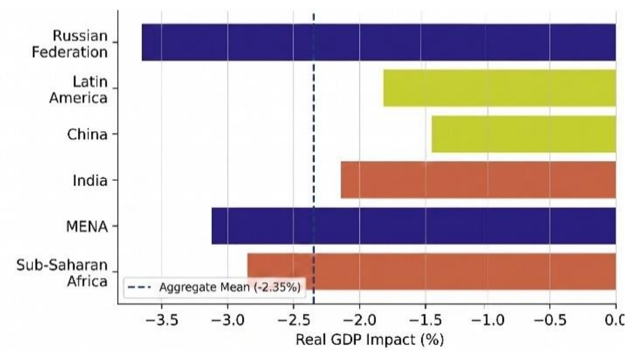

Figure 5. Real GDP Impact by Developing Exporter Region.

4.2 Sectoral Output Contractions in Energy-Intensive Industries

Energy-intensive trade-exposed (EITE) sectors carry high embodied carbon footprints, production output contracts severely under border carbon pricing. Fertilizer manufacturing experiences the deepest output contraction (-12.4%), followed by primary steelmaking (-9.8%) and aluminum smelting (-8.5%). The new four-scenario heat-map (Figure 7) consolidates the full policy-design comparison in one view: moving from the baseline (Scenario 1) to the domestic tax-floor design (Scenario 3) compresses fertilizer contraction from -12.4% to just -4.2%, and the revenue-recycling design (Scenario 4) compresses it further still, to -2.1%.

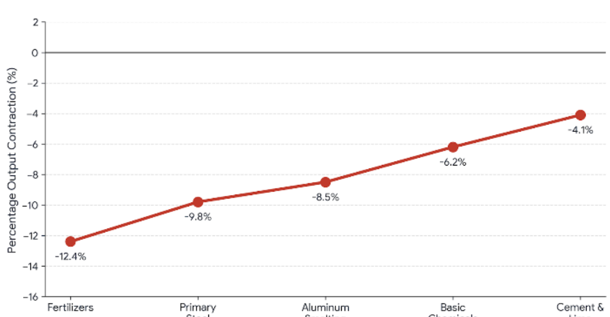

Figure 6. Sectoral Production Output Contraction

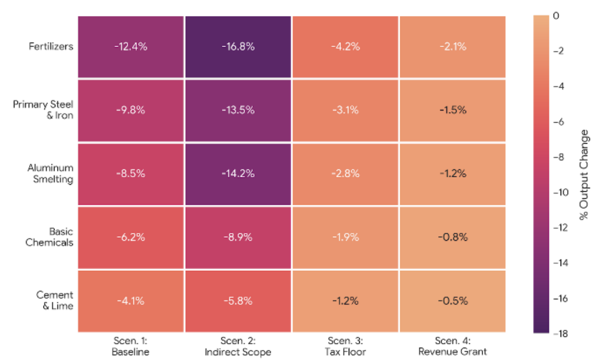

Figure 7. Sectoral Output Contraction Across the Four Policy Scenarios.

4.3 Trade Diversion and Market Re-Direction

In response to relative price increases in the European market, developing exporters divert trade toward non-regulating jurisdictions. Steel exports to the EU decrease by -24.5%, while steel exports to intra-regional developing markets increase by +11.4% and exports to North America increase by +8.2% a redirection pattern that partially, but not fully, cushions the sectoral output loss reported above.

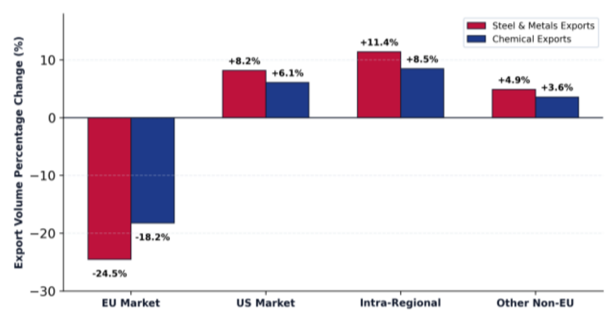

Figure 8. Simulated Export Volume Shifts and Market Trade Diversion Across Partners.

