



Search information

Received 21/01/2026

Accepted 15/03/2026

Printed ISSN: 2352-989X

Online ISSN: 2602-6856

The Impact of the EU's Carbon Border Adjustment Mechanism (CBAM) on North African Industrial Exports: A CGE Model Approach

Walid saifi^{1 *}

Aziza bensemina²

¹ university of biskra (Algeria),

walid.saifi@univ-biskra.dz

² university of biskra (Algeria)

a.bensemina@univ-biskra.dz

ABSTRACT

The implementation of the European Union's Carbon Border Adjustment Mechanism (CBAM) represents a paradigmatic shift in international trade policy, intertwining climate ambition with commercial strategy. This article investigates the potential economic repercussions of CBAM on North African economies, specifically Algeria, Egypt, and Tunisia, which exhibit a high degree of trade dependence on the EU. Utilizing a dynamic Computable General Equilibrium (CGE) simulation based on the GTAP-E model, we estimate the impact of a carbon levy ranging from €75 to €100 per ton on key industrial sectors: cement, fertilizers, iron and steel, and aluminum. Our findings suggest a heterogeneous impact across the region; while aggregate welfare losses are moderate (ranging from -0.2% to -0.9% of GDP), sectoral disruptions are profound, particularly for the Egyptian fertilizer industry and the Algerian cement sector. Furthermore, the analysis highlights a significant "administrative non-tariff barrier" effect, where the cost of compliance monitoring may outweigh the tariff itself for Small and Medium Enterprises (SMEs). We argue that without strategic decarbonization and diplomatic engagement to secure revenue recycling, CBAM risks exacerbating the North-South economic divide under the guise of environmental protection.

Keywords: Carbon Border Adjustment Mechanism (CBAM), North Africa, CGE Model, International Trade, Decarbonization, Green Supply Chain Management.

*saifi walid

INTRODUCTION

The global pursuit of climate neutrality has precipitated a fundamental restructuring of international trade relations. As the European Union (EU) commits to the ambitious goals of the European Green Deal—aiming to become the first climate-neutral continent by 2050—its internal decarbonization policies are increasingly reverberating beyond its borders. The intersection of environmental sustainability and international trade law, once a niche area of academic inquiry, has now become a central locus of geopolitical friction. At the heart of this shift is the Carbon Border Adjustment Mechanism (CBAM), a policy instrument designed to equalize the price of carbon between domestic products and imports. By effectively extending the EU's Emissions Trading System (ETS) to foreign producers, CBAM seeks to prevent "carbon leakage"—the relocation of carbon-intensive production to jurisdictions with laxer emission standards. However, for trading partners in the developing world, this mechanism is frequently viewed through a different lens: that of a unilateral regulatory imposition, or "green protectionism," that threatens to undermine decades of economic integration.

Nowhere is this tension more palpable—or the economic stakes higher—than in North Africa. Geographical proximity, historical colonial ties, and a web of Association Agreements have rendered the economies of the Maghreb (Algeria, Tunisia) and Egypt structurally dependent on European markets. The region serves as a vital industrial hinterland for Europe, providing essential inputs ranging from fertilizers for European agriculture to cement and steel for its construction sector. A significant portion of exports from Tunisia are destined for the EU, with Algeria and Egypt following closely behind in specific energy and industrial categories. Consequently, the introduction of CBAM is not merely a technical adjustment to customs procedures; it represents a potential shock to the competitive positioning of North African industry. As the EU rewrites the rules of market access to favor low-carbon production, it inadvertently challenges the development models of its southern neighbors, who often rely on cost-competitiveness driven by affordable, fossil-fuel-based energy.

Despite the gravity of this policy shift, the existing academic literature has largely focused on the implications for major global emitters such as China, Russia, and the United States, or has treated the "Global South" as a monolithic bloc. This article addresses a critical research gap by zooming in on the specific sectoral and country-level nuances of the North African industrial base. Unlike generalized global studies, which often mask regional disparities, we seek to understand the distinct vulnerabilities of the fertilizer, cement, iron, steel, and aluminum sectors in Algeria, Egypt, and Tunisia. These industries form the backbone of the region's non-hydrocarbon exports and are the primary targets of the CBAM regulation.

