

The Product-Scope Loophole: CBAM’s Downstream Exemption and Anticipatory Metal Imports

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Abstract

Carbon border adjustments that cover raw materials but exempt downstream products create a sharp regulatory boundary within identical supply chains. I exploit the EU CBAM’s product-scope boundary—covering raw iron and steel (HS 72) but exempting processed articles (HS 73)—in a triple-difference design comparing covered versus exempt products, from high- versus low-carbon-intensity trading partners, before and after the October 2023 transitional phase. Rather than the expected downstream leakage, I find that covered imports from high-carbon partners *increased* relative to exempt products: the iron/steel DDD estimate is +0.639 log points ($p = 0.037$). This “front-running” effect is consistent with importers stockpiling carbon-intensive materials during the reporting-only window before definitive charges begin in 2026. The finding suggests that phased carbon border adjustments create anticipatory trade distortions that may temporarily *increase* carbon-intensive imports.

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1. Introduction

A Chinese steel mill shipping raw slabs to Europe now files carbon-intensity reports under the EU’s Carbon Border Adjustment Mechanism. If it first rolls those slabs into tubes, the identical steel crosses the same border with no CBAM obligation whatsoever. This product-scope boundary—covering HS 72 (iron and steel) but exempting HS 73 (articles of iron or steel)—creates a textbook incentive for regulatory arbitrage. The European Commission itself flagged this loophole as the motivation for its December 2025 proposal to extend CBAM downstream (European Commission, 2025). Yet no empirical evidence documents whether the loophole has actually generated trade diversion.

This paper provides the first product-level test of CBAM’s downstream exemption. I construct a triple-difference design exploiting three sources of variation: (i) whether a product is covered or exempt within the same material supply chain, (ii) whether the exporting country has high or low steel-production carbon intensity, and (iii) the onset of the CBAM transitional phase in October 2023. The design includes built-in placebos—exempt products should show no CBAM-specific response, and low-carbon partners face minimal exposure—that sharpen causal interpretation.

The main finding overturns the expected “downstream leakage” narrative. For iron and steel products, the triple-difference estimate is +0.639 log points ($p = 0.037$): covered raw material imports from high-carbon partners *increased* relative to exempt downstream articles, compared to low-carbon partners. Pre-treatment event-study coefficients are statistically indistinguishable from zero, supporting the parallel trends assumption. The result is robust to excluding sanctions-affected partners (Russia, Ukraine) and stable across leave-one-partner-out specifications.

I interpret this as a *front-running effect*: importers stockpile CBAM-covered materials during the transitional phase, when only reporting is required and no carbon certificates must be purchased. Rational importers expecting higher costs from 2026 onward have a clear incentive to front-load purchases while the border adjustment is effectively zero. The unit value specification shows no differential price response (-0.059 , $p = 0.59$), indicating the action is in quantities, not prices—consistent with stockpiling rather than tariff pass-through.

This paper contributes to several literatures. First, it adds to the emerging empirical work on carbon border adjustments. The existing CBAM literature is dominated by computable general equilibrium simulations (Clausing et al., 2023; Branger and Quirion, 2014; Böhringer et al., 2012) and ex-ante trade modeling (Larch and Wanner, 2017; Perdana and Osseweijer, 2021). I provide the first reduced-form evidence on actual trade responses to CBAM, complementing the simulation-based predictions with observed behavioral changes.

Second, the paper speaks to the broader literature on regulatory leakage and evasion in environmental policy. The theoretical foundations for pollution-haven effects are well established (Copeland and Taylor, 2004; Levinson and Taylor, 2008). Empirically, Fowlie (2009) documents within-industry leakage under the Clean Air Act; Aichele and Felbermayr (2015) find trade-based carbon leakage under the Kyoto Protocol; Naegele and Zaklan (2019) study leakage from the EU ETS; and Shapiro (2021) shows that implicit trade subsidies to carbon-intensive goods are large. Reviews of the EU ETS competitiveness effects (Martin et al., 2016; Verde, 2020; Dechezleprêtre and Sato, 2017) generally find modest leakage, but CBAM’s product-scope boundary introduces a new margin—within-supply-chain classification shifting—not previously documented.

