Carbon Border Adjustment Mechanism vs. Carbon Tax: General Equilibrium Insights from South Africa

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1. Introduction and Motivation

The increasing alignment of trade policy with climate objectives marks a significant shift in the global economic landscape. Among the most consequential developments is the European Union's Carbon Border Adjustment Mechanism (CBAM)**,** introduced under the *Fit for 55* package to support the EU's emissions reduction target of at least 55 per cent by 2030. By imposing a carbon price on imports of emissions-intensive goods, CBAM aims to prevent carbon leakage and safeguard the competitiveness of EU producers. However, for carbon-intensive exporting economies in the Global South, CBAM introduces a new form of climate-conditioned trade exposure.

South Africa represents a particularly outstanding case. The country is highly carbon-intensive, with coal accounting for the majority of electricity generation and a large share of total emissions. At the same time, the European Union is a key export destination, especially for CBAM-covered products such as aluminium, iron, and steel. While South Africa introduced a national carbon tax in 2019, its effective rate remains low due to extensive exemptions, allowances, and the exclusion of the electricity sector, limiting its credibility as a mitigation instrument and its recognition under CBAM.

This paper examines whether domestic carbon tax reform can serve as a strategic response to CBAM, mitigating adverse trade and welfare impacts while advancing national decarbonization objectives. Rather than analysing CBAM as a unilateral external shock, we explicitly examine the interaction between border carbon measures and domestic fiscal climate policy**,** an area that remains underexplored in the CGE literature.

2. Background and Stylised Facts:

2.1 Carbon Border Adjustment Mechanism (CBAM)

2.1.1 Definition and Description of CBAM

The Carbon Border Adjustment Mechanism (CBAM) is a policy instrument introduced by the European Union (EU) to impose a price on carbon emitted in the production of imported carbon-intensive goods. The policy is to be implemented in phases, beginning with a transitional reporting period from 2023 to 2025 and moving to full financial adjustment in 2026 (European Commission, 2023a; 2023b). The CBAM is a border carbon pricing measure that ensures imported goods reflect the GHG emissions embedded in their production (European Parliament, 2022). The mechanism is primarily designed to address carbon leakage, the phenomenon where firms relocate production to jurisdictions with weaker climate regulations, thereby undermining global mitigation efforts (Tvinnereim & Mehling, 2023). Through CBAM, imports are charged a carbon cost equivalent to the European Union Emission Trading System (EU ETS) allowance price, thus aligning domestic and foreign climate cost burdens and maintaining fair competition between EU and non-EU producers (Dröge et al., 2009; Görlach & Zelljadt, 2018).

CBAM seeks to equalise the carbon costs faced by domestic producers under the EU Emissions Trading System (EU-ETS) and those by foreign producers exporting carbon-intensive goods into the EU market. The EU ETS is a cornerstone of EU's climate policy, requiring polluters to pay for their greenhouse gas (GHG) emissions (European Commission, 2025). Launched in 2005 as the world's first carbon market, it is now one of the largest globally. The system contributes to reducing overall EU emissions while generating revenues to finance the green transition. It covers emissions from electricity and heat generation, industrial manufacturing, and the aviation sector, which collectively account for approximately 40% of the EU's total GHG emissions. In 2024, the EU ETS expanded to include emissions from maritime transport. The system operates across all EU member states, as well as in Iceland, Liechtenstein, and Norway, and has been linked to the Swiss ETS since 2020 (European Commission, 2025). As seen in Figure 1, EU ETS allowance prices increased markedly from below €10/tCO_2 in 2018 to peaks near €90–100/tCO_2 in 2022, reflecting tightening climate ambition and market expectations. Although prices became more volatile thereafter, they remained elevated through 2024–2025, consistently well above pre-2020 levels.

Figure 1: EU ETS Allowance prices from 2018 to 2025

Source: European Commission (2025)

A key determinant of the impact of CBAM on exporting countries is the level and extent to which domestic climate policies already make provision for a price on carbon and how strictly. Countries with existing carbon taxes or emission trade systems can partially offset CBAM liabilities, as domestic carbon costs reduce the net adjustment owed at the EU border. Conversely, countries with low or no carbon pricing face higher CBAM costs, paying the full ETS-equivalent adjustment.

South Africa's carbon tax, being introduced in 2019 and strengthened under Phase Two from 2026, is projected to reach an effective rate of approximately US\$20/tCO_2e (≈R308/tCO_2e) in 2026 (National Treasury, 2024), which remains below the 2026 EU ETS price of roughly US\$100/tCO_2e (≈ €90-€100/tCO_2e (European Commission, 2025). As a result, South African exporters of steel, aluminium, cement, and chemicals will still incur significant CBAM costs, whereas countries with carbon prices closer to the EU ETS face minimal adjustments (World Bank, 2016; Dröge et al., 2009). The EU ETS itself has helped reduce the carbon intensity of the EU economy while establishing a common carbon price that CBAM will extend to imports, gradually replacing free allowances as the main tool to mitigate carbon leakage risk from 2026 onward (European Commission, 2025).