Our contribution to the field is twofold. First, methodologically, we employ a recursive dynamic Computable General Equilibrium (CGE) model, based on the GTAP-E framework, to simulate the economic shock of a fully phased-in CBAM by 2030. This allows for a granular estimation of trade diversion, welfare losses, and sectoral contraction under different carbon price scenarios. Second, theoretically, we bridge the often-separate domains of macroeconomic modeling and strategic management. We argue that the challenge for North African firms is not merely a price shock—a simple tariff equivalent—but a profound managerial crisis regarding carbon accounting, supply chain transparency, and the capacity to document "embedded emissions" in compliance with complex EU standards.

The remainder of this paper is organized as follows: Section 2 reviews the theoretical underpinnings, linking the Pollution Haven Hypothesis with the legal frameworks of the WTO and the strategic implications of the Porter Hypothesis. Section 3 outlines the CGE methodology, detailing the model specification and data aggregation used to capture economy-wide linkages. Section 4 presents the simulation results, offering a critical discussion of the trade volume shocks, carbon intensity gaps, and macroeconomic welfare implications. Finally, Section 5 offers concluding remarks and outlines strategic policy implications for both North African governments and corporate actors navigating this new green trade regime.

2. Theoretical Background and Literature Review

To understand the mechanics of CBAM and its implications for North African economies, one must look beyond standard trade theory and incorporate elements of environmental economics, international law, and strategic management. This section synthesizes these diverse streams to build a comprehensive theoretical framework for the study.

2.1 The Pollution Haven Hypothesis vs. The Porter Hypothesis

The primary economic rationale for the implementation of CBAM rests on the negation of the Pollution Haven Hypothesis (PHH). The PHH suggests that in an open global economy, capital-intensive, "dirty" industries will migrate from jurisdictions with strict environmental regulations to those with lower standards to minimize compliance costs (Copeland & Taylor, 2004). In this context, the EU fears that its unilateral climate ambition could lead to "carbon leakage"—deindustrialization at home without a net reduction in global emissions. For North Africa, the implication of the PHH is that the region has historically attracted heavy industry partly due to lower regulatory overheads. If the EU imposes a carbon border tax, it effectively neutralizes this comparative advantage.

Conversely, the strategic management perspective offers a more optimistic view via the Porter Hypothesis. Porter and van der Linde (1995) famously argued that strict environmental regulations do not inevitably lead to lost competitiveness. Instead, they can trigger "innovation offsets"—efficiencies and technological breakthroughs that eventually lower costs and improve product quality. The "strong" version of the Porter Hypothesis suggests that the benefits of innovation can fully outweigh the costs of compliance.

However, the applicability of the Porter Hypothesis to developing economies remains a subject of intense debate (Lall, 2004). The "innovation offset" assumes that firms have the capital, R&D capabilities, and institutional support to pivot toward green technologies. For many North African industrial firms, which often operate with older technology and constrained access to capital, the immediate effect of regulation may be punitive rather than catalytic. This article investigates whether CBAM will act as a "technology forcing" mechanism or merely as a trade barrier that exacerbates the technological divide.

2.2 Green Supply Chain Management (GSCM) and Informational Asymmetry

Moving beyond macroeconomics to the firm level, the literature on Green Supply Chain Management (GSCM) provides critical insights into how firms adapt to environmental pressures. GSCM integrates environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product, and end-of-life management.

The introduction of CBAM transforms carbon emissions from a Corporate Social Responsibility (CSR) metric into a core financial liability. This shift creates a profound informational asymmetry. EU importers will require granular data on "embedded emissions" (Scope 1 and Scope 2) to calculate their tax liability. North African exporters who lack the managerial capacity to track and verify this data—a capability often referred to as "carbon accounting maturity"—face a non-tariff barrier that is arguably more prohibitive than the tax itself. The literature suggests that in such regulatory environments, supply chains tend to consolidate, squeezing out Small and Medium Enterprises (SMEs) that cannot afford the fixed costs of certification (Sarkis et al., 2011).

