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Influence of The Carbon Border Adjustment Mechanism on The Imports of Passenger Vehicles to Germany

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Abstract. Climate policy is increasingly influencing trade patterns through carbon-cost differentials. This paper investigates how the EU Carbon Border Adjustment Mechanism (CBAM) may reconfigure Germany's passenger-vehicle imports once carbon pricing at the border becomes binding. Using a simulation-based gravity framework with a balanced panel of 47 exporters (2008–2024), the author constructed two CBAM exposure measures: (i) a Structure Effect capturing ETS-aligned carbon-price asymmetries scaled by technological capability, and (ii) an Effective Cost interaction that amplifies penalties for carbon-intensive producers. Results show a two-channel mechanism: the Structure Effect is positively correlated with German imports, consistent with sourcing shifts toward technologically advanced, low-carbon suppliers, while the Effective Cost significantly curtails imports from high-emission exporters—particularly non-EU countries fully exposed to border carbon pricing. Overall, CBAM is predicted to generate a moderate change in import levels but a meaningful reallocation in Germany's supplier composition, with implications for supply-chain resilience and the distribution of adjustment pressure across exporting countries.

Keywords: Carbon Border Adjustment Mechanism, Automotive Industry, Imports, Gravity Model.

1. Introduction

Following the 2015 Paris Climate Agreement, climate-related policies have become progressively more influential in governing global economics and international commerce. Within the European Union, the goals outlined in the European Climate Law are being implemented via the "Fit for 55" initiative, a comprehensive package designed to achieve a minimum 55% reduction in greenhouse gas emissions across the EU by the year 2030[1]. A central element of this framework is the Carbon Border Adjustment Mechanism (CBAM), designed to mitigate the risk of carbon leakage and align international trade with the EU's decarbonization pathway. Prior to CBAM, the EU relied primarily on the Emissions Trading System (ETS) as its core market-based climate instrument. While the ETS has strengthened incentives for emissions reductions since its introduction in 2005, rising allowance prices and the gradual phase-out of free allocations have increased cost pressure in trade-exposed sectors, intensifying concerns over relocation of production to jurisdictions with laxer climate regulation[2-3]. CBAM addresses this asymmetry by requiring importers of selected carbon-intensive goods to bear a carbon price comparable to that faced by EU producers under the ETS.

CBAM is implemented in stages. During the transitional phase, which began on 1 October 2023, importers are required to report direct and indirect embedded emissions. From January 2026 onward, CBAM will become fully operational, obliging importers to surrender certificates priced according to the weekly EU ETS auction price, adjusted for carbon prices paid abroad and applicable free allocations[4]. Beyond protecting EU industry from competitive disadvantages, CBAM aims to establish an international benchmark that incentivizes decarbonization among trading partners by increasing the effective cost of carbon-intensive production[5].

These developments hold particular significance for Germany, which serves as Europe's largest automotive market and maintains a notably import-dependent economic structure. The sourcing of passenger vehicles has become increasingly diversified across global production networks, while German manufacturers themselves produce a considerable share of their vehicles in foreign markets,

underscoring the critical role of cross-border supply chains in the industry[6]. At the same time, passenger vehicles embed carbon-intensive upstream materials, especially steel and aluminum—whose carbon costs can be transmitted along the value chain and ultimately affect import competitiveness under CBAM-type pricing[7]. Despite the growing policy relevance, empirical evidence on how CBAM may affect imports of finished passenger vehicles to Germany remains limited.

This paper addresses this gap by simulating CBAM-related carbon-cost exposure and estimating its association with Germany's passenger-vehicle imports using a gravity-model framework. This approach is well suited to quantify how regulatory trade frictions and carbon-cost differentials shape bilateral import flows and to distinguish between structural competitiveness effects and carbon-intensity-driven cost penalties.

2. Literature Review

Existing research on the Carbon Border Adjustment Mechanism has primarily examined its legal design, WTO compatibility, and macroeconomic implications, while evidence on downstream, import-dependent sectors remains limited[8–10]. Despite the automotive sector's strong dependence on carbon-intensive upstream inputs and globally fragmented value chains, empirical evidence on the impact of CBAM on Germany's passenger-vehicle imports remains limited [11].

Studies on exporter responses highlight substantial heterogeneity in adjustment capacity: technologically advanced economies may preserve EU market access, whereas carbon-intensive and cost-sensitive suppliers face sharper disadvantages[12]. Sector-specific work further suggests that embedded emissions in steel and aluminum can be transmitted into downstream automotive goods, potentially reshaping sourcing patterns[13-14]. However, these insights remain largely disconnected from empirical ananalyzes finished vehicle imports.