2.1.2 CBAM Scope

Within the EU context, CBAM applies to imports of iron and steel, aluminum, electricity, cement, hydrogen, and certain fertilisers as well as selected precursors and limited number of downstream products (for example, screws and bolts) (Takeda & Arimura, 2024). Ensuring a more comprehensive representation of carbon content in traded products, the mechanism covers both direct emissions from industrial processes (Scope 1) and indirect emissions associated with electricity consumption (Scope 2) (European Commission, 2023b). During the transitional phase, default values are used to estimate emissions when firm-specific data are unavailable, but over time, exporters will be required to provide verified emissions information to improve accuracy (European Commission, 2023b). The certificate prices will mirror prevailing ETS allowance prices, thereby aligning internal and external carbon costs with core climate-policy principles. The mechanism is designed to progressively include more economic sectors and products, expanding thus the scope: coverage of plastics and chemicals in 2026/2027 and all EU-ETS sectors by 2030.

The CBAM regulation does not currently allow the suspension or removal of goods from the scope of CBAM. Therefore, the EC has "included, as part of the proposal adopted last December 17, a new Article 27a would allow the Commission to remove goods temporarily." Crucially, Article 27a can apply retrospectively. Once it has been adopted by the co-legislators, affected goods can be removed from the scope of CBAM with retroactive effect. This means, in a worst-case scenario, the EC has the power to remove any CBAM good from CBAM's scope, retroactive to any date from January 1, 2026, the "serious and unforeseen circumstances" were deemed to have begun. Providing there has been no objection from the European Parliament or Council, the EC can invoke Article 27a for up to five years and it can also be "tacitly extended for further periods of an identical duration," the article read. (Eurometal, 2025).

2.1.3 Global Implications of CBAM and countries' exposure

By design, CBAM focuses on sectors that are globally emissions-intensive and trade-exposed. Beyond mitigating carbon leakage, CBAM has profound effects on the global trading system, altering value chains, distributional outcomes, and competitiveness. The mechanism disproportionately impacts export-oriented developing nations that specialise in carbon-intensive, low-value-added production stages, even though it strengthens the position of the EU and other developed economies with established carbon pricing. CBAM risks exacerbating carbon-economic inequality by allocating carbon costs at the point of production rather than at the point of consumption, placing environmental responsibility on nations that bear a large share of embedded emissions but capture a relatively small share of global value added. These disparities are predicted to worsen as CBAM's sectoral reach and emission coverage increase, raising questions about equity, North-South trade relations, and the inclusiveness of global climate governance. (Li et al, 2026).

The World Bank Group (World Bank, 2025) created a framework to evaluate countries' potential exposure to the CBAM, using measures of excess carbon payments relative to EU producers (% of total exports), gross sectoral output, and economic conditions (economic growth proxied by GDP). "Although macroeconomic impacts are expected to be small, some countries (like Mozambique in aluminium and Egypt in fertiliser) could see economically meaningful reductions in competitiveness in the EU market." (World Bank, 2025). Figure 2 demonstrates the Trade Exposure Index and the Output exposure Index for the example of the Iron and Steel sector globally: in the top graph, the Carbon payment per dollar of EU Production and imports (%) is shown vis-à-vis the Exports of iron and steel to EU as a % share of exports iron and steel to the world while in the second graph vis-à-vis the % share of iron and steel output.