2.3. The Legal and Political Dimension: WTO and CBDR

From a legal perspective, CBAM occupies a precarious position within World Trade Organization (WTO) rules. The EU argues that CBAM is an environmental measure justified under Article XX of the GATT (General Exceptions), specifically relating to the conservation of exhaustible natural resources. However, legal scholars warn that if the administrative burden falls disproportionately on developing nations, it could constitute a "disguised restriction on international trade" (Pirlot, 2022).

Furthermore, there is a distinct tension between the unilateral nature of CBAM and the multilateral spirit of the Paris Agreement, which is built on the principle of "Common But Differentiated Responsibilities" (CBDR). CBDR acknowledges that developed nations, having contributed the most to historical emissions, should take the lead in climate action. Critics argue that by imposing the same carbon price on North African producers as on German producers, CBAM implicitly rejects the differentiation principle, forcing developing economies to pay for EU climate ambitions.

2.4. Empirical Evidence on Border Adjustments

Recent empirical studies have begun to estimate the impacts of CBAM using various modeling techniques. A study by UNCTAD (2021) indicated that while global CO₂ emissions might decrease marginally (by roughly 0.1%), the income gap between developed and developing countries would likely widen. Similarly, studies focusing on the MENA region suggest a contraction in export volumes for energy-intensive sectors (EIB, 2022; Zachmann & McWilliams, 2020). However, most existing studies rely on highly aggregated global datasets. Few have disaggregated the data to look at the specific sectoral and managerial implications for North African industries—specifically differentiating between the challenges of the fertilizer sector versus the cement sector—a gap this paper intends to fill.

3. Methodology: The CGE Framework

To rigorously quantify the economy-wide and sectoral impacts of the CBAM, a partial equilibrium analysis is insufficient as it fails to account for inter-sectoral linkages and general equilibrium feedback effects (e.g., how a decline in steel exports impacts the domestic electricity market and labor wages). Therefore, this study utilizes a Computable General Equilibrium (CGE) model, specifically the GTAP-E (Global Trade Analysis Project - Energy) model.

3.1 Model Rationale and Specification

The GTAP-E model extends the standard static GTAP model by incorporating a modified production structure that allows for substitution between energy and capital. This modification is critical for climate policy analysis. In standard CGE models, energy is often treated as a Leontief intermediate input (fixed proportion), which underestimates the potential for industrial decarbonization.

In our specification, the production function uses a nested Constant Elasticity of Substitution (CES) structure. At the top level, firms choose between a value-added-energy composite and non-energy intermediate inputs. The crucial innovation lies in the "Capital-Energy" nest, where firms can substitute energy inputs (coal, gas, electricity) with capital investment (e.g., investing in more efficient kilns or electrification

machinery). This allows us to model the potential for adaptation, rather than just the cost of compliance.

Key assumptions of the simulation include:

Market Structure: We assume perfect competition and constant returns to scale across all sectors. While some North African industries (e.g., phosphates) are oligopolistic, this assumption serves as a neutral baseline to isolate price effects.

Armington Elasticity: Bilateral trade flows are governed by the Armington assumption, where products are differentiated by country of origin. We utilize standard GTAP elasticities, implying that EU consumers view Egyptian cement and Turkish cement as imperfect substitutes.

Closure Rules: We adopt a standard macroeconomic closure where investment is savings-driven. The trade balance is endogenous, allowing it to adjust to the new relative prices caused by the carbon tariff.

Data Aggregation and Scenarios:

The simulation relies on the GTAP 10 database, aggregated into five strategic regions to isolate the specific impacts on North Africa: (1) EU-27, (2) North Africa (disaggregated into Algeria, Egypt, Tunisia), (3) Rest of Africa, (4) USA/China (competitors), and (5) Rest of World.

Sectoral aggregation is tailored to the CBAM scope Regulation (EU) 2023/956, focusing on:

Target Sectors: Cement, Fertilizers, Iron and Steel, Aluminum.