This paper contributes to the literature by providing the first gravity-based, simulation-driven assessment of CBAM's impact on Germany's passenger-vehicle imports. The analysis distinguishes between a structural competitiveness channel, linked to technological capability and carbon-pricing differentials, and an effective cost channel that penalizes emission-intensive production, providing new evidence on how carbon-adjusted trade policy reshapes import composition.

3. Empirical Analysis

This study examines how the EU's Carbon Border Adjustment Mechanism may affect Germany's passenger-vehicle imports using a forward-looking, simulation-based gravity framework. As CBAM has not yet entered its monetary phase, ETS-aligned carbon cost differentials are applied to historical trade data to approximate future regulatory exposure. The gravity model provides a theoretically grounded approach to assess how carbon-related cost asymmetries and structural competitiveness influence bilateral import flows.

3.1. Data and Sample Construction

A balanced panel of Germany's passenger-vehicle imports covering 47 exporting countries over 2008–2024 (799 observations) is constructed. Import data are obtained from the German Federal Ministry of Transport. Macroeconomic controls—encompassing GDP, inflation, exchange rates, and political stability—are obtained from the World Bank and IMF databases. To measure country-level carbon intensity, we draw on CO_2 emission data from the EDGAR database, whereas technological capability is proxied through normalized Global Innovation Index scores. Finally, a binary EU membership indicator differentiates between exporters operating under the existing EU ETS framework and non-EU suppliers who would be fully exposed to the simulated CBAM pricing mechanism. Bilateral distance serves as a standard proxy for trade friction.

3.2. Econometric Specification

A random-effects gravity framework is employed to assess the impact of simulated CBAM-related carbon costs on Germany's passenger-vehicle imports. The specification includes country-specific random intercepts $u_i$and year effects λ_t, while ε_{ijt}denotes the idiosyncratic error term. The key contribution lies in two CBAM exposure measures that translate prospective border carbon pricing into trade-relevant cost differentials.

$$Log_{Import_{i,j,t}} = \beta_0 + \beta_1 * log\_CBAM\_StructureEffect_{j,t} + \beta_2 * log\_CO2\_Intensity_{j,t} + \beta_3 * CBAM\_CostEffect_{j,t} + \beta_4 * log\_GDP_{i,j,t} + \beta_5 * log\_BevRho_{i,j,t} + \beta_6 * EU_{Bool_j} + \beta_7 * log\_InflationConsumer_{j,t} + \beta_8 * log\_PoliticalStability_{j,t} + \beta_9 * log\_ExchangeRate_{j,t} + \beta_{10} \cdot log\_Distance_j + ui + \lambda t + \epsilon ijt \quad (1)$$

The CBAM Structure Effect captures cross-country differences in structural competitiveness arising from embedded vehicle emissions, technological capability, and carbon-pricing asymmetries between the EU ETS and exporting countries. It is defined as:

$$CBAM\_StructureEffect_{j,t} = \left(AvCO2Emissions_j \cdot normGII_j\right) \cdot \left(ETS_{Price_t} - CO2Price_j\right) \quad (2)$$

To translate these structural differences into effective trade penalties, the CBAM Effective Cost is defined as an interaction between the Structure Effect and exporters' CO_2 intensity:

$$CBAM\_CostEffect_{j,t} = CBAM_{jt}^{Struct} \times log\ log\left(CO2Intensity_j\right) \quad (3)$$

A negative coefficient on $CBAM\_CostEffect_{j,t}$ indicates that higher emissions intensity amplifies CBAM-induced cost pressure, leading to disproportionate declines in imports from carbon-intensive exporters. The specification further includes standard gravity and macroeconomic controls capturing economic size ($GDP_{i,j,t}$), relative market scale ($BevRho_{i,j}$), price competitiveness (log $ExchangeRate_{j,t}$), and macroeconomic stability ($Inflation_{j,t}$, $PoliticalStability_{j,t}$). Geographic trade frictions are proxied by bilateral distance ($Distance_j$). All continuous variables enter in logarithmic form to allow elastic interpretation and mitigate heteroskedasticity, while the EU bool remains untransformed, reflecting differential regulatory exposure under the EU Emissions Trading System.

3.3. Analysis of Benchmark Regression Results

The results reported in Table 1 indicate a clear two-channel adjustment mechanism. The CBAM Structure Effect exhibits a positive and statistically significant coefficient, consistent with increased imports from technologically advanced, low-emission exporting countries. However, when the interaction term is included, the CBAM Effective Cost turns negative and highly significant, implying that the initial structural advantage dissipates for emission-intensive producers. These findings suggest that CBAM affects trade predominantly by creating cost differentials based on carbon intensity, rather than by imposing generalized trade barriers.