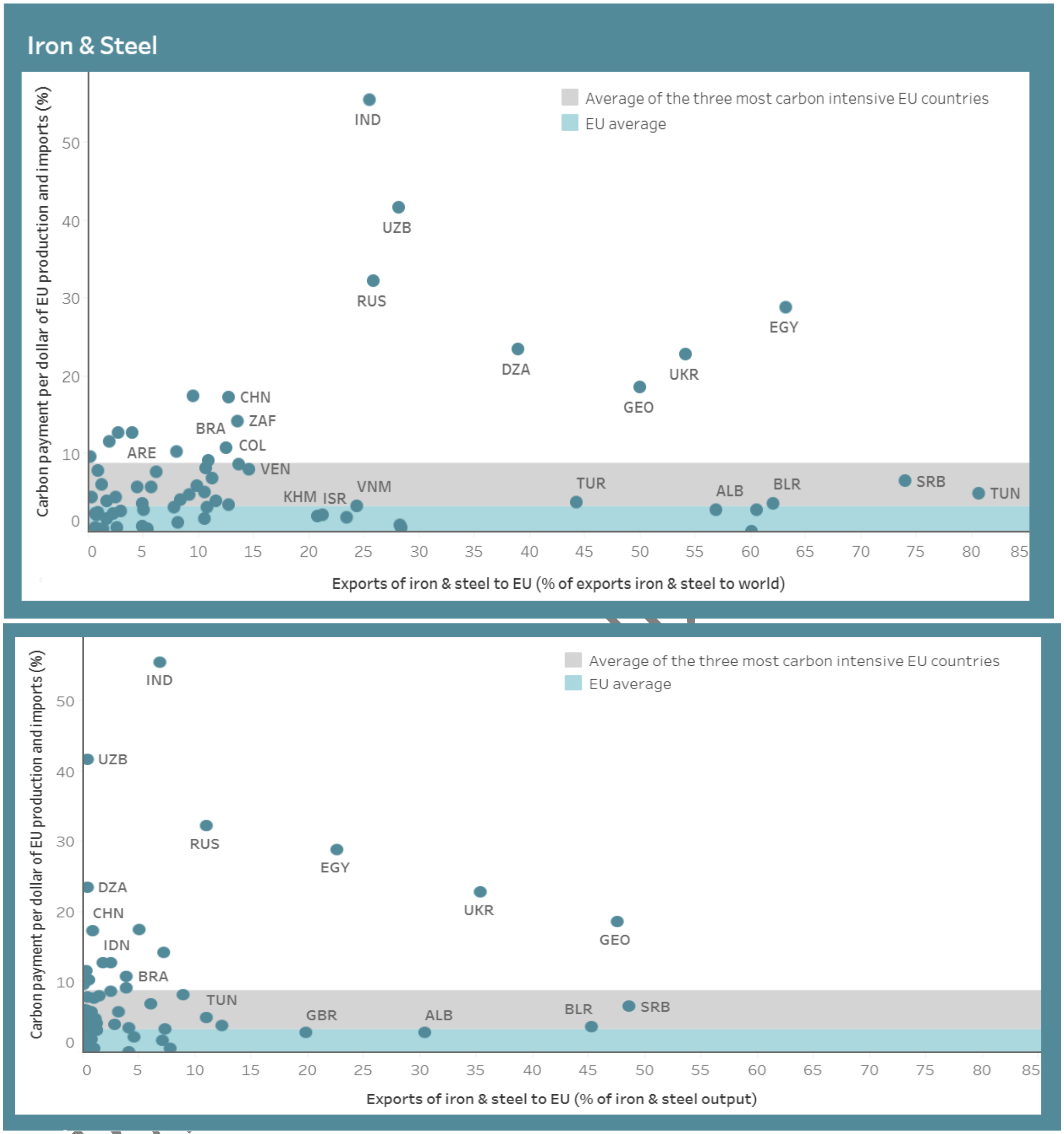

Figure 2: CBAM Trade Exposure Index and Output Exposure Index; Iron and Steel

Source: World Bank (2026)

The figure shows important cross-country heterogeneity, with countries such as India, Russia and Ukraine showing both high carbon payments per dollar and non-negligible export exposure, making them highly vulnerable to CBAM-related costs. On the other hand, countries such as Serbia and Tunisia have a high share of iron and steel exports to the EU but low carbon intensity, making them less vulnerable to CBAM pressures.

For export-oriented developing economies like South Africa, the specific sectors are particularly significant. South Africa's iron and steel, aluminium, and chemicals industries are major contributors to national exports, yet they are highly carbon-intensive due to the country's reliance on coal for nearly 80% of electricity generation (Anekwe et al., 2025; Bohlmann et al., 2023). This combination of high carbon intensity, export exposure, and limited adaptive capacity constitutes South Africa's total vulnerabilities under CBAM, as outlined by Maimele (2023). Approximately US$2.8 billion of South African exports, representing key manufacturing and industrial outputs, face short-term exposure to CBAM, with potential repercussions for production, employment, and overall economic competitiveness. The vulnerability is amplified by South Africa's export profile, as carbon-intensive sectors such as steel, aluminium, and cement are directly subject to CBAM tariffs, and the EU accounted for 21% of South Africa's total exports in 2022 (Maimele, 2023). Based on the finalised list of CBAM-covered products adopted on 16 May 2023, roughly US$2.8 billion (≈R52.4 billion) of exports are exposed, representing approximately 10.3% of South Africa's exports to the EU, 2.2% of global exports, and 0.8% of national GDP (Maimele, 2023b). These total vulnerabilities are expected to increase as the EU expands the scope of CBAM and as other countries adopt similar carbon-border measures.