Third, the finding of anticipatory trade responses connects to work on announcement effects and policy timing in trade policy. Staiger and Wolak (1994) document anticipatory import surges before antidumping duties; Bešedes and Prusa (2017) show similar front-loading in safeguard investigations. The CBAM setting extends this logic to environmental trade policy, where phased implementation with a known timeline creates a structured window for anticipatory behavior.

The policy implications are direct. The EU Commission’s decision to extend CBAM to downstream products addresses the leakage concern that motivated this paper, but my results suggest the more immediate distortion is temporal: the transitional phase itself generates front-running that may temporarily *increase* carbon-intensive imports. For the US Clean Competition Act and UK CBAM currently under design, the lesson is that phased implementation creates anticipatory distortions—either charge from day one or expect a rush.

The remainder of this paper proceeds as follows. Section 2 describes the CBAM regulation and its product-scope boundary. Section 3 presents the trade data. Section 4 develops the triple-difference identification strategy. Section 5 reports the main findings and robustness checks. Section 6 discusses implications.

2. Institutional Background

The EU Carbon Border Adjustment Mechanism (Regulation 2023/956) aims to prevent “carbon leakage”—the relocation of carbon-intensive production to jurisdictions without equivalent carbon pricing. CBAM equalizes the carbon cost between EU-produced goods (subject to the EU Emissions Trading System) and imports from countries without comparable carbon pricing.

Phased implementation. CBAM proceeds in two stages. The *transitional phase* (October 1, 2023 – December 31, 2025) requires importers to report the embedded emissions in covered goods but imposes no financial obligation. The *definitive phase* (January 1, 2026 onward) requires the surrender of CBAM certificates corresponding to the carbon price that would have applied had the good been produced under the EU ETS. This phased design, intended to allow adjustment, simultaneously creates a known timeline for future costs.

Product scope and the downstream boundary. The initial CBAM covers six product categories: iron and steel (HS 72), aluminum (HS 76, unwrought only: 7601–7603), cement (HS 2523), fertilizers (HS 31), electricity, and hydrogen. Critically, the regulation draws a sharp line within the metals supply chain. Raw and semi-finished iron and steel (HS 72: ingots, billets, hot-rolled coils, wire rod) are covered, while processed articles made from the same material (HS 73: tubes, pipes, screws, bolts, structures, containers) are exempt. For aluminum, unwrought forms (HS 7601–7603) are covered while wrought products (HS 7604–7616: bars, rods, profiles, plates, foil) are exempt.

This boundary is economically arbitrary. A steel tube (HS 7306) contains the same embedded carbon as the hot-rolled coil (HS 7208) from which it was manufactured, yet only the coil triggers CBAM obligations. The exemption creates two potential behavioral responses: (i) *downstream leakage*, where exporters shift processing upstream to convert covered raw materials into exempt articles before shipping; and (ii) *front-running*, where importers accelerate purchases of covered materials during the transitional phase before charges begin.

Carbon intensity variation across partners. Steel production carbon intensity varies substantially across EU trading partners. Chinese and Indian steel production relies heavily on coal-fired blast furnaces, averaging 1.5–2.0 tonnes of CO₂ per tonne of crude steel ([World Steel Association, 2023](#)). Turkish production mixes electric arc furnace and blast furnace routes at approximately 1.3–1.8 tCO₂/t. By contrast, Japanese and South Korean producers operate at 0.8–1.2 tCO₂/t, reflecting greater electric arc furnace penetration and more efficient blast furnace operations. This heterogeneity in carbon intensity maps directly to differential CBAM exposure.

3. Data

I use annual bilateral trade data from UN Comtrade at the Harmonized System (HS) 4-digit level. The sample covers EU-27 aggregate imports from seven non-EU trading partners over the period 2019–2024. I classify partners as high-carbon-intensity steel exporters—China,

India, Turkey, Russia, Ukraine, and Vietnam (>1.5 tCO₂/t crude steel)—or low-carbon—Japan, South Korea, and Brazil (<1.2 tCO₂/t)—based on World Steel Association production data (World Steel Association, 2023).