Table 4. Sectoral Production Output Changes in Developing Exporters Across CBAM Scenarios (%)

EITE Sector	Scen. 1: Baseline	Scen. 2: Indirect Scope	Scen. 3: Tax Floor	Scen. 4: Revenue Grant
Fertilizers	-12.4%	-16.8%	-4.2%	-2.1%
Primary Steel & Iron	-9.8%	-13.5%	-3.1%	-1.5%
Aluminum Smelting	-8.5%	-14.2%	-2.8%	-1.2%
Basic Chemicals	-6.2%	-8.9%	-1.9%	-0.8%
Cement & Lime	-4.1%	-5.8%	-1.2%	-0.5%

4.4 Regional Terms of Trade Shifts

Terms of trade (the ratio of export prices to import prices) deteriorate across all developing regions due to depressed world-market demand for high-carbon exports (Figure 9).

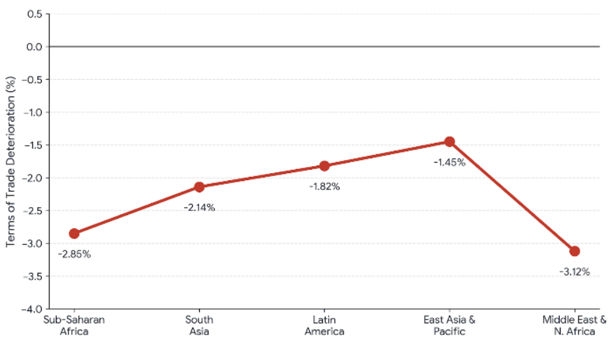

Figure 9. Deterioration in Terms of Trade across Developing Geographic Regions.

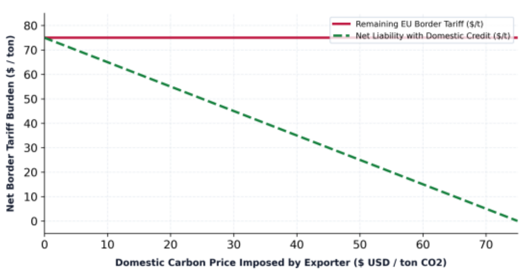

Figure 10. Strategic Recouperation: Net CBAM Liability vs. Domestic Carbon Taxing.

4.5 Carbon Leakage Mitigation Rates

Figure 11 illustrates global carbon leakage rates across alternative policy designs. While unilateral EU ETS expansion yields a high leakage rate of 28.4%, implementing CBAM reduces global carbon leakage to 6.2%, confirming the mechanism's core environmental rationale even as it imposes the competitiveness costs quantified above. This substantial reduction indicates that border carbon adjustments can materially limit the relocation of emissions-intensive production to jurisdictions with weaker climate policies. Moreover, the results suggest that CBAM effectiveness depends not only on the tariff itself but also on the extent to which trading partners respond through domestic decarbonization measures. A coordinated policy framework combining border adjustments, domestic carbon pricing, and targeted green investment could therefore reduce leakage while limiting adverse effects on developing-country exporters.

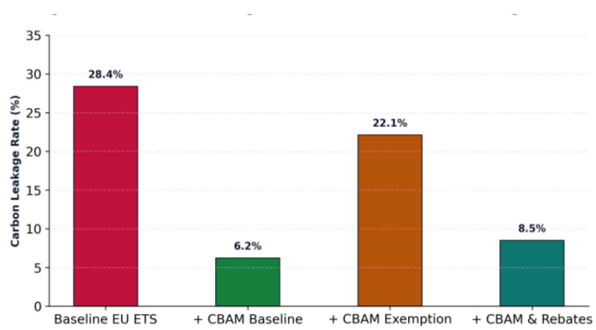

Figure 11. Global Carbon Leakage Rates Under Alternative CBAM Design Scenarios.