2.2 Carbon Tax in South Africa

2.2.1 Current Carbon Tax and Industries Affected

South Africa's carbon tax, introduced in June 2019, is the country's primary domestic mitigation instrument and the first economy-wide carbon pricing system in Africa (National Treasury, 2019). The tax began at a headline rate of R120/tCO_2e , reflecting a phased approach consistent with the polluter-pays principle, aimed at encouraging firms to internalise the external costs of greenhouse gas emissions and to shift towards cleaner technologies (NCCRP, 2011; NDP, 2012). During Phase 1 (2019-2025), the carbon tax provided extensive transitional relief, including 60-95% tax-free allowances based on trade exposure, performance, and carbon budgets, as well as offset opportunities (National Treasury, 2019). Revenue-recycling measures such as the electricity generation levy credit, renewable energy premium, and energy-efficiency savings incentive further reduced compliance costs and supported low-carbon investment (National Treasury, 2023). To protect energy-intensive and trade-exposed sectors such as mining, iron and steel, aluminium, and chemicals, the government ensured that the carbon tax did not immediately raise electricity prices during the first phase, a critical concession given South Africa's coal-dependent energy system (Bohlmann et al., 2023). The phased introduction allowed industries time to adapt operations, improve reporting systems, and invest in cleaner technologies.

The carbon tax operates within the country's broader climate policy framework, including the South Africa Low-Emissions Development Strategy (SA-LEDS) and updated Nationally Determined Contributions (NDCs). South Africa has committed to a net-zero economy by 2050, with NDC targets of 398-510 MtCO_2e for 2025 and 350-420 MtCO_2e for 2030, submitted at COP26 (UNFCCC, 2021). Meeting these goals requires rapid emissions reductions in electricity and transport, alongside declines in industrial process emissions. The NDCs identify the carbon tax as a central instrument for delivering cost-effective mitigation and supporting the transition to a low-carbon, climate-resilient economy (NCCRP, 2011; NDP, 2012). Complementary fiscal instruments-such as the carbon fuel levy and electricity-related environmental levies-broaden the carbon pricing signal across the economy and reinforce the tax's role in supporting South Africa's long-term decarbonisation strategy (National Treasury, 2024).

2.2.2 Planned Carbon Tax (Phase Two and Future Trajectory)

South Africa’s carbon tax is expected to enter Phase Two in 2026, marking a deliberate tightening of the carbon-pricing framework in line with the country’s long-term decarbonisation commitments, including its Nationally Determined Contributions (NDCs) under the Paris Agreement (UNFCCC, 2021). According to the National Treasury’s Phase Two Discussion Paper (2024), the next phase introduces several key reforms to strengthen the tax's environmental effectiveness. These reforms include reductions in tax-free allowances, adjustments to the carbon budget allowance, and a recalibration of the offset mechanism, all aimed at reducing reliance on transitional reliefs and ensuring that the effective carbon price rises over time (National Treasury, 2024). International evidence suggests that carbon taxes with extensive exemptions and low effective prices tend to have limited mitigation impacts, whereas gradually tightening tax designs are more likely to induce sustained emissions reductions and technological change (World Bank, 2016; Ntombela et al., 2019).

Under Phase Two, the effective carbon price paid by major emitters is projected to increase significantly as allowances are gradually phased down and the gap between statutory and net tax liabilities narrows. This stronger price signal is viewed as essential to driving sustained emissions reductions in electricity generation, mining, iron and steel, chemicals, cement, and petroleum refining, which collectively account for a large share of national greenhouse gas emissions and are central to South Africa’s industrial structure and export competitiveness (TIPS, 2020). Dynamic computable general equilibrium (CGE) modelling for South Africa indicates that higher effective carbon prices can achieve meaningful emissions reductions, particularly in energy-intensive sectors, although the magnitude of economic impacts depends critically on allowance design, revenue recycling, and complementary policies (Bohlmann et al., 2019; Ntombela et al., 2019). However, the negative impact of the carbon tax on GDP is greatly reduced by the manner in which the tax revenue is recycled in the form of production subsidy for all industries (Van Heerden et al., 2016).

Industry analyses similarly anticipate further statutory tax rate increases beyond 2025, supported by declining allowances to ensure alignment with South Africa's 2025 and 2030 NDC targets (National Treasury, 2023). To enable South Africa to meet its NDC commitments for 2025 and 2030, revisions to the carbon tax rates for Phase Two (1 January 2026–31 December 2030) were therefore deemed necessary. These revisions aim to strengthen the carbon price signal, reduce the gap between statutory and effective carbon prices, and provide long-term policy certainty regarding the evolution of carbon pricing in South Africa. The 2022 Budget first outlined this trajectory, proposing annual increases of at least US$1 per tonne between 2023 and 2025, followed by sharper escalations to US$20/$tCO_2e$ in 2026, at least US$30/$tCO_2e$ by 2030, and US$120/$tCO_2e$ by 2050 (National Treasury, 2024). Such trajectories are broadly consistent with international guidance suggesting that predictable and rising carbon prices are essential for aligning investment decisions with long-term decarbonisation pathways (World Bank, 2016).