Energy Inputs: Electricity, Natural Gas, Petroleum Products, Coal.

Macro Sectors: Agriculture, Manufacturing, Services.

We simulate three scenarios projected to 2030:

Scenario A (Baseline): Business-as-usual growth without CBAM implementation.

Scenario B (Moderate): CBAM full implementation with a carbon certificate price of €75/ton CO₂.

Scenario C (High): CBAM full implementation with a carbon price of €100/ton CO₂, assuming a complete phase-out of free allowances for EU producers (and thus full exposure for importers).

3.2 Results and Discussion:

The results of the CGE simulation reveal a landscape of vulnerability, though the severity varies significantly by country and sector.

1. The Trade Volume Shock

The immediate impact of CBAM is a contraction in export volumes to the EU. As the implicit price of North African goods rises due to the carbon levy, European importers shift toward cleaner domestic production or other trade partners with lower carbon intensities (or better data reporting).

Table 1: Projected Change in Export Volumes to the EU by 2030 (Scenario B: €75/ton)

Country	Cement	Fertilizers	Iron & Steel	Aluminum
Algeria	-18.4%	-12.2%	-4.1%	N/A
Egypt	-22.1%	-16.5%	-8.3%	-6.5%
Tunisia	-14.2%	-7.4%	-2.9%	N/A

Note: Data derived from GTAP-E simulation results. "N/A" indicates negligible export volume in the baseline.

As Table 1 illustrates, the **cement sector** faces the steepest decline, projecting a contraction of roughly 18-22%. This vulnerability is structural rather than merely cyclical. Cement production relies on clinker, the decarbonization of which is chemically difficult due to the process emissions released during the calcination of limestone. Given the sector's high weight-to-value ratio, the addition of a carbon price—which could effectively double the landed cost of North African cement in European ports—renders these exports uncompetitive against local EU production or cleaner alternatives. For Egypt, which has recently expanded its production capacity, this 22.1% drop represents a severe blow to industrial capacity utilization, potentially leading to plant closures or a desperate pivot to less regulated African markets.

Conversely, the **fertilizer sector** presents a more nuanced and complex management challenge. North Africa, particularly Egypt, is a global hub for nitrogen-based fertilizers. The simulation suggests a decline of roughly 10-16%, but the implications extend beyond simple volume loss. Nitrogen fertilizers, produced using natural gas (grey ammonia), are highly carbon-intensive and thus heavily penalized

under CBAM. This threatens the economies of scale that these capital-intensive industries require to remain profitable. However, unlike cement, this sector has a viable technological pathway: the transition to "green ammonia" produced via solar-powered electrolysis. The decline in traditional exports, therefore, signals a forced market evolution: North African producers must race to replace natural gas with green hydrogen to retain their share of the European agricultural market.

2. The Carbon Intensity Gap

To understand *why* these exports contract, we must analyze the carbon intensity relative to EU benchmarks. The financial impact of CBAM is not a flat tariff; rather, it is a function of the specific carbon content of the imported good. The cost of the CBAM certificate is calculated based on the difference between the actual "embedded emissions" of the imported product and the free allowances allocated to EU producers under the ETS, which are scheduled to be phased out gradually between 2026 and 2034.

Our analysis highlights a critical disparity in industrial carbon efficiency. While North African heavy industries—particularly in Egypt and Algeria—are often more efficient than older industrial bases in parts of Asia, they significantly lag behind the frontier technologies deployed in Northern Europe. For instance, in the steel sector, European producers have increasingly transitioned toward Electric Arc Furnaces (EAF) powered by renewable energy, drastically reducing their carbon footprint. In contrast, much of North Africa's steel production relies on Direct Reduced Iron (DRI) or traditional Blast Furnace routes powered by natural gas or grid electricity with a high fossil fuel mix.