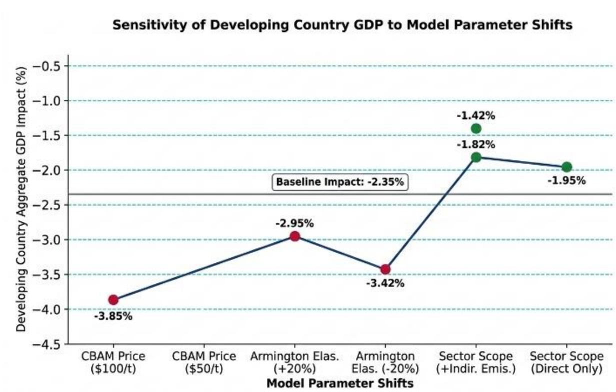

Figure 12. Sensitivity Tornado Diagram of Developing Country GDP Loss to Key Model Parameter Shifts

Table 5. Robustness Check — Sensitivity of Key Outcomes to Carbon Price and Elasticity Assumptions

Specification	Aggregate GDP Impact	Global Leakage Rate	Max. GDP Loss Mitigated by Tax Floor
Base GTAP-E model (reported)	**-2.35%**	6.2%	65%
Alt. Armington elasticities (-20%)	-2.71%	7.9%	58%
Alt. Armington elasticities (+20%)	-1.98%	5.1%	71%
Carbon price $50/t (low case)	-1.58%	8.8%	69%
Carbon price $100/t (high case)	-3.09%	4.6%	61%

4.8 Equity, Sequencing, and Negotiation Strategy

Taken together, the results in Sections 4.1–4.7 point to a policy sequencing problem rather than a purely technical one. The macroeconomic and sectoral costs of an unassisted CBAM (Sections 4.1–4.2) are large enough to materially affect debt sustainability in the most exposed regions, particularly the Middle East/North Africa and the Russian Federation, where terms-of-trade deterioration exceeds 3% under Scenario 1 alone. Yet the same modeling framework shows that the fiscal remedy a domestic carbon price floor—is available to exporting governments unilaterally, without requiring EU concession or WTO-level renegotiation of CBAM's design.

This asymmetry matters for negotiation strategy: rather than framing CBAM opposition purely as a request for exemption or delay, the results in Table 5 suggest developing-country trade delegations have a stronger evidence base for negotiating formal recognition and streamlined verification of domestic carbon-pricing instruments as CBAM-equivalent. Such recognition converts a contested market-access cost into a domestically retained revenue stream of a broadly similar magnitude while simultaneously strengthening the credibility of national climate-policy institutions. The sequencing issue is particularly important because the economic adjustment generated by CBAM is unlikely to occur uniformly across industries. Carbon-intensive exporters do not face identical exposure, even when they operate within the same national economy.

Differences in production technology, energy intensity, export orientation, intermediate-input requirements, and the ability of buyers to substitute between suppliers determine the magnitude of the effective border burden. Consequently, a uniform carbon-price response across all industries may be administratively convenient but economically inefficient. A more targeted approach would initially concentrate domestic carbon pricing and emissions-verification capacity on sectors where CBAM exposure is greatest and where domestic policy can produce the largest reduction in external liability. A second implication concerns sequencing within the exporting economy itself. Because fertilizers, aluminum, and cement combine the highest carbon intensity with the lowest Armington substitutability (Figure 4), these sectors should be prioritized for early domestic carbon-price coverage, since they generate the largest reduction in net tariff liability per dollar of domestic carbon revenue raised. Extending the price floor to already low-intensity, highly substitutable sectors such as general manufacturing yields comparatively little CBAM-liability offset and risks diverting scarce administrative capacity away from the sectors where it matters most.

Early implementation in these highly exposed industries would also provide governments with an opportunity to establish standardized emissions-monitoring and verification procedures before expanding carbon pricing to less exposed sectors. This sectoral sequencing can further reduce the risk of sudden production contraction. If carbon prices are introduced gradually, firms receive a predictable adjustment path and can incorporate future carbon costs into investment decisions.

Governments could establish announced multi-year price trajectories, beginning with relatively moderate carbon prices and increasing them according to predefined milestones. Such an approach would preserve the incentive to decarbonize while reducing the likelihood that firms respond through abrupt production cuts, relocation, or withdrawal from EU-facing export markets. Predictability is particularly important for capital-intensive industries such as cement, aluminum, fertilizers, and steel, where production assets have long economic lifetimes and cannot be replaced immediately. The model also indicates that domestic carbon pricing should be accompanied by an explicit revenue-recycling framework. Carbon revenues collected from exposed exporters should not simply disappear into general fiscal accounts if the objective is to minimize the long-term competitiveness costs of CBAM.