Following public consultations, these proposed carbon tax price paths were converted into Rand-denominated rates and formally incorporated into the 2022 Taxation Laws Amendment Act, which now sets out the legally binding schedule for carbon tax increases during Phase Two. The revised price path is expected to result in significantly higher effective carbon prices faced by major emitters, particularly as tax-free allowances are gradually reduced and offset provisions become more stringent, thereby strengthening incentives for decarbonisation in electricity generation, mining, metals, chemicals, and other energy-intensive sectors. Evidence from South African CGE studies suggests that such policy certainty and rising effective prices are critical for inducing firms to adopt cleaner technologies and adjust production processes over time, rather than merely absorbing the tax as a cost (Van Heerden et al., 2016 ; Bohlmann et al., 2019).

Table 1 shows a steady and substantial increase in South Africa's carbon tax rate between 2023 and 2030, reflecting the transition to Phase Two of the carbon tax regime. The rate rises from R159/tCO_2e in 2023 to R308/tCO_2e in 2026 and is projected to reach R462/tCO_2e by 2030, signalling a gradual strengthening of domestic carbon pricing and increasing cost pressures on carbon-intensive activities over time.

Table 1: Carbon Tax rates -2023 to 2030

YEAR	CARBON TAX RATE (R/tCO_2e)
2023	159
2024	190
2025	236
2026	308
2027	347
2028	385
2029	424
2030	462

Source: National Treasury. (2024).

A central component of South Africa's Phase Two carbon tax reforms is the proposed adjustment to the basic tax-free allowance, which currently grants a 60% exemption on all taxable emissions during Phase One. This allowance, provided without requiring firms to undertake emissions-reducing investments, was designed as a transitional measure to ease the initial introduction of the carbon tax. However, it now constitutes the most significant policy lever for strengthening the country's effective carbon price in line with its updated Nationally Determined Contribution (NDC) trajectory and the net-zero commitments articulated in the South Africa Low-Emissions Development Strategy (SA-LEDS) (National Treasury, 2022; DFFE, 2020).

Both international and domestic evidence indicate that substantially higher carbon prices will be required for South Africa to achieve its medium- and long-term mitigation targets. Studies conducted suggests that developing economies need carbon prices in the range of US$25-

50/tCO_2e by 2030 to remain consistent with the Paris Agreement's 2°C pathway, ultimately converging toward US$100/$tCO_2e$ (IMF, 2023). More specific modelling by the International Monetary Fund (2023) concludes that South Africa would require a carbon price of roughly US$120/$tCO_2e$ by 2030 to achieve the NDC emissions range of 350- 420 $MtCO_2e$ and to remain on course for net-zero emissions by 2050. Complementary domestic projections by the National Business Initiative (2021) estimate that South Africa's carbon price would need to reach approximately US$40 in 2030, US$110 in 2040, and US$175/$tCO_2e$ by 2050 to support a credible decarbonisation pathway.

In response to these findings, and to align the carbon tax with South Africa's mitigation commitments while enabling a just transition, the National Treasury has proposed a phased tightening of the basic tax-free allowance, accompanied by expanded incentive-based allowances. The proposed reforms include a 10-percentage-point reduction in the basic tax-free allowance in 2026, followed by annual reductions of 2.5 percentage points between 2027 and 2030 (National Treasury, 2024). These reductions will be complemented by a 15-percentage-point increase in the carbon offset allowance in 2026, and a 5-percentage-point increase in the performance allowance for combustion emissions in the same year. After 2031, further reductions of at least 2.5 percentage points per year are envisaged, calibrated to reflect South Africa's evolving obligations under the Paris Agreement and future NDC submissions. Collectively, these adjustments are expected to increase the effective carbon price, encourage emissions reductions, and incentivise the adoption of low-carbon technologies. By strengthening carbon-pricing signals and shifting the emphasis toward performance and offset-based mechanisms, the Phase Two reforms aim to drive investment in clean technologies, support a socially inclusive low-carbon transition, and enhance South Africa's readiness to participate in rapidly expanding global carbon markets aligned with the 2°C and 1.5°C temperature-stabilization goals (National Treasury, 2024; IMF, 2023; NBI, 2021).

3. Literature Review

In this section, we situate this paper within the economic literature that analyzes the relationship between carbon pricing, international trade, and climate policies from a general equilibrium perspective. Our aim is not to provide an exhaustive country-by-country review, but rather to identify the main analytical approaches and findings established in the CGE literature that are relevant for studying the interaction between border adjustment mechanisms and domestic climate fiscal policies. Given the methodological nature of this contribution, we adopt a comparative perspective that combines South African-specific evidence with findings from other regions and multi-regional frameworks.

3.1 Macroeconomic, Sectoral and Distributional Effects of Carbon Pricing in South Africa

First, we review the literature examining carbon pricing in South Africa. A substantial part of the literature assessing carbon pricing in South Africa is based on Computable General Equilibrium (CGE) models, complemented by partial equilibrium or macro-econometric approaches. Taken together, these approaches are consistent with the finding that the economic effects of carbon pricing depend heavily on South Africa's production structure, which is characterized by high energy consumption, heavy reliance on coal, and a highly-concentrated electricity sector.