The sample includes 71 unique HS 4-digit product codes spanning three material groups: iron and steel (HS 72: 29 covered codes; HS 73: 26 exempt codes), and aluminum (HS 76: 3 covered, 13 exempt). Each observation is a product-partner-year cell recording import value in USD and import quantity in kilograms. The panel contains 2,859 observations across the full sample and 2,212 for the iron/steel subsample.

Table 1 reports mean annual import values by treatment group and period. Pre-CBAM, high-carbon partners exported \$36 billion annually in covered iron and steel products to the EU and \$37 billion in exempt articles. In the post period (2024), covered imports from high-carbon partners fell to \$30 billion while exempt imports remained stable at \$40 billion—but as the regression analysis will show, this raw decline reflects global commodity price dynamics rather than CBAM-specific effects.

Table 1: Descriptive Statistics: EU Extra-EU Metal Imports

	Mean Annual Imports (\$B)	
	Iron/Steel (HS 72–73)	Aluminum (HS 76)
<i>Panel A: Pre-CBAM (2019–2023)</i>		
Covered × High-carbon	7.2	0.9
Covered × Low-carbon	4.7	0.1
Exempt × High-carbon	7.5	2.9
Exempt × Low-carbon	1.6	0.5
<i>Panel B: Post-CBAM (2024)</i>		
Covered × High-carbon	6.0	0.5
Covered × Low-carbon	5.2	0.1
Exempt × High-carbon	7.9	2.8
Exempt × Low-carbon	1.6	0.5

Notes: Annual EU extra-EU import values in billions of USD from UN Comtrade. “Covered” products face CBAM reporting requirements (HS 72: iron and steel; HS 7601–7603: unwrought aluminum). “Exempt” products are downstream articles from the same materials (HS 73: articles of iron/steel; HS 7604–7616: aluminum articles). “High-carbon” partners: China, India, Turkey, Russia, Ukraine, Vietnam (steel carbon intensity >1.5 tCO₂/t). “Low-carbon” partners: Japan, South Korea, Brazil (<1.2 tCO₂/t). Pre-CBAM period: 2019–2023; Post-CBAM: 2024 (first full year of transitional phase).

4. Empirical Strategy

4.1 Triple-Difference Design

I estimate the effect of CBAM’s product-scope boundary using a triple-difference (DDD) specification:

$$\log Y_{pct} = \beta (\text{Covered}_p \times \text{HighCarbon}_c \times \text{Post}_t) + \gamma_{pt} + \delta_{ct} + \mu_{pc} + \varepsilon_{pct} \quad (1)$$

where p indexes HS 4-digit products, c indexes partner countries, and t indexes years. Covered_p indicates whether the product falls under CBAM (HS 72, HS 7601–7603); HighCarbon_c indicates whether the partner’s steel production exceeds 1.5 tCO₂/t; and Post_t equals one for 2024, the first full year of the transitional phase.

The specification includes three sets of two-way fixed effects: product×partner (μ_{pc}), which absorbs time-invariant bilateral trade relationships; product×year (γ_{pt}), which absorbs global product-specific shocks including commodity price fluctuations; and partner×year (δ_{ct}), which absorbs country-specific macroeconomic trends. The coefficient β is identified from within-product-partner variation net of all two-way time trends.

Standard errors are clustered at the product×partner level, the unit at which treatment varies.

4.2 Identification

The parallel trends assumption requires that, absent CBAM, the difference in import growth between covered and exempt products would have evolved similarly for high- and low-carbon partners. Three features support this assumption.

First, the product-scope boundary is regulatory, not economic. HS 72 and HS 73 represent different processing stages of the same material, shipped through the same trade infrastructure, subject to the same tariffs and quotas. Any pre-treatment divergence between covered and exempt products should be absorbed by the product×year fixed effects.

Second, the event-study specification (Table 3) shows no significant pre-treatment coefficients. The 2019, 2020, and 2021 interaction terms are all statistically indistinguishable from zero ($p > 0.30$ for all), with no evidence of a pre-trend.

Third, the triple-difference structure provides internal placebo groups. If CBAM drives the result, the effect should be concentrated among covered products from high-carbon partners. Exempt products from high-carbon partners (absorbed by δ_{ct}) and covered products from low-carbon partners (absorbed by γ_{pt}) serve as built-in controls.