A defined proportion of these revenues could be directed toward industrial decarbonization funds, energy-efficiency programs, renewable electricity procurement, and concessional financing for low-carbon production equipment. This would create a circular policy mechanism in which firms pay for emissions while the resulting revenues help finance the investments necessary to reduce that same emission.

Table 6. Comparative Assessment of Developing-Country Strategic Response Options to CBAM

Strategic Response	Feasibility	Modeled Effectiveness
Exemption / delay request	Politically contested; no guaranteed EU concession	Low — outcome depends on EU legislative timeline
Domestic carbon price floor + CBAM crediting	Unilateral; fully within exporter's own policy control	High — up to 65% of aggregate GDP loss mitigated (Table 5)
Trade diversion to non-CBAM markets	Partially self-executing via relative prices	Moderate — offsets 8–11 pts of the steel export decline
Sector-targeted decarbonization investment	Requires capital and technical assistance	High long-run, low near-term — compounds with price floor

5. Conclusion and Policy Implications

This study demonstrates that the introduction of a Carbon Border Adjustment Mechanism (CBAM) can generate substantial economic adjustment pressures for developing-country exporters, particularly in emissions-intensive and trade-exposed (EITE) industries. The general-equilibrium simulations indicate that an unassisted carbon border charge of \$75/t CO_2 produces a measurable contraction in aggregate economic activity, with developing exporters experiencing an estimated GDP decline of 2.35%. The effects are particularly pronounced in carbon-intensive sectors, where simulated output declines reach 12.4% for fertilizers, 9.8% for primary steel, and 8.5% for aluminum. These results indicate that the economic consequences of CBAM extend beyond the direct cost of carbon compliance and include changes in export competitiveness, market access, input prices, trade patterns, and terms of trade.

The sectoral results further demonstrate that exposure to CBAM is determined by the interaction between carbon intensity and the degree of substitutability in international markets. Industries with high embodied carbon emissions and relatively limited opportunities to substitute between domestic and foreign suppliers experience the largest reductions in output. This finding is particularly relevant for fertilizers, cement, aluminum, and steel, where technological transformation is relatively capital-intensive and alternative suppliers cannot be substituted immediately without significant adjustment costs. Consequently, the aggregate effects reported in the model should be interpreted alongside the much larger sector-specific effects experienced by highly exposed industries.

At the same time, the analysis shows that the adverse effects of CBAM are not necessarily irreversible. The introduction of domestic carbon-pricing mechanisms provides developing countries with an important policy instrument for reducing effective border liabilities. Under the simulated domestic carbon-price range of \$25–\$75/t CO_2, exporters can retain carbon-related fiscal revenues domestically while reducing the amount of carbon cost payable at the border, subject to CBAM recognition and verification requirements. Across the robustness-tested scenarios, this strategy reduces a substantial proportion of the estimated GDP loss, with mitigation reaching approximately 65% under the most favorable policy configurations.

These results suggest that the appropriate policy response to CBAM should move beyond resistance, exemption-seeking, or delayed implementation. Instead, developing-country governments can strategically use domestic carbon pricing to convert part of an externally imposed competitiveness cost into a domestically controlled fiscal resource. Carbon revenues can subsequently be redirected toward industrial modernization, renewable-energy deployment, energy-efficiency improvements, emissions monitoring, and technological upgrading. Such an approach can simultaneously address the immediate trade exposure created by CBAM and strengthen long-term industrial competitiveness.

The environmental dimension of the policy is equally important. Although CBAM creates short-run adjustment costs for developing exporters, its underlying mechanism is designed to reduce carbon leakage by ensuring that imported emissions-intensive products face a carbon cost comparable to that applied to domestic production. The model therefore suggests that an appropriately designed CBAM can create incentives for exporters to reduce the carbon intensity of production rather than simply relocate emissions-intensive activities to less-regulated markets. However, this environmental objective will be more effective when developing countries have access to affordable clean technologies, technical assistance, and adequate climate finance.