Early CGE assessments on a South African carbon tax provide a consistent picture of the trade-offs involved. Devarajan et al. (2011) examine a stylized carbon tax designed to achieve an exogenous −15% CO_2 reduction target and report relatively small aggregate welfare costs (around −0.33% equivalent variation), highlighting the role of pre-existing distortions (in labor markets). In a dynamic framework, Alton et al. (2014) show that a phased-in carbon tax rising to US$30/t$CO_2$ can reduce emissions by roughly 36–41% by 2025, with GDP losses around 1.1–1.2% and employment about 0.5–0.6% below baseline, and with border carbon adjustments mitigating competitiveness-related losses. Van Heerden et al. (2016) further highlight the sensitivity of macroeconomic outcomes to revenue recycling. Using a dynamic CGE model calibrated to South Africa, they report substantial reductions in emissions growth (35-44%) under a carbon tax, while cumulative GDP effects vary widely (cumulative 1.5% to 6.5%) depending on whether revenues are recycled through reductions in distortionary taxes, transfers, or other policy instruments. Their analysis also shows that output and employment losses are concentrated in energy-intensive sectors, whereas targeted recycling schemes can significantly soften adverse effects.

These results reinforce a core result from broader environmental taxation literature, i.e., the economic costs of carbon pricing depend on how revenues are used as on the level of the tax itself. This finding is consistent with earlier theoretical and applied contributions emphazising interactions between environmental taxes and pre-existing fiscal distortions

(Bovenberg & de Mooij, 1994; Goulder, 1995), and reflects the applied general equilibrium tradition formalized by Shoven and Whalley (1992).

More recent methodological advances introduce greater sectoral and emissions detail. Nong (2020) develops an electricity-detailed extension of the global GTAP-E framework that allows for flexible carbon liability rules and explicit coverage of non-CO_2 emissions. Applied to South Africa, this framework suggests that a carbon price of around US$9 per ton of CO_2e can reduce total emissions by approximately 12–16%, while real GDP declines by about 1–1.5%. The contraction is most pronounced in coal-related and other fossil-based sectors, whereas renewable electricity technologies expand. These results illustrate how broader emissions coverage and more detailed electricity representation tend to increase estimated economic costs relative to CO_2-only specifications, while amplifying structural reallocation effects.

A growing strand of the literature assesses the distributional impact of carbon pricing policies. Ntombela et al. (2019) and Okonkwo (2020) show that the effects on household welfare depend heavily on the use of income and the interaction between the carbon tax and the existing tax system— an approach consistent with the traditional double-dividend literature and the analysis of welfare effects in the presence of pre-existing distortionary taxes (Goulder, 1995). In line with the double-dividend literature, recycling revenues through targeted transfers or reductions in distortionary taxes can substantially attenuate welfare losses and, in some cases, yield net gains for lower-income households (Alton et al., 2014; Ntombela et al., 2019; Okonkwo, 2020). These studies show that carbon pricing in South Africa serves as a mitigation tool, but that the main drivers and sectors are contextualized in terms of an effective level, sectoral pricing, and the regulatory framework employed.

Recent contributions also place carbon pricing in South Africa within its post-implementation context. Alongside CGE-based assessments, institutional and political economy analyses emphasize challenges related to policy credibility, legitimacy, and coordination (Winkler et al., 2010). From a development perspective, broader studies argue that in emerging economies the effectiveness of climate fiscal policies depends critically on their interaction with existing inequalities and structural constraints (Jakob et al., 2014). Complementing these perspectives, Makrelov and Gasealahwe (2024) show that effective carbon tax rates in South Africa remain very low—typically well below levels associated with meaningful technological change—suggesting that current policy settings are unlikely to generate strong environmental or economic effects without further reform.

Non-CGE evidence.

Complementary empirical evidence based on quasi-experimental and firm-level methods suggests that carbon pricing can reduce emissions without large adverse macroeconomic effects. Andersson (2019) finds that Sweden's carbon tax led to substantial emissions reductions with no detectable negative impact on GDP growth, while Metcalf and Stock (2020) report no robust evidence that carbon taxes hinder macroeconomic growth across countries. Firm-level analyses indicate that emissions reductions are driven mainly by efficiency improvements rather than large output contractions (Martin et al., 2016; Best et al., 2020). In the South African context, institutional analyses show that effective carbon tax rates remain very low, limiting incentives for technological change (Gasealahwe et al., 2024). While these approaches provide credible causal and institutional insights, they abstract from the economy-wide feedbacks central to CGE analysis.