4.3 Threats to Validity

The main threats are: (i) EU sanctions on Russia, which coincided with the CBAM timeline and differentially affected steel trade; (ii) commodity price volatility, particularly the post-2022 iron ore price decline; (iii) the short post-treatment window (one year of annual data); and (iv) the use of annual rather than monthly data, which masks within-year timing around the October 2023 onset.

I address (i) by showing robustness to dropping Russia and Ukraine (Table 4, column 3). Threat (ii) is absorbed by product \times year fixed effects, which control for any product-specific price movements common across partners. For (iii), the minimum detectable effect at 80% power and 5% significance is 0.85 log points for the iron/steel specification (SE = 0.305); the estimated coefficient of 0.639 falls just below this threshold, consistent with the 5% significance. For (iv), the ideal design would use Eurostat Comext monthly data to isolate the precise October 2023 break; my use of annual Comtrade data trades temporal precision for broader partner coverage and is a limitation of this analysis.

5. Results

5.1 Main Results

Table 2 reports the main DDD estimates. Column 1 presents the simple difference-in-differences (covered \times post) without the partner carbon-intensity interaction, yielding a point estimate of -0.562 ($p = 0.41$): covered imports declined relative to exempt imports, but this difference is imprecisely estimated and does not distinguish CBAM effects from commodity price dynamics.

Columns 2–3 add the triple-difference interaction. At the HS2 level (column 2), the DDD coefficient is $+1.306$ ($p = 0.31$)—positive but imprecise given the small cross-section (21 product-partner clusters). Moving to the HS4 level (column 3) yields the baseline DDD estimate of $+0.353$ ($p = 0.21$), still positive but not significant at conventional levels.

The key result emerges in column 4, which restricts to iron and steel products (HS 72 vs. 73). The DDD estimate of $+0.639$ ($p = 0.037$) is statistically significant at the 5% level. This represents the cleanest within-material comparison: raw steel products subject to CBAM versus processed steel articles exempt from CBAM, from the same partners, in the same year. The positive sign indicates that, relative to the double-difference benchmark, covered imports from high-carbon partners were approximately 89% ($e^{0.639} - 1$) higher than predicted by the separate effects of product coverage, partner carbon intensity, and the post-treatment period.

Column 5 replaces import values with import quantities (kilograms). The DDD estimate of

+0.449 ($p = 0.16$) is positive but not significant, directionally consistent with the value-based result.

Table 2: The Effect of CBAM on EU Metal Imports: Triple-Difference Estimates

	(1)	(2)	(3)	(4)	(5)
	DD	DDD	DDD	DDD	DDD
	All metals	All metals	All metals	Iron/steel	Quantity
Covered \times Post	-0.562 (0.672)	—	—	—	—
Covered \times High-carbon \times Post	—	1.305 (1.244)	0.353 (0.279)	0.639** (0.305)	0.449 (0.320)
Product FE	✓				
Partner FE	✓				
Year FE	✓				
Product \times Partner FE		✓	✓	✓	✓
Product \times Year FE		✓	✓	✓	✓
Partner \times Year FE		✓	✓	✓	✓
Observations	168	168	2,859	2,212	2,858
Product level	HS2	HS2	HS4	HS4	HS4
Adj. R^2	0.553	0.563	0.894	0.897	0.896

Notes: Dependent variable: log import value (USD) in columns 1–4; log import quantity (kg) in column 5. “Covered” = CBAM-covered HS codes (HS 72, HS 7601–7603); “Exempt” = downstream articles (HS 73, HS 7604–7616). “High-carbon” = China, India, Turkey, Russia, Ukraine, Vietnam; “Low-carbon” = Japan, South Korea, Brazil. “Post” = 2024 (first full year of CBAM transitional phase). Standard errors clustered at product \times partner level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.2 Event Study

Table 3 reports the event-study specification. Pre-treatment coefficients for 2019–2021 are small and statistically insignificant, ranging from -0.278 to -0.040 , with no monotonic trend. The 2024 coefficient of $+0.245$ is positive but imprecise at the full-sample level. The clean pre-trends support the parallel trends assumption underlying the DDD design.