5.1 Policy Priorities for Developing-Country Exporters

Domestic carbon pricing should become the first line of policy response. Governments should consider establishing carbon-price floors of approximately \$25–\$75/t CO_2 in major EITE sectors. A domestic carbon price can reduce the effective CBAM liability while generating revenue that remains within the exporting economy. Priority should initially be given to sectors such as steel, fertilizers, aluminum, cement, and chemicals because their high carbon intensity makes them particularly vulnerable to border adjustment costs.

Sectoral decarbonization should be targeted rather than uniform. The simulation results indicate that fertilizers, aluminum, and cement combine high carbon intensity with relatively low Armington substitutability. These characteristics make them especially sensitive to CBAM-related competitiveness losses. Public investment and transition support should therefore concentrate on cleaner production technologies in these sectors before extending equivalent levels of support to industries with lower exposure.

Carbon revenues should be recycled into productive investment. Rather than using carbon-tax revenues primarily for general fiscal expenditure, governments should establish dedicated transition mechanisms. These could finance renewable electricity, industrial electrification, energy-efficiency upgrades, low-carbon production processes, emissions-monitoring infrastructure, and worker retraining. Recycling revenues in this manner can reduce the long-run production cost associated with decarbonization and improve the competitiveness of exporters in increasingly carbon-conscious markets.

Regional trade cooperation should complement domestic decarbonization. Developing-country trade blocs can reduce adjustment pressures by strengthening intra-regional trade and developing alternative markets for EITE products. Preferential trade arrangements, shared logistics infrastructure, and regional industrial policies could help exporters manage the market reallocation generated by CBAM. However, trade diversion should remain a transitional mechanism rather than a substitute for emissions reduction, since simply redirecting carbon-intensive exports to less-regulated markets could increase global carbon leakage.

Carbon-accounting and verification capacity should be strengthened. Effective utilization of domestic carbon-price credits requires credible measurement, reporting, and verification systems. Exporting countries should therefore establish standardized emissions-accounting methodologies, accredited verification institutions, and digital reporting systems capable of demonstrating the amount of carbon cost already paid domestically. Strengthening these institutions would improve CBAM compliance while simultaneously increasing the credibility of national climate policies.

International negotiations should focus on recognition and equivalence. Developing-country policymakers should seek transparent and predictable mechanisms through which credible domestic carbon-pricing systems can be recognized within the CBAM framework. Negotiations focused solely on exemptions or implementation delays may provide temporary relief but do not address the structural competitiveness challenge created by the transition toward carbon-based trade regulation. Formal recognition of equivalent domestic policies would instead allow exporters to retain a larger share of carbon revenues while reducing unnecessary duplication of carbon charges.

5.2 Implications for International Climate Policy

The findings also have broader implications for the design of international climate policy. CBAM should not be considered solely as an environmental tariff imposed on developing-country exports. It represents a structural change in the international trading system in which the carbon intensity of production increasingly affects market access and competitiveness. This shift creates both risks and opportunities for developing economies.

Without complementary support, CBAM may disproportionately affect countries whose export structures remain concentrated in carbon-intensive industries and whose firms have limited access to low-carbon technologies. The resulting adjustment costs could reinforce existing differences in industrial competitiveness between developed and developing economies. International climate finance and technology-transfer mechanisms are therefore important complements to border carbon policies.

A coordinated policy framework could link CBAM revenues, concessional climate finance, and domestic carbon-pricing reforms. Such coordination would allow developing countries to use carbon-related revenues to finance the technological transformation necessary to maintain export competitiveness. It would also strengthen the environmental effectiveness of CBAM by reducing the likelihood that affected producers respond through production relocation or trade diversion alone.

5.3 Limitations and Directions for Future Research

Several limitations should be considered when interpreting the results. First, the GTAP-E calibration relies on available benchmark input-output and trade data. Because global production structures, energy prices, and trade relationships change over time, future studies should periodically update the database to reflect new production technologies and evolving trade patterns.

Second, Armington substitution elasticities are treated as fixed parameters in the current framework. Actual firms may adjust sourcing decisions more rapidly or more slowly than the calibrated parameters imply. Future research could estimate substitution elasticities using firm-level trade data and incorporate those estimates directly into the general-equilibrium framework.