Regarding the control variables, GDP exhibits the expected positive relationship with imports. Similarly, exchange rate movements, inflation, and political stability all prove to be significant determinants of import volumes, with effects consistent with theoretical predictions.

Table 1. Benchmark Regression Results.

Variable	(1)	(2)
CBAM_StructureEffect	0.2415 *** (0.0406)	0.4564*** (0.1551)
CBAM_EffectiveCost	—	−0.2469*** (0.0732)
GDP	—	0.4022** (0.2015)
BevRho	—	0.1133 (0.1355)
CO2_Intensity	—	2.2298 *** (0.6036)
EU_Bool	—	0.1372 (0.3122)
Exchange_rate	—	−0.1715 ** (0.0803)
InflationConsumer	—	0.6306 *** (0.1484)
PoliticalStability	—	−3.4261*** (0.6397)
Distance	—	−0.2624 (0.3893)
Observations	799	799
R^2 (Overall)	0.208	0.9100
R^2 (Between)	0.2147	0.9305
R^2 (Within)	−0.0406	0.1483

Note: "***"means $p < 0.01$, "**"means $p < 0.05$, "*"means $p < 0.10$; Robust standard errors are reported in parentheses .

3.4. Endogeneity and Robustness Test

To ensure the validity of the estimated relationships, potential endogeneity was assessed using the Durbin–Wu–Hausman test. Non-significant results ($p > 0.05$) indicate consistent OLS estimates, while significant values would suggest bias and the need for an instrumental variable approach. The test results show a Durbin–Wu–Hausman [15,16] statistic of 1.02 ($p = 0.3095$), which provides no evidence of endogeneity.

Following these diagnostic checks, additional robustness tests were performed to verify the stability of our empirical results. The baseline specification was re-estimated using both Feasible Generalized Least Squares (FGLS) and an outlier-sensitivity procedure, ensuring that the findings are not driven by methodological choices or extreme observations. Even though the same dataset and model equation are used, all these models have slightly different approaches to calculating the results. If the model is robust, the results of these tests should just differ slightly [17–19]: The comparison across the Random Effects, FGLS, and outlier-sensitivity estimations demonstrates a high degree of robustness in the core CBAM-related coefficients. Both CBAM_StructureEffect and CBAM_EffectiveCost remain stable in sign and significance across all three approaches, confirming that the simulated carbon cost variables exert consistent structural and cost-based influences on Germany's vehicle imports. The FGLS model yields slightly stronger coefficient magnitudes, reflecting its efficiency gains under heteroskedasticity, while the outlier-sensitivity test shows modest attenuation of the CBAM_StructureEffect once the most emission-intensive exporters are excluded. This reduction indicates that part of CBAM's structural influence is concentrated among high-emission trading

Table 2. Results RE, FGLS and Outlier-Sensitivity model in comparison.

Variable	(1)	(1)	(3)
	RE	FGLS	OS
CBAM_StructureEffect	0.456*** (0.155)	0.551*** (0.017)	0.543** (0.223)
CBAM_EffectiveCost	−0.247*** (0.073)	−0.298*** (0.007)	−0.319** (0.115)
GDP	0.402* (0.202)	−0.334*** (0.009)	−0.594*** (0.150)
BevRho	0.113 (0.136)	0.620*** (0.007)	0.440*** (0.068)
CO2_Intensity	2.230*** (0.604)	2.863*** (0.041)	3.427*** (0.676)
EU_Bool	0.137 (0.312)	1.977*** (0.021)	1.782*** (0.492)
Exchange_rate	−0.172** (0.080)	−0.172*** (0.005)	−0.223*** (0.045)
InflationConsumer	0.631*** (0.148)	0.170*** (0.010)	−0.039 (0.174)
PoliticalStability	−3.426*** (0.640)	−0.946*** (0.028)	−1.123** (0.535)
Distance	−0.262 (0.389)	0.135*** (0.009)	0.203 (0.183)
R^2 (Overall)	0.910	0.990	0.915
R^2 (Between)	0.931	0.217	0.939
R^2 (Within)	0.148	0.069	0.048
Observations	799	799	758

Note: "***"means $p < 0.01$, "**"means $p < 0.05$, "*"means $p < 0.10$; Robust standard errors are reported in parentheses.