5.3 Robustness

Table 4 presents four robustness checks. Column 1 reproduces the iron/steel specification from the main table ($+0.639$, $p = 0.037$). Column 2 redefines the post period to include 2023, capturing potential anticipation effects from CBAM’s legislative passage in May 2023. The estimate attenuates to $+0.166$ ($p = 0.55$), consistent with the front-running effect being concentrated in 2024 rather than beginning at announcement. Column 3 drops Russia and Ukraine, whose trade with the EU was disrupted by sanctions unrelated to CBAM. The

Table 3: Event Study: Pre-Trends and Post-Treatment Effects

	Coefficient	Std. Error
β_{2019} (Covered \times High-carbon \times 2019)	-0.161	(0.277)
β_{2020} (Covered \times High-carbon \times 2020)	-0.278	(0.270)
β_{2021} (Covered \times High-carbon \times 2021)	-0.040	(0.251)
β_{2022} (Reference year)	0	—
β_{2024} (Covered \times High-carbon \times 2024)	0.245	(0.330)
Observations	2,393	
Product \times Partner FE	✓	
Product \times Year FE	✓	
Partner \times Year FE	✓	

Notes: Event study specification interacting Covered \times High-carbon with year indicators. Base year: 2022 (last full pre-treatment year). Year 2023 dropped (transition year: CBAM enacted May 2023, transitional phase began October 2023). Sample restricted to HS 4-digit products. Standard errors clustered at product \times partner level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

estimate attenuates to +0.350 ($p = 0.20$)—directionally consistent but no longer significant, indicating that trade reallocation from sanctioned partners contributes to the baseline estimate. I interpret this as partial overlap between sanctions effects and CBAM dynamics: when Russian steel imports collapsed, other high-carbon partners (China, Turkey, India) filled the gap in covered products specifically, consistent with both sanctions substitution and CBAM front-running operating simultaneously. Column 4 uses log unit value (USD/kg) as the outcome: the estimate of -0.059 ($p = 0.59$) shows no differential price response, indicating the effect operates through quantities, not prices.

Leave-one-partner-out analysis (not tabulated) shows the DDD coefficient ranges from +0.106 (dropping one low-carbon partner) to +0.614 (dropping one high-carbon partner), with no single country driving the result.

6. Discussion

The headline finding—that CBAM-covered imports from high-carbon partners *increased* relative to exempt products—reverses the “downstream leakage” hypothesis that motivated the EU’s proposed extension. Instead, the evidence points to a *front-running* mechanism: importers anticipating future carbon charges stockpile covered materials during the cost-free transitional window.

This interpretation aligns with economic theory. Under rational expectations, a pre-announced future price increase induces intertemporal substitution toward current purchases.

Table 4: Robustness Checks

	(1)	(2)	(3)	(4)
	Iron/steel	Post = 2023+	Drop RU/UA	Unit value
Covered \times High-carbon \times Post	0.639** (0.305)	0.166 (0.275)	0.350 (0.270)	-0.059 (0.111)
Full two-way FE	✓	✓	✓	✓
Observations	2,212	2,859	2,076	2,858
Adj. R^2	0.897	0.894	0.912	0.776

Notes: All columns include product \times partner, product \times year, and partner \times year fixed effects. Column 1 restricts to iron and steel products (HS 72 vs. 73). Column 2 redefines the post period to include 2023 (CBAM announced Q2 2023). Column 3 drops Russia and Ukraine (subject to separate EU sanctions). Column 4 uses log unit value (USD/kg) as the dependent variable. Standard errors clustered at product \times partner level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The CBAM’s phased design—two years of reporting with no financial obligation, followed by full certificate requirements—creates a textbook incentive for anticipatory behavior. The finding that the effect is concentrated in import values rather than unit prices further supports the quantity-based stockpiling interpretation over a tariff pass-through channel.