3.2 The role of domestic carbon pricing in relation to international climate–trade instruments, with a focus on the EU CBAM

Second, we examine the literature analyzing the interaction between domestic climate policies and international trade. CGE models have been widely used to study carbon leakage effects and loss of competitiveness associated with unilateral climate policies[1], following the methodological tradition established by general equilibrium models applied to fiscal and trade policy (Shoven and Whalley, 1992). In this context, border carbon adjustments (BCA) are proposed as an effective instrument to level the playing field between domestic and foreign producers.

Early CGE analyses show that, while border carbon adjustments cannot eliminate carbon leakage, they can reduce it significantly. Böhringer et al. (2012) find that BCAs offset 30% and 50% of the leakage induced by unilateral policies. By means of a CGE calibrated to the United States, Winchester et al. (2011) obtain leakage reductions of approximately 30%when adopted unilaterally and, reaching around 60% when implemented by a coalition of countries. However, both studies agree that, despite the substantial reduction in carbon leakage, the additional contribution of border adjustments to reducing global emissions is limited, as these mechanisms do not significantly alter incentives for decarbonization outside the regulated regions.

subsequent CGE analyses extend these insights to welfare outcomes. Several studies obtain global welfare losses in the range of 0.1–0.5%, disproportionately concentrated in carbon-intensive export economies. Sun et al. (2023) quantify that CBAM delivers only marginal additional global emissions reductions (below 2% relative to unilateral climate policies) while generating welfare losses for carbon-intensive exporting countries in the range of 0.2% to 0.6%, reinforcing concerns about its environmental inefficiency and distributive inequity.

Recent multiregional CGE-based studies come to the same conclusion that BCAs have a differential impact on global and regional welfare and the developing countries are the ones who experience relatively larger welfare losses. Böhringer et al. (2022) find that the EU CBAM is mainly successful in transferring the adjustment costs over to the carbon-intensive exporters but does not generate strong incentives for domestic decarbonization or policy responses in affected countries. Ernst et al. (2023) use a dynamic CGE model to analyze BCAs as part of climate clubs. They find reduced impacts of BCAs on global emissions without broad participation, while non-member regions frequently experience welfare reductions of more than 0.5% of their GDP. In the absence of compensatory transfers, these results create very weak incentives for countries outside the climate clubs to become members. Lin and Zhao (2024) state that under expanded BCA scenarios, developing countries reduce their GDP on a higher basis compared to advanced economies. Zhang et al. (2024) further show that under the current EU CBAM design, global emissions reductions remain below 1%, while GDP losses in carbon-intensive exporting regions typically range between 0.3% and 0.8%. When CBAM coverage is expanded to additional sectors or broader emissions scopes, these losses can exceed 1% of GDP, with only marginal additional gains in global emissions mitigation. Lim and Kim (2025) examine the collective implementation of border carbon adjustments using a multi-regional CGE model. They find that coordinated adoption reduces carbon leakage more effectively than unilateral policies, but global emissions reductions remain limited (below 3%) while GDP losses in carbon-intensive exporting economies range between 0.5% and 1.2%. Therefore, coordination mitigates leakage but does not eliminate the welfare–efficiency trade-off inherent to CBAM-type instruments.

In addition to CGE literature, various impact assessment studies and institutional reports have identified the countries and sectors most exposed to CBAM based on trade and emissions data. These analyses agree that vulnerability is concentrated in carbon-intensive sectors and fossil fuel-based electricity—particularly iron and steel and aluminum—although, in general, they do not incorporate general equilibrium modeling or allow for the evaluation of macroeconomic and intersectoral reallocation effects (e.g., Bellora and Fontagné, 2022; UNCTAD, 2021; Eicke et al., 2021).

Closely related to our approach, Ramadhani and Koo (2022) use a multi-region GTAP-E CGE model for Indonesia to jointly analyze exposure to trading partners' border carbon adjustments and alternative domestic carbon tax responses, finding that a border tax adjustment reduces Indonesia's real GDP by about 0.03% while increasing its emissions by around 1.3%, whereas the introduction of a modest domestic carbon tax (US\$5/tCO_2) lowers domestic emissions by approximately 1.7% with GDP losses below 0.02%, thereby mitigating the trade and welfare distortions associated with border measures.

Non-CGE based evidence

Non-CGE assessments of the EU CBAM focus on exposure, trade impacts, and distributional effects using trade data, emissions accounting, and input–output techniques, providing quantitative benchmarks for carbon-intensive exporters.

Using detailed trade and emissions data, **UNCTAD (2021)** estimates that CBAM could reduce exports from developing countries by up to **1.4%**, with particularly large effects concentrated in carbon-intensive sectors such as iron and steel, aluminum, and cement. The report further shows that CBAM coverage initially applies to sectors accounting for **5–10% of total exports** in several developing economies, implying non-negligible trade exposure even under a limited design. By means of a global multi-regional input–output framework, **Li et al. (2025)** estimate that under expanded CBAM coverage, export losses for major developing economies can exceed **€10 billion**, with associated GDP losses in the range of **0.1–0.6%**. Importantly for this paper, they find that the introduction of a domestic carbon price can offset approximately **30–60%** of CBAM-induced export losses.