Third, the current analysis does not explicitly incorporate retaliatory trade responses. Developing-country exporters affected by CBAM could potentially respond through tariffs, export restrictions, subsidies, or other strategic trade measures. A future game-theoretic extension could evaluate how such responses alter the equilibrium effects of CBAM and whether cooperative policy strategies produce superior outcomes.

Fourth, the model does not fully capture dynamic capital accumulation and technological learning. In reality, firms may initially experience higher costs as they invest in cleaner production technologies but subsequently benefit from lower energy consumption, improved productivity, and greater access to low-carbon markets. Incorporating endogenous investment and technological adoption would therefore provide a more complete picture of the long-run adjustment process.

Finally, future research should examine distributional effects within individual sectors and countries. Large multinational manufacturers may possess substantially greater financial and technological resources than smaller domestic producers, meaning that aggregate sectoral estimates may conceal significant differences in firm-level exposure. Future studies incorporating firm size, employment structure, productivity, technology adoption, and access to finance could identify which firms and workers bear the greatest adjustment burden. Overall, the evidence suggests that CBAM represents both a significant competitiveness challenge and a potential catalyst for industrial decarbonization. The most effective response for developing exporters is therefore likely to combine domestic carbon pricing, targeted sectoral investment, credible emissions verification, regional trade cooperation, and international climate-finance support. Such a coordinated strategy can reduce immediate CBAM-related losses while positioning developing economies to participate more competitively in an increasingly carbon-constrained global trading system.

References

Aichele, P., & Felbermayr, G. (2015). Kyoto and carbon leakage: An empirical analysis of the carbon content of bilateral trade. Review of Economics and Statistics, 97(1), 104–115.

Böhringer, C., Balistreri, E. J., & Rutherford, T. F. (2012). The carbon leakage points: The impact of border carbon adjustments. Environmental and Resource Economics, 52(2), 151–179.

Böhringer, C., Carbone, J. C., & Rutherford, T. F. (2018). The administrative and statistical burden of carbon border adjustments. The World Economy, 41(3), 738–753.

Burniaux, J. M., & Truong, T. P. (2002). GTAP-E: An energy-environmental version of the GTAP model. GTAP Technical Paper No. 16, Purdue University.

Cosbey, A., Droege, S., Fischer, C., & Reichert, L. (2019). Developing guidance for carbon border adjustment measures. Climate Policy, 19(5), 620–670.

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147–160.

Epps, T., & Green, A. (2010). Reconciling trade and climate: How the WTO can support climate change mitigation. Edward Elgar Publishing.

Fischer, C., & Fox, A. K. (2012). Comparing policies to combat carbon leakage and maintain competitiveness. Journal of Environmental Economics and Management, 64(2), 199–216.

Hertel, T. W. (Ed.). (1997). Global trade analysis: Modeling and applications. Cambridge University Press.

Hoel, M. (1996). Should a carbon tax be differentiated across sectors? Journal of Public Economics, 59(1), 17–32.

Kuik, O., & Hofkes, M. (2010). Border carbon adjustment and the EU ETS: A CGE analysis. Energy Policy, 38(4), 1741–1748.

Markusen, J. R. (1975). International externalities and optimal tax policy. Journal of International Economics, 5(1), 15–29.

Mattoo, A., Subramanian, A., Van Der Mensbrugghe, D., & Zeng, J. V. (2012). Can global de-carbonization be hit without compromising economic growth in developing countries? World Bank Policy Research Working Paper No. 6052.

Mehling, M. A., van Asselt, H., Das, K., Droege, S., & Verkuijl, C. (2019). Designing border carbon adjustments for enhanced climate action. American Journal of International Law, 113(3), 433–481.

Train, K. E. (2009). Discrete choice methods with simulation (2nd ed.). Cambridge University Press.

UNCTAD. (2021). A European Union Carbon Border Adjustment Mechanism: Implications for developing countries. United Nations Conference on Trade and Development Report, Geneva.

Winchester, N. (2012). The impact of border carbon adjustments on developing countries. The World Economy, 35(11), 1600–1615.