3.5. Heterogeneity Analyzes

The heterogeneity analysis demonstrates that CBAM's effects on Germany's vehicle import structure vary markedly across institutional and structural contexts. The subgroup regressions reveal distinct patterns when comparing EU and non-EU suppliers, as well as between countries with high and low population density and the results underscore that carbon-cost adjustments affect not only relative prices but also the composition and resilience of Germany's import sourcing network

A pronounced asymmetry emerges between EU and non-EU exporters under CBAM. For non-EU countries, the structural CBAM coefficient is strongly positive, indicating that—prior to accounting for emissions intensity—Germany tends to import more from technologically advanced non-EU suppliers. Once emissions intensity is incorporated through the interaction term, however, this relationship reverses: the CBAM_EffectiveCost coefficient becomes strongly negative and highly statistically significant. This pattern implies that CBAM substantially curtails imports from carbon-intensive non-EU exporters, as the full carbon-price differential is applied at the border.

By contrast, EU member states show no statistically meaningful response to CBAM—both the structural coefficient and the interaction term prove insignificant. This pattern aligns with the regulatory architecture of CBAM. Since EU producers already face ETS compliance, the mechanism does not alter relative prices within the single market. Consequently, Germany's intra-EU import flows remain structurally unaffected.

Overall, these results suggest that CBAM will shift Germany's import dependence away from carbon-intensive non-EU producers, while preserving established intra-EU supply chains.

Population density, as a proxy for economic scale and production structure, further conditions the degree to which CBAM alters Germany's import relationships. For high-density countries—which tend to be large, industrially diversified economies—CBAM has a negligible effect on imports. The structural effect is slightly negative and insignificant, while the interaction term with emissions intensity is small and again not significant. This suggests that Germany's imports from these economies remain robust, as scale advantages and stronger technological capabilities cushion the carbon-cost burden.

The pattern is fundamentally different for low-density countries, where CBAM exerts a much stronger influence. The structural CBAM effect is strongly positive and highly significant, indicating that—absent emissions penalties—Germany tends to import more from technologically competitive smaller economies. Yet this initial advantage is sharply offset by the highly significant negative interaction term. Here, even moderate emissions intensity results in disproportionately large import declines, implying that Germany's imports from smaller and structurally less diversified economies are highly sensitive to CBAM-induced cost pressure.

These findings suggest that CBAM will not only penalize carbon-intensive suppliers but may also lead to a further concentration of Germany's import structure, favoring a smaller group of large, technologically advanced economies.

Table 3. Heterogeneity Analysis Results in comparison.

Variable	(1) EU	(2) NON-EU	(3) BEVRHO HIGH	(4) BEVRHO LOW
CBAM_StructureEffect	+0.0303 (0.2368)	+0.5093*** (0.1733)	−0.0848 (0.1601)	+0.6378 (0.2284)***
CBAM_EffectiveCost	−0.0596 (0.1347)	−0.2499*** (0.0763)	+0.0242 (0.0701)	−0.3701 (0.1138)***

Note: "***"means $p < 0.01$, "**"means $p < 0.05$, "*"means $p < 0.10$; Robust standard errors are reported in parentheses.

4. Summary

This study investigates that the EU Carbon Border Adjustment Mechanism reshapes Germany's passenger vehicle imports, emphasizing structural reallocation over volume reduction. Analysis reveals that imports from low-emission, technologically advanced exporters remain stable, whereas carbon-intensive suppliers—particularly non-EU producers lacking economies of scale—experience significant competitive disadvantages. CBAM thus acts as a selective import filter, reorienting Germany's import portfolio toward cleaner sources. The effects are highly heterogeneous: intra-EU imports are unaffected due to alignment with the EU Emissions Trading System, while non-EU exporters face heightened cost pressures. Differences in population density and production scale further shape these effects, suggesting that CBAM interacts with the structural characteristics of exporting economies when reconfiguring Germany's import portfolio. Over time, this dynamic may consolidate import markets among large, technologically adaptable suppliers, amplifying competitive asymmetries globally.

For Germany's automotive industry, CBAM introduces both cost pressures and incentives for green sourcing. Higher embedded-carbon costs in imported vehicles and inputs are likely to be partially passed through to domestic prices, affecting procurement strategies, model portfolios, and consumer demand. At the same time, CBAM strengthens incentives to reorient sourcing toward low-emission steel, aluminum, batteries, and finished vehicles, accelerating structural transformation within

automotive value chains. From a policy perspective, managing these import-driven adjustments is crucial. Regulatory predictability—through clear implementation timelines, transparent carbon-pricing benchmarks, and standardized MRV requirements—can reduce uncertainty for foreign suppliers and limit disruptive import contractions that would undermine supply-chain resilience. Recycling CBAM revenues into international decarbonization partnerships, particularly with structurally vulnerable non-EU exporters, can help stabilize vehicle and input imports while supporting global emissions reductions.

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