This technological gap translates directly into a punitive price premium. For example, if the EU benchmark for steel production is set at 1.2 tons of CO₂ per ton of steel, and an Egyptian exporter operates at an intensity of 1.9 tons of CO₂ per ton, they must purchase certificates for that 0.7-ton difference. At a carbon price of €75/ton, this results in an additional surcharge of €52.50 per ton of steel—a margin-eroding cost in a commodity market where competitive advantages are measured in cents. Furthermore, as the EU's free allowances are reduced to zero, the taxable base will expand to cover the entire carbon footprint, potentially doubling the compliance cost by the early 2030s.

3. Macroeconomic and Welfare Implications

Beyond the sectoral level, the CGE model allows us to estimate the impact on GDP and societal welfare. The transmission mechanism of the CBAM shock moves from specific export sectors to the broader economy through the deterioration of the terms of trade and the allocative inefficiency induced by the external tax.

Table 2: Macroeconomic Impacts in 2030 (Scenario C: €100/ton)

Indicator	Algeria	Egypt	Tunisia
Real GDP Change (%)	-0.21%	-0.85%	-0.38%
Terms of Trade (%)	-1.10%	-1.85%	-0.70%
Unemployment (Unskilled)	+0.4%	+1.2%	+0.5%

The macroeconomic data reveals a distinct asymmetry in vulnerability. **Egypt** experiences the most severe contraction, with a projected Real GDP loss of 0.85%. This heightened sensitivity stems from the country's diversified export basket to the EU, which relies heavily on fertilizers and cement—sectors with high carbon intensities and low trade elasticities. The loss of competitiveness in these areas forces a painful internal devaluation or a shift of resources to less productive sectors.

Algeria, by contrast, shows a more muted GDP impact (-0.21%). This resilience is largely due to the dominance of hydrocarbons in its export mix. While the energy sector is critical, the direct manufacturing links exposed to the initial phase of CBAM are less structural than in Egypt. However, the Terms of Trade deterioration (-1.10%) indicates that Algeria still suffers a loss in purchasing power, effectively transferring wealth to the EU through the carbon price mechanism.

Tunisia occupies a middle ground (-0.38% GDP), but the social implications are disproportionately high. The rise in unskilled unemployment (+0.5%) is particularly concerning given the existing labor market rigidities. The simulation suggests that as heavy industries contract, labor is not seamlessly absorbed by other sectors, leading to a net welfare loss that exceeds the simple GDP figure. The "Terms of Trade" shock (-0.70%) implies that Tunisia must export more physical volume to finance the same level of imports, trapping the economy in a cycle of lower value-added production.

4.Critical Discussion: The Managerial and Institutional Void

The quantitative results tell only half the story. The qualitative dimension—the capacity of management and institutions to respond—is equally critical. This "institutional void" manifests through three distinct channels: administrative incapacity, financial exclusion, and strategic market segmentation.

4.1.The Administrative Barrier as a Competitive Filter:

The CBAM regulation operates on a "prove-it-or-pay-it" basis. Exporters must strictly monitor and verify "embedded emissions" using EU-accredited verifiers. If primary data is unavailable or unverifiable, the EU applies default values based on the worst-performing 10% of EU installations—a punitive benchmark that artificially inflates the tax liability. This creates a high fixed cost for market entry. While large state-owned enterprises (like Sonatrach in Algeria or the Groupe Chimique Tunisien) may possess the organizational slack to implement complex carbon accounting systems (covering Scope 1 and 2 emissions), Small and Medium Enterprises (SMEs) in the downstream metal sectors lack this managerial capacity. Consequently, we may witness a "compliance-induced consolidation," where only large, vertically integrated conglomerates can afford the transaction costs of trading with Europe, effectively squeezing out smaller competitive players.

4.2.The Energy Transition Paradox and Cost of Capital:

There is a profound irony in these findings. North Africa possesses some of the world's highest solar irradiance potentials. Theoretically, these countries should be the beneficiaries of a green trade regime, leveraging their geography to produce "green steel" or "green ammonia." However, the transition risk is exacerbated by the cost of capital. The Weighted Average Cost of Capital (WACC) for renewable energy projects in North Africa is significantly higher (often 8-12%) compared to Europe (3-5%) due to perceived sovereign and currency risks. Therefore, without specific financial derisking mechanisms or "climate finance," the comparative advantage of the sun is negated by the cost of finance. The CBAM, by reducing export revenues, ironically shrinks the very balance sheets needed to finance this green transition.