The existing CGE literature provides valuable insights into both carbon taxation and border carbon adjustments. Studies focusing on South Africa show that carbon pricing can reduce emissions but may impose short-run costs in terms of GDP and household welfare, particularly in the absence of revenue recycling. International CBAM studies demonstrate its potential to limit carbon leakage, while also highlighting the risk of disproportionate burdens on carbon-intensive exporters in developing economies.

This study makes two main contributions to the literature. First, it shifts the analytical focus from one-sided CBAM impacts to policy interaction, examining how domestic carbon pricing reforms can offset CBAM-induced trade costs and retain carbon revenues within the exporting country. Second, it develops South Africa-specific fiscal and structural scenarios, explicitly accounting for the current carbon tax design, exemption structure, and the role of the electricity sector; features often treated generically in global GTAP-based assessments.

In addition, the paper addresses ongoing uncertainty surrounding CBAM implementation, such as emissions scope, sectoral coverage, and emissions factors, through scenario and sensitivity analysis, thereby enhancing policy relevance in a rapidly evolving regulatory environment.

4. Methodology and Data

The analysis is conducted using the GTAP-E computable general equilibrium model, which extends the standard GTAP framework by incorporating energy substitution and CO_2 emissions accounting. The model captures interlinkages between production, consumption, trade, and emissions across regions and sectors, making it well-suited for analysing climate/trade policy interactions.

South Africa's economy is calibrated using GTAP data, supplemented by country-specific information on energy use, emissions intensity, and carbon taxation. The EU CBAM is modelled as an exogenous tariff-equivalent shock on South African exports of covered products, reflecting embedded emissions and prevailing EU carbon prices. Domestic carbon taxes are introduced as internal price instruments applied to emissions from production and energy use.

i. To address known CGE limitations in CBAM analysis, the study employs: the most disaggregated GTAP sectoral structure available for CBAM-relevant industries;
ii. concordance between GTAP sectors and CBAM-regulated products; and
iii. sensitivity analysis around emissions intensities and substitution elasticities. While firm-level heterogeneity cannot be explicitly modelled, results are interpreted with reference to observed variation in emissions intensities across South African firms and sectors.

5. Policy Scenarios

Three combined CBAM–carbon tax scenarios are simulated:

1. **Baseline scenario**: Current EU CBAM design (limited sectoral coverage and Scope 1 emissions) combined with South Africa's existing carbon tax, characterised by low effective rates, extensive exemptions, and exclusion of the electricity sector.
2. **Policy alignment scenario**: Expanded CBAM coverage to include indirect emissions and additional sectors, alongside domestic carbon tax reforms that raise the effective carbon price, reduce exemptions, and incorporate the electricity sector, including the state-owned utility Eskom.
3. **Full CBAM scenario**: Comprehensive CBAM coverage across goods and emissions, combined with a near-uniform domestic carbon pricing regime in South Africa with minimal exemptions and broad sectoral coverage.

Across scenarios, we track impacts on GDP, welfare, sectoral output, exports and imports, CO_2 emissions, energy use, and fiscal flows, distinguishing between carbon payments transferred abroad through CBAM and revenues retained domestically via carbon taxation.

6. Results and Discussion

Preliminary results highlight important trade-offs between competitiveness, emissions reduction, and fiscal outcomes. Under the baseline scenario, CBAM imposes non-trivial costs on South African exports of emissions-intensive goods, with limited offset from the existing carbon tax due to its low effective rate and narrow base. This leads to welfare losses and declining export competitiveness in key sectors.

We expect scenarios involving domestic carbon tax reform to demonstrate that higher and broader carbon pricing can partially mitigate the impacts of CBAM. Although stronger domestic pricing increases production costs, it reduces net CBAM liabilities by internalising carbon costs at home, thereby retaining revenues within South Africa rather than transferring them to the EU. Emissions reductions are also larger and more economy-wide, particularly when the electricity sector is included.

The preliminary analysis suggests that CBAM can serve as an external incentive for domestic climate policy reform, but the outcomes depend critically on the policy design. Poorly designed carbon taxes may exacerbate competitiveness losses, while well-aligned reforms can improve environmental effectiveness and fiscal sustainability. These findings are highly relevant for developing economies facing similar trade and climate pressures.

7. Conclusion and Policy Implications

This paper demonstrates that the economic impact of CBAM on developing exporters cannot be fully understood without considering domestic climate policy responses. For

South Africa, domestic carbon tax reform has the potential to transform CBAM from a purely external trade threat into a catalyst for accelerated decarbonisation and fiscal realignment.

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