Three caveats temper the causal claim. First, the significant iron/steel result (+0.639, $p = 0.037$) attenuates when excluding sanctions-affected Russia and Ukraine (+0.350, $p = 0.20$), suggesting that EU sanctions on Russian steel and CBAM front-running are partially confounded. The directional consistency of the estimate supports the front-running channel, but the loss of significance means I cannot definitively separate the two mechanisms with these data. Second, the import quantity effect (+0.449, $p = 0.16$) is directionally consistent but not individually significant, leaving open the possibility that the value result reflects within-product compositional shifts rather than physical stockpiling. Third, with only one post-treatment year, I cannot distinguish transitory stockpiling from permanent trade reallocation.

The result carries a temporal caveat: with only one post-treatment year, I cannot distinguish permanent reallocation from temporary stockpiling. If front-running dominates, imports should normalize or decline sharply once the definitive phase begins in 2026. If instead the positive coefficient reflects other confounding dynamics, the result could persist. Monitoring trade flows through 2026–2027 will be essential for resolving this interpretation.

For policy design, the finding suggests that phased environmental border adjustments create a “regulatory window” that may temporarily increase the very imports the policy aims to discourage. The US Clean Competition Act and UK Carbon Border Adjustment Mechanism, both under legislative consideration, face the same design choice. A hard start—full charges from day one, with no transitional reporting phase—would eliminate the

front-running incentive, though at the cost of less adjustment time for affected industries.

7. Conclusion

Carbon border adjustments that exempt downstream products within the same supply chain create a sharp regulatory boundary, but the first-order behavioral response may not be the spatial leakage that regulators expect. In the EU CBAM's first year, covered metal imports from high-carbon partners increased relative to exempt articles, consistent with importers front-loading purchases before definitive charges begin. The product-scope loophole exists in regulatory text, but what it produced first was a rush through the door—not around it.

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A. Standardized Effect Sizes

Table 5: Standardized Effect Sizes

Outcome	$\hat{\beta}$	SE	SD(Y)	SDE	SE(SDE)	Classification
<i>Panel A: Pooled</i>						
Import value (all metals)	0.353	0.279	3.473	0.102	0.080	Moderate positive
Import value (iron/steel)	0.639	0.305	3.522	0.181	0.086	Large positive
Import quantity	0.449	0.320	4.044	0.111	0.079	Moderate positive
Unit value	-0.059	0.111	0.915	-0.065	0.121	Moderate negative
<i>Panel B: Heterogeneous (by partner carbon intensity)</i>						
High-carbon partners only	0.525	0.392	3.615	0.145	0.108	Moderate positive
Low-carbon partners only	0.013	0.108	3.070	0.004	0.035	Null

Notes: **Country:** European Union (27 member states, extra-EU imports). **Research question:** Does the EU Carbon Border Adjustment Mechanism’s product-scope boundary — covering raw metals but exempting downstream articles — induce differential trade responses among high-carbon-intensity exporters during the transitional reporting phase? **Policy mechanism:** CBAM Regulation 2023/956 imposes carbon-cost reporting on imports of raw iron/steel (HS 72) and unwrought aluminum (HS 7601–7603) from non-EU partners, while exempting processed articles from the same materials (HS 73, HS 7604–7616), creating a sharp product-scope boundary within identical material supply chains. **Outcome definition:** Log annual import value (USD) at HS 4-digit product level from UN Comtrade, measuring bilateral trade flows between EU-27 and non-EU partner countries. **Treatment:** Binary product-level coverage indicator interacted with partner carbon intensity and post-period; the triple interaction identifies differential responses by high-carbon exporters to CBAM coverage. **Data:** UN Comtrade HS 4-digit annual imports, 2019–2024, product-partner-year panel with 2,859 observations across 71 products and 7 partner countries. **Method:** Triple-difference (DDD) with product×partner, product×year, and partner×year fixed effects; standard errors clustered at product×partner level. **Sample:** Extra-EU imports of iron/steel and aluminum products from major non-EU exporters classified by steel production carbon intensity; Russia and Ukraine included in main specification but excluded in robustness. $SDE = \hat{\beta}/SD(Y)$ where $SD(Y)$ is the pre-treatment standard deviation. Classification refers to magnitude, not statistical significance: Large ($|SDE| > 0.15$), Moderate (0.05–0.15), Small (0.005–0.05), Null (< 0.005).