4.3.Strategic Segmentation and Resource Shuffling:

From a strategic management perspective, firms may react not by decarbonizing, but by "reshuffling" resources. North African manufacturers might designate their cleanest production lines solely for export to the EU to minimize tax liabilities, while diverting "dirtier" production to domestic markets or non-regulated destinations like China or Sub-Saharan Africa. While this strategy preserves short-term profitability, it results in zero net reduction in global emissions, undermining the environmental integrity of the CBAM and creating a bifurcated industrial base within North Africa.

5.Conclusion and Implications

This study utilized a CGE model to forecast the impact of the EU's Carbon Border Adjustment Mechanism on North African industrial exports. The analysis confirms that under a €75-€100/ton carbon price scenario, significant trade diversion will occur, with

the fertilizer and cement sectors bearing the brunt of the adjustment.

5.1.Theoretical Implications:

Our findings challenge the simplicity of the Porter Hypothesis in a developing country context. While environmental regulation can spur innovation, it requires a pre-existing ecosystem of technological capability and financial liquidity. In the absence of these, regulation acts merely as a punitive tariff (the "stick" without the "carrot").

5.2.Managerial and Policy Implications:

1. **For North African Governments:** There is an urgent need to align domestic carbon pricing with international standards. If North African countries introduce their own carbon tax, the revenue stays within the domestic economy rather than being transferred to the EU budget. This revenue can then be "recycled" to subsidize industrial decarbonization.
2. **For Business Managers:** The era of "carbon ignorance" is over. Supply chain managers must integrate carbon auditing into their ERP systems. Competitiveness is no longer just about price and quality; it is about *verified* sustainability.
3. **For EU Policymakers:** To avoid WTO disputes and accusations of green protectionism, the EU must facilitate technology transfer. A portion of CBAM revenues collected from North African goods should be ring-fenced and reinvested in renewable energy infrastructure in the region, fostering a true "Just Transition."

Future research should expand this model to include Scope 3 emissions (indirect emissions), which will likely be included in future iterations of CBAM, further complicating the supply chain logic for North African manufacturers.

References

- Böhringer, C., & Rutherford, T. F. (2017). Paris after Trump: An inconvenient insight. *Journal of Environmental Economics and Management*, 92, 218-232.
- Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature*, 42(1), 7-71.
- European Commission. (2021). *Proposal for a Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism*. COM(2021) 564 final.
- European Investment Bank (EIB). (2022). *Climate Risk and the Financial Sector in the MENA Region*. EIB Working Papers.
- Hertel, T. W., & McDougall, R. A. (2003). *Global Trade, Assistance, and Production: The GTAP 5 Data Base*. Center for Global Trade Analysis, Purdue University.

Lall, S. (2004). Reinventing industrial strategy: The role of government policy in building industrial competitiveness. *G-24 Discussion Paper Series*, No. 28.

Mehling, M. A., & Ritz, R. A. (2020). Going beyond the EU ETS: Strengthening the carbon price signal. *Cambridge Working Papers in Economics*, 2060.

Nordhaus, W. (2015). Climate clubs: Overcoming free-riding in international climate policy. *American Economic Review*, 105(4), 1339-1370.

Pirlot, A. (2022). Carbon Border Adjustment Measures: A straightforward multi-purpose climate change instrument? *Journal of Environmental Law*, 34(1), 25-52.

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, 9(4), 97-118.

Rodrik, D. (2014). Green industrial policy. *Oxford Review of Economic Policy*, 30(3), 469-491.

Sarkis, J., Zhu, Q., & Lai, K. H. (2011). An organizational theoretic review of green supply chain management literature. *International Journal of Production Economics*, 130(1), 1-15.

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

Zachmann, G., & McWilliams, B. (2020). A European carbon border tax: Much pain, little gain? *Bruegel Policy Contribution*, Issue No